INDOOR POLLUTANTS IN DUST FROM NONHAZCITY PILOT FAMILIES IN STOCKHOLM

TEST REPORT ON DUST CAMPAIGN

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NONHAZCITY

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TEST REPORT ON DUST CAMPAIGN, REPORT FROM WORK IN GOA 5.4 ”TEST YOUR ENVIRONMENT”

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INNEHÅLL

1 SAMMANFATTNING

Inomhusdamm från fem hushåll i Stockholmsområdet har varit föremål för undersökningen som utförts av kemikaliecentrum, Stockholms stad. Målet med studien var att lyfta frågan och öka medvetenheten kring vilka vanligt förekommande miljöföroreningar som vi omges av i vår hemmamiljö. Sex grupper av kemikalier har analyserats däribland mjukgörare som ftalater, organiska fosfatestrar, bisfenoler och klorparaffiner samt flamskyddsmedel och perfluorerade ämnen.

Vissa av de analyserade ämnena är reglerade enligt lagar och förordningar eller via globala överenskommelser, som Stockholmskonventionen, därför att de utgör en uppenbar fara för människor och miljön. Flera av dessa ämnen har producerats industriellt och i stor skala under decennier för användning i konsumentprodukter. Ämnenas inneboende kemiska egenskaper men även hur de har tillsats i den färdiga produkten kommer att påverka risken för att dessa kemikalier läcker ut och frigörs. Detta sker succesivt och damm anses vara en naturlig källa till miljöföroreningar i inomhusmiljön där de även koncentreras över tid.

Resultatet från den här studien visar på generellt låga halter av de analyserade miljöföroreningarna i jämförelse med tidigare studier från bostäder eller förskolor i Stockholmsområdet. Det är dock viktigt att understryka studiens begränsningar. De rapporterade halterna bör ses som stickprov på hushållsdamm från Stockholm under 2017 snarare än en fullvärdig studie.

De uppmätta koncentrationerna av ftalater och deras ersättningsprodukter i hushållsdamm är generellt längre än vad som har rapporterats i tidigare studier och beror antagligen på att parkett/trägolv eller linoleum används som golvytskikt i samtliga hushåll. DEHP återfanns i högst koncentrationer bland de analyserade ftalaterna följt av DEHT och DiNP som har använts som ersättningsprodukter för DEHP.

De mellankedjiga klorparaffinerna var de klorparaffiner som förekom i högst halt i dammproverna följt av de lång- och kortkedjiga klorparaffinerna. De reglerade kortkedjiga paraffinerna stod för ca 20% av den totala mängden av analyserade klorparaffiner i hushållsdammet.

Bland de perfluorerade ämnena förekom PFOA i högst halt i dammproverna. PFOA är en föreslagen kandidat till Stockholmkonventionens lista över persistenta, bioackumulerande och toxiska ämnen, vilket innebär att PFOA är föremål för globalt förbjud.

Koncentrationer av idag reglerade eller förbjudna organofosfatestrar och bromerade flamskyddsmedel från denna studie jämfördes med tidigare studier av damm från hushåll och förskolor i Stockholmsområdet. Dammkoncentrationer av dessa reglerade ämnen visar på en nedåtgående trend. Den dominerande organofosfaten i denna studie var den icke-reglerade TBEP. Denna har företrädelsevis används som mjukgörare och inte ett flamskyddsmedel. De högsta halterna av bromerade flamskyddsmedel i damm uppmättes för DBDPE och BEH-TEBP vilka båda är ersättningsprodukter för de förbjudna PBDE:erna.

Halter av de reglerade kemikalierna i damm från inomhusmiljöer påverkas av flera faktorer. Exempelvis så har kemikaliers reaktivitet, produktionsvolymer samt tidsaspekten sedan införandet av den legala restriktionen betydelse för hur länge kemikalier förekommer i dammprover. Dessutom påverkas halterna i damm av varans livslängd, d v s hur ofta den byts ut inom hushållet. En annan aspekt gäller privatpersoners och företags direktimport av varor och produkter producerade utanför EU, exempelvis USA eller Asien, där produkter och varor inte måste klara Europeisk lagstiftning.

