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Hazardous Chemicals in Belgian House Dust

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Report on chemical content in house dust samples collected in Belgian homes and offices

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Executive Summary

Basis for study

House dust is a repository for environmental pollutants that may accumulate indoors (Lewis *et al.*, 1999). The objective of this study is to investigate the hazardous chemical content of house dust collected in Belgian houses and offices, as well as in the European Parliament based in Brussels. Dust samples were collected from 69 locations and analysed for five different groups of hazardous chemicals: phthalate esters, alkylphenols, brominated flame retardants, organotin compounds and short-chain chlorinated paraffins.

The occurrence of hazardous chemicals in the outdoor environment has been the subject of innumerable studies. However, investigation of chemical exposure inside the homes and offices where people spend the majority of their lives has only recently begun. Indoor dust provides a record of chemicals that are present within a home or office since degradation processes indoors are typically slow (Roberts *et al.*, 1993). House dust is also an important exposure pathway in young children (Butte and Heinzow, 2002). Contamination of house dust makes continuous exposure to harmful chemicals possible, *via* inhalation, ingestion or direct skin contact.

Phthalates, alkylphenols, brominated flame retardants, organotins and short-chain chlorinated paraffins are all in widespread use in everyday consumer products such as toys, cosmetics, furnishings and electrical goods. They share the following properties: they break down very slowly (persistence), they build up in fat and other bodily tissues and fluids (bioaccumulation) and they are potentially toxic. Some of these chemicals have been demonstrated to be potential carcinogens, to damage the immune system, to have adverse effects on the reproductive system, and/or to cause a range of other health effects potentially associated with disruption of the endocrine system.

Method

Dust samples were collected from the homes of 51 volunteers in and around eight Belgian towns and in a village in the Ardennes. The Ardennes, which is a region commonly regarded as having low levels of outdoor pollution, was selected to serve as a control in distinguishing, to some extent, the potential contribution of outdoor contaminants. Samples were also collected from the European Parliament building in Brussels. Samples from the same region (province) were pooled, e.g. the five Hainaut samples made one pooled sample.

In addition, 12 individual samples were collected in the homes or offices of 10 Belgian politicians, the home of one Swedish Member of the European Parliament and in the press briefing room of the European Parliament in Brussels.

All samples were sent to the laboratory of TNO Environmental Sciences, Energy Research and Process innovation, Apeldoorn, The Netherlands for chemical analysis.

Main findings

- The samples were widely contaminated with a variety of hazardous chemicals.

  - Phthalate esters, alkylphenol compounds and organotin compounds were detected in all the samples.

  - Brominated flame retardants (BFRs) were detected in more than 85% of samples.

  - Short-chain chlorinated paraffins were detected in 35% of samples.

- No region of Belgium was systematically more contaminated than the others.

- Homes and offices were equally contaminated with the analysed chemicals.

Samples from the Ardennes were not markedly less contaminated than samples collected in cities, indicating that outdoor contamination is unlikely to be factor in indoor contamination by these chemicals. It seems most likely that contamination results from losses of chemicals from products used indoors.

Levels of contamination were broadly consistent with previous studies conducted in Europe – variations are discussed in the relevant chapters.

Specific results

- Phthalate esters were the most abundant chemical group with a mean concentration value of 942.5 mg per kg of house dust

- The dust from the European Parliament building contained higher concentrations of total phthalates, alkylphenols, organotins and some brominated flame retardants than the mean concentrations of these chemicals in European dust

- Dust from the office of the Belgian Environment Minister, Ms Van Den Bosche, contained higher concentrations of total alkylphenols, organotins and brominated flame retardants than the European mean concentrations. Moreover, some individual brominated flame retardants were present at considerably higher concentrations than those measured in earlier studies of house dust

- The concentrations of total phthalates and total alkylphenols are, respectively, higher in the dust from the offices of Mr Kubla (Economy Minister for Wallonia) and Mr Gosuin (Environment Minister for Brussels) than the European mean concentrations

- The pooled dust sample collected from ecologically-constructed houses in Limburg was not generally less contaminated than the other samples.

Regulation

The only way to end contamination in homes and offices is to adopt strong legislation that adequately controls the production and use of chemicals.

The fact that the concentrations of hazardous chemicals documented in this study can accumulate in the dust in homes and offices is a clear indication that current legislation to control such chemicals has failed.

The European Union is preparing plans for the most comprehensive system of chemicals regulation yet seen: Registration, Evaluation, and Authorisation of Chemicals (the REACH system) is currently being discussed by the European Parliament and Council and may become law by 2005. At present, however, REACH is being systematically weakened through the efforts of the chemical industry.

REACH does not currently include the substitution principle, which holds that if a product currently being manufactured using a hazardous chemical can be manufactured using a safer chemical at a reasonable cost, the hazardous substance will no longer be permitted for that use and must be replaced by the safer alternative (mandatory substitution). It is also important that the REACH proposals continue to incorporate the precautionary principle, which holds that precautionary measures should be taken over potentially harmful activities even when conclusive proof has not been established, and that the burden of proof and costs of testing should fall on manufacturers. These two principles could help to reduce levels of exposure to hazardous chemicals in both indoor and outdoor environments.

Introduction

The global production of chemicals has increased from 1 million tonnes in 1930 to 400 million tons today (The White Paper).[1] While some of these substances are useful and bring great benefits to our lives and our health, some are also extremely dangerous. Everyday products (cosmetics, electrical goods, furniture etc.) may contain chemicals that are persistent (they break down very slowly), bioaccumulative (they build up in the fatty tissues of humans and other organisms), and toxic. Where chemicals are in such wide use, it is almost impossible to prevent them from ending up in unintended places. Thus it now seems that no part of the planet is free from chemical contamination. Hazardous chemicals have been found in almost every environmental sector, including lake and marine sediments, remote polar regions and terrestrial and water organisms.

As a consequence, hazardous chemicals are common, even ubiquitous, contaminants in the bodies of the human population. For instance, brominated flame retardants, phthalates and organotins have been measured in human breast milk, blood, serum and livers (Thomsen *et al.*, 2002; Colon *et al.*, 2000; Meironyte *et al.*, 1999; Takahashi *et al.*, 1999). Moreover, their concentration in human tissues has in some cases dramatically increased during the last decades. Some of these compounds are capable of seriously damaging human health by causing disturbance of the neurological and hormone systems, reduced fertility or an increased risk of cancer.

Chemical compounds in house dust may enter the human body by inhalation of suspended particles or chemicals volatilised from the particles, by nondietary ingestion and ingestion of particles adhering to food, and by direct skin contact. Analysis of the chemical content of the indoor environment and more particularly of house dust is thus of prime importance for assessing human exposure to toxic chemicals. Indeed, it has been estimated that an average person generally spends more than 90% of their time indoors (Butte and Heinzow, 2002). Indoor sources of chemicals, coupled with limited ventilation and slow chemical degradation processes, cause increased pollutant concentrations inside buildings. Where comparison data are available, hazardous chemical levels detected in indoor air are higher that those reported for outdoor air, suggesting that most of these chemicals originate in household products and materials (Rudel *et al.*, 2003). This contrasts with the arguments of the manufacturers, who claim that most of these chemicals are bound into products and do not therefore represent an exposure threat.

Although outdoor contamination by persistent, bioaccumulative and toxic chemicals has been studied extensively, the extent of the indoor contamination and its significance in terms of overall chemical exposure has rarely been investigated until very recently. However, where indoor studies have been conducted, evidence points to widespread contamination of the home environment with a variety of man-made chemicals.

The objective of the present study is to investigate the hazardous chemical content of house dust collected in Belgian houses and offices, as well as in the European Parliament based in Brussels. Considering the limited information currently available on the presence of hazardous chemicals in indoor environments, the aim of this study is to make sure that there is no question as to how seriously and universally our buildings are contaminated.

[1] In 2001, the European Commission issued a White Paper on a "Strategy for a future Chemicals Policy" (ref.: COM(2001) 88 final).

Chemicals targeted for investigation

Since the purpose of this study is to investigate the presence of hazardous chemicals in house dust, which arises as a consequence of the widespread use of such chemicals in everyday consumer products, the chemicals to be analysed have been chosen according to the two following criteria:

- their reported high volume use in common household furnishings and other products
- their intrinsic hazardous properties

Therefore, the presence and concentrations of five main compound groups has been assessed:

- *Alkylphenols*: used as non-ionic surfactants, emulsifiers, lubricants or anti-oxidants in the following kind of products: detergents, textiles, leather, paints, shampoos, cosmetics, adhesives, some plastics and pesticides. Alkylphenols have recently been reported to be ubiquitous in German food.

- *Brominated flame retardants*: used to prevent or retard the spread of fire. May be applied to textiles or incorporated into plastics, foams and components of electrical goods. The concentration in Norwegian human blood of one of the brominated flame retardants increased 9-fold from 1977 to 1999.

- *Organotin compounds*: used as stabiliser, biocide, fungicide, antifouling compound or catalyst in plastics (especially PVC), carpets and paints or applied to fruits and vegetables.

- *Phthalate esters*: used as softeners, heat-transfer fluids or solvents in PVC, wallpapers, furnishings, cables, cars, medical equipment, clothing, toys, ink, paint, adhesives, pesticides, perfumes and cosmetics. Phthalates are considered as the most widespread man-made chemicals.

- *Short-chain chlorinated paraffins*: used as flame retardants, plasticisers or high-pressure additives in lubricants, PVC, paints, adhesives, metal cutting fluids and textiles.

All these chemicals are toxic, break down very slowly, are able to leach out of, or otherwise be lost from, consumer products during normal use and have been reported to contaminate the human body. These characteristics justify the existing and increasing concern surrounding their use.

Indoor contaminants

Information on indoor contamination has been very scarce until recently. In the last few years, interest in the presence of hazardous chemicals in indoor air and house dust has risen.

Rudel *et al.* (2001) reported the presence of phthalates and nonylphenol compounds in residential air and dust samples. Several other studies identified phthalates, alkylphenols or brominated flame retardants in indoor air or dust collected at an electronics recycling plant, in several child day care centres and in homes (Sjödin *et al.*, 2001; Wilson *et al.*, 2001; Rudel *et al.*, 2003).

The pollutant content of house dust is now recognised as a relevant indicator of indoor contamination. House dust has been demonstrated to be an important exposure pathway in young children (Butte and Heinzow, 2002). Dust also provides a record of chemicals that have been used in the past since degradation processes indoors are typically slow. Moreover, irrespective of the potential for exposure to hazardous substances through contact with dust, the disposal of dust from vacuum cleaners may represent a significant input of these hazardous substances to waste repositories and, ultimately, the surrounding environment.

Therefore, Greenpeace has chosen to analyse house dust in order to assess indoor pollution in Europe. During the year 2000, Greenpeace International, in conjunction with Greenpeace national offices, collected samples from Parliament buildings in a total of 8 countries. Samples of dust from all countries studied contained significant levels of brominated flame retardants and organotins (Santillo *et al.*, 2001). In order to extend the existing knowledge base, similar techniques were applied over a wider area and to a greater number of potential chemical contaminants in two successive Greenpeace studies.

In the first study, samples of dust were collected for analysis from 100 houses and other buildings across the UK (Santillo *et al.*, 2003a). All these dust samples contained phthalates, brominated flame retardants and organotin compounds. More than three-quarters also contained nonylphenol and short-chain chlorinated paraffins. On average, each gram of dust contained a total of around half a milligram of the five hazardous chemical groups specifically measured. A range of other human-made chemicals, including solvents, pesticides and plastic additives were also detected.

In the second study, the same chemicals were analysed in other European countries, following the same protocols (Santillo *et al.*, 2003b). The purpose of this second study was to increase the number of samples in order to achieve a better picture of indoor pollution in Europe. 58 samples were collected in France, 22 samples in Spain, 5 samples each in Germany and Italy and 8 samples in Slovakia. The results of this second study generally indicated a higher concentration of phthalate esters and short-chain chlorinated paraffins than the first study carried out in the UK. Organotin concentration was largely similar and concentrations in alkylphenols and brominated flame retardants were generally lower in continental Europe than in the UK. All the continental European samples contained phthalates, brominated flame retardants, organotins and short-chain chlorinated paraffins. In contrast with the UK samples, only a few European samples contained detectable alkylphenols. On average, each gram of dust contained a total of around a milligram of the five chemical groups specifically measured. The highest concentration was generally measured for phthalate esters, especially DEHP, which is toxic to reproduction.

