

# **POISON UNDERFOOT**

**Hazardous Chemicals in PVC Flooring**

**and**

**Hazardous Chemicals in Carpets**

Two reports compiled for the Healthy Flooring Network by  
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## **EXECUTIVE SUMMARY**

This study was undertaken to identify and quantify the levels of certain chemical additives in fitted carpet and PVC flooring. Eight brands of carpet and five brands of PVC flooring that were available for retail in the UK were studied<sup>1</sup>. Both the PVC flooring and carpet were analysed for certain organotins and phthalate plasticisers. In addition, the carpets were analysed for the pesticide permethrin, brominated flame retardants, formaldehyde and triclosan (an anti-microbial chemical). These chemicals were selected for study because of their hazardous properties, combined with the knowledge that they are used in some consumer products.

The intention of the study was solely to provide empirical data on the chemical composition of carpets and PVC flooring. It was not intended to generate data for calculating potential leaching rates from flooring or for calculating potential doses that individuals may take from exposure to such flooring in the home and potential consequences for human health.

The PVC flooring samples were found to contain high levels of several organotin compounds, in particular dibutyltin (DBT, 37.7 - 569 ppm), and tributyltin (TBT, 128 - 17,940 ppb). These compounds are known to be used as stabilisers in some PVC products. Two of the eight carpet samples were also found to contain substantial levels of TBT (2700 - 47500 ppb). It is notable that these carpet samples were registered as being treated with "Ultrafresh" for protection against dust mites, bacteria, moulds and fungi. It is possible, though not certain, that this biocide incorporated organotins as active agents.

The presence of high levels of organotins in PVC flooring and carpets is of particular concern since they are persistent and are toxic to the immune system. As a consequence of the use of TBT in anti-fouling paints on ships hulls, this chemical has been responsible for major reproductive problems in some species of shellfish and in some instances has been linked to massive population declines of these organisms. Recently, concern regarding commercial uses of organotins has led to a German proposal to ban the use of these chemicals in paints for shipping, biocides in textiles and other uses from the end of 2002.

High concentrations of certain phthalate plasticisers were found in the PVC flooring samples. In the carpet samples, phthalates were not found above the limit of detection. Phthalates are added to PVC to make it flexible. Diisononyl phthalate (DINP) was found in all the PVC flooring samples at levels ranging from 4.7 to 15.8% by weight and butyl benzyl phthalate (BBP) was present in three samples at levels between 1.6 to 5.0%. The presence and quantity of DINP and BBP in PVC flooring is of concern given the potential for human exposure in the indoor environment and their potential toxicity.

Phthalates cause a wide range of toxic effects in laboratory animals. In particular, BBP has been shown to have teratogenic (birth defects), reproductive and developmental effects as well as endocrine-disrupting effects (that is, it interferes with the body's hormonal system). Due to its high toxicity the presence of BBP in PVC flooring was surprising. Previous research has shown that phthalates leach from PVC flooring and are consequently found in dust particles in the home and in wash water from PVC floors. Young children may be subjected to the highest exposure to phthalates from PVC floors because their breathing zone is closer to the floor and

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<sup>1</sup> The samples of carpet were manufactured by Brintons Ltd, Riding Hall Carpets, Whitestone Weavers Ltd, Rawson Carpets, Kingsmead Carpets, Westex and B & Q carpet tiles. The samples of PVC flooring were manufactured by Gerflor, Armstrong, Forbo Nairn, Marley Floors and B & Q.

they have a larger volume of respiration than adults per kilo bodyweight. The health of young children is of particular concern with regard to phthalates in PVC floors. A study in Norway found that children living in homes with PVC floors had a higher incidence of bronchial obstruction than children living in homes with wooden floors. It was suggested that this may have been due to exposure to plasticisers in the PVC.

Three of the eight carpet samples were found to contain significant levels of permethrin (up to 78 ppb), a pesticide used against dust mites. Permethrin has been reported to have effects on the nervous system (neurotoxic) in laboratory animals. Previous research in Germany has demonstrated that elevated concentrations of permethrin found in domestic homes were largely due to the presence of treated carpets. The presence of permethrin in carpets analysed in the present study is of concern given the potential human exposure in the home via its migration to air and dusts. It is of note that a previous study reported that typical permethrin treatment of carpets, where permethrin penetrates the carpet fibres, was not effective in preventing habitation by dust mites.

One of the eight carpet samples contained significant levels (1600 ppb) of 2,2',3,3',4,4',5,5',6,6'-decabromodiphenyl ether (BDE-209), a brominated flame retardant chemical. This is of concern given the persistent and toxic nature of this compound. While fire safety is an issue which cannot be compromised, it can be achieved through the use of other less hazardous fire retardants or through redesign and/or reformulation of materials to achieve lower flammability. Five of the carpet samples were also found to contain formaldehyde at low ppm concentrations.

In conclusion, several hazardous chemicals were found in significant concentrations in new PVC flooring and carpets. This highlights the continued widespread use of hazardous chemicals in consumer products, uses for which most of the public will be unaware. The presence and the high concentrations of some of the chemicals in PVC floors and carpets was unexpected given that they are recognised as hazardous chemicals at both national and international levels and, in some cases, plans exist to reduce their use or phase them out.

The results of this study are of concern as the presence of hazardous chemicals in PVC flooring and carpets inevitably leads to human exposure in the indoor environment. Flooring makes up a substantial surface area within the home; in particular, young children who breathe and play close to the floor are more likely to be exposed to hazardous chemicals in both PVC flooring and fitted carpet. Although the consequences of long-term exposure to these chemicals in the indoor environment is uncertain, the chemicals have properties which make them potentially hazardous to human health and the environment. The identification of hazardous chemicals in PVC flooring and carpets by this study has revealed an important product sector which will need attention to prevent human exposure to such chemicals and possible health consequences.

The data for the above study has been published as two individual technical notes, one on PVC flooring and the other on carpets. The former has already been submitted to the European Commission's public consultation on Environmental Issues of PVC, in November 2000.

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## **ABSTRACT**

This study investigated the composition of PVC flooring with respect to certain chemical additives, namely phthalate plasticisers and organotins. The study included analysis of five PVC flooring samples that were available for retail in the UK. Samples were found to contain high levels of several organotin compounds, in particular DBT (37.7 to 569 ppm) and TBT (128 to 17,940 ppb). Two phthalates were also detected at high concentrations. Diisononyl phthalate (DINP) was found in all samples at levels ranging from 4.7 to 15.8% by weight and butyl benzyl phthalate (BBP) was present in three samples at levels from 1.6 to 5.0%.

