

SCIENTIFIC REPORT

ESF Exploratory Workshop on

INDOOR CONTAMINATION WITH PERSISTENT ORGANIC COMPOUNDS: AN IMPORTANT EXPOSURE PATHWAY FOR PEOPLE?

Stockholm (Sweden), 23-25 March 2009

Convened by:

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The last four decades have seen tremendous growth in public, scientific and governmental interest in the environmental effects of semivolatile organic compounds (SVOCs) such as persistent organic pollutants/compounds (POPs/POCs). Human and ecosystem exposures occur as a function of compound distribution and time after release across a range of pathways. The persistence and bioaccumulation of POPs has resulted in their wide distribution in the outdoor environment and significant human exposure *via* the diet, for example for dioxins. For many POPs, the major human exposure pathway is diet and other pathways such as inhalation are negligible. However, it has recently become clear that exposures can arise as some POPs such as PCBs, brominated flame retardants (BFRs), particularly polybrominated diphenyl ethers (PBDEs), and hexabromocyclododecane (HBCD) as well as poly/perfluoroalkyl compounds (PFCs), are released from building and vehicle construction materials, consumer and household goods leading to contamination of domestic, transportation and workplace indoor environments.

For example, the three PBDE technical products, PentaBDE, OctaBDE, DecaBDE as well as HBCD are additive flame retardants used in textile coatings, foams, and plastics that are in turn used in TVs, computers, various electric and electronic equipment, insulation sheets, upholstery, bed-ticking, carpeting, etc. These products are found in homes, public buildings such as daycare centers and schools, office buildings as well as in cars, subways, trains, airplanes, etc. Penta- and OctaBDE were banned within the EU in 2004 but will remain for decades in consumer products sold before the ban. There are currently few restrictions on the use of DecaBDE and no restrictions on the use of HBCD. PFCs are a varied class of chemicals used in the production of fluoropolymers or in polymers/copolymers themselves, as refrigerants, surfactants, in fire-fighting foams, paints, waxes, polishes, adhesives, stain-resistant coatings for textiles, carpets and paper, as lubricants and insecticides. PFCs can be subdivided into two classes of compounds, according to their physico-chemical properties. PFCs of the first class possess a perfluorinated carbon chain and an acidic head group, which is dissociated (ionic) at environmental pH (carboxylate or sulfonate). These compounds (hereafter referred to as “ionic PFCs”) are water soluble according to their chain lengths and extremely persistent in the environment. Two ionic PFCs, perfluorooctane sulfonate (PFOS) and perfluorooctanate (PFOA) have received wide attention because they bioaccumulate and have been found in wildlife samples from all over the world including humans. PFOS was banned within the EU in 2007 because of its carcinogenicity and it was recently classified as a POP under the Stockholm Convention in May 2009. For PFOA, a restriction in use or even a ban is under discussion in the EU Parliament. PFCs of the second group are volatile compounds, often called neutral PFCs due to their physio-chemical properties. They are precursors for the ionic PFCs. Fluorotelomer alcohols (FTOHs) are characterized by a perfluorinated carbon chain with a CH₂-CH₂ plus a hydroxy head group. Fluoroalkylsulfonamides (FOSAs) and -sulfonamidoethanols (FOSEs) consist of perfluorinated carbon chains with a sulfonamide or sulfonamidoethanol head, where a methyl or an ethyl group is bonded to the nitrogen molecule.

Due to their physico-chemical properties, many semivolatile POPs are in the vapour phase, while others are less volatile and sequester on air particulates and in dust. The number of studies of POCs in non-occupational, indoor environments is quite limited. Of these studies of indoor microenvironments, primarily components of PentaBDE have been studied and found in air and dust. Fewer studies have included DecaBDE, HBCD and even fewer, the PFCs. Environmental concentrations of some of these compounds are rising, reflecting their increasing use. Given the disproportionate fraction of time that European citizens spend

indoors (typically in excess of 90%), indoor contamination of air and dust potentially represents a substantial pathway of human exposure. This is further compounded by the tendency of very young children to ingest appreciable quantities of indoor dust, which if contaminated may constitute an important vector of exposure to this particularly vulnerable sector of the population. For example, it has recently been suggested that current body burdens of the components of the PentaBDE technical product in US adults are higher than can be explained by exposure to diet alone. A few studies indicate that young children have higher PentaBDE concentrations than adults, further supporting the hypothesis that dust ingestion may be an important exposure route although breast-feeding in very young children is also probably a source.