The results of these Greenpeace studies demonstrate the widespread contamination of house dust with a variety of hazardous chemicals. Although these studies do not provide data from which human exposure could be estimated, the results clearly indicate the possibility for continuous exposure to these compounds through inhalation, ingestion or direct contact of the skin with dust.

This assumption is reinforced by the recent study of Rudel *et al.* (2003), which shows that the same phthalates were detected at high concentrations in air, dust and human urine. This suggests that inhalation exposure may be important.

Contamination of the human body

The chemicals analysed in this study are very persistent. Some have a high affinity for fatty tissues and may therefore accumulate over time in the bodies of animals, through the food chain and in humans. Numerous studies have measured these hazardous chemicals in the human body.

Brominated flame retardants have been found in adipose tissue samples, breastmilk and blood (Meironyte *et al*., 1999; Meneses *et al*., 1999; Schecter *et al.*, 2003). Moreover, Meironyte *et al*. (1999) has shown that there was a dramatic increase in the level of these chemicals in breastmilk between 1972 and 1997. A 9-fold increase in the level a brominated flame retardant compound was recorded in Norwegian human blood from 1977 to 1999. Electronic equipment was identified as a possible contamination source. Jakobsson *et al.* (2002) investigated exposure to brominated flame retardants in a group of technicians doing intense computer work. Hospital cleaners with no computer experience and clerks working full-time at computer screens were used as comparison. Results indicated that the computer technicians had concentrations of some chemicals 5 times higher than those reported among hospital cleaners and computer clerks. Moreover, chemical levels could be positively correlated with the duration of computer work among technicians. The authors concluded it is evident that the brominated flame retardants used in computers and electronics accumulate in the workers' tissues. A clear relation between air chemical concentration and human serum levels has also been observed by Sjoding *et al*. (2001).

Two years ago, Covaci *et al.* (2002) measured brominated flame retardants in 20 human adipose tissues from Belgium. It appeared that the concentrations, ranging between 2.2 and 11.7 ng/g lipid weight, were in the same range as concentrations found in other European countries, but lower than in UK and much lower than in US.

Different studies also report the presence of phthalates in human urine (Blount *et al.*, 2000; Jakobsson *et al.*, 2002; Abidi *et al;* 2003). Here again, statistically significant correlation was found between individuals air and urine levels (Abidi *et al.* 2003).

Finally, the presence of organotin has also been shown in human livers (Takahashi *et al.*, 1999).

Taken together, all these results indicate the widespread and sometimes increasing presence of hazardous chemicals in the human body. These experiments also strongly suggest that we are living with the consequences of the general use of hazardous chemicals in consumer goods.

Environmental distribution

The occurrence of these hazardous compounds in the environment has gained increasing scientific attention over the past decade. Environmental studies conducted primarily in Europe, the Far East and North America indicate that these chemicals are universally present in sediments and living organisms.

Alkylphenols are widely distributed in farmlands in fresh and salt water and particularly in sediments. Alkylphenols have been measured in water samples and sediments of the North Sea and the Elbe river (Heemken *et al.*, 2001), in sediment from the lower Rouge River (Kannan *et al.*, 2001) and in river water and bay sediments in the Tokyo metropolitan area (Isobe *et al.*, 2001). However, alkylphenol levels in animals and humans have been poorly studied so far, although it is well known that these compounds can accumulate in fishes and sea birds. Alkylphenols have been measured in edible molluscs, filter feeders and predators in the Adriatic Sea (Ferrara *et al.*, 2001). A recent German study indicated that these chemicals are ubiquitous in German food (Guenther *et al.*, 2002).

Numerous studies have already shown the widespread distribution of brominated flame retardants in nearly all environmental sectors including sediments, freshwater and sea organisms including in remote polar regions (de Wit, 2002). Since the first report of their presence in the environment in the early 1980s, numerous studies have been performed to stress the universal presence of these compounds. Brominated flame retardants have recently been measured in lake trout from the Laurentian Great Lakes (Luross *et al.*, 2002), in Baltic salmon (Asplund *et al.*, 1999), in green mussels from Singapore (Bayen *et al.*, 2003), in perch collected along the coast of Latvia (Olsson *et al.*, 1999) and in marine species from the Belgian North Sea and the Western Scheldt Estuary (Voorspoels *et al.*, 2003).

Organotins were recently measured in Pacific oysters collected along the west coats of Taiwan (Hsia and Liu, 2003), in the subtidal zone of the waters between Denmark and Sweden (Strand *et al.*, 2003), and in Caspian Seals (Kajiwara *et al.*, 2002). Previous studies indicated that organotin compounds tend to concentrate in certain organs (e.g. the liver) of aquatic organisms such as fishes, dolphins and whales (Kannan *et al.*, 1996). Organotins are also present in sediments and are especially found along shipping routes. There is less information about their presence in other environments. However, Takahashi *et al.* (1999) reported their presence in ape and human livers.

All uses of phthalates (e.g. as PVC plasticisers) result in large-scale losses to the environment during the lifetime of the product. As a consequence, phthalates are considered as the most widespread man-made chemicals. A recent investigation has identified phthalates in sediment at various locations in The Netherlands (Lahr *et al.*, 2003).

Short-chain chlorinated paraffins have been found in several terrestrial organisms (e.g. in rabbits), freshwater (mussels, fishes) and marine organisms (fishes, whales and seals) including in remote polar regions (Stern and Tomy, 2000; Tomy *et al.*, 1999). A recent study has detected short-chain chlorinated paraffins in Lake Ontario sediments (Marvin *et al.*, 2003).

Taken together, these results indicate that these hazardous chemicals are now widely distributed in our environment. High concentrations of certain of these chemicals may be sufficient to elicit adverse effects in some wildlife and in humans. Moreover, analyses of temporal trends in the concentration of some of these chemicals in animal organisms indicate a significant increase (sometimes an exponential increase) in concentration during recent decades (Ikonomou *et al.*, 2002; Norstrom *et al.*, 2002).

Brief description of toxicity

Although the direct consequences of such exposure have not yet been established, it seems reasonable to predict that these chemicals could have adverse effects on health, given their intrinsic hazardous properties. Until now, the hazardous properties of these chemicals have been mainly determined on animals. The hazardous properties of the chemical compounds analysed in this study, are summarised below:

- Alkylphenols: they have the ability to mimic oestrogen and are thus hormone-disrupting. This activity can modify the sexual development of river fish (Jobling *et al.*, 2002). These chemicals can also have direct effects on DNA structure (Atienzar *et al.*, 2002). It has also been shown that they can have effects on the fertilising ability of mouse sperm (Adeoya-Osiguwa *et al.*, 2003). Alkylphenols are thus suspected to be toxic to reproduction. Dangers to human health remain unclear. However, it has been shown that alkylphenols can modify DNA in human lymphocytes (Harreus *et al.*, 2002).

- Brominated flame retardants: experiments on rats after chronic exposure to these chemicals have shown disturbances of skeletal and brain development and permanent neurotoxic effects (Eriksson *et al.*, 1999). Moreover, mice exposed to some brominated flame retardants can display permanent aberration in spontaneous motor behaviour (Eriksson *et al.*, 2002). Experiments on human breast cancer cells also indicated that brominated flame retardants can interfere with the hormone system, potentially affecting growth and development (Meerts *et al.*, 2001).

- Organotin compounds: some of these chemicals, particularly TBT, are extremely toxic to aquatic organisms and the immune system. Hormone-mimicking effects in molluscs and fish can lead to severe reproductive disorders. Immune disorders also occur in rodents following exposure. Organotins have been shown to alter the cytoskeleton, to inhibit the oxidative phosphorylation of marine invertebrate embryos (Cima *et al.*, 1996), to cause malformations in rat foetuses (Ema *et al.*, 1995), to decrease the *in vitro* survival of human B lymphocytes (de Santiago and Aguilar-Santelises, 1999) and to affect testes development in mice (Kumasaka *et al.*, 2002).

- Phthalates: due to their effects on rodents, phthalates are classified as toxic to reproduction. It has been shown that phthalates alter sexual differentiation and the development of the reproductive system in male rats (Ema and Miyawaki, 2002; Gray *et al.*, 2000). Moreover, a relationship has been demonstrated between exposure to phthalates and DNA damage in human sperm (Duty *et al.*, 2003). Phthalates may also have impacts on the development and function of the liver. Correlation has been established between child exposure to plasticizers and asthma (Oie *et al.*, 1997).

- Short-chain chlorinated paraffins: information about the dangers and especially long-term impacts of these compounds is very scarce. It has been shown that they can cause damage to the liver, kidneys and thyroid of rats following long-term exposure in the laboratory (Farrar, 2000). Judging from their effects on rodents, they are suspected to be toxic to reproduction and carcinogenic.

These findings demonstrate that the chemicals analysed in this study evoke a wide range of adverse health effects in animals. Of course, one can never be certain that exposure is causing the same adverse effects in humans, since it is unethical to perform toxicity experiments on humans. However, given their demonstrable hazards for animals, the chemicals analysed in the present study must be regarded as potentially very harmful to human health. Moreover, these chemicals may particularly affect children. Small children are subject to higher exposures due to having twice as much volume of respiration per kg body weight as adults and spending a lot of time indoors. In addition, young children have a breathing zone close to the floor. It is estimated that children may ingest 100 mg of house dust per day, five times greater than adults (Ott and Roberts, 1998). This is of great concern given that infants and children, being at a stage when organs are developing, are generally more susceptible to toxic effects from chemical exposure.

Developing regulation

Although the European Union is one of the most important chemical producers in the world, the current rules governing the production and use of chemicals in Europe are failing to protect people and the environment from dangerous substances. In 2001, the European Commission recognised that certain chemicals have caused serious damages to human health and to the environment. Moreover, the incidence of some diseases (e.g. cancers and allergies) has increased significantly in recent decades. The European Commission has declared that certain chemicals could play a causative role in this. But the main problem remains the lack of knowledge about the impact of many chemicals on the human health and the environment.

In 2001, the European Commission adopted a proposal ("the White Paper") to reform EU chemical legislation. In this Paper, the Commission recognised that 99% of chemicals marketed in EU have not been properly tested for their effects on human health and the environment and that the risk assessment system is slow and inefficient. As a solution, the European Commission has proposed the outline of what could become the world's most comprehensive system of chemicals regulation: REACH (Registration, Evaluation and Authorisation of Chemicals). According to this proposal, chemicals must be registered and then tested. Chemicals of high concern would need authorisation to be put on the market.

This legislation is a step forward. However, industry pressure has resulted in a weakening of the REACH proposal since the original White Paper. It is vital that the REACH system include the substitution principle: hazardous chemicals used in consumer goods should be systematically substituted by less hazardous alternatives. This is the only way in which the chemical safety of our homes can be ensured.

Objective of the study

Among the thousands of chemicals on the market, some have become universally distributed in all sectors of our environment and have been demonstrated to accumulate in animal and human bodies. Moreover, their adverse effects on animal life have been demonstrated. These results strongly suggest that these chemicals are potentially very hazardous to human health.

Two recent studies have shown that these hazardous chemicals could be present as additives in typical consumer products such as textiles, personal care products, toys and electronic equipment (Peters, 2003; Peters, 2004). These additives may migrate from the products during normal use and thus accumulate in the indoor environment. The contamination level of the indoor environment has been poorly investigated until now. The objective of this study is to assess the hazardous chemical content of house dust collected in Belgian homes and offices, as well as in the European Parliament building in Brussels. This investigation measures the levels of chemicals known to be persistent, bioaccumulative and toxic and to be present in everyday consumer products.

This study, together with previous studies performed by Greenpeace elsewhere in Europe, should provide strong impetus to the Members of the European Parliament and European Ministers to adopt a sustainable chemicals policy, which keeps the environment and human health at the heart of the regulation.