These findings are of concern in relation to the presence of hazardous substances in consumer products, their potential release to the environment and, in turn, their potential impacts on the environment and human health. Phthalates and organotins are hazardous chemicals. Organotins cause toxicity to the immune system in laboratory animals whilst phthalates exhibit a wide range of toxicity's. The use of PVC flooring and other household furnishings has generated concern recently after it was hypothesised that the release to air and particulates of the phthalate plasticiser di(2-ethylhexyl) phthalate (DEHP), present in PVC interior surfaces, may increase the risk of childhood asthma. Another study linked exposure to PVC floors in the home with increases in bronchial obstruction in children, possibly caused by plasticisers. In respect of the known and suspected toxicity's of phthalates and organotins and their possible impacts on human health, the results of this study are of great concern.

## **INTRODUCTION**

PVC (polyvinyl chloride, or vinyl) is currently a very widely used plastic with many applications including flooring, furniture, window frames, pipes and short-life packaging. The use of PVC has increased greatly during recent decades and consumption is predicted to increase still further in the future (see van der Naald and Thorpe 1998). PVC is always formulated with a range of additives to enhance its properties (Ehrig 1992). Additives for PVC have included hazardous substances such as lead, cadmium, organotins and phthalate plasticisers. The use of such additives has generated concern regarding environmental contamination and human health, in part, because of potential leaching of these additives from PVC products. For instance, children's toys made from soft PVC have been shown to contain 10-40% by weight of phthalate plasticisers (Stringer *et al.* 2000), and an emergency ban has been ordered by the European Union since December 1999 on the use of certain phthalates in toys designed to be chewed by children of under three years old (Official Journal of the European Communities 1999). A permanent ban is under discussion. In addition to concerns about chemical additives in PVC, there are also concerns about contamination of the environment by hazardous chemicals during the production of PVC (Stringer 1998), and the serious waste problems posed by the now perpetually growing mountain of PVC waste (van der Naald and Thorpe 1998).

The present study was undertaken as part of a wider study on the identification of hazardous chemicals as additives in carpets and PVC flooring. The intention of the present study was to identify and quantify levels of chemical additives in PVC flooring, specifically, phthalates and organotins. PVC is commonly used for the production of flooring for homes because it provides inexpensive, easy to clean surfaces and is especially practical in kitchens, bathrooms and children's playrooms and bedrooms (see Jaakkola *et al.* 1999). PVC flooring is constructed

from soft PVC that has been plasticised to make it flexible. The most commonly used plasticisers for manufacturing soft PVC are phthalates (phthalate esters). Historically, diethylhexyl phthalate (DEHP) has been the most commonly used phthalate but and more recently there appears to be increased market use of di-isononyl phthalate (DINP) (Stringer 2000). Phthalates do not bind to PVC chemically, but are present as freely mobile and leachable components of the plastic matrix. Consequently phthalates are gradually lost from PVC over time by volatilisation to the air (Cadogan *et al.* 1993). It is however not possible to measure directly the amount of phthalates emitted from PVC flooring to air using currently available technologies (Friedberg and Karlsson 1993, Howick 1996). Moreover, the results of such studies will always be strongly influenced by the particular conditions employed. Phthalates have a high affinity for particles and a recent study in Norway showed that as well as vaporising to air, these chemicals were also present in suspended particles in air and in sedimented dust samples from homes (Oie *et al.* 1997). The study demonstrated that phthalates migrated from PVC flooring to sedimented house dust. For PVC floors, washing has also been shown to release phthalates into the water (Moller *et al.* 1996).

Human exposure to phthalates in the indoor and outdoor environment occurs via background contamination of air, food and water. Of these, by far the greatest exposure has been estimated to occur via food intake (0.25 mg per day or >90%) (US ATSDR 1997). Nevertheless, a recent study on exposure via air in the indoor environment concluded that exposure through this route was greater than previously assumed because of the presence of phthalates in suspended particles in the air and in house dust (Oie *et al.* 1997). Human exposure to phthalates may also occur from direct contact with PVC products, for instance, skin contact with the surface of floors and, in the case of young children, chewing of soft PVC toys (CSTEE 1998). A recent study in the USA that investigated levels of phthalate metabolites (breakdown products) in urine concluded that human exposure to phthalates was greater than previously assumed (Blount *et al.* 2000). Studies on laboratory animals have shown that phthalates exhibit a wide range of toxic effects (KEMI 1994, US ATSDR 1997). In humans, data on health effects are mainly limited to a few studies on occupational exposure to phthalates and impacts on health. However, one recent study (Oie *et al.* 1997) hypothesised that exposure to the phthalate DEHP in the home, especially from inhalation of particulate matter containing DEHP, may increase the risk of inflammation of the lung airways and as a consequence, increase the risk of asthma. The hypothesis was partly formed on the basis of previous research evidence that mono (2-ethylhexyl) phthalate (MEHP), which is the major breakdown product of DEHP, was found to induce bronchial hypersensitivity in rats, and that pre-term human infants exposed to PVC respiratory tubing systems had a higher risk of bronchial asthma. Recently, a further study in Norway indicated that PVC flooring may increase the risk of bronchial obstruction in young children (Jaakkola *et al.* 1999). Exposure to phthalate plasticisers from surface materials in the home was hypothesised to be the causal agent.

Regarding organotins, these compounds have been used for a variety of applications following their discovery and initial use as a moth repellent in the 1920's (Moore *et al.* 1991). Organotins, specifically tributyltin (TBT), has been used on a worldwide basis as an antifouling agent in paints for boats and ships. Organotins are also used as heat stabilisers in PVC and as biocides in industry and agriculture. It has recently been reported that the major use of organotins is for the heat stabilisation of PVC which represents about two-thirds of the global consumption of these compounds (Sadiki and Williams 1999). Both butyltins and octyltins have been used. The latter group of compounds were specifically developed in an attempt to overcome toxicity problems of the generally toxic butyltins (Matthews 1996). Studies on laboratory rodents have shown that TBT is toxic to the immune system (see e.g. Kergosien and Rice 1998). As a consequence of its

use in paint for marine shipping, TBT has caused major reproductive problems some species of shellfish and in some instances has been related to massive populations declines (Gibbs 1988, 1993, Bryan *et al.* 1986, 1987). This has led to national restrictions on its use for shipping and more recently to a decision for a global phase out for this use by 2008 adopted under the International Maritime Organisation Assembly Resolution A.895(21). Concern has also been expressed about the level of intake of TBT from consumption of contaminated fish and shellfish (Belfroid *et al.* 2000). A recent study in Germany raised concern about the presence of comparatively high levels of TBT and other organotins in PVC flooring (Oeko-Test 2000). Research on organotins has suggested that they leach from PVC under laboratory simulated landfill conditions (Mersiowsky *et al.* 1999) and from PVC water pipes to water (Sadiki and Williams 1999).