The databases for carrying out exposure and risk assessment of PBDEs (DecaBDE in particular), HBCD and PFCs from indoor environments are incomplete. In particular, there is limited information on the source-exposure-dose continuum, limited information on how these compounds are emitted and enter the indoor environment, limited population-based data for adults and general lack of biomonitoring data for children, particularly those under 2 years of age.

The purpose of the exploratory workshop was therefore to bring together experts in the development and application of indoor sampling techniques, chemical analysis, exposure and risk assessments of these particular POCs to explore the current state-of-the-science, further our understanding of indoor exposure, highlight knowledge gaps, discuss ways to fill these gaps and stimulate future research collaborations. The workshop brought together 20 scientists from 9 European countries, the US and Canada, each with expertise in one or more of the above areas. The workshop consisted of some presentations as well as in-depth discussions exploring current research in identifying sources, emission strengths and pathways of transfer from treated goods to air/dust; strategies and methods for monitoring indoor contamination, current exposure implications of indoor contamination and future exposure scenarios – e.g. links to outdoor contamination via ventilation and e-waste disposal.

Another key aspect of this workshop was to identify areas of research collaboration and funding to address these knowledge gaps. Possible collaboration in a Marie Curie initial training network program for graduate students and post-docs is expected and the workshop is also expected to lead to a proposal within the EU FP7 program.

2. Scientific content

Emission sources of POCs to indoor environments

How, in what amounts and from which consumer products POCs are emitted is poorly understood as is the environmental behavior of these compounds in the indoor environment. This topic was introduced by Thomas Webster. Once emitted from various consumer products, POCs can distribute into various parts of the microenvironment such as dust, which can be analyzed to quantify the presence of POCs indoors. These results can be used together with published exposure factors to estimate human intake, but the quality of these exposure factors is questionable, as they are mostly based on soil ingestion. More direct measures of human exposure have been used such as measuring personal air, diet and by taking hand wipes. Better still is measurement of internal dose, for example by measuring blood concentrations of POCs to determine body burdens. These data are needed to couple exposure

to potential effects in humans. Studies were presented of relationships between concentrations of PBDEs in indoor air and dust and the room contents of potentially flame-retarded items like furniture and electronic goods, but no correlations were found. Another intriguing method that Webster presented is the use of a hand-held X-ray fluorescence (XRF) apparatus to relate the bromine content in household items to BFR concentrations in dust and this gave better correlations. Otmar Geiss then gave a presentation of the INDOORTRON, a stainless steel chamber at the Joint Research Centre in Ispra, Italy, which allows for studies of emissions of chemicals from materials to indoor air. Although primarily used for studies of volatile organic compounds, it could also be used to determine emission factors for the POCs considered at the workshop. Modelling is another valuable tool for understanding emissions and environmental behavior of POCs in indoor microenvironments and this topic was presented by Miriam Diamond. In particular, she showed how room furniture could actually be a sink for many POCs, not a source as is generally supposed. She identified key parameters needed for understanding the dynamics of POCs in indoor microenvironments such as the source strength, mass of POC in the room, release rates, room characteristics (temperature, air exchange rates, cleaning frequency) and the POC physico-chemical properties.

Knowledge gaps identified

- How are we primarily exposed to PentaBDE in dust – via inhalation of small particles, from hand-mouth contact, uptake via the skin?
- Penta- and OctaBDE, PFCs and other POCs: Information is lacking or too little is available on how they are emitted from products, the importance of ingestion versus dermal uptake, internal dose, correlations between dust and blood, concentrations in children compared to adults.
- DecaBDE: Information is lacking on how is emitted from products, the importance of ingestion versus dermal uptake, internal dose, dietary intakes, correlations between dust and blood, concentrations in children compared to adults, levels in offices and cars, possibility of geographic differences in concentrations in dust and humans within the US (a preliminary study from California implies this for dust but better studies are needed).
- Emission rates of POCs from materials are poorly understood
- More studies using XRF to identify and quantify POC sources in indoor environments
- The key parameters needed for modelling are mostly estimates and more accurate numbers are needed
- Better estimates of dust ingestion rates are needed than the currently available exposure factors that everyone is using
- Most data generated is for PBDEs, primarily from the PentaBDE product and data for HBCD, PFCs and other compounds is needed