Flera av de reglerade kemikalierna förekom i dammproverna och den dagliga dosen av dessa kemikaliers exponering från damm beräknades och jämfördes med ett referensvärde för acceptabel risk, exempelvis EFSAs tolerable daily intake (TDI). De uppmätta halterna för de fem hushållen i denna studie låg i storleksordningen 100 – 10 000 ggr lägre än satta referensvärden. Det är dock av vikt att räkna på fler exponeringsvägar än damm (så som upptag via hud eller intag av vatten och föda) för den totala bedömningen om risk och när halter jämförs mot ett riskvärde.

2 SUMMARY

Indoor dust from five private homes including four houses and one apartment in the Stockholm area was collected to measure common indoor pollutants. The aim was to raise the awareness of which kind of industrial, commonly used, man-made chemicals that are present in our homes. Six groups of chemical classes were investigated; phthalates, organophosphorous esters (OPEs), bisphenols and chlorinated paraffins (CPs), brominated flame retardants (BFRs) and perfluoroalkyl substances (PFAS).

For some of the analyzed compounds, legal restrictions apply because of their inherent hazardous properties to humans and the environment. Many of these legally restricted compounds are chemicals that have been produced industrially for several decades and are present in many consumer products. Because of their chemical properties and how these additives were incorporated to the article, they may leak out of the product over time. In indoor environments, dust is a natural sink, in which indoor pollutants will accumulate.

The results from this study indicate overall low concentrations of indoor pollutants in comparison to earlier published data from Swedish homes or day care facilities. However, the author would like to emphasize that the data presented in this study ought to be treated as examples of concentrations of house dust in homes of Stockholm in 2017, rather than a thorough study.

The measured levels of traditional phthalates and replacement substances in this present study are much lower than reported previously in dust from Sweden, probably because hardwood dominates as flooring material in these households. DEHP was present in highest concentration amongst the reported phthalates followed by DEHT and DiNP used as replacement substances for DEHP.

The median-chain chlorinated paraffins (MCCPs) were found in the highest concentrations followed by long-chain chlorinated paraffins (LCCPs) and short-chain chlorinated paraffins (SCCPs). Of these chlorinated paraffins (CP), the SCCPs are restricted, and constitute for about 20% of the total concentration of CP in the house dust reported in this study.

Amongst the perfluoroalkyl substances, PFOA was found in highest concentration in house dust, a candidate proposed for listing under the Stockholm Convention.

Concentrations of several OPEs and BFRs in house dust, now subject for restriction, were compared to previous studies of reported house dust/pre-schools from the Stockholm area. The reported levels are declining over time. The dominating OPE in this study was TBEP. This chemical is primarily used as a plasticizer and not as a flame retardant. DBDPE and BEH-TEBP were the two dominating flame retardants present in dust from this study. They are both used as replacement substances of the legally restricted PBDEs. Current dust concentrations of the restricted chemicals are a result of many different factors e.g. the stability or reactivity of the chemical, time span since the article where the chemical is used was produced, production volumes and when legal restrictions have entered force. Another important aspect here is also the lifetime of the product in use. Importing articles/chemical products from outside EU, e.g. US and Asia, implies a risk of taking in restricted or banned chemicals to our homes, since the European chemical legislation does not apply to these products.

Several harmful and legally restricted chemicals were abundant in the household dust. For these compounds, the exposure from dust was calculated. The assessed exposures were compared to a risk number such as tolerable daily intake. The exposure levels measured for these harmful compounds in the five homes were within 100 – 10 000 times lower than the set value for the chemical. However, dust alone seldom constitutes for the entire exposure, thus other sources such as dermal uptake and dietary sources are of importance when comparing numbers to a risk value.

3 INTRODUCTION

Dust from different indoor environments such as households may be a source of non-dietary human exposure considering we spend a considerable amount of the time indoors. Of importance is to add dietary and non-dietary exposures to assess the total exposure for comparison to a risk value. The scope of this study covers pollutants relevant for indoor environments originating from e.g. surface layers of commonly used building materials, flame retardants in electronics (TV-screens, cell phones, etc.) and textiles, furniture or plasticizers in plastic polymers. The selected chemicals included in this study are commonly used as additives, present in numerous products used in our daily living and produced in large volumes. Several of these have shown to be harmful to human and have been subject for legal regulation in order to control the production and use of these chemicals in material and articles.