The intention of the present study was to provide information on the quantity and type of phthalates and organotins in five PVC flooring samples that were purchased in the UK. The study was undertaken to provide empirical data on the chemical composition of PVC flooring. It was not intended to generate data for calculating potential leaching rates of phthalates and organotins from PVC flooring, or for calculating potential doses that individuals may take from exposure to PVC flooring in the home and potential consequences for human health.

## **METHODS**

### **Samples**

Five different samples of PVC flooring for analysis (NGP009, NGP010, NGP011, NGP012, NGP013) were purchased from various retail suppliers in the UK (see table 1).

**Table 1. List of PVC Flooring Samples**

<b>Sample Number</b>	<b>Sample Brand</b>
NGP009	Marley Floors. The Tile Collection, Cushioned tiles 5 010 941 207 609
NGP010	B & Q plc. Vinyl tiles. Item no. 24408486 Batch no. 0294
NGP011	Gerflor Limited. Classical collection, Rembrandt with roctop surface, 181 R
NGP012	Armstrong. Rhinofloor, Diamond with Rhinogloss, 30806
NGP013	Forbo Nairn. Cushionflor, Ultima, Gemini, 35128

### **Phthalates**

Analysis of phthalates was carried out by the Laboratory of the Government Chemist, Teddington, Middlesex, UK, using a UKAS accredited method, LGC SOP OTH/C1-0015 (details provided on request). The above PVC flooring samples were analysed for six phthalates, as listed by the EU Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE), (Di-isononyl phthalate (DINP), Di-ethylhexyl phthalate (DEHP), Di-n-octyl phthalate (DnOP), Di-butyl phthalate (DBP), Di-isodecyl phthalate (DIDP), Butyl Benzyl Phthalate (BBP). The limit of detection for all phthalate compounds tested for was  $\leq 0.05$  % by

weight. Also tentatively identified was diheptyl phthalate which was co-extracted with the other phthalates.

### **Organotins**

Organotin analysis was carried out by GALAB, D-21502 Geesthacht, Germany, using an accredited method (details available on request). The PVC flooring samples were analysed for organotins (monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), tetrabutyltin, monooctyltin, dioctyltin, tricyclohexyltin and triphenyltin). The limit of determination was 0.3 µg/kg, limit of detection 0.1 µg/kg, measurement uncertainty 10-20% and recovery 75-100%.

### **RESULTS**

Results of the analysis of 5 PVC flooring samples for phthalates and organotins are presented in tables 2 and 3 respectively. With regard to phthalates, DINP was found in all of the samples and BBP was present in three out of the five samples. Given the hazardous nature of these compounds the levels of DINP and BBP found in the samples are clearly of concern. Diheptyl phthalate was also detectable in 3 of the samples. All other phthalates that were analysed, including DEHP, were below the detection limit.

Several organotins were identified as components of all the PVC flooring samples. Dibutyltin (DBT) compounds are the most commonly used organotin stabilisers in PVC (see Matthews 1996). It was not surprising, therefore that DBT was found to be present at the greatest concentrations (range 37,700 to 569,000 ppb or 37.7 to 560 ppm).. Levels of TBT were also high (2,730 to 17,940 ppb) in four out of the five samples. The TBT concentrations in the PVC flooring samples were similar to those reported by in a recent study on 16 samples of PVC flooring from Germany (range, not detectable to 3520 ppb) (Oeko-Test 2000), with the exception of sample NGP009, for which the concentration (17,940 ppb) was nearly an order of magnitude higher than samples previously tested in Germany.

**Table 2. Percentage Concentration by Weight of Phthalates in Samples of PVC Flooring**

<b>Phthalate (%m/m)</b>	<b>Sample NGP009</b>	<b>Sample NGP010</b>	<b>Sample NGP011</b>	<b>Sample NGP012</b>	<b>Sample NGP013</b>
Di-isononyl phthalate (DINP)	8.26	4.7	14.3	15.8	7.4
Bis ethylhexyl phthalate (DEHP)	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
Di-n-octyl phthalate (DnOP)	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
Di-butyl phthalate (DBP)	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05
Di-isodecyl phthalate (DIDP)	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05



Butyl Benzyl Phthalate (BBP)	≤ 0.05	≤ 0.05	4.0	1.6	5.0
<b>Compounds tentatively identified:</b> Diheptyl phthalate (DHP)	-	-	√	√	√

**Table 3. Concentration of Organotin Compounds (µg/kg) in Samples of PVC Flooring**

Organotin (µg/kg)	Sample NGP009	Sample NGP010	Sample NGP011	Sample NGP012	Sample NGP013
Monobutyltin	5,300	1,620	48,800	330	2620
Dibutyltin	569,000	37,700	200,000	107,000	351,000
Tributyltin	17,940	128	4,390	2,730	5,100
Tetrabutyltin	12,300	138	5,770	1,440	4,350
Monooctyltin	120	980	400	<50	54
Diocetyl tin	110	10,200	2,120	990	1,560
Tricyclohexyl-tin	<50	<50	<50	<50	<50
Triphenyltin	<50	<50	<50	<50	<50

## **DISCUSSION**

In this study, five different samples of PVC flooring purchased in the UK were analysed for phthalates and organotins. Even though the number of samples was small, some general trends were apparent. DINP was the predominant phthalate found and DBT was the organotin which was found at the highest concentrations in the PVC flooring samples. Monobutyltin, TBT, tetrabutyltin and dioctyltin were also found as chemical components in all samples, while monooctyltin was found at somewhat lower concentrations. Tricyclohexyltin and triphenyltin were below the limit of detection in all samples.

Regarding phthalates, DEHP has generally been recognised as the most commonly used phthalate plasticiser for PVC, at least until recently, and Blount *et al.* (2000) noted that DEHP and DINP are the phthalate esters produced in the largest quantities. In the current study, DINP, a mixture of 30 or more isomers of dinonyl phthalate, was found in all samples in quantities ranging from 4.7 to 15.8% by weight, whereas DEHP was below the limit of detection. The use of DINP in PVC flooring rather than DEHP may reflect a market shift away from DEHP towards the use of the much more poorly characterised isomeric phthalates. This shift may be a consequence of serious concerns relating to suspected reproductive toxicity and other hazards associated with DEHP (CSTEE 1998, Stringer *et al.* 2000). However, a shift to using DINP instead of DEHP should give no room for complacency because even though DINP has been not been studied as extensively as DEHP, it has also been shown to exhibit a range of toxic effects in laboratory animals. Therefore there is little reason to assume that it presents less of a potential hazard than DEHP.