Sources of variability in POC concentrations

The distributions of POC concentrations in dust from microenvironments are highly skewed, with a few samples always having very high concentrations. The major PBDE component in dust is usually DecaBDE, which is difficult to explain as it is non-volatile and should not be emitted from materials by outgassing. Thomas Webster discussed other possible pathways of PBDEs into indoor environment besides volatilization, such as partitioning from plastic or physical weathering. In particular, he presented results for DecaBDE in dust from homes, offices and cars from the US and Europe. Three highly-contaminated dust samples were analyzed using forensic microscopy (e.g., scanning electron microscopy) to study the components of dust combined with

micro-XRF analysis to analyze dust particles for bromine content. The results of this analysis suggested that high concentrations of DecaBDE in the dust samples were due to weathering or physical degradation of flame-retarded plastics/fibres as the main source, while it is hypothesised that for PentaBDE both processes (volatilization and partitioning) are possible. It was suggested that environmental forensic microscopy provides novel insights into the origins of DecaBDE in dust and its mechanisms of transfer from products. However, this method has some limitations as dust is a very complex heterogeneous substance and the process of its characterization is subject to interferences. Therefore, this method is a good semi-quantitative tool which should be used in conjunction with more traditional methods such as gas chromatography/mass spectrometry. Another possible method is to use particle-induced X-ray emission (PIXE), but this is an expensive technique.

Our current understanding of how POC concentrations vary over space (different rooms in a home, different parts of the same room) and time is very sparse. Sampling campaigns carried out using active air sampling over 1 day (active sampling) and where dust sampling is performed at the end of the air sampling period give only a snapshot picture of exposure from indoor air and dust. Passive air samplers integrate air concentrations over several weeks/months but miss POCs that are particle bound, such as DecaBDE. If dust is taken from a home vacuum cleaner bag, variable time periods of exposure are represented. So the question is, how representative of human exposure is the widely-used approach of taking a single sample from 1 room at 1 point in time? Stuart Harrad discussed several aspects of spatial and temporal variability in contamination of indoor dust with PBDEs and HBCD which were determined in various rooms of private houses or offices in the UK. Both within-room spatial and temporal variability in BFR concentrations in dust were found (the BDE-209 concentration in one sample was 400 times higher than that detected in a later sample from the same room) which may have to be taken into account when estimating human exposure via dust ingestion. However, Thomas Webster pointed out that they did not see much temporal variation in homes in Boston, USA, and that this may not be very important given the many other variables that can play a role in exposure variability. Spatial variability was often related to the proximity to a source, for example, declining HBCD concentrations with distance from a TV. For HBCD, the isomer profile also changed with distance from the TV, from predominantly gamma-HBCD to more alpha-HBCD in the dust, due to photolysis. It was also suggested that within-room spatial variability in concentrations of BFRs in dust is attributable to spatial variability in dust loadings. Temporal variability in BFRs concentrations offers insights into potential emission sources as it could be linked to changes in room contents (introduction or removal of TV set, DVD, and new carpet).

Variability in PBDE concentrations was also seen by Manolis Mandalakis in microenvironments from Greece, with highest concentrations in internet cafés and electronics stores and lowest concentrations in homes, probably due to the presence of larger numbers of flame-retarded products in the cafés and stores. Workers in such microenvironments may thus be more highly exposed to PBDEs. However, even in these extreme cases, the contribution of air to total intake of PBDEs is rather low, not higher than a few percent (typically 1%). He also presented results from studies of air in cars, and found that the PBDE concentrations were highest in new cars and then declined with time. Air concentrations in cars were comparable to internet cafés. The ratio of BDE47 to BDE99 also changes with car age, with higher proportions of BDE47 with increasing age. Concentrations of tetra- and pentaBDEs increased with car temperature, but no increase was seen for decaBDE.