Materials and Methods

Sample collection

Between 21st October and 7th November, Greenpeace Belgium collected 69 house dust samples in Belgium:

1. 51 samples were collected in volunteers' houses. The houses were selected according to their geographic location, with the aim of covering as much of the country as possible. Therefore, samples were collected in the following places:

   - 5 samples in the province of Hainaut (in and around the town of Mons)
   - 5 samples in the province of Namur (in and around the town of Namur)
   - 5 samples in the province of Liège (in and around the town of Liège)
   - 11 samples in the provinces of Brabant Wallon and Vlaamse Brabant (in and around Brussels)
   - 5 samples in the province of West-Vlaanderen (in the town of Oostende)
   - 5 samples in the province of Oost-Vlaanderen (in and around the town of Gent)
   - 5 samples in the province of Antwerpen (in and around the town of Antwerpen)
   - 5 samples in the province of Limburg
   - 5 samples in a small village in the Ardennes (Gros-Fays) – province of Namur

   Samples from the village in the Ardennes were collected as controls, as far as possible from chemical industry contamination. Samples from each region were pooled for chemical analysis. However, samples from the province of Limburg were split into 2 pools: one pool of 3 samples from normal homes and one pool of 2 samples specifically collected in "ecologically constructed" homes - meaning that mainly ecological materials were used in the building. Therefore, 10 pools were formed from these 51 samples.

2. 6 samples were collected in the offices of Members of the European Parliament in Brussels. These samples were pooled in one European Parliament sample.

3. 12 individual samples. These samples were collected in the homes or offices of 11 Belgian politicians, the home of 1 Swedish Member of the European Parliament and in the press briefing room of the European Parliament in Brussels. As two politicians shared the same office, the same individual sample corresponds to the working environment of these 2 politicians.

The type of samples, the pooling strategy and the place where they were collected is summarised in Table 1.

Volunteers were asked to avoid vacuum cleaning their homes for at least one week prior to the sample collection in order to collect sufficient quantity of dust for analysis.

All the samples were collected using the same model of vacuum cleaner (AEG Vampyr 1700 Watt), using a new AEG dust bag for each sample. In each house or office, the maximun number of rooms was vacuum-cleaned. Thus, the dust results obtained may be considered representative of the household in question.

After each sampling, the dust filter bag was removed from the vacuum cleaner, sealed with tape, sealed again inside a strong polyethylene (PE) bag and stored at room temperature. Samples were then sent to the laboratory of TNO Environmental Sciences, Energy Research and Process Innovation, Apeldoorn, The Netherlands for sample processing and quantitative analysis of a range of alkylphenols and bisphenol-A, phthalates, brominated flame retardants, organotin compounds and chlorinated paraffins. The TNO laboratory operates from an independent position, performing analysis and research for the government, industries and organisations. The individual chemicals that are determined in this study are listed in Table 2.

Sample pre-treatment

Samples were stored at room temperature until analysis. All individual samples were sieved through a pre-cleaned, solvent rinsed 2 mm sieve. Material that could be identified as not being house dust, e.g. small pieces of paper, plastic and metals, as well as human and animal hairs, were removed as far as possible. The sieved house dust was collected in a glass jar. Individual samples were set aside while samples to be pooled were further homogenised. An equal quantity by weight was taken from each constituent sample and these were mixed to form the pooled samples. Each individual and pooled sample was homogenised and analytical samples were collected for the chemical tests.

Analytical procedures

1. Sample extraction and clean-up:

- *Alkylphenols* – The analytical sample was soxhlet extracted overnight with dichloromethane. The extract was filtered and brought to a final volume of 25ml with dichloromethane. A part of this extract was evaporated to dryness under nitrogen. The residue was re-dissolved in a 50/50 mixture of milli-Q water and methanol. Finally, the extract was filtered through a 0.45 µm filter and prepared for instrumental analyses.

- *Flame retardants* – The analytical sample was soxhlet extracted overnight with dichloromethane. The extract was filtered and brought to a final volume of 25ml with dichloromethane. Diazomethane was added for the derivatization of tetrabromobisphenol-A in the sample extract. The extract was purified using column chromatography, concentrated to 0.2 ml and 1,2,3,4-tetrachloronaphthalene was added as an injection standard.

- *Organotin determination* – A sub-sample was sonicated for 60 minutes in a sodium dithiocarbamate solution in ethanol after the addition of tripropyltin chloride (TPrT) as an internal standard. The extracts were left in the dark at room temperature overnight and sonicated a second time for 60 minutes. Next, the extracts were centrifuged and the sample residue removed. Two additional internal standards, mono- and diheptyltin chloride (MHT and DHT) were added to control the extraction and derivatization procedure. After the addition of an acetate buffer (pH 4), HPLC water and a solution of sodium tetraethylborate (the derivatization agent) in ethanol, the mixture was extracted twice with hexane. The combined hexane fraction were dried and concentrated to a small volume. After purification of the extract using column chromatography on alumina, the extract was concentrated to a final volume of 1 ml and 1,2,3,4-tetrachloronaphthalene is added as an injection standard.

- *Phthalates and chlorinated paraffins* – The analytical sample was soxhlet extracted overnight with dichloromethane after the addition of surrogate standards. The extract was filtered and brought to a final volume of 25 ml with dichloromethane. The extract was divided in sub-extracts, which were purified for the different compound groups using column chromatography. The purified extracts were concentrated to a volume of 0.2 ml and 1,2,3,4-tetrachloronaphthalene was added to each as an injection standard.

2. Instrumental analysis

Alkylphenols and bisphenol-A were analysed using liquid chromatography in combination with mass spectrometry (LC/MS). The LC/MS was a Hewlett Packard 1100 LC/ESI/MS system equipped with a guard column and a Waters Symmetry C_{18} analytical column, length 15 cm, 3.9 mm i.d., 5 µm particle size. The mass spectrometer was used in the selected ion monitoring mode with negative ionisation and typically three ions were monitored.

Phthalates, flame retardants and organotin compounds were analysed using gas chromatography in combination with mass spectrometry (GC/MS). The GC/MS was a Hewlett Packard 6890 gas chromatograph equipped with HP-5MS capillary column, length 30 m, 0.25 mm i.d., 0.25 µm film thickness, and interfaced to a Hewlett Packard 5973 mass spectrometer. The mass spectrometer was used in the selected ion monitoring mode and typically two or three ions were monitored for each compound.

Chlorinated paraffins were analysed using gas chromatography in combination with mass spectrometry (GC/MS). The GC/MS was a Hewlett Packard 6890 gas chromatograph equipped with HP-5MS capillary column, length 30 m, 0.25 mm i.d., 0.25 µm film thickness, and interfaced to a Hewlett Packard 5973 mass spectrometer. The mass spectrometer was used in the negative ionisation mode with selected ion monitoring.

3. Calculation of results

Identification of target compounds was based on retention time and qualifier ion ratios. Quantification was based on external standards analysed within the same series as the sample extracts. The external standards were prepared from commercially available pure substances. The recovery of the added internal standards was calculated but only the organotin results were corrected for this recovery. No correction for blank value was applied. All results are expressed in mg/kg based on the sieved house dust sampl

Table 1: **Samples collected for the Belgian house dust study.** Summary of places where samples were collected (location and type of building), names of volunteers providing individual samples and pooling strategy**.**

Regions or Locations	Volunteers	Occupation of the volunteers	Type of building	Type of sample	Number of samples
Hainaut	anonymous	not communicated	homes	pooled	5
Namur	anonymous	not communicated	homes	pooled	5
Liège	anonymous	not communicated	homes	pooled	5
Brabant Wallon / Vlaamse Brabant	anonymous	not communicated	homes	pooled	11
West-Vlaanderen	anonymous	not communicated	homes	pooled	5
Oost-Vlaanderen	anonymous	not communicated	homes	pooled	5
Antwerpen	anonymous	not communicated	homes	pooled	5
Limburg	anonymous	not communicated	homes	pooled	3
Limburg (ecological homes)	anonymous	not communicated	homes	pooled	2
Gros-Fays (in the Ardennes)	anonymous	not communicated	homes	pooled	5
Brussels- European Parliament	Torben Lund Olga Zrihen Guido Sacconi Patricia McKenna Eija-Riitta A. Korhola Hans Kronberger	Member of the European Parliament Member of the European Parliament Member of the European Parliament Member of the European Parliament Member of the European Parliament Member of the European Parliament	office office office office office office	pooled	6
Press briefing room of the European Parliament	/	/	pressroom	individual	1
Brussels	Ludo Sannen	Environment minister for Flanders	office	individual	1
Brussels	Didier Gosuin	Environment minister for Brussels	office	individual	1
Namur	Serge Kubla	Finance minister for Wallonia	office	individual	1
Temse	Magda De Meyer	Member of the Belgian Parliament	home	individual	1
Antwerpen	Bart Staes	Member of he European Parliament	home	individual	1
Gent	Anne Van Lancker	Member of the European Parliament	home	individual	1
Nijlen	Els Van Weert	President of the "Spirit" party	home	individual	1
Sprimont	Thierry Detienne	Health minister for Wallonia	home	individual	1
Brussels	Inger Schörling	Member of the European Parliament	home	individual	1
Brussels	Freya Van den Bossche	Environment minister for Belgium	office	individual	1
Namur	Paul Lannoye Marie-Rose Cavalier	Member of the European Parliament Member of the Walloon Parliament	office	individual	1

Table 2: **Compound groups and specific compounds included in this study.**

Group	Specific compounds	Abbreviation
Alkylphenols (AP)	octylphenol	OP
	nonylphenol	NP
	bisphenol-A	BPA
Phthalates	dimethyl phthalate	DMP
	diethyl phthalate	DEP
	di-iso-butyl phthalate	DIBP
	di-n-butyl phthalate	DBP
	butylbenzyl phthalate	BBP
	dicyclohexyl phthalate	DCHP
	di-(2-ethylhexyl) phthalate	DEHP
	di-n-octyl phthalate	DOP
	di-iso-nonyl phthalate	DINP
	di-iso-decyl phthalate	DIDP
Brominated flame retardants (BFR)	2,2',4,4'-tetrabromo diphenylether	BDE 47
	2,2',4,4',5-pentabromo diphenylether	BDE 99
	2,2',4,4',6-pentabromo diphenylether	BDE 100
	2,2',4,4',5,5'-hexabromo diphenylether	BDE 153
	2,2',4,4',5,6'-hexabromo diphenylether	BDE 154
	2,2',3,4,4',5',6-heptabromo diphenylether	BDE 183
	octabromo diphenyl ether	BDE octa
	decabromo diphenylether	BDE 209
	hexabromo cyclododecane	HBCD
	tetrabromobisphenol A	TBBA
Organotins	monobutyltin	MBT
	dibutyltin	DBT
	tributyltin	T3BT
	tetrabutyltin	T4BT
	monooctyltin	MOT
	dioctyltin	DOT
	triphenyltin	TPT
Chlorinated paraffines	Short-chain chlorinated paraffines	SCCP

Results and Discussion

General Belgian results

The Belgian samples consisted of 11 pooled samples (collected in different Belgian regions and in the EU Parliament) and 12 individual samples. Each pooled sample resulted from the pooling of 2 to 11 individual samples (see Materials and Methods). Concentrations of the five target groups of compounds analysed quantitatively in the current study are summarised in Table 3. This table displays the frequency with which each chemical was found (occurrence) and the mean, median, minimum and maximum concentration values for each chemical.

The mean value was calculated from individual and pooled samples, taking into account the number of samples that were grouped in each pool (e.g. individual samples had a weight of 1 and the Hainaut pooled sample had a weight of 5). The median value represents the middle concentration value (the value that has the same number of lower and higher values for the specified chemical) and has only been determined for the pooled samples. The median has the advantage of not taking into account some abnormal values, which could disproportionately influence the mean. However, it is difficult to identify abnormal values with confidence, considering the small number of values available here for the pooled samples. Using only the median value, some interesting results could thus be missed. Therefore, the mean value was also used and offers the opportunity to take into account the individual sample results. Values below the limits of detection were taken as zero for both means and medians. Ranges of concentration for each chemical are also given, in the form of the highest (maximum) and lowest (minimum) values recorded for all the Belgian samples.

Phthalate esters, alkylphenols and organotin compounds were present in every sample. Phthalate esters were the most abundant chemical group with a mean concentration value of 942.5 mg/kg. This is consistent with the results of previous analyses performed in other European countries (Santillo *et al.*, 2003a; Santillo *et al.*, 2003b).