BBP was found in samples NGP011, NGP012 and NGP013 at concentrations of 4.0, 1.6 and 5%. Given the high toxicity of BBP, it was not expected that this phthalate would be found as a plasticiser in PVC flooring. This phthalate has been shown to have teratogenic, reproductive and developmental effects in laboratory animals (see Blount *et al.* 2000). It has also been shown to have endocrine-disrupting properties in offspring of rats that were exposed to the chemical during gestation. Male offspring had significant decreases in sperm count as well as other reproductive abnormalities at an exposure dose which approached levels to which humans are exposed to in everyday life (Sharpe *et al.* 1995). Although two other studies could not repeat these results and the reasons for these inconsistencies are not clear, the authors remain confident of the validity of the original results (Sharpe *et al.* 1998). A study was undertaken recently in the US which investigated human exposure to phthalates (Blount *et al.* 2000). The study reported the presence of metabolites (breakdown products) of several phthalates in urine of nearly 300 individuals from the general population. It concluded that phthalate exposure is both higher and more common than previously expected, especially for BBP, DEP, and DBP. The authors noted that this was of concern given the reproductive and developmental toxicity of these chemicals in laboratory animals.

The presence and quantity of DINP and BBP found in PVC flooring in the present study is of concern given the potential toxicity of these compounds and their ability to leach from PVC potentially resulting in human exposure. It is of particular concern with respect to the health of children. According to Oie *et al.* (1997) small children are subject to the highest exposure risk from phthalate plasticisers used in surfaces in the home due to having a volume of respiration, per kg body weight, twice as large as adults and spending much time indoors. In addition, young children have a breathing zone close to the floor and this potentially increases their exposure (Jaakola *et al.* 1999). A study in Norway recently reported a higher incidence of bronchial obstruction among children living in homes with PVC flooring compared to children living in homes with wood or parquet floors. The link between exposure to PVC flooring and bronchial obstruction was suggested to possibly due to exposure to plasticisers (Jaakola *et al.* 1999). On this note, the use of PVC flooring in the home is of obvious concern.

The present study identified several organotin compounds as additives in PVC flooring samples. It was not an unexpected result to find organotins in PVC flooring, particularly DBT, since it is known that these chemicals are used as stabilisers in PVC plastic. However, the concentrations of some organotins in the flooring samples, most notably DBT and TBT, may be considered to be high. This is of concern given the immunotoxicity of these compounds.

PVC plastic is known to contain many different chemical additives. In the present study, a number of organotins and phthalate plasticisers were identified in PVC flooring samples, but these chemicals will not be the only additives present. Other hazardous chemicals such as chlorinated paraffins will most likely also be present in some cases. Given the potential toxicity of additives in PVC plastic to human health and to the environment, the future of this plastic is highly questionable. Indeed, decisions have already been made by national governments of Sweden (Swedish government Environmental Bill, adopted April 28<sup>th</sup> 1999) and Denmark (Strategy on PVC, June 1999) which involve restrictions on PVC. At the international level, legislation under the auspices of the OSPAR Convention is in place with regard to the phase out of all hazardous chemicals, including organotins and certain phthalates. This agreement to phase out all hazardous chemicals by the year 2020 was undertaken by 15 states of the North East Atlantic Region and the European Commission. As a first step towards implementation of the agreement, OSPAR also agreed in 1998 on a "List of Chemicals for Priority Action" (the

Priority List). The list includes organotins and the phthalates DBP and DEHP. It was agreed that chemicals on the priority list required urgent action to address their discharges, emissions, and losses by 2003. For the organotins, the priority action has focused on the main sources of organotins, that is TBT in shipping and triphenyltin in agricultural use (PRAM 2000).

## **CONCLUSION**

In conclusion, hazardous chemical additives, phthalates and organotins, were identified in five samples of PVC flooring purchased in the UK. These chemicals have the potential to leach into the environment from flooring resulting, in turn, in human exposure. This is of concern given potential effects on health of these compounds. Measures have already been agreed at international and national levels to phase out the use of certain phthalates and organotins on the basis of concerns for human health and the environment. The presence of these hazardous substances in PVC flooring highlights an important product sector which will need urgent attention in this regard. Moreover, given that the use of hazardous additives in PVC is seemingly unavoidable, and their leaching inevitable, the use of PVC for such applications must be questioned.

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# **Hazardous Chemicals in Carpets**

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## **ABSTRACT**

This study was undertaken to investigate whether certain hazardous chemicals were present as components in new carpets, and if so, in what quantities. The study included analysis of eight new carpet samples that were available for retail in the UK. Some of the carpet samples contained high levels of organotins, in particular TBT (up to 47,500 ppb). One sample contained high levels (1600 ppb) of 2,2',3,3',4,4',5,5',6,6'-decabromodiphenyl ether (BDE-209), a brominated flame retardant chemical. Three samples also contained significant levels of permethrin (up to 78 ppb), a pesticide used against dust mites. Five of the samples contained formaldehyde, albeit at low ppm concentrations. None of the samples contained phthalates or triclosan (an anti-microbial chemical) at levels above limits of detection.

The presence of the above hazardous chemicals in carpets is of great concern given the potential for human exposure to these compounds in the indoor environment and possible impacts on health. Exposure may occur via inhalation of contaminated air, ingestion of contaminated dusts or dermal contact. Although possible impacts on health are presently uncertain, the use of chemical treatments and additives in carpets clearly represents a significant source of chemical exposure in the home. The presence of organotins, permethrin and the brominated flame retardant BDE-209 in new carpets is particularly undesirable given their hazardous properties, a matter which therefore demands urgent attention.

## **INTRODUCTION**

The majority of industrially produced carpets contain a range of chemical additives. Chemicals are impregnated during the manufacture of the carpet fibre or are introduced externally as topical treatments on the final product. The proposed purpose of some of these chemicals is to protect against dust mites, bacteria, moulds and fungi [do we have a suitable reference?]. However, the addition of chemicals to carpets results in potential human exposure to hazardous chemicals in the home and other indoor environments. Health impacts resulting directly from such exposure are difficult to elucidate though some observed health effects have been associated with exposure to new carpet. For instance, the US Consumer Product Safety Commission (CPSC) has received numerous health and odour complaints associated with the installation of new carpets (see Schaeffer *et al.* 1996). The nature and timing of the reported health symptoms (primarily immediate onset of sensory and pulmonary irritation and central nervous system effects) suggests the possible involvement of chemical off-gassing from carpet system materials. A recent review of pesticides in carpets noted that while allergy sufferers may welcome a house dust mite free carpet, the consideration of possible sensitivity to pesticides must also be taken into account (Pesticide News 2000).