Very little data are available for PFCs in dust and almost no data for PFCs in indoor air samples. This is due to problems with air sampling methodology for PFCs, where standard

methods for other POCs do not work. Since many PFCs are very volatile, they are not captured on the sampling train. Sandra Huber presented methodology and results from a pilot study in Norway investigating distribution and levels of PFCs in indoor air and dust samples collected from rooms of various activities (living rooms, bedrooms, offices). Air sampling was done using glass columns filled with PUF-XAD_PUF sandwiches, which capture the volatile PFCs. It was found that methods applied are suitable for most of the analytes except 4:2 FTOH (showed approximately 50% breakthrough). Among PFCs investigated in this study the carboxylates were predominant in almost all dust samples with the exception of those collected from the office and storage rooms where sulfonates have been the most prominent. Differences in PFC composition were seen in samples from different rooms of the same home. In some cases they could relate concentrations of some PFCs with room contents (carpets) but in other cases they could not.

Knowledge gaps identified

- Several different dust sampling techniques are used by different groups (resident's vacuum cleaner bag dust, researcher sampling of floors using different protocols, researcher sampling of above-floor surfaces) and the comparability between these needs to be established so we know concentration data are comparable.
- Comparability of dust of different size fractions – some groups sieve samples, others do not.
- Comparability of air sampling methods is also unclear (passive vs active).
- More types of microenvironments need to be studied to understand sources but also to quantify exposure from these as well as homes.

Indoor exposure to POCs and contribution to body burdens

The first presentation by Conny Ostman introduced us to a very interesting approach for air sampling, involving both targeted (chemical specific) and non-targeted sampling and analysis. This was part of a large project supported by the City of Stockholm trying to classify sick and healthy buildings based on questionnaires (where people described their complaints), but also via air analysis for a range of pollutants. Targeted analysis included active air sampling of organophosphate flame retardants (~15 OP-FR compounds) and phthalate esters (~8 compounds) using SPE cartridges. Phthalates were found in relatively similar concentrations in the different homes, day-care centers and offices. However, large differences in concentrations and profiles of OP-FRs were found between the investigated indoor environments. Non-target analysis involved a similar sampling approach, but the extracts were analysed by GC-EI/MS in full scan, encompassing a broad range of compounds. Through appropriate statistical and combinatorial methods, characteristics of the range of chemicals that separate sick and healthy buildings from each other could be found and the identification of these compounds is still on-going.

Several different dust ingestion rates are currently used based on exposure factors derived by regulatory authorities in different countries from studies of inadvertent soil ingestion in adults and children. They were never developed for estimating dust ingestion as such but are the only exposure factors currently available. Using these various exposure factors, a few studies have estimated intake of various brominated flame retardants from dust ingestion, inhalation of indoor air and diet. The results depend on which dust ingestion factors (average, maximum) are used and also on which dust concentrations are utilized (median, mean, various percentiles). Depending on which estimates are used, dust ingestion may play a minor role compared to diet, or may be the major exposure pathway, particularly in estimates for toddlers. This is not very satisfying and it is clear that either better exposure factors need to be

derived and/or that more direct measures of exposure, such as actual body burdens, need to be determined.

Another question that needs answering is just how bioavailable the different POCs are from dust after ingestion. Mohamed Abdallah presented very interesting and new data on the bioaccessibility of HBCD isomers from dust using an *in vitro* gastrointestinal tract (GIT) model. Bioaccessibility was defined as the fraction of HBCD that dissolved into the GIT fluids. The GIT simulation media mimicked the stomach, the small intestine and the colon in terms of conditions and enzymes and the release of HBCDs from contaminated dust was studied for each of these individually as well as by simulating the passage through the entire GIT. The alpha-HBCD isomer was more bioaccessible than the beta- and gamma-isomers, but in total, 77% of the HBCD on the dust was bioaccessible. Further experiments are needed here and the participants have suggested some improvements which can simulate the real-life situations in the GIT much better. This was thought to be a very interesting method for testing bioaccessibility of POCs in general.