Results of the studies of house dust in Germany, Spain, France, Italy, Slovakia and the UK are compared to the Belgian results in Figure 1. This figure shows the mean concentration for the following groups of compounds: phthalate esters, organotin compounds and alkylphenols. The phthalate concentrations in Belgium dust are generally in the range of the phthalate concentrations found in the other European countries, although higher than in the UK and lower than in France, Germany and Slovakia. However, German and Slovak results have to be treated with caution considering the small number of samples collected in these countries.

The concentration of organotin compounds in Belgian house dust (a mean of 2.47 mg/kg) is also within the range of concentrations found in the other European countries (Figure 1). In contrast, the alkylphenol concentration (a mean of 5.5 mg/kg) measured in Belgium is markedly higher than in house dust collected in other continental European countries, although half the UK average concentration. Similar conclusions can be drawn if the contribution of Bisphenol-A, that was not previously assessed, is withdrawn from the total alkylphenol concentration.

Brominated flame retardants were also detected in nearly all the Belgian samples, but several compounds were found in only few samples. As the Belgian mean concentration arises from a few high values, the mean concentration is not representative for the population.

Then, comparisons should be based on the medians and not on the means. However, comparisons of the Belgian results with other European results are very speculative, as the detection limit of the method followed in this study is much higher than that used in the previous studies. Therefore, some of the chemical presence measured in the other European countries would not be detected with the method used in this study. The comparison is also speculative because the concentration of brominated flame retardants has been calculated on the basis of different compounds. However, it is remarkable that some specific brominated flame retardants are less frequently present in Belgian samples than in other European samples. For example, BDE-209 that has generally been abundantly found in dust in the other studies was only detected in one heavily contaminated Belgian sample. But it is as remarkable that the maximum concentration of some brominated flame retardants (HBCD and BDE-209) measured in Belgium was between 8 and 15 times higher than that measured elsewhere in Europe.

Finally, chlorinated paraffins were present in 35% of the Belgian samples at a concentration lower than in other European countries (Santillo *et al.*, 2003b).

Taken together, this first analysis of the Belgian results demonstrates the universal presence of most of the hazardous chemicals analysed in this report. Moreover, the concentrations of some chemical groups are very high (e.g. phthalates) and/or higher than in other European countries (alkylphenols). The Belgian house dust registered some worrisome European records in hazardous chemical concentrations

Concentrations of specific chemicals are discussed below for each of the five chemical groups. Detailed results for each pooled and individual sample are also presented and discussed in the following section.

Table 3: **summary of analytical results for chemicals measured in the Belgian dust samples**					
Compound	**occurrence**	**Belgian mean value**	**Belgian median value**	**minimum value**	**maximum value**
type of samples	individual and pooled	individual and pooled	pooled	individual and pooled	individual and pooled
Phthalate esters			mg/kg dust		
DMP	23/23	1.5	0.6	0.3	13.7
DEP	23/23	10.0	3.8	0.2	36.9
DIBP	23/23	74.6	56.8	23.0	231.1
DBP	23/23	32.4	32.3	12.7	113.4
BBP	23/23	195.8	97.6	9.7	968.2
DCHP	21/23	1.7	0.8	<0.1	18.9
DEHP	23/23	338.7	245.0	63.1	840.7
DPP	0/23	<0.1	<0.1	<0.1	<0.1
DOP	20/23	3.3	2.7	<0.1	15.5
DIOP	18/23	55.7	18.9	<1	481.4
DINP	23/23	162.9	102.9	19.9	1560.6
DIDP	23/23	66.0	61.2	12.6	171.5
total	**23/23**	**942.5**	**702.3**	**210.2**	**2861.0**
Alkylphenol compounds			mg/kg dust		
BPA	23/23	2.2	1.2	0.8	7.2
OP	1/23	<0.2	<0.2	<0.2	0.3
NP	23/23	3.2	2.3	1.4	7.9
total	**23/23**	**5.5**	**4.5**	**2.4**	**14.7**
Brominated flame retardants			mg/kg dust		
BDE-47	10/23	0.026	<0.02	<0.02	0.751
BDE-100	4/23	0.006	<0.02	<0.02	0.207
BDE-99	18/23	0.054	0.029	<0.02	0.944
BDE-154	1/23	0.000	<0.02	<0.02	0.033
BDE-153	3/23	0.002	<0.02	<0.02	0.086
BDE-183	2/23	0.001	<0.02	<0.02	0.075
BDE-octa	0/23	<0.1	<0.1	<0.1	<0.1
BDE-209	1/23	4.401	<0.1	<0.1	303.677
HBCD	6/23	4.805	<0.02	<0.02	57.554
TBBA	8/23	0.068	<0.02	<0.02	0.385
total	**20/23**	**9.3634**	**0.085**	**<0.02**	**361.520**
Organotin compounds			mg/kg dust		
MBT	23/23	0.567	0.147	0.044	3.729
DBT	23/23	1.417	0.499	0.071	6.085
TBT	22/23	0.280	0.051	<0.01	2.499
TeBT	7/23	0.006	<0.01	<0.01	0.024
MOT	23/23	0.086	0.061	0.008	0.289
DOT	23/23	0.113	0.062	0.012	0.913
TPT	2/23	0.001	<0.01	<0.01	0.019
total	**23/23**	**2.469**	**0.690**	**0.154**	**10.020**
Chlorinated paraffins			mg/kg dust		
total	**8/23**	**2.08**	**<1**	**<1**	**12.79**

The occurrence represents the frequency with which a given chemical was found. The mean values were calculated from individual and pooled samples, taking into account the number of samples grouped in each pool. The median values represent the middle concentration and have only been calculated from the pooled samples. Minimum and maximum values respectively represent the lowest and highest recorded value among all the Belgian samples. Meaning of abbreviations is given in Table 2.

Comparison of chemical content in house dust from several EU countries

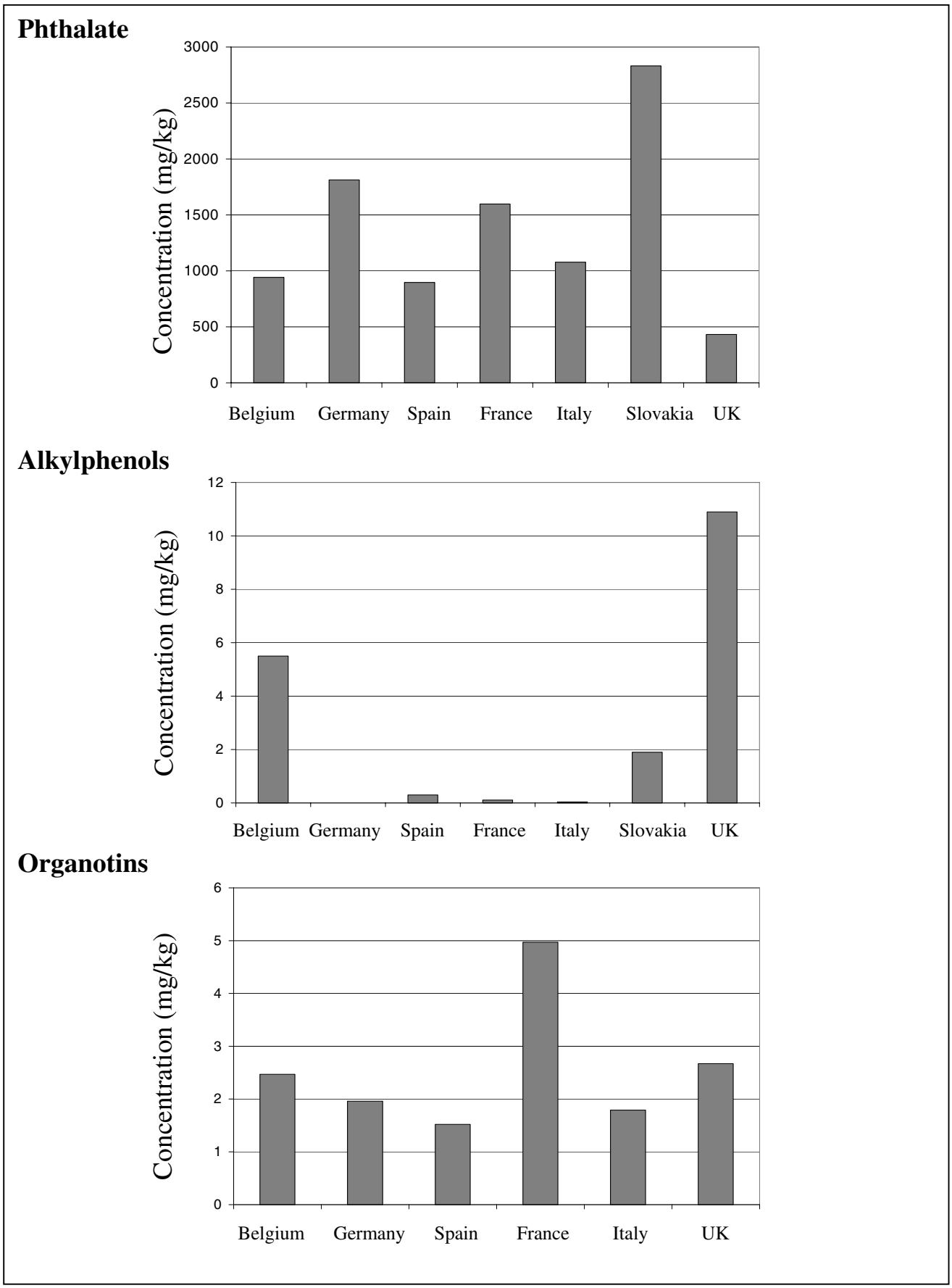

Figure 1: **Comparision of the mean concentrations of phthalate esters, organotin compounds and alkylphenols measured in house dust collected in Belgium with those from other EU countries (Santillo *et al.* (2003a) and Santillo *et al.* (2003b)).**

Phthalate esters

1. General Belgian results

Twelve phthalates were measured in the Belgium house dust samples. With the exception of diphenyl phthalate (DPP) all phthalates were found in almost all samples (Table 3). The most prominent phthalate was di-(2-ethylhexyl) phthalate (DEHP) at a mean concentration of 339 mg/kg (median concentration: 245 mg/kg). This is consistent with the phthalate content of house dust collected in all the other European countries (Santillo *et al.*, 2003a; Santillo *et al.*, 2003b). The high concentration of DEHP can be explained by its reported common and widespread use in soft PVC products in the home. Moreover, a recent study has measured DEHP in children pyjamas (Peters, 2003). DEHP is a known developmental toxin, classified in Europe as "toxic to reproduction". The high DEHP concentration in house dust demonstrates that its high volume use leads to continuous and substantial human exposure to this hazardous chemical.

Of the other phthalates, the most abundant were di-isononyl phthalate (DINP), butylbenzyl phthalate (BBP) and, to a somewhat lesser extent, di-isodecyl phthalate (DIDP), di-n-butyl phthalate (DBP), di-isooctyl phthalate (DIOP) and di-isobutylphtalate (DIBP). The highest concentration, 1561 mg/kg, was found for DINP. DIDP, DINP and BBP have been measured, sometimes at very high concentrations, in several consumer products including textiles, toys and paints (Peters, 2003). Another phthalate, di-ethylphthalate DEP, was a common component of all the Belgian samples at a mean concentration of 10 mg/kg. This probably results from its widespread use in perfumes, cosmetics and other personal care products. Duty *et al.* (2003) have recently suggested that this phthalate may be capable of interfering with sperm development in humans.

2. Pooled samples

The most contaminated sample was collected in the European Parliament, with a total phthalate content of 2861 mg/kg (Table 4A). Among the pooled samples, Oost-Vlaanderen, Namur and Hainaut were the three regions where the highest phthalate content was measured, with a total concentration ranging from about 1100 to about 1300 mg/kg. These concentrations result mainly from the DEHP content but it should be noted that these samples also had the highest concentrations of most of the other phthalates. For most phthalates, the lowest concentration was measured in the samples collected in Antwerpen en Liège regions and in the ecological homes from the Limburg region. Their total phthalate concentration ranged from 283.5 to 494.3 mg/kg.