Contact with consumer products and dusts in the office and home is increasingly widely recognised as an important route of human exposure to various hazardous substances. For instance, the US EPA note that 80% of most people's exposure to pesticides occurs indoors (see Pesticide News 2000). Carpets are often sold with "pest proof" guarantees which can last up to ten years. Therefore, the chemicals applied to carpets for pest control may persist for long periods. Considering the large proportion of time spent indoors by many people, exposure to chemicals in carpets can occur on a frequent basis. For instance, it has been estimated that an

average person generally spends about 93% of their time indoors, 5% in traffic and only 2% of time outdoors (Spengler and Sexton 1983). Moreover, for infants and children exposure is even greater than adults. It is estimated that children may ingest 100 milligrams (mg) of house dust per day, five times greater than adults, as they play or crawl on carpets (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 insult from chemical exposure.

Regarding consumer protection, it is interesting to note that chemicals introduced into carpets during their manufacture or applied as topical treatments are not covered by the Control of Pesticide Regulations 1986 or the Chemicals (Hazard Information and Packaging for Supply) Regulations 1994. Furthermore, the US Environmental Protection Agency recommend that new carpets are aired outdoor before installation, and indoor areas should be well ventilated for 48-72 hours after carpet fitting (see Pesticide News 2000).

The present study was conducted as part of a broader study on the identification and quantification of chemical additives in carpets and PVC flooring. The intention of the present study was to identify and quantify levels of certain chemicals in new carpets that were selected on the basis of their hazardous nature. Specifically, organotins, phthalates, permethrin, triclosan, brominated flame retardants and formaldehyde were analysed in eight carpets that were available for retail in the UK. The purpose of the study was to provide empirical data on the chemical composition of carpets. It was not the intention of the study to generate data for calculating potential doses of chemicals that individuals may receive from exposure to carpets in the home or to determine potential consequences for human health.

There appeared to be no research published in the scientific literature regarding the presence of phthalates or organotins in carpet, although their presence in PVC flooring was recently highlighted by Allsopp *et al.* (2000). It was not known whether these chemicals are used in the production of carpets. On the other hand, it was suspected that permethrin and triclosan may be present in carpets that had been treated with anti-microbial/anti-dust mite agents. Formaldehyde has also been reported to be present in some carpets as a preservative and it was possible that brominated flame retardants may be added as fire retardant chemicals.

Further information on each of the chemical groups investigated in this study is given in Appendix 1.

## **METHODS**

### **Samples**

Eight different samples of carpet for analysis were purchased from various retail suppliers in the UK (see table 1). The carpet fibres were analysed for organotins, phthalates, brominated flame retardants, permethrin and triclosan by laboratories and methods given below.

**Table 1. List of Carpet Samples.**

<b>Sample Number</b>	<b>Sample Brand, and data on carpet composition</b>	<b>Listed as Including Anti-microbial or Anti-Dust Mite Treatment</b>
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NGP001	Brintons Limited, Axminster, Annabelle Classique 244/16668 c 1997, Summer Spray, Apple. 80% wood, 20% nylon. Backing, Jute, polyester, polypropylene, conductive EVA latex. Made in England.	
NGP002	Riding Hall Carpets. Weardale, quality British Axminster, Woodland Brown, Ref 149/1. 80% Wood 20% nylon. Made in County Durham.	
NGP003	Whitestone Weavers Ltd. Fine Quality Woven Axminster, 85/8885 Blenheim. 80% Wool 20% nylon. Woven in Poland, British Wool	
NGP004	Rawson Carpets. Primary Colours, (created for the exacting demands of primary school activities) red. 100% polypropylene, Bitumen backing. Made in Britain.	Constructed from Permafresh fibre (100% control of house dust mites, bacteria, mould, mildew and fungi). Treated with Ultrafresh.
NGP005	Kingsmead Carpets Limited. Richards Pristine Twist, 80% wool,, 10 polypropylene, 10% polyester Yarn-Loc. Backing, woven polypropylene.	Scotchguard treated, Dynamite applied (dust mite protection).
NGP006	Kingsmead Carpets Limited. Moderna, 100% Charisma Polypropylene, Backing woven	Scotchgard Treated, Dynamite applied (dust mite protection).
NGP007	Westex . Ultima Major, Paprika. 80/20 Wool/Nylon. Treated with Ultra Fresh built in deodorant (proven to eradicate house dust mites), rotproof, mothproof and Scotchguard protection.	Treated with Ultrafresh (to protect against bacteria, moulds, fungi and dust mites).
NGP008	B & Q. B & Q classic plain carpet tile, emerald. A 5019 17.03:35	

### Organotins

Organotin analysis was carried out by GALAB (Geesthacht, Germany), using an accredited method (details available on request). All eight carpet samples were analysed for monobutyltin (MBT), dibutyltin (DBT), tributyltin (TBT), tetrabutyltin, monooctyltin, dioctyltin, tricyclohexyltin and triphenyltin. The limits of determination and detection were 0.3 and 0.1 µg/kg respectively, with a measurement uncertainty of 10-20% and recovery of 75-100%.

### Permethrin

Analysis of permethrin was carried out on all samples by Central Science Laboratory, Sand Hutton, York., (details of method available on request).

### **Triclosan**

Analysis of triclosan was carried out by PIRA International, Randalls Road, Leatherhead, Surrey, UK, (details of method available on request). Analysis was carried out on 6 of the 8 samples, (NGP001, NGP002, NGP003, NGP004, NGP007, NGP008).

### **Formaldehyde**

Analysis of formaldehyde was carried out by ALAB (Analyse Labor in Berlin GmbH), (details of method available on request).

### **Brominated Flame Retardants**

Analysis of brominated flame retardants was carried out by the Netherlands Institute for Fisheries Research (RIVO, Ymuiden)(details of method available on request). The analyses included 15 polybrominated diphenylethers (IUPAC nr. BDE-28, BDE-47, BDE 60, BDE-71, BDE-75, BDE-77, BDE-85, BDE-99, BDE-100, BDE-119, BDE-138, BDE-153, BDE-154, BDE-190, BDE-209), 7 polybrominated biphenyls (BB-15, BB-49, BB-52, BB-101, BB153, BB155, BB209), and 3 other brominated flame retardants (tetrabromobisphenol-A or TBBPA, methyl derivative of tetrabromobisphenol-A or Me-TBBPA, and hexabromocyclododecane or HBCD).

### **Phthalates**

Analysis of phthalates was carried out by the Laboratory of the Government Chemist, (Teddington, UK), using UKAS accredited method LGC SOP OTH/C1-0015 (details provided on request). The above eight carpet samples were analysed for six phthalates, as listed by the EU Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE), Di-isononyl phthalate (DINP), Di-ethylhexyl phthalate (DEHP), Di-n-octyl phthalate (DnOP), Di-butyl phthalate (DBP), Di-isodecyl phthalate (DIDP), Butyl Benzyl Phthalate (BBP). The limit of detection for all phthalate compounds tested for was  $\leq 0.05$  % by weight.