Body burden will depend on exposure from all possible routes, the primary ones identified being diet and dust ingestion. However, the few studies available for BFRs have studied human serum concentrations related to either dust concentrations in the home or from diet, with varying results. Adrian Covaci presented results from a new study from Belgium measuring PBDEs, including BDE-209, and HBCD stereoisomers in the diet, dust and blood serum of around 20 human subjects in order to determine the proportions of each exposure route that might explain the body concentrations found. For the tri-heptaBDEs no correlations were found between serum concentrations and dust exposure alone, dietary intake alone or dust in combination with dietary exposure. In contrast, the data indicated that exposure to HBCDs via dust (but not diet) was correlated with concentrations in blood serum. BDE-209 was not detected in any serum samples. The absence of any correlation between dust and dietary exposure and serum concentrations for PBDEs may be due to exposures not accounted for during the week-long study duration which may influence body burdens strongly. Intake from dust ingestion and diet were calculated and diet was found to be the predominant exposure pathway (90-95%) for the PBDEs, including BDE-209. However, calculated intakes of HBCD from dust ingestion were 35% in an average dust ingestion scenario and 50% in the high dust scenario, compared to diet. The HBCD isomer profile in food was predominantly the gamma-isomer, whereas the alpha-isomer dominated in dust and was the only isomer present in serum. In general, the dust concentrations of BFRs were low compared to other European and international studies and at the higher concentrations reported in other countries, dust ingestion would become more important as an exposure pathway.

Another approach, presented by Pim Leonards, is to try to back-calculate the concentrations needed from all exposure routes to produce the concentrations found in the body. He used a one-compartment pharmacokinetic model, including a bioavailability term and ran this for specific BDE congeners. The model needs values for the half-life of the particular compound (or the elimination rate), the assimilation efficiency (bioavailability) and the total intake rate for humans. Literature values were used for the first three parameters, and different intake values were then tested. In the model, serum levels of BDE-209 reach an equilibrium level after 2 months of stable exposure, but if the exposure was decreased to 10% for 2 weeks, a rapid drop in serum concentrations was modelled to occur. In contrast, BDE-153 requires much longer time to reach equilibrium in serum (12 years), hence no change in concentrations occurs if exposure levels decrease over a short period of time. This is important information for designing sampling strategies. Using published data on BDE-209, -153 and -47 concentrations in human serum,

Leonards calculated the intakes needed to establish these concentrations, and compared them to the congener patterns of different sources: dust, indoor air and various foodstuffs (meat, fish). Dust and fish were found to match best. The model parameters are dependent on the availability of data and there is a lack of good data on body burdens of BDE-209.

A further development was presented by Line Haug, where samples of dust and air from the home, diet, blood and breast milk from 40 women in a cohort will be analyzed for BFRs and PFCs. An XRF instrument has been used to measure bromine content in various consumer products in the room sampled for dust and air. This cohort is complemented by another cohort from the Norwegian Fish and Game study. The use of the XRF instrument revealed some products with very high (up to 10%) bromine contents and in unexpected products such as chargers, transformers, extension cords, touch pads of laptops. She also presented a recently published method for measuring PFCs in very small volumes of serum, and the method allows high throughput at low cost. Serum PFOS and PFOA concentrations increased from 1976 to 1995 but have then declined slowly, there are no differences in concentrations between women and men, but concentrations increase with age.

A comparison of PBDE concentrations in dust and air from different microenvironments from different countries was presented based on published data. The general picture that emerged was that for PentaBDE, concentrations are higher in North America compared to Europe, but that BDE-209 concentrations are higher in the UK and the US. There may be geographical differences in PentaBDE concentrations on a state-wide level in the US, but the data is too sparse to draw conclusions. The UK also seems to display far higher concentrations of BDE-209 than elsewhere in Europe. Offices seem to have higher PBDE concentrations than homes. Cars have measurable PBDE concentrations in air and dust, with some vehicles displaying extremely high concentrations. There are less data available for HBCD, but it is found in dust and air samples in homes, cars, classrooms and offices in Europe. For the PFCs, very little data is available. A general comment when discussing the comparisons was the problem of comparability between studies due to different dust and air sampling methods used, number of microenvironments sampled, classification of microenvironments and the problems presented previously with spatial and temporal variability.

Knowledge gaps identified:

- We need a better understanding of why there is breakthrough of DecaBDE from filters to PUFs when air sampling, which has been seen by three different research groups.
 - Organophosphate esters are replacing some of the BFRs in various applications and we need more information on their production and use volumes, and their regulatory status.
 - A number of new BFRs are being used as replacements for PBDEs and we need more information about these including production volumes. Many of them are being marketed in technical products where the exact ingredients are considered trade secrets, for example. There will be a need to develop analytical techniques and determine the toxicity of these as well.
 - Body burdens of POPs in children and adults are conventionally determined by the analysis of serum samples. However, for children blood samples can be difficult to obtain. There is thus a strong need to develop non-invasive methods (hair, other tissues?) to sample children.
 - Some of the half-lives that have been suggested for PBDEs are questionable and more studies are needed to give better estimates.
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- Up to now, the toxic effects of POPs are mostly investigated on the basis of individual compounds. However, the combined exposure to multiple POPs can pose a larger effect compared to the summed effects of individual components. There is an urgent need for more studies about the effects of exposure to POP cocktails.
- More studies combining multiple exposure routes, body burdens, pharmacokinetic modeling and epidemiology are needed.
- More studies characterizing exposure from different microenvironments in more countries are needed.
- Data on the bioavailability of POCs, particularly DecaBDE, from dust particles is needed.
- The suite of POCs measured needs to be expanded.
- More geographical coverage is needed to better understand the connection between production/use volumes in different countries and concentrations found in indoor microenvironments.

Relationships between indoor and outdoor contamination

Concentrations of BFRs are much higher indoors than outdoors. Concentration gradients are seen with higher concentrations in city centers and declining concentrations with distance from the centers. These observations have led to speculation that indoor microenvironments may be a major source of BFRs to the outdoor environment via ventilation systems. Justina Björklund presented some research results supporting this hypothesis. Active air samples were collected in ventilation drums as well as in 1-4 rooms within each building for a number of daycare centers, office buildings and apartment buildings. The results showed similar PBDE concentrations in the room air and in the outgoing air in the ventilation system, with a predominance of BDE-209 in both. The congener profile was somewhat different, however, and the results need further data analysis to determine possible explanations for this.

Miriam Diamond then presented how releases from indoor microenvironments to outdoors can be modelled, linking her previous indoor model exercise of PBDEs to an urban fate model. The modelled concentrations released from sources indoors were combined with ventilation rates to estimate releases to the outdoors. Once outdoors, PBDEs will deposit on buildings and surfaces, rain will wash them off and they will enter sewers and eventually the aquatic environment. Dry deposition will deposit them on vegetation and soils. From these pathways, the PBDEs will then enter the food chain, and we will be exposed to them via diet. Her model estimates that the majority of PBDEs released from buildings will be exported out of the city.

Knowledge gaps identified:

- More studies are needed to understand the role of emissions from indoors to the outdoors and the magnitude of these emissions.
- More POCs need to be measured so they can be included in models.
- More data on the physico-chemical characteristics of many POCs needed to enable accurate modelling.

3. Assessment of the results, contribution to the future direction of the field, outcome

All participants in the workshop were pleased with the outcome, and with having plenty of time for discussion. The following actions were discussed. An application will be prepared to the Marie Curie initial training network (ITN) program for an exchange program for graduate students and post-docs between the participating research groups. The call opens on September 8 and the proposal deadline is January 8, 2010. A new call within the EU Framework Programme (FP7) is coming in July, with a deadline probably in early 2010. We will look at this for any possible areas that could be addressed and write a proposal if such a topic is available. This would be linked to the ITN program as well.

A possible outcome may be a proposal to compare the different dust sampling methods used by the different research groups. We also discussed plans to write a review article based on the current state-of-the-science with identification of the key knowledge gaps. This would be an excellent background document to then use when preparing the various research applications.

4. FINAL PROGRAMME

Sunday, 22 March 2009

Afternoon	<i>Arrival</i>
18.00-20.00	<i>Get-together and simple dinner (Lunch room, 4th floor, Geosciences Building)</i>