3. Individual samples

Among the individual samples, the highest concentration of total phthalates was found in the European Parliament **press briefing room**, with a total concentration of 2048 mg/kg (Table 4B). This is consistent with the high phthalate level found in the pooled European Parliament sample. The primary contributors to the total phthalate concentration were DEHP, DINP, DIDP and DIBP. The total phthalate content of house dust collected in the offices of **Mr Kubla** and **Mr Gosuin** and in the homes of **Mrs Van Weert** and **Mr Staes** was in each case higher than the average total phthalate level in the Belgian house dust. Although a wide range of phthalates contribute to the total phthalate content in the dust from **Mr Staes**'s house, the high total phthalate level is primarily due to elevated concentrations of DEHP and DIDP for **Mr Gosuin**; DINP, DEHP and DIDP for **Mr Kubla**; and DINP, DEHP and DBP for **Mrs Van Weert**.

For the other individual samples, the presence of total phthalates at a concentration of at least 210 mg/kg is cause for concern given the persistent, bioaccumulative and toxic properties of these chemicals. The total phthalate concentration does not seem to be associated with the kind of building in which the dust was collected. On the one hand, the lowest total phthalate levels were found in the houses of **Mrs Van Lancker** and **Mrs Schörling** as well as in the office of **Mr Lannoye** and **Mrs Cavalier**. On the other hand, the highest levels were found in the offices of **Mr. Gosuin** and **Mr. Kubla** as well as in the houses of **Mr Staes** and **Mrs Van Weert**. The following specific results can also be noted:

- The dust collected in **Mrs Van Lancker** and **Mrs Schörling** house contained a level of DBP higher than the Belgian mean.

- **Mr Sannen**'s office contained a level of DINP higher that the Belgian mean and a high DEHP concentration.

- **Mrs De Meyer**'s house contains levels of DINP and DBP higher that the Belgian mean.

- The phthalate concentration in **Mr Detienne**'s house mainly comes from the DEHP level which is higher than the Belgian mean.

- The DMP and DBP content in the office of **Mr Lannoye** and **Mrs Cavalier** is higher than the Belgian mean. The highest phthalate concentration is of DEHP.

- The following phthalate levels found in **Ms Van den Bossche**'s office were higher than the Belgian mean: DBP, DOP, DINP and DIDP.

Results indicated that DINP was the next most abundant phthalate after DEHP. Allsopp *et al.* (2000) found only DINP in five samples of new PVC flooring purchased in the UK, suggesting a market shift away from DEHP for this application in the recent years. Peters (2003) also measured a higher DINP than DEHP concentration (up to 53.7 g/kg) in textiles, toys and paints. This shift may be a consequence of serious concerns relating to suspected reproductive toxicity and other hazards associated with DEHP. However, this shift should give no room for complacency, as DINP has also been shown to exhibit a range of toxic effects in laboratory animals.

Taken together, these results indicate that phthalates are contaminants of the indoor household environment. It does not appear that the contamination level depends on outdoor contamination, as the total phthalate concentration was higher in house dust collected in the Ardenne region than in the Antwerpen region where there is a high level of chemical industry activity. Similarly, the contamination level does not seem to depend on the type of building where the dust was collected. This suggests that these hazardous chemicals have probably been released from materials or consumer products used indoors. Although it is not possible to deduce specific source products, the differences in total and relative abundance of phthalates probably reflect differences in the type and number of products in the rooms.

Table 4A: **Phthalate content of pooled dust samples collected in Belgium**

	Phthalates												
	DMP	**DEP**	**DIBP**	**DBP**	**BBP**	**DCHP**	**DEHP**	**DPP**	**DOP**	**DIOP**	**DINP**	**DIDP**	**Total**
Pooled samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Hainaut	1.0	16.9	149	36	214	2.8	352	<0.1	4.2	30	232	61	1099.8
Namur	0.3	12.4	77	36	207	4.6	447	<0.1	1.7	35	197	112	1129.5
Liège	0.5	18.9	66	21	89	<0.1	203	<0.1	1.1	7.2	59	28	494.3
Gros-Fays (in the Ardennes)	0.5	3.3	53	18	43	0.5	242	<0.1	1.1	4.4	78	90	533.9
Brabant Wallon / Vlaamse Brabant	0.7	3.3	57	32	98	0.8	245	<0.1	3.7	15	50	32	536.3
Antwerpen	0.6	3.4	40	32	30	0.3	204	<0.1	1.8	11	45	24	392.0
Oost-Vlaanderen	3.5	3.8	60	37	369	0.8	610	<0.1	11	23	117	61	1296.5
West-Vlaanderen	0.3	20.8	37	17	87	1.1	291	<0.1	3.7	<1	221	50	729.4
Limburg	0.6	1.5	46	31	193	3.6	231	<0.1	2.7	26	100	67	702.3
Limburg (ecological homes)	0.7	3.1	28	44	14	0.7	63	<0.1	0.7	4.8	103	22	283.5
Brussels- European Parliament	5.2	36.9	231	34	968	<0.1	780	<0.1	3.1	481	168	152	2861.0
method detection limit	0.1	0.1	0.1	0.1	0.1	0.1	1	0.1	0.1	1	1	1	
Belgian mean	1.5	10.0	74.6	32.4	195.8	1.7	338.7	<0.1	3.3	55.7	162.9	66.0	942.5
Belgian median	0.61	3.77	56.82	32.32	97.56	0.78	244.99	<0.1	2.68	18.91	102.91	61.15	702.3

Abbreviations: DMP- dimethyl phthalate, DEP- diethyl phthalate, DIBP- di-iso-butyl phthalate, DBP- di-n-butyl phthalate, BBP- butylbenzyl phthalate, DCHP- dicyclohexyl phthalate, DEHP- di-(2-ethylhexyl) phthalate, DPP- diphenyl phthalate, DOP- di-n-octyl phthalate, DIOP- di-iso-octyl phthalate, DINP- di-iso-nonyl phthalate, DIDP- di-iso-decyl phthalate

Table 4B: **Phthalate content of individual dust samples collected in Belgium**

	Phthalates												
	DMP	**DEP**	**DIBP**	**DBP**	**BBP**	**DCHP**	**DEHP**	**DPP**	**DOP**	**DIOP**	**DINP**	**DIDP**	**Total**
Individual samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Mr Sannen	0.4	6.8	40	16	30	0.8	279	<0.1	1.7	9.3	313	62	759.9
Mr Gosuin	1.0	3.9	47	17	27	19	735	<0.1	1.1	4.5	111	172	1138.4
Mr Kubla	6.4	3.1	38	13	14	0.3	157	<0.1	<0.1	<1	1561	141	1933.0
Mrs De Meyer	0.4	1.5	29	43	106	0.5	116	<0.1	<0.1	12	186	63	557.7
Mr Staes	0.6	0.2	76	20	409	2.4	103	<0.1	6.4	91	298	66	1072.8
Mrs Van Lancker	0.7	0.8	23	64	14	0.5	74	<0.1	0.7	<1	20	13	210.2
Mrs Van Weert	0.6	0.6	45	113	36	0.3	203	<0.1	<0.1	2.3	696	33	1130.3
Mr Detienne	0.3	1.1	28	13	10	0.6	380	<0.1	0.5	7.7	53	26	520.3
Mrs Schörling	0.9	1.2	42	56	10	0.8	114	<0.1	0.7	4.8	152	22	403.9
Ms Van den Bossche	0.5	2.8	36	34	20	0.4	202	<0.1	16	<1	171	140	621.6
Mr Lannoye Mrs Cavalier	14	2.1	31	96	39	17	220	<0.1	1.2	<1	59	44	522.1
EU Parliament press briefing room	0.8	2.7	97	25	107	1.1	841	<0.1	4.2	19	818	132	2048.4
method detection limit	0.1	0.1	0.1	0.1	0.1	0.1	1	0.1	0.1	1	1	1	
Belgian mean	1.5	10.0	74.6	32.4	195.8	1.7	338.7	<0.1	3.3	55.7	162.9	66.0	942.5
Belgian median	0.61	3.77	56.82	32.32	97.56	0.78	244.99	<0.1	2.68	18.91	102.91	61.15	702.3

Abbreviations: DMP- dimethyl phthalate, DEP- diethyl phthalate, DIBP- di-iso-butyl phthalate, DBP- di-n-butyl phthalate, BBP- butylbenzyl phthalate, DCHP- dicyclohexyl phthalate, DEHP- di-(2-ethylhexyl) phthalate, DPP- diphenyl phthalate, DOP- di-n-octyl phthalate, DIOP- di-iso-octyl phthalate, DINP- di-iso-nonyl phthalate, DIDP- di-iso-decyl phthalate

Alkylphenol compounds

1. General Belgian results

Nonylphenol (NP) and bisphenol-A (BPA) were detected in all the Belgian samples at concentrations ranging from 0.75 to 7.9 mg/kg (Table 3). In contrast, octylphenol (OP) was detected in only one sample with a concentration of 0.31 mg/kg.

These Belgian results contrast with the analysis of house dust collected in continental European countries (Santillo *et al.*, 2003b). Indeed, NP was not detectable in the majority of their samples. In house dust from the UK (Santillo *et al.*, 2003a), the NP mean concentration was higher (10.5 mg/kg house dust) than in the Belgian samples (Figure 1). However, NP was not detected in all the collected UK samples (22/29). The abundance of NP in the Belgian samples suggests that this substance has widespread use and/or occurrence in household products. Indeed, NP was recently measured, sometimes at high concentration (2.3 g/kg), in a variety of consumer goods including children pyjamas, plastic toys and paints (Peters, 2003). Nonylphenol is widely recognised as an endocrine disruptor and is also suspected of exerting direct effects on sperm function in mammals (Adeoya-Osiguwa *et al.*, 2003).

BPA, present in the Belgian samples at a mean concentration of 2.2 mg/kg, was not analysed in the previous house dust investigations performed by Greenpeace. The widespread presence of BPA in Belgian samples is consistent with its wide use as intermediate in the production of epoxy resins, polycarbonate plastics and flame retardants. Peters (2003) has measured BPA in baby feeding bottles at a concentration of 14 mg/kg. Research of a few years ago indicated that BPA has oestrogenic potency and it is therefore generally included as one of the suspected endocrine disruptors.

2. Pooled samples

The most contaminated sample was collected in the European Parliament, with a total alkylphenol content of 14.7 mg/kg (Table 5A). Among the other pooled samples, that from West-Vlaanderen had the highest alkylphenol content, with a total concentration of 7.1 mg/kg. Although BPA and NP were equally present in the dust collected in the European Parliament, the West-Vlaanderen concentration mainly comes from NP (6.3 mg/kg). The lowest alkylphenol concentrations were measured in the samples collected in Antwerpen, the Ardennes and Hainaut regions with concentrations ranging from 2.7 to 3.1 mg/kg. The sample collected in the ecological homes from the Limburg region did not have a markedly lower alkylphenol concentration than the Belgian mean. Except for the sample from Oost-Vlaanderen, concentrations of NP were always higher than of BPA.

3. Individual samples

Among the individual samples, the highest concentration was found in the office of **Mr Gosuin** with an alkylphenol concentration of 12.7 mg/kg (Table 5B). This mainly comes from the NP concentration (7.9 mg/kg). The NP concentration in **Mr Gosuin**'s office is the highest among all the Belgian samples. The **press briefing room** of the EU Parliament also contained a high alkylphenol concentration (11.9 mg/kg). This is consistent with the high alkylphenol level found in the pooled European Parliament sample. As for the EU Parliament sample, BPA and NP concentrations in this **press briefing room** are roughly similar.

The office of **Ms Van den Bossche** was also highly contaminated by alkylphenols with a concentration of 10.7 mg/kg. In contrast with most of the other samples, the main contribution to this alkylphenol concentration is the BPA level (6.4 mg/kg). High level of alkylphenols were also found in the offices of **Mr Kubla** and **Mr Sannen** with total concentrations of 8.7 and 6.3 mg/kg, respectively. BPA concentration at **Mrs Schörling**'s house (2.4 mg/kg) is higher than the Belgian mean BPA concentration. All the other individual samples, although under the Belgian mean concentration, generally contained an alkylphenol level higher than that found in other European countries (Santillo *et al.*, 2003a, Santillo *et al.*, 2003b). Moreover, given the hazardous and persistent properties associated with alkylphenols, all the concentrations found in this study are of very high concern.