## **RESULTS**

### **Organotins**

Results of analysis of organotins in carpet samples are given in table 2. High levels of tributyltin were evident in sample NGP004 (2700  $\mu\text{g}/\text{kg}$  (ppb) and NGP007 (47500 ppb). Monobutyltin and dibutyltin were also found in these samples at  $>100$  ppb, with sample NGP007 containing the highest levels. MBT, DBT, and TBT were detectable at much lower levels ( $<30$  ppb) in most other samples. Other organotins were below the detection limit. It is notable that the samples which contained high levels of organotins were those registered as being treated with "Ultrafresh" (to protect against bacteria, moulds, fungi and dust mites). Given the hazardous nature of TBT, the levels in samples NGP004 and NGP007 are of clear concern.

### **Permethrin**

Results of analysis of carpet samples for permethrin are given in table 5. Samples NGP005, NGP006 and NGP007 contained permethrin at levels of 68, 69 and 78  $\mu\text{g}/\text{kg}$  (ppb) respectively. In other samples (NGP001, NGP002 and NGP003), permethrin was detectable, but at much lower levels (2.0 to 4.2 mg/kg), and was below the limit of detection in samples NGP004 and NGP008. It is notable that permethrin was detectable in high levels in 3 of the 4 the carpet samples which were registered as having being treated for dust mite protection. This includes treatment with "Dynomite" in samples NGP005 and NGP006, while sample NGP007 was

treated with “Ultrafresh” built in deodorant. However, permethrin was not detectable in sample NGP004 which was listed as being constructed with “Permafresh” fibre for protection against dust mites, bacteria, mould, mildew and fungi.

### Triclosan

No triclosan was detected in the samples at the limits of detection employed. It is not known whether this reflects the absence of triclosan or poor efficiency of extraction of triclosan from the carpet matrices.

### Formaldehyde

Results of analysis of carpet samples for formaldehyde are given in table 4. In samples NGP004 and NGP008, levels of formaldehyde were below the limit of detection. In other samples, levels ranged from 1.1 to 7.6 mg/kg.

### Brominated Flame Retardants

BDE-209 was identified and quantified in three (NGP002, NGP003 and NGP008) of the eight carpet samples at levels of 33, 28 and 1600 µg/kg (ppb) respectively. Given the hazardous nature of brominated flame retardants the level of BDE-209 in sample NGP008 is of particular concern. The levels of other brominated flame retardants were below the limit of detection in all samples (further details available on request).

### Phthalates

In all eight samples, (NGP001 to NGP008), no phthalate compounds were detected at levels above the limit of detection (0.05%)

**Table 2. Concentration of Organotin Compounds(µg/kg) in samples of carpet**

Organotin (µg/kg)	Sample NGP001	Sample NGP002	Sample NGP003	Sample NGP004	Sample NGP005	Sample NGP006	Sample NGP007	Sample NGP008
Monobutyltin	9.3	5.5	7.4	501	0.5	<0.3	1140	3.3
Dibutyltin	21.5	29.6	10.9	103	1.1	<0.3	7200	29.5
Tributyltin	3.1	6.5	3.2	2700	<0.3	<0.3	47500	1.7
Tetrabutyltin	<0.3	<0.3	<0.3	10.8	<0.3	<0.3	124	<0.3
Monooctyltin	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Diocetyl tin	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Tricyclohexyl-tin	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Triphenyltin	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3

**Table 3: Concentration of Permethrin (mg/kg) in Samples of Carpet**

Sample NGP001	Sample 1.1 NGP002	Sample NGP003	Sample NGP004	Sample NGP005	Sample NGP006	Sample NGP007	Sample NGP008
2.0	3.1	4.2	<0.05	68	69	78	<0.05

**Table 4: Concentration of Formaldehyde (mg/kg) in Samples of Carpet**

Sample NGP001	Sample 1.2 NGP002	Sample NGP003	Sample NGP004	Sample NGP005	Sample NGP006	Sample NGP007	Sample NGP008
2.2	4.1	3.1	<0.5	1.2	1.1	7.6	<0.5

## **DISCUSSION**

In this study, eight different samples of carpet purchased in the UK were analysed for certain hazardous chemicals, namely organotins, permethrin, triclosan, formaldehyde, brominated flame retardants and phthalates. The analysis revealed that some of the carpet samples contained substantial levels of organotins, permethrin and brominated flame retardants. In particular, it was apparent that some of the carpets listed as being treated against dust mites had high levels of organotins and permethrin. With regard to other chemicals, formaldehyde was detectable in six of the eight samples at low ppm levels. While this does not give direct evidence that the carpets will act as a source of formaldehyde to the surrounding air in the home, the presence of such levels combined with the volatility of formaldehyde may result in new carpets acting as a significant additional source of this chemical in the indoor environment. Phthalates and triclosan were not identified in any of the samples at levels above limits of detection for the specific analytical procedures employed.

Organotins, in particular TBT, was found at high levels in 2 of the 8 carpet samples tested (NGP004 and NGP007). These 2 carpets were listed as being treated with “Ultrafresh” for protection against dust mites and other microorganisms. It is possible, though not certain, that biocides used for this treatment incorporated organotins as active agents. The use of organotins in carpets is surprising and is of great concern, given the persistent nature of these compounds and their immunotoxic properties. Measures have already been adopted at international levels to phase out certain uses of these chemicals. Under the OSPAR Convention’s strategy for hazardous substances (OSPAR 1998a), organotins are included as a group on the list of chemicals requiring priority action towards meeting the target of cessation of releases of hazardous substances to the marine environment.. The agreement to cease all discharges, emissions and losses of hazardous chemicals by the year 2020 was undertaken by 15 states of the North East Atlantic Region and the European Commission in 1998 (OSPAR 1998b). As a first step towards implementation of the agreement, OSPAR also agreed in 1998 on the detailed strategy and the “List of Chemicals for Priority Action” (the Priority List). It was further agreed that chemicals on the priority list required the development of measures to address their discharges, emissions, and losses by 2003. For the organotins, the priority action has focused up to now on TBT antifouling paints and triphenyltin compounds in agricultural use (OSPAR 2000a). Following progress within IMO on the development of the draft convention on harmful antifoulants, The Netherlands (as OSPAR lead country for these substances) is now considering whether to extend its focus to include the use of organotins in a range of consumer products (OSPAR 2000b). In Germany, a recent decision was taken to implement national legislation which will prohibit the use of TBT and other organotins after 31 December 2002 for uses

including biocides in textiles and paints for shipping. Products, which contain greater than 1 mg organotin/kg will no longer be permitted on the market. It is noteworthy that carpet sample NGP007 would substantially exceed this 1 mg/kg limit for TBT (by 47 times) and would also exceed this limit for both mono- and dibutyltin.