Monday, 23 March 2009

09.00-09.20	Welcome and introductions Cynthia de Wit (Overall Workshop Chair, Stockholm University, Stockholm, Sweden)
09.20-09.40	Presentation of the European Science Foundation (ESF) Katarina Polakova (ESF Standing Committee for the European Medical Research Councils (EMRC) and Sonja Lojen Standing Committee for Life, Earth and Environmental Sciences (LESC)
09.40-12.30	Morning Session: Emission sources to indoor environments (Session chair: Stuart Harrad; Rapporteur: Pim Leonards)
09.40-10.00	Residential Exposure to PBDEs: From product to person Thomas Webster (Boston University, Boston, USA)
10.00-10.20	The INDOORTRON Laboratory: a stainless steel walk-in-type environmental chamber used in all kinds of indoor air emission tests Otmar Geiss (Joint Research Centre, Ispra, Italy)
10.20-10.50	<i>Coffee / Tea Break</i>
10.50-11.10	Indoor fate of PBDEs – emissions, sinks and sources Miriam Diamond (University of Toronto, Toronto, Canada)
11.10-12.30	Discussion
12.30-14.00	<i>Lunch</i>
14.00-18.15	Afternoon Session: POC concentrations in air and dust: sampling, sources of variability (Session chair: Jacob de Boer; Rapporteur: Iryna Labunska)
14.00-14.20	Identifying sources of DecaBDE in indoor environments using forensic microscopy Thomas Webster (Boston University, Boston, USA)
14.20-14.40	Spatial and temporal variability in contamination of indoor dust with BFRs Stuart Harrad (University of Birminham, Birmingham, UK)
14.40-15.00	Screening of PFCs in indoor environments by active sampling – a pilot study Sandra Huber (National Institute for Air Research, Tromsø, Norway)
15.00-15.30	<i>Coffee /Tea break</i>
15.30-18.15	Discussion
18.30	<i>Workshop Dinner</i>

Tuesday, 24 March 2009

- 09.00-12.30** **Morning Session: Estimating exposure from indoor microenvironments (Session chair: Miriam Diamond; Rapporteur: Adrian Covaci)**
- 09.00-09.20 **Organophosphate and phthalate esters in air and settled dust in indoor environments**
Conny Östman (Stockholm University, Stockholm, Sweden)
- 09.20-09.40 **Indoor air pollution by PBDEs in specialized occupational settings, houses and car interiors**
Manolis Mandalakis (University of Crete, Heraklion, Crete, Greece)
- 09.40-10.00 **Bioavailability of HBCDs from indoor dust**
Mohamed Abdallah (University of Birminham, Birmingham, UK)
- 10.00-10.30 *Coffee / Tea Break*
- 10.30-12.30 **Discussion**
- 12.30-14.00 *Lunch*
- 14.00-18.30** **Afternoon Session: Relating body concentrations to exposure via inhalation, dust ingestion and diet (Session chair: Per-Ola Darnerud; Rapporteur: Manolis Mandalakis)**
- 14.00-14.20 **How important are food and dust for human exposure to brominated flame retardants (BFRs)?**
Adrian Covaci (University of Antwerp, Wilrijk, Belgium)
- 14.20-14.40 **Associations between body concentrations of PBDEs and exposure sources?**
Pim Leonards (Vrije Universiteit, Amsterdam, the Netherlands)
- 14.40-15.00 **BROFLEX – Human exposure pathways of polyfluorinated compounds and brominated flame retardants used in consumer products as inputs to risk assessment**
Line Haug/Cathrine Thomsen (Norwegian Institute of Public Health, Oslo, Norway)
- 15.00-15.30 *Coffee / Tea break*
- 15.30-16.30 **International comparisons presentation with discussion (Chairs Cynthia de Wit and Stuart Harrad)**
- 16.30-18.30 **Discussion of session**
- 19.00 *Dinner*

Wednesday, 25 March 2009

- 09.00-12.00** **Morning Session: Relationships between indoor and outdoor contamination (Session chair: Tom Webster; Rapporteur: Caroline Bergh)**
- 09.00-09.20 **Indoor air as a source of tri-decaBDEs and HBCD to outdoor air**
Justina Björklund (Stockholm University, Stockholm, Sweden)
- 09.20-09.40 **Relating indoor and outdoor exposure (if it doesn't get you indoors it will get you outdoors)**
Miriam Diamond (University of Toronto, Toronto, Canada)
- 09.40-10.00 *Coffee / Tea Break including discussion of session*
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10.00-12.00	Discussion of follow-up activities (for example, collaborative proposals for funding, collaborative state-of-the-science review article, Marie Curie initial training network, etc.)
12.30-13.30	<i>Lunch</i>
13.30	<i>End of Workshop and Departure</i>

5. Statistical information on participants (age structure, gender, countries of origin etc.)

Participation by age

Age bracket	Number
20-29	4
30-39	5
40-49	4
50-59	7

Participation by gender

Female 10

Male 10

Institutional participation by country

Belgium	1
Canada	1
Greece	1
Italy	1
The Netherlands	2
Norway	3
Slovakia	1
Slovenia	1
Sweden	5
UK	3
USA	1

6. Final List of Participants

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