Taken together, these results indicate that alkylphenols are widespread contaminants of the indoor environment. The concentrations of these chemicals in house dust are of very high concern given the properties of these chemicals. Their hazards were officially recognised when the Ministerial Meeting of OSPAR included NP on the first list of chemicals for priority action (cessation of discharges, emissions and losses of all hazardous substances to the marine environment by 2020). The Belgian alkylphenol concentrations are significantly higher than levels detected in other European countries, except the UK. This demonstrates that alkylphenol concentrations are not linked to geographic location, as suggested by previous studies, given the differences between continental European countries and the UK (Santillo *et al.*, 2003a; Santillo *et al.*, 2003b). The Belgian study also brings new information about the high BPA content in each house dust sample. Finally, as for phthalates, it does not seem that the contamination level depends on outdoor contamination, as alkylphenol concentrations were similar in house dust collected in the Ardenne region and in the Antwerpen region where there is a high level of chemical industry activity.

Table 5A: **Alkylphenols content of pooled dust samples collected in Belgium**				
	BPA	**OP**	**NP**	**Total**
Pooled samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Hainaut	1.2	<0.2	1.8	3.1
Namur	2.0	<0.2	2.5	4.5
Liège	1.2	<0.2	2.3	3.5
Gros-Fays (in the Ardennes)	1.2	<0.2	1.9	3.1
Brabant Wallon / Vlaamse Brabant	1.5	<0.2	2.3	3.9
Antwerpen	1.2	<0.2	1.5	2.7
Oost-Vlaanderen	3.6	<0.2	2.0	5.6
West-Vlaanderen	0.75	<0.2	6.3	7.1
Limburg	1.0	<0.2	3.9	4.9
Limburg (ecological homes)	1.1	<0.2	4.0	5.1
Brussels- European Parliament	7.2	<0.2	7.5	14.7
method detection limit	0.1	0.2	0.2	
Belgian mean	2.2	<0.2	3.2	5.5
Belgian median	1.2	<0.2	2.3	4.5

Abbreviations: BPA-bisphenol-A, OP-octyphenol, NP-nonylphenol

Table 5B: **Alkylphenol content of individual dust samples collected in Belgium**				
	BPA	**OP**	**NP**	**Total**
Individual samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Mr Sannen	2.3	<0.2	4.0	6.3
Mr Gosuin	4.8	<0.2	7.9	12.7
Mr Kubla	4.8	<0.2	4.0	8.7
Mrs De Meyer	0.87	<0.2	1.6	2.4
Mr Staes	1.7	0.31	2.3	4.4
Mrs Van Lancker	1.0	<0.2	1.4	2.4
Mrs Van Weert	0.79	<0.2	1.7	2.5
Mr Detienne	0.85	<0.2	2.0	2.8
Mrs Schörling	2.4	<0.2	2.9	5.2
Ms Van den Bossche	6.4	<0.2	4.3	10.7
Mr Lannoye Mrs Cavalier	1.4	<0.2	2.3	3.7
EU Parliament press briefing room	5.0	<0.2	6.9	11.9
method detection limit	0.1	0.2	0.2	
Belgian mean	2.2	<0.2	3.2	5.5
Belgian median	1.2	<0.2	2.3	4.5

Abbreviations: BPA-bisphenol-A, OP-octyphenol, NP-nonylphenol

Brominated flame retardants

1. General Belgian results

In this study, 10 different brominated flame retardants (BFRs) were analysed in the house dust samples. Two types of BFRs can be distinguished, the so-called additive flame retardants such as polybrominated diphenyl ethers (PBDE) and hexabromocyclododecane (HBCD), and reactive flame retardants such as tetrabromobisphenol-A (TBBA), which is chemically bound to, and part of, the polymer material. BFRs were detected in most of the Belgian samples (87%), although some specific compounds are present in only few samples. The BFRs found most often were BDE-99, BDE-47 and TBBA (Table 3). BDE-99 and BDE-47 were also widely detected in house dust collected elsewhere in Europe (Santillo *et al.*, 2001; Santillo *et al.*, 2003a; Santillo *et al.*, 2003b). The presence of TBBA is particularly interesting as it is generally thought that this chemical is very tightly bound to the plastics or resins in which it is used and, therefore, unlikely to be lost to the environment. The fact that this chemical is more strongly bound to the material could explain why TBBA has been quantified in relatively low amount. In contrast to previous studies, which found BDE-209 in all house dust samples at high concentrations, this chemical was measured in only one Belgian sample, though at a very high concentration (303.7 mg/kg). HBCD was found in about 25% of the samples with a maximum concentration of 58 mg/kg.

Santillo *et al.* (2003b) have indicated that BFR levels were markedly lower in house dust samples collected in continental European countries than in the UK. However, these chemicals were found in most of the analysed samples. It is difficult to compare results from these studies with those of the present study since detection limits were different. For example, some concentrations measured in the other European countries would not be detectable with the method used in this study. Therefore, neither the mean value (too influenced by the extreme values) nor the median value (hiding some interesting results) are able to give a relevant view of the Belgian contamination. Two conclusions can however be drawn:

- BDE-209 and HBCD concentrations in Belgian dust are generally lower than in other European countries.

- For 5 BFRs, higher maximum values were measured in Belgium than in other European countries. Indeed, the maximum Belgian concentrations of BDE-209 (303.7 mg/kg), HBCD (57.6 mg/kg) and TBBA (0.38 mg/kg) were higher than maximum values from the other European countries. Moreover, the Belgian maximum values of BDE-99 (0.94 mg/kg) and BDE-47 (0.76 mg/kg) were higher than the maximum concentrations measured in the other continental European countries.

2. Pooled samples

Among the pooled samples, the highest BFR concentrations were measured in house dust collected in the European Parliament and the regions of Limburg (including the ecological houses) and West-Vlaanderen (Table 6A). This comes from an especially high concentration of HBCD, ranging from 11 mg/kg to 21 mg/kg (for the EU Parliament). These concentrations were all higher than the maximum concentrations previously measured in house dust from other European countries. Moreover, two other BFRs (BDE-47 and BDE-99) were measured in the dust samples from the Limburg region and the EU Parliament.

According to the detection limit problems explained before, it would be too speculative to analyse the results of these pooled samples more deeply.

3. Individual samples

The most worrying individual result comes from the office of **Ms Van den Bossche**. Here, the BDE-209 and HBCD concentrations were respectively 15 times and 8 times higher than the maximum concentrations ever measured in the other European dust samples. Moreover, three other BFRs (TBBA, BDE-99 and BDE-47) were detected in the dust of this office (Table 6B).

The **press briefing room** of the EU Parliament was also highly contaminated with HBCD (13 mg/kg). This is consistent with results from the pooled EU Parliament sample. BDE-99 and BDE-183 were also detected in the **press briefing room** sample.

Results from the offices of **Mr Sannen**, **Mr Gosuin** and **Mr Kubla** and from the house of **Mrs Schörling** are also of concern. Between 4 and 7 different BFRs were measured in these samples.

Finally, two different BFRs were detected in the house of **Mrs De Meyer** and one BFR compound each in the house of **Mr Staes**, the house of **Mr Detienne** and the office of **Mr Lannoye** and **Mrs Cavalier**.

Taken together, these results indicate the presence of BFRs in most of the Belgian samples. Due to the high detection limit of the analytical method, the presence of some BFRs has surely been missed. Therefore, the failure to detect measurable levels of some BFRs does not mean that they were entirely absent and that people are not exposed to them. However, their detected presence surely raises important concerns for human health.

This is especially worrying in the locations with high levels of HBCD and BDE-209 compounds. Indeed, BDE-209 is a highly persistent chemical, which has been shown to affect bone development (Olsson *et al.*, 1998). HBCD is highly persistent, very bioacumulative and capable of interfering with genetic material in human cell lines (Helleday *et al.*, 1999), a possible indicator of carcinogenic potential. Given these properties, the extremely high concentrations in the office of **Ms Van den Bossche**, in the EU parliament and in some pooled samples suggest that human health could be potentially affected in these locations. This contamination probably comes from the use of BFRs in a wide range of industrial and consumer products including electrical appliances, lighting, wiring, textiles and other furnishings.

Table 6A: **Brominated flame retardant content of pooled dust samples collected in Belgium**

	Brominated flame retardants										
	BDE-47	**BDE-100**	**BDE-99**	**BDE-154**	**BDE-153**	**BDE-183**	**BDE-octa**	**BDE-209**	**HBCD**	**TBBA**	**Total**
Pooled samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Hainaut	0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.04
Namur	0.03	<0.02	0.06	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.08
Liège	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.05
Gros-Fays (in the Ardennes)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.00
Brabant Wallon / Vlaamse Brabant	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.03
Antwerpen	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	0.38	0.38
Oost-Vlaanderen	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.02
West-Vlaanderen	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.1	<0.1	16	<0.02	16.15
Limburg	0.04	<0.02	0.06	<0.02	<0.02	<0.02	<0.1	<0.1	11	<0.02	11.20
Limburg (ecological homes)	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.1	<0.1	12	<0.02	11.97
Brussels- European Parliament	0.03	<0.02	0.07	<0.02	<0.02	<0.02	<0.1	<0.1	21	0.32	21.03
method detection limit	0.02	0.02	0.02	0.02	0.02	0.02	0.1	0.1	0.02	0.02	
Belgian mean	0.026	0.006	0.054	<0.02	0.002	<0.02	<0.1	4.401	4.805	0.068	9.36
Belgian median	<0.02	<0.02	0.029	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.09

Abbreviations: BDE-brominated diphenylethers (tribromo- to decabromo-), HBCD-hexabromo cyclododecane, TBBA-tetrabromobisphenol-A

Table 6B: **Brominated flame retardant content of individual dust samples collected in Belgium**

	Brominated flame retardants										
	BDE-47	**BDE-100**	**BDE-99**	**BDE-154**	**BDE-153**	**BDE-183**	**BDE-octa**	**BDE-209**	**HBCD**	**TBBA**	**Total**
Individual samples	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Mr Sannen	0.32	0.11	0.40	<0.02	0.04	<0.02	<0.1	<0.1	<0.02	0.02	0.90
Mr Gosuin	0.06	0.02	0.13	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	0.23	0.44
Mr Kubla	0.75	0.21	0.94	0.03	0.09	0.08	<0.1	<0.1	<0.02	0.23	2.33
Mrs De Meyer	0.05	<0.02	0.06	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.11
Mr Staes	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.02
Mrs Van Lancker	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.00
Mrs Van Weert	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.00
Mr Detienne	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.03
Mrs Schörling	0.07	0.04	0.15	<0.02	0.02	<0.02	<0.1	<0.1	<0.02	0.03	0.31
Ms Van den Bossche	0.03	<0.02	0.05	<0.02	<0.02	<0.02	<0.1	304	58	0.21	361.52
Mr Lannoye Mrs Cavalier	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	0.10	0.10
EU Parliament press briefing room	<0.02	<0.02	0.07	<0.02	<0.02	0.03	<0.1	<0.1	13	<0.02	12.61
method detection limit	0.02	0.02	0.02	0.02	0.02	0.02	0.1	0.1	0.02	0.02	
Belgian mean	0.026	0.006	0.054	<0.02	<0.02	<0.02	<0.1	4.401	4.805	0.068	9.36
Belgian median	<0.02	<0.02	0.029	<0.02	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.09

Abbreviations: BDE-brominated diphenylethers (tribromo- to decabromo-), HBCD-hexabromo cyclododecane, TBBA-tetrabromobisphenol-A

Organotin compounds

1. General Belgian results

In this study, the house dust samples were analysed for seven individual organotin compounds. Monobutyltin (MBT), dibutyltin (DBT), mono-octyltin (MOT) and di-octyltin (DOT) were found in all samples, tributyltin (TBT) in all but one. Triphenyltin (TPT) and tetrabutyltin (TeBT) were found in 9% and 30% of the samples respectively (Table 3). The mean Belgian concentration of organotin compounds (2.47 mg/kg) is within the range of the concentrations measured in house dust collected in the other European countries (Santillo *et al.*, 2003a; Santillo *et al.*, 2003b), including Parliament buildings from eight countries (Santillo *et al.*, 2001).

The most prominent organotin was DBT at a mean concentration of 1.42 mg/kg (median concentration: 0.5 mg/kg). This concentration is higher than that in most of the house dust samples collected in other countries, where DBT was also among the most abundant organotins. The DBT concentrations measured in 8 Belgian samples were higher than the maximum DBT level ever measured in samples from the other European countries. This high DBT concentration in Belgian samples is very worrying, given that DBT is toxic to the developing immune and nervous systems in mammals (Kergosien and Rice, 1998). The predominance of DBT among organotins was also detected in samples of new PVC flooring (Allsopp *et al.*, 2000).