Permethrin was detected in 3 of the 4 carpets that were listed as being treated against dust mites. The presence of permethrin in carpet is of concern given the hazardous nature of this pesticide and the potential for long-term exposure in the home environment. Indeed, one study found elevated concentrations of permethrin in domestic homes that was largely a consequence of treated carpeting (Boege et al. 1996). This raises serious questions regarding the use of such hazardous chemicals in the home environment, especially as Brown (1996) demonstrated that permethrin treatment of carpets may not even be effective against dust mite habitation.

One brominated flame retardant, BDE-209, was found in 3 of the eight carpet samples tested. In one sample (NGP008), levels were particularly high (1600 ppb). This is of concern given the fact that brominated flame retardants are toxic and persistent chemicals. Fire safety is clearly a central issue which should not be compromised, but can be achieved through the use either of less hazardous fire retardants or through redesign and/or reformulation of materials to achieve lower flammability. This has already been recognised both at national and international levels. For instance, due to the fundamental problems posed by brominated flame retardants, the Swedish National Chemicals Inspectorate (KEMI 1999) has proposed a national ban on the manufacture and use of brominated flame retardants. The World Health Organisation has also recommended their substitution with less hazardous alternatives wherever these are available (WHO 1998). Brominated flame retardants are also included on the OSPAR List of Chemicals for Priority Action (OSPAR 2000c).

## **CONCLUSION**

In conclusion, organotins, permethrin and BDE-209 (a brominated flame retardant) were identified in a number of carpet samples purchased in the UK. The presence of these chemicals in carpets in the indoor environment inevitably results in human exposure. Although the consequences of long term exposure to chemicals such as these in the indoor environment is uncertain, the above chemicals have properties which make them potentially hazardous to human health and the environment. Recently, a report by the British Society for Allergy, Environmental and Nutritional Medicine noted that it is likely that increase in exposure to synthetic and pollutant chemicals makes a substantial contribution to increases in allergic disease (Eaton *et al.* 1999). The presence of the above chemicals in carpets highlights an important product sector which will need attention to prevent human exposure to hazardous chemicals and possible health consequences.

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## **APPENDIX 1**

### **Chemical Groups Investigated in this Study**

#### **1. Organotins**

Organotins are a group of compounds that have been used for a variety of applications following their initial use as a moth repellent in the 1920's (Moore *et al.* 1991). Organotins, specifically tributyltin (TBT), have been used on a worldwide basis as an antifouling agent in paints for boats and ships. According to Sadiki and Williams (1999), two thirds of current global consumption of organotins results from their use as stabilisers in PVC (especially mono-

and dibutyltin). Organotins are also used as biocides in industrial applications and some consumer products and as pesticides in agriculture.

Studies on laboratory rodents have shown that TBT is toxic to the immune system (see e.g. Kergosien and Rice 1998). As a consequence of its use in paint for marine shipping, TBT has caused major reproductive problems in many species of shellfish, in some instances leading to massive population declines (Gibbs 1988, 1993, Bryan *et al.* 1986, 1987). This has led to national and regional restrictions on its use for ships (including bans on use on small vessels) and more recently to a decision for a global phase out for this use by 2008 adopted under the International Maritime Organisation Assembly Resolution A.895(21). Concern has also been expressed about the level of intake of TBT from consumption of contaminated fish and shellfish (Belfroid *et al.* 2000). Organotins as a group are included on the list of chemicals identified by the OSPAR Commission as requiring priority action, as part of its strategy to reach the target of cessation of releases of hazardous substances to the marine environment by 2020 (OSPAR 2000c).

A recent study in Germany raised concern about the presence of comparatively high levels of TBT and other organotins in PVC flooring (Oeko-Test 2000), a use subsequently confirmed by Allsopp *et al.* (2000). To the knowledge of the authors, however, no research has been published in the scientific domain on the identification or quantification of organotins in carpet.

## **2. Permethrin**

Permethrin is a synthetic pyrethroid which is used as a pesticide. It is used in agriculture and in public health schemes for the control of insects, including mosquitoes. Permethrin is also used as an anti-dust mite chemical in carpets. In 1996, a German study demonstrated that elevated concentrations of permethrin found in domestic homes arose mainly from pyrethroid-treated carpeting (Boege *et al.* 1996). House dust found in carpets readily attracts and holds indoor chemical pollutants. Since permethrin absorbs to dust and surfaces, ingestion of permethrin may be an important route of exposure in the home in addition to inhalation (IEH 1999). Studies on laboratory animals have shown that permethrin can be toxic to the nervous system (eg. Ray 1991).

According to Brown (1996), a study by Allanach *et al.* (1990) showed that fabric treated with permethrin repelled dust mites. A mite culture (1000 mites plus food) was applied to permethrin-treated overlay fabric of a wool mattress and untreated fabric was used as a control. The fabric was left for 3 months after which the treated fabric was found to contain 761 dust mites while the untreated fabric contaminated 50,000 dust mites. However, another study (Brown 1996) indicated that carpet that was treated with permethrin did not prevent habitation of dust mites. Samples of wool carpet were treated with a range of concentrations of permethrin, and untreated carpet was used as a control. The treatment process used in the study results in penetration of permethrin into the fibre of the carpet with little absorbed onto fibre surfaces. The samples of permethrin-treated and untreated carpet were placed on a fitted wool carpet of a house that was known to be inhabited by dust mites. After a period of 14 months, analysis of the carpet samples showed there was no difference in the numbers of dust mites between the treated and the untreated carpet. The study suggested that permethrin treatment of carpet had no influence on habitation of house dust mites, even at high concentrations. It was noted that the different finding to the study by Allanach *et al.* (1990) described above, in which dust mites were reported to be repelled by permethrin-treated fabric, suggested that surface residues of permethrin may have been present in the fabric samples and acted as contact insecticides for the house dust mite. By contrast, permethrin would not be present on the surface of the carpet

samples in the study by Brown (1996) but was impregnated into the carpet fibre. Such penetration is characteristic of typical commercial permethrin-treated carpets (Brown 1996).

### **3. Triclosan**

Triclosan, (5-chloro-2 (2,4-dichlorophenoxy) phenol), is a chlorinated diphenyl ether. It has been used for more than 30 years as a general antibacterial agent and is used in commercial products as diverse as carpets, toothpaste, cosmetics, antiseptic soaps, washing-up liquid, plastic kitchenware, toys, socks and underwear (see Adolfsson-Erici et al. 2000, Levy et al. 1999). It has been shown that dioxins, a group of persistent chemicals renowned for their toxic impacts on health and the environment, may be formed on incineration of triclosan and under the influence of sunlight (Kanetoshi et al. 1988). Dioxins may also be formed during the manufacture of triclosan.