Many of these additives are organic molecules and by nature semi-volatile, i.e. high boiling points and are very persistent, also known as persistent organic pollutants (POPs). A persistent chemical is very stable and have a long degradation time in humans and/or environment, hence have a long half-life.

3.1 PERSISTENT ORGANIC POLLUTANTS (POPS)

A trademark for many POPs, except for being persistent (P), is that they may also possess bioaccumulative (B) and toxic (T) properties. To be bioaccumulative means that the chemical is bioavailable and will concentrate over time in humans and biota. Toxicity is referring to the toxic effect of the compound to human health and to the environment. Chemicals possessing all of these three characteristics are most likely to be subject for regulation (ban or restriction of use). When a chemical is listed on the REACH Candidate list, it means it has been identified as substance of very high concern (SVHC), and the chemical risk using this substance is being evaluated. This may be the first step towards a restriction. A restriction may include authorization of use or regulation in terms of maximum weight percent allowance. Stockholm Convention is a global treaty, which has been signed by 152 parties around the world, hence spanning further and outside EUs chemical regulation REACH.

The problem with additives is that they are not chemically bound to the product, and may leak out of products over time. This continues beyond the end of the article lifecycle if the material is being recycled. In indoor environments, POPs accumulate or enrich in dust or attached to small particles in air. Thus, exposure to these chemicals in our day living occurs through ingestion of dust, via dermal uptake from dust or through inhalation of air. Exposure via water and food is another important source of exposure and has been commonly studied for the legacy POPs.

Tolerable daily intake (TDI) is a calculated value of safe exposure, which is dependent on the chemical hazards. The unit is in ng or µg/kg bw per day, where bw stands for body weight. The European Food Safety Agency (EFSA) issues these assessment documents. Reference dose (RfD) is a measure of maximum acceptable oral dose of exposure, issued by the US Environmental Protection Agency (US EPA). Derived no-effect level (DNEL) is another measure set by the European Chemicals Agency (ECHA) and states the level of exposure to a chemical above which humans should not be exposed to.

3.1.1 Phthalates

Phthalates are additives used as softeners or plasticizers in a variety of polymer materials such as PVC and in personal care products. Phthalates are the group of indoor pollutants generally found in largest concentration in indoor dust due to their extensive usage. Many of the phthalic acid esters have been classified as potential carcinogens and/or endocrine disruptors. Four of the phthalates, DEHP (Bis(2-ethylhexyl)phthalate), DiBP (Diisobutyl phthalate), DnBP (Di-n-butylphthalate) and BBzP (Benzyl butyl phthalate) are substances added to

REACH authorization list, Annex XIV due to their cancerogenic and reproductive hazard. Any use of the four phthalates in products requires legal authorization, which in practice strongly restrict their use. In addition, REACH Annex XVII restricts usage of DiNP (Diisobutyl phthalate) and DiDP (Diisodecyl phthalate) in children's toys where their use must not exceed 0.1% by weight.

As a consequence of the insight of the phthalates reproductive toxicity, replacement substances, still used as additives, but with less toxicity has been put on the market. ATBC (Acetyltributylcitrate), DEHA (Bis(2-ethylhexyl)adipate), DEHT (Bis(2-ethylhexyl)terephthalate) and DINCH (1,2-Cyclohexane dicarboxylic acid diisononyl ester) have no identified hazards or toxicity according to the European Chemicals Agency (ECHA)s.

3.1.2 Organophosphate esters

Organophosphate esters (OPE) are additives used both as flame retardants (PFR) and plasticizers in polymeric materials. Halogenated phosphorous esters such as tris(2-chloroethyl)phosphate (TCEP), tris(2-chloroisopropyl) phosphate (TCPP) and tris(2,3-dichloropropyl)phosphate (TDCPP) have mainly been used in textiles and polyurethane foam. Non-halogenated phosphate esters such as tris(phenyl)phosphate (TPP) and tris(2-butoxyethyl)phosphate (TBEP) has preferable been used as plasticizers. In addition, TBEP is also used in floor polishing to achieve gloss. The chlorinated PFR, TCEP has been shown to have several adverse health effects such as cancer, neurodevelopmental and endocrine disrupting effects. TCEP is classified according to REACH harmonized classification system with following hazards; cancerogenic (Category 2, suspect of causing cancer) and teratogenic (may damage fertility) and is acutely toxic (if swallowed). The use of TCEP requires authorization within REACH.