The mean concentration of MBT (0.567 mg/kg), TBT (0.280 mg/kg), DOT (0.113 mg/kg) and MOT (0.086 mg/kg) in the Belgian samples was also very worrying. The same chemicals were predominant in house dust from the other European countries (Santillo *et al.*, 2001; Santillo *et al.*, 2003a; Santillo *et al.*, 2003b). Two Belgian samples had higher levels of TBT than the highest concentration measured in the other European samples. This high and universal presence of TBT is probably a consequence of its use as fungicide or treatment against dust-mites in carpets, textiles and PVC. Allsopp *et al.* (2000) reported levels of TBT in PVC flooring samples in the range of 0.13-17.9 mg/kg. Although best known for its effect on sexual development in marine snails, TBT is also reported to be toxic to the immune system in mammals (Belfroid *et al.*, 2000).

The relatively low level of TPT in dust samples is not surprising, as there is no known domestic use of this hazardous chemical. It has been most commonly used as an agricultural fungicide, especially on potato crops.

2. Pooled samples

Among the pooled samples, the most contaminated one was collected in the European Parliament, with a total organotin content of 9.4 mg/kg (Table 7A). This comes from an especially high concentration of DBT (4.6 mg/kg), TBT (2.5 mg/kg) and MBT (1.7 mg/kg). All these concentrations were above the Belgian mean. Moreover, the concentrations of DBT and TBT are higher than any concentration previously measured in European house dust samples (Santillo *et al.*, 2001; Santillo *et al.*, 2003a; Santillo *et al.*, 2003b).

The regions with the highest organotin level in house dust were Namur, Hainaut and Liège with a total concentration ranging from 2.9 to 4.03 mg/kg. These levels mainly come from DBT and MBT concentrations but levels of the other organotin compounds were also comparatively higher than in other regions. Samples collected in the Limburg and Ardennes

regions contained the lowest organotin levels (about 0.4 mg/kg). The organotin level in the ecological homes from Limburg was not especially lower than in the other regions, although below the Belgian mean.

3. Individual samples

The highest organotin content in the Belgian samples was found in the dust collected in the office of **Ms Van den Bossche** (10.02 mg/kg). This result comes from high DBT (6.1 mg/kg) and MBT (3.7 mg/kg) levels (Table 7B). The DBT concentration found in the office of **Ms Van den Bossche** represents a worrying European record: this is the highest concentration ever measured in house dust. The DOT concentration (0.12 mg/kg) of this sample was also higher than the Belgian mean.

Particularly high organotin levels (8.36 mg/kg) were also found in the house dust of **Mr Staes** who shares the European record with **Ms Van den Bossche** for DBT level (6.1 mg/kg). MBT (1.5 mg/kg) and TBT (0.61 mg/kg) concentrations were also much higher than the Belgian mean.

A high contamination level was also found in the house dust collected in the home of **Mrs Schörling** (5.79 mg/kg), with a high MBT and TBT content and in the home of **Mrs De Meyer** (3.45 mg/kg), with a high DBT content. The office of **Mr Gosuin** (2.92 mg/kg) was contaminated by a particularly high MBT content (2 mg/kg).

The lowest organotin concentrations (from 0.15 to 0.18 mg/kg) were found in the dust collected in the house of **Mrs Van Lancker** and in the office of **Mr Lannoye** and **Mrs Cavalier**.

Regarding all these results, it appears that, as for the phthalate content, the organotin level does not seem to be associated with the type of building in which the dust was collected.

The following specific results can also be noted:

- the DOT content (0.91 mg/kg) in **Mr Sannen**'s office is much higher than the Belgian mean.
- the DBT (1.8 mg/kg) and DOT (0.16 mg/kg) concentrations in **Mr Kubla**'s office are higher than the Belgian mean.
- the house dust of **Mr Detienne** was the only individual sample that contained TPT. TPT is used as an agricultural fungicide. The presence of TPT in this sample could be a consequence of the house being near farmland.
- the DOT content (0.32 mg/kg) in the house of **Mrs Van Weert** is higher than the Belgian mean.
- the organotin content (2.21 mg/kg) in the EU Parliament **press briefing room** is lower than in the pooled sample collected in the EU Parliament.

Taken together, these results indicate that organotins are widespread contaminants of the indoor environment. Moreover, the concentrations found in the Belgian samples are generally very high and sometimes higher than in the house dust analysed in previous studies. This is of

serious concern because organotins are known to be toxic to mammals as well as to marine invertebrates at relatively low levels of exposure. Their hazards were officially recognised when the Ministerial Meeting of OSPAR included organotins on the first list of chemicals for priority action. The contamination in Belgian buildings is probably a consequence of the use of organotins in consumer goods. They are abundant in PVC products, textile products containing polymer parts, such as T-shirts with prints, sanitary towels, plasters and diapers. In some occasions, organotin compounds are used as fungicides on textiles.

Table 7A: **Organotin content of pooled dust samples collected in Belgium**								
	Organotin compounds							
	MBT	DBT	TBT	TeBT	MOT	DOT	TPT	**Total**
Pooled samples	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg	mg/kg	**mg/kg**
Hainaut	0.77	2.1	0.04	0.02	0.07	0.06	0.01	3.12
Namur	0.53	3.2	0.05	0.02	0.11	0.14	<0.01	4.03
Liège	0.78	1.8	0.13	0.01	0.07	0.08	<0.01	2.90
Gros-Fays (in the Ardennes)	0.11	0.18	0.01	<0.01	0.05	0.06	<0.01	0.40
Brabant Wallon / Vlaamse Brabant	0.08	0.32	0.05	<0.01	0.04	0.08	<0.01	0.58
Antwerpen	0.14	0.27	0.07	<0.01	0.04	0.05	<0.01	0.57
Oost-Vlaanderen	0.15	0.27	0.01	<0.01	0.12	0.14	<0.01	0.69
West-Vlaanderen	0.52	0.98	0.05	<0.01	0.06	0.05	<0.01	1.65
Limburg	0.07	0.17	0.10	<0.01	0.01	0.02	<0.01	0.38
Limburg (ecological homes)	0.08	0.50	0.01	<0.01	0.03	0.03	<0.01	0.65
Brussels- European Parliament	1.7	4.6	2.50	0.02	0.29	0.30	<0.01	9.40
method detection limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Belgian mean	0.567	1.417	0.280	0.006	0.086	0.113	0.001	2.47
Belgian median	0.147	0.499	0.051	<0.01	0.061	0.062	<0.01	0.69

Abbreviations: MBT-monobutyltin, DBT-dibutyltin, TBT-tributyltin, TeBT-tetrabutyltin, MOT-monooctyltin, DOT-dioctyltin, TPT-triphenyltin

Table 7B: **Organotin content of individual dust samples collected in Belgium**								
	Organotin compounds							
	MBT	DBT	TBT	TeBT	MOT	DOT	TPT	**Total**
Individual samples	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Mg/kg	mg/kg	**mg/kg**
Mr Sannen	0.12	0.47	0.01	<0.01	0.20	0.91	<0.01	1.72
Mr Gosuin	2.0	0.46	0.02	<0.01	0.15	0.27	<0.01	2.92
Mr Kubla	0.09	1.8	0.05	<0.01	0.03	0.16	<0.01	2.13
Mrs De Meyer	0.54	2.7	0.02	0.01	0.10	0.06	<0.01	3.45
Mr Staes	1.5	6.1	0.61	0.02	0.09	0.10	<0.01	8.36
Mrs Van Lancker	0.04	0.08	0.01	<0.01	0.01	0.01	<0.01	0.15
Mrs Van Weert	0.12	0.44	<0.01	<0.01	0.17	0.32	<0.01	1.05
Mr Detienne	0.05	0.20	0.02	<0.01	0.03	0.04	0.02	0.36
Mrs Schörling	3.6	1.3	0.81	0.01	0.04	0.02	<0.01	5.79
Ms Van den Bossche	3.7	6.1	0.01	<0.01	0.07	0.12	<0.01	10.02
Mr Lannoye Mrs Cavalier	0.06	0.07	0.01	<0.01	0.02	0.03	<0.01	0.18
EU Parliament press briefing room	0.57	1.4	0.10	<0.01	0.09	0.08	<0.01	2.21
method detection limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Belgian mean	0.567	1.417	0.280	0.006	0.086	0.113	0.001	2.47
Belgian median	0.147	0.499	0.051	<0.01	0.061	0.062	<0.01	0.69

Abbreviations: MBT-monobutyltin, DBT-dibutyltin, TBT-tributyltin, TeBT-tetrabutyltin, MOT-monooctyltin, DOT-dioctyltin, TPT-triphenyltin

Short-chain chlorinated paraffins

1. General Belgian results

Short-chain chlorinated paraffins (SCCPs) were found in about one third of the Belgian house dust samples, at concentrations ranging from 3.3 to 12.8 mg/kg (Table 3). These concentrations are within the range of the SCCP levels in house dust from the UK, although present in fewer samples, but are markedly lower than levels found in dust from other European countries.

2. Pooled samples and individual samples

SCCPs were measured at a concentration of 6.1 mg/kg in the dust from the European Parliament (Table 8A). This is consistent with the concentration found in the EU Parliament **press briefing room** (7.5 mg/kg). Among the other pooled samples, the only sample where SCCPs were detected came from the Ardennes region. Once again, this suggests that the SCCP contamination level is not a consequence of outdoor contamination, the Ardennes being generally assumed to be the least chemically polluted region in Belgium.

Among the individual samples (Table 8B), the highest concentrations were found in the house of **Mr Detienne** (12.8 mg/kg) and in the office of **Ms Van den Bossche** (7.2 mg/kg). A concentration of about 4mg/kg was measured in the house of **Mrs Schörling**, the house of **Mrs De Meyer** and the office of **Mr Kubla**. Once again, this presence in houses as well as in offices suggests that the SCCP concentration is not linked to the type of building where the dust was collected.

The Belgian results report the presence of SCCPs in several house dust samples. The lower concentration compared to previous studies could be a consequence of measures already taken to limit the use of these hazardous chemicals. Indeed, SCCPs have been shown to cause damage to the liver, kidneys and thyroid in mammals (Farrar, 2000). SCCPs are recognised as "Category 3" carcinogens in Europe, presenting "possible risks of irreversible effects". As a consequence of the toxic properties of SCCPs, they were included on the first list of chemicals for priority action (OSPAR). The EU has completed a risk assessment for SCCPs (EC 2000) and agreed to restrict the use of SCCPs in metal working and leather processing (EU 2002). However, half of the current uses of SCCPs, mainly in consumer products (e.g. additives in plastics and paints, flame retardants and finishing agents in textiles), are still unregulated. These uses explain why SCCPs are still found in house dust.

Although rather encouraging, the Belgian results stress the importance of going further and adopting measures that address the use of SCCPs in consumer products. If this does not happen, SCCPs will continue to accumulate in house dust and expose human health to irreversible problems.

Table 8A: **Short-chain chlorinated paraffins content of pooled dust samples collected in Belgium**

	Chlorinated paraffins
	CP
Pooled samples	**mg/kg**
Hainaut	<1
Namur	<1
Liège	<1
Gros-Fays (in the Ardennes)	3.4
Brabant Wallon / Vlaamse Brabant	<1
Antwerpen	<1
Oost-Vlaanderen	<1
West-Vlaanderen	<1
Limburg	<1
Limburg (ecological homes)	<1
Brussels- European Parliament	6.1
method detection limit	1
Belgian mean	2.08
Belgian median	<1

Table 8B: **Short-chain chlorinated paraffins content of individual dust samples collected in Belgium**

	Chlorinated paraffins
	CP
Individual samples	**mg/kg**
Mr Sannen	<1
Mr Gosuin	<1
Mr Kubla	3.5
Mrs De Meyer	3.3
Mr Staes	<1
Mrs Van Lancker	<1
Mrs Van Weert	<1
Mr Detienne	13
Mrs Schörling	4.0
Ms Van den Bossche	7.2
Mr Lannoye Mrs Cavalier	<1
EU Parliament press briefing room	7.5
method detection limit	1
Belgian mean	2.08
Belgian median	<1

Analytical quality control measures

All chemical analyses were performed by the laboratory of TNO Environmental Sciences, Energy Research and Process Innovation. As well as the samples analysis, a number of control analyses and checks were performed. A brief description the quality control measures is given in this section.