Triclosan has not yet been shown to be toxic to mammals, but it is acutely toxic to aquatic organisms such as fish. A recent study showed that triclosan is resistant to degradation during sewage treatment and is available for absorption by aquatic organisms in the environment (Adolfsson-Erici et al. 2000). High levels of triclosan (up to 80 µg /g) were present in the bile of fish that were placed in cages for 3 to 4 weeks downstream of sewage treatment works in Sweden and triclosan was also present in wild fish caught further downstream (Adolfsson-Erici et al. 2000). In addition, the study also found triclosan in breast milk samples from 5 women. High levels of triclosan were present in 3 of the 5 samples (up to 300 µg/kg). Following this research, concerns on the aquatic toxicity of triclosan led soap and detergent manufacturers in Europe to agree a ban on any increase in its use over 1998 levels (ENDS 2000a).

There has been a recent proliferation in the use of antibacterial products in the European market place. This appears to be a consequence of companies rushing to introduce them to avoid the need for authorisation. The 1998 EC directive on biocides was due to be implemented in April 2000, after which any biocidal products launched onto the market will require authorisation (see ENDS 2000b). The increased and widespread use of triclosan in commercial products is of great concern given the possibility that biocide use in household products may increase resistance among bacteria. Research showed that triclosan is bactericidal due to its action as a powerful inhibitor of an enzyme used in fatty acid synthesis (Levy et al. 1999). In Sweden, the use of phenolic antibacterial agents like triclosan was abandoned in most hospitals several years ago. In April 2000, the Swedish government's *Swedenvironmental* journal called for an end to "unnecessary uses of biocides", with triclosan being targeted in particular (ENDS 2000a). It was endorsed by the Swedish National Chemical Inspectorate (KEMI), and 5 consumer, medical and public health protection agencies. The report included a survey that showed that washing-up liquids containing antibacterial agents were no more effective than other detergents. It noted that the benefits of antibacterial agents are doubtful and the risks have not been fully investigated.

### **4. Formaldehyde**

Formaldehyde is used in the manufacture of a wide range of products including plastics, fibre-board, in the dyeing, rubber, and explosives industries and is also an antiseptic, germicide and fungicide. Some carpets and textiles contain formaldehyde and this can contribute to domestic exposure. It has been shown to cause cancer in laboratory animals. In a study on organic chemicals emitted from carpets, the U.S CPSC did not find significant quantities of formaldehyde were released (Schaeffer et al. 1996). Nevertheless, new carpets clearly represent an additional source of indoor exposure to formaldehyde.

## 5. Brominated flame retardants

Brominated flame retardants, including polybrominated biphenyl (PBBs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD) and tetrabromobisphenol-A (TBBPA), are used in the manufacture of a wide range of products. According to Bergman (2000), brominated flame retardants made up about 25% of all flame retardants used ten years ago and, although recent world data on production is not easily accessible, there is no reason to believe that the production profile has undergone any major changes. These chemicals may be included in carpets and soft furnishings, computers, televisions, kettles and other electronic goods and in materials used in vehicle and aircraft construction. However, brominated flame retardants are released to the environment not only during their manufacture, but also during the routine use and final disposal of household products which contain them. They are toxic, persistent, and bioaccumulative (build up in the tissues of animals and humans), (Kamrin and Fischer 1991, Robertson *et al.* 1991, Jansson *et al.* 1993, Kholkute *et al.* 1994). Recent research has confirmed the widespread presence of these contaminants in fish, marine mammals and in human tissues (Klasson Wehler *et al.* 1997, de Boer *et al.* 1998, Ohta *et al.* 2000).

Understanding of the breadth of toxic effects of these groups is developing rapidly (Hornung *et al.* 1996, Kang *et al.* 1996). For example, Eriksson *et al.* (1998) reported subtle impacts on brain development in rodents, resulting in permanent changes in behavior, memory and learning, although the mechanisms have yet to be elucidated. It is also known that PBDEs can reduce the levels of circulating thyroid hormones in blood plasma (Darnerud and Sinjari 1996) and impact retinoid levels (Olsson *et al.* 1998). Some are suspected endocrine disruptors (Olsson *et al.* 1998, Meerts *et al.* 1998).

Like the organotins, brominated flame retardants are included as a group on the OSPAR List of Chemicals for Priority Action (OSPAR 2000c). The World Health Organisation has recommended that brominated flame retardants should not be used wherever less hazardous alternatives are available (WHO 1998). In addition, the proposed EU Directive on restrictions on the use of hazardous substances in electrical and electronic equipment (CEC 2000) includes the intention to phase out the use of two groups of brominated flame retardants, including the polybrominated diphenyl ethers (PBDEs).

## 6. Phthalates

Phthalates are a group of chemicals that have been used extensively in a broad range of applications, including as additives in plastics, paints, pesticides, inks, perfumes, cosmetics and insect repellents. By far the largest use of phthalates is for plasticisers in soft PVC products which accounts for approximately 90% of phthalate use. Due to their widespread industrial uses, phthalates have become globally ubiquitous contaminants in the environment. They are moderately persistent (Jobling *et al.* 1995). Studies on laboratory animals have shown that phthalates exhibit a wide range of toxic effects (KEMI 1994, US ATSDR 1997). In humans, a recent study in the USA that investigated levels of phthalate metabolites (breakdown products) in urine concluded that human exposure to phthalates was greater than previously assumed (Blount *et al.* 2000). A recent study (Oie *et al.* 1997) hypothesised that exposure to the phthalate DEHP in the home, especially from inhalation of particulate matter containing DEHP, may increase the risk of inflammation of the lung airways and as a consequence, increase the risk of asthma. Further research in Norway indicated that PVC flooring may increase the risk of bronchial obstruction in young children (Jaakkola *et al.* 1999). Exposure to phthalate plasticisers from surface materials in the home, such as PVC flooring, was hypothesised to be the causal agent. The present study analysed for the possible presence of phthalates in carpets

since no previous research on the analysis of phthalates in carpet appeared to be published in the scientific literature.

The OSPAR list of chemicals for priority action also includes certain phthalates, specifically DBP and DEHP (OSPAR 2000c). Moreover, according to the progress report presented by Denmark and France to OSPAR's working group on point and diffuse sources (PDS) in December 2000, the OSPAR background document on phthalates will also now include consideration of the need for measures for three other phthalates, specifically BBP, DINP and DIDP (OSPAR 2000d).