3.1.3 Bisphenols

Bisphenol A (BPA) is a chemical compound used as a reactive plastic hardener in large quantities in the production of synthetic polymers such as polycarbonate (thermoplastics) and epoxy plastics. Another important usage for the compound is in thermal paper for receipts. BPA have endocrine disrupting effects, as shown in *in vitro* and *in vivo* studies as well as in epidemiological studies. BPA is identified as a SVHC due to its reproductive toxicity and skin sensitizer properties, and is included on the Candidate list and Annex XVII. For usage of BPA in thermal paper, restrictions will be effective as of January 2020. By then BPA cannot be abundant in greater concentrations than 0.02% by weight. Bisphenol F (BPF), Bisphenol AF (BPAF) and Bisphenol S (BPS) are BPA analogues, i.e. they have structural resembles to BPA. They have been used for the same chemical purposes. The BPA analogues possible adverse health effects are currently under investigation.

3.1.4 Chlorinated paraffins

Chlorinated paraffins (CP) are another group of industrial chemicals that has been in use since the 1930s. Their use has been as anti-wear lubricants in metal machinery, as plasticizers and flame retardants in plastics as well as additives in paint and sealant. CP consist of chlorinated n-alkanes of a length of 10-30 carbons and a chlorine content of about 40-70% by mass. CP are divided into short (SCCPs, C10-13), medium (MCCPs, C14-17), and long chain (LCCPs, C18-30) CP depending on the length of the carbon chain. The SCCP and MCCPs replaced the use of polychlorinated biphenyls (PCBs) in many building material applications. SCCPs have shown PBT properties and has been adopted in the Stockholm Convention. SCCPs are classified as a suspect of causing cancer and is included on the Candidate list. The use and production of MCCPs have no restriction although being recognized with hazards as very toxic to aquatic life with long lasting effects and may cause harm to breast-fed children. For the LCCPs, no hazards have been identified, i.e. they are not classified and no restrictions apply.

3.1.5 Brominated flame retardants (BFR)

Flame retardants (FR) have a wide range of applications and are used in many of our household materials including furniture's, textiles and electrical equipment to protect us from fire by slowing down the process of

developing a fire. Brominated flame retardants (BFRs) are organic compounds containing bromine and are by nature semi-volatile chemicals. This group of flame retardants constitute for a large portion of the total world production since they are cost-efficient in how much FR that is needed to add to a product to meet the flammability standards. They are further divided into two groups; reactive and additives. The reactive FR are chemically bound to the product, e.g. tetrabromobisphenol-A (TBBPA), whereas the additive FR are added to the final product, e.g. polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCDD). TBBPA is a high production volume chemical and is primarily used in printed circuit boards as a reactive flame retardant, hence present in a wide range of applications such as TVs, computers, printers, cell phones, washing machines (de wit et al. 2010). TBBPA may also be used as an additive FR. TBBPA is readily degraded in human and does not bioaccumulate. There are no established human hazard identified towards humans although the chemical has been subject for evaluation as an endocrine disruptor. At present, there are no TDI values established for TBBPA and no restrictions of use applies.

PBDEs were sold as three technical mixtures, Penta-, Octa- och DecaBDE depending on bromine content. Compound BDE-47, BDE-100, BDE-99 and BDE-153 are the predominantly congeners found in commercial PentaBDE and the dominating congener of DecaBDE is BDE-209. In the OctaBDE formulation (not analysed here) BDE-183 and BDE-197 constitutes for the major part of the total content of brominated diphenyl ethers. PBDEs have been used in a variety of products such as thermoplastics, electronic equipment such as TV-screens, computers), textiles and in building and construction materials since the 1970s. HBCDD consists of three isomers (α-, β- and γ- HBCDD) and their main use have been as additive in polystyrene foam. PBDEs and HBCDD are recognized POPs and they are strictly regulated under the Stockholm Conventions Annex A. The production and use of these chemicals are to be eliminated by the parties signing the convention.

1,2-dibromo-4-(1,2 dibromoethyl) cyclohexane (TBECH), 2,3,4,5-tetrabromo-ethylhexylbenzoate (EHTBB) andbis (2-ethylhexyl) tetrabromophthalate (BEHTBP) are replacement substances put on the market to replace legacy FR such as