- *Method validation parameters* – All methods applied had been used in earlier studies and were validated in accordance with research and development protocols. The linearity of the instrumental analysis is known but in this case the linearity of the complete method is not a very useful parameter since the concentrations in the products can be so far apart that extracts have to be concentrated or diluted for the result to fall in the linear range of the instrumental analysis. The repeatability for each of the methods is determined by replicate analyses of a test sample of house dust received prior to this study. For homogenous samples the repeatability is better than 15%. The quantification limits are given in the tables in each paragraph and generally vary between 0.01 mg/kg and 1 mg/kg, depending on the type of analysis.

- *Recovery of extraction standard* – Internal (extraction) standards were added for the determination of the organotin compounds. In all cases the recovery was above 70% and the results for the organotin compounds are corrected for this recovery. For the other compounds an extraction standard was added to the samples prior to extraction. The recovery of this standard was between 78% and 96%. Results were not corrected for this recovery.

- *Blank samples* – With each series blank samples were included. These consisted of a complete analysis in the same series as the samples but without the addition of sample material. With the exception of the phthalate DEHP no blank values were observed. Since the blank was less than 1% of the DEHP concentration in the samples, no blank correction was applied.

Conclusions

This study found all dust samples collected from Belgian homes and offices were contaminated with a variety of hazardous chemicals. Phthalate, alkylphenols and organotin compounds were detected in all dust samples, while brominated flame retardants (BFRs), sometimes at high concentrations, were detected in more than 85% of the collected samples. The present study brings data complementary to that of previous studies that have found persistent, bioaccumulative and toxic chemicals in house dust from buildings in other European countries. The results confirm that dust samples collected in continental European countries carry higher phthalate concentrations and lower BFR levels than dust samples collected in the UK. However, some individual BFR levels in Belgian dust were considerably higher than the maximum concentrations reported in other European countries. Belgian results also confirm the mean concentration of total organotins found elsewhere in Europe. However, concentrations of some individual organotin compounds were considerably higher in Belgian dust than the maximum values previously reported for dust from other European countries.

Previous studies have found alkylphenol concentrations in dust samples from the UK to be considerably higher than those from continental European countries. However, in Belgian dusts, alkylphenol concentrations were higher than in other European countries but lower than in the UK. This study also found bisphenol-A in all Belgian dust samples. Bisphenol-A was not measured in the previous house dust studies conducted by Greenpeace. Finally, the previous studies found that concentrations of short chain chlorinated paraffins (SCCPs) were markedly lower in the UK than in other European countries, which is opposite to the findings for BFRs. Since SCCPs are also used as flame retardants, the authors had hypothesised a difference in the type of flame retardants used in consumer goods between the UK and the rest of Europe. However, the low SCCP levels in Belgian dust do not appear to support this hypothesis.

The present study also supports the hypothesis that the hazardous chemicals in house dust are primarily from sources inside the house or office since the chemical concentrations in the dust from homes in a village in a relatively unpolluted area were not markedly lower than those in dust from homes in more industrialised areas. Taking all the results together, no region had dusts that were systematically more contaminated than the others. This clearly appears on the summary-graph in Figure 2, where the mean concentration values of each chemical group measured in different locations were reported to the respective Belgian mean concentrations. For example, a phthalate value higher than 100% in the EU Parliament means that the phthalate concentration in this location is higher than the Belgian mean concentration for phthalates. In addition, contaminants and their concentrations in dusts were quite similar in both homes and offices. This suggests that contamination levels may depend on the types of consumer products used. Although these data cannot be used to identify which specific products the chemical contaminants arise from, they undoubtedly enter the dust as a result of losses from a wide variety of goods and furnishings present in the rooms where the samples were collected. Such losses may occur through volatilisation to air, followed by adsorption to dust particles or more direct attachment to fine particles lost through abrasion during normal wear and tear.

Some of the chemical concentrations detected in the homes and offices of politicians are of serious concern. The very high concentrations found in the dust from the **European Parliament** building (Figure 2) and its **press briefing room**, indicate that the members of the European Parliament, while working in their Brussels offices, are exposed to contamination levels which could potentially damage their health in the long term.

Similarly, people working at **Ms Van den Bossche**'s office are exposed to very high levels of hazardous chemicals (Figure 2); in some cases the levels are higher than the maximum ever found in European house dust. Although generally lower, the contamination levels measured in the offices of **Mr Kubla** and **Mr Gosuin** are also of concern for the people working there (Figure 2). The dramatic concentrations measured in the offices of **Ms Van den Bossche** and **Mr Kubla** may be due in some part to their offices being new or recently renovated. The unusual use of some products (e.g. paints) could have contributed to this high level. However, these results strongly indicate that, even several weeks after renovation or moving, workers are still exposed to a high level of contamination from everyday dust. The two offices were very clean and probably vacuum-cleaned daily. Therefore, it can be deduced that this high chemical level results from recent releases to new dust.

Once inhaled or otherwise absorbed, the chemicals analysed in this study accumulate in fatty tissues as well as in some organs such as the liver. In order to demonstrate the potential health threat associated with the high indoor contamination indicated by the house dust, blood analysis could be performed in a future experiment. In such a study, chemical concentrations in the blood of the members of the **European Parliament** and people working in the offices of **Ms Van den Bossche**, **Mr Kubla** and **Mr Gosuin** could be compared with those of people working or living in less contaminated places. Chemical concentrations in dust from the office of **Mr Lannoye** and **Mrs Cavalier**, although of concern, are systematically lower than those elsewhere (Figure 2). This could be explained by the "ecological" products used in this office. Nevertheless, the pooled sample collected in houses built with "ecological" materials (in the Hasselt region) was not markedly less contaminated than the other homes. It is, therefore, very difficult to draw conclusions regarding the impact of the use of "ecological" materials or products. Until sufficient information is made available about the chemical content of consumer goods, it will be impossible to identify the specific products or particular brands that are the sources of the chemicals found in this study.

The results presented here provide strong and direct evidence that the ongoing use of hazardous chemicals in consumer products is leading to universal contamination of our homes and offices and, consequently, the possibility for continuous human exposure to these compounds through inhalation, ingestion or direct skin contact with dust. This may be of particular concern for children, since other studies have shown that they have the greatest sensitivity to dust-related contamination (Butte and Heinzow, 2002).

The only way to protect families and workers who live in and otherwise occupy homes and offices from exposure to these hazardous chemicals is to adopt strong legislation that adequately controls the production and use of chemicals and requires that manufacturers provide consumers with adequate information about the chemical content of products. At the moment, although the European Union is the largest chemical-producing region in the world, the rules controlling chemicals in Europe are failing to protect people and the environment from these dangerous substances. However, opportunities are now emerging to develop new regulation of chemicals. Firstly, the OSPAR convention agreed to stop releases of hazardous substances to the environment within one generation (by 2020). The chemical groups analysed in this study have been included in the OSPAR list of chemicals for priority action to meet this target. Secondly, the European Union is currently preparing what could become the most comprehensive system of chemicals regulation ever adopted to control intentionally produced chemicals.

This system, proposed by the European Commission in October 2003, was named REACH for Registration, Evaluation and Authorisation of Chemicals. According to this proposal, chemicals must be registered and then evaluated. Chemicals of high concern would need authorisation to be put on the market. The text is currently being discussed in the European Parliament and the European Council in order to become law by 2005. However, the industry lobby has succeeded in dramatically watering down the Commission's text, which currently largely ignores the substitution principle. This principle, which is essential to make the REACH system effective, means that if a product that uses a hazardous chemical can be manufactured using a safer alternative, at a reasonable cost, the hazardous substance will no longer be permitted for that use and will be replaced by the safer alternative. It is now up to the European Parliament and the European Council to strengthen the new regulation to ensure that the substitution principle is embodied in the final text. The present study has shown worrying concentrations of hazardous chemicals in the European Parliament and in the offices of politicians who will be involved in the REACH adoption. Therefore, it is to be hoped that the members of the European Parliament and the European ministers will take these results into consideration and exercise their responsibility to adopt an effective REACH legislation. It is the only way to ensure that European house dust does not maintain the alarmingly high levels of contamination shown in the present study.

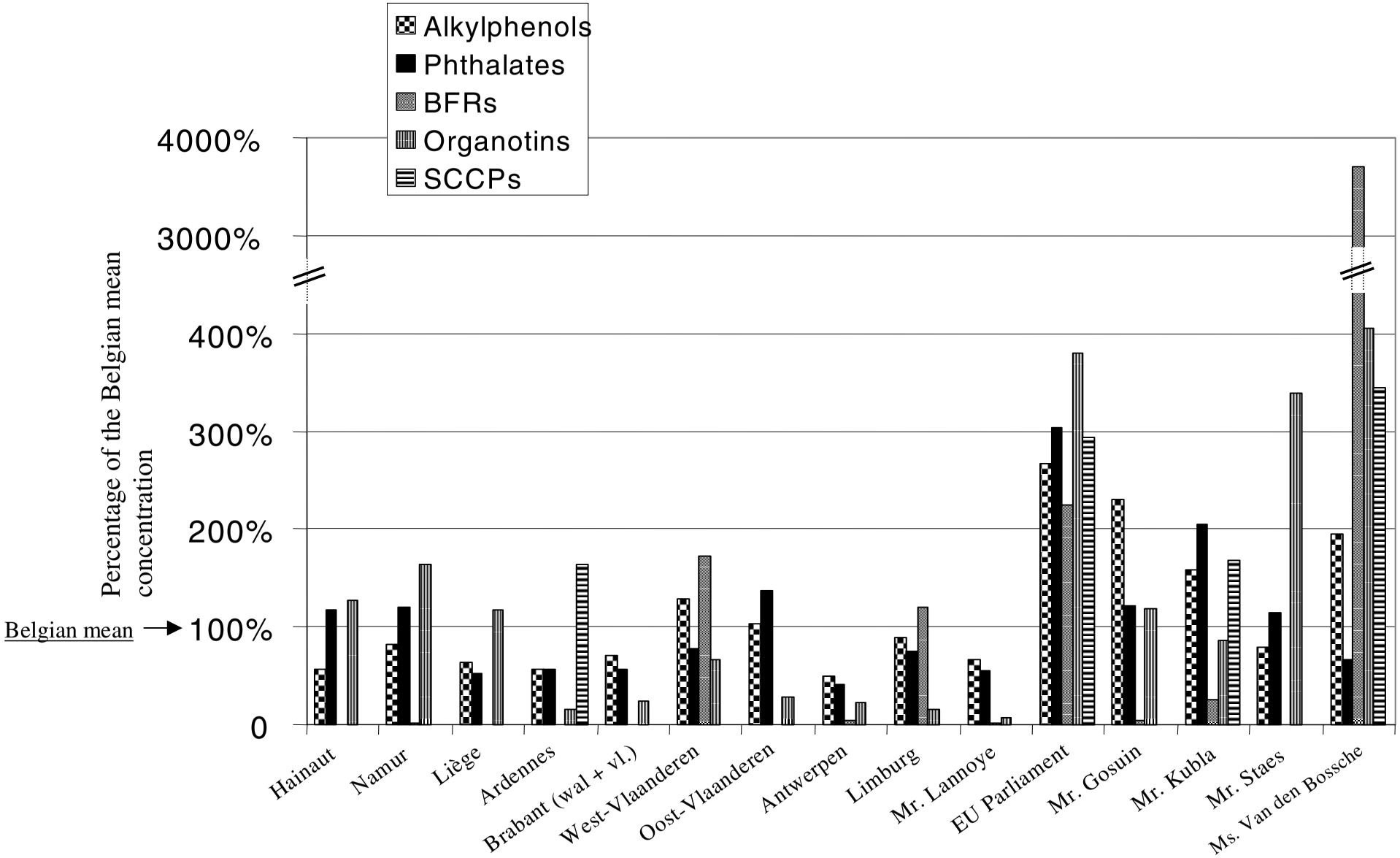

Figure 2: **Comparison of the mean concentrations of several hazardous chemicals measured in different Belgian locations**
The mean concentrations in alkylphenols, phthalate esters, brominated flame retardants (BFRs), organotins and short chain chlorinated paraffins (SCCPs) were expressed in percentage of the respective Belgian mean concentration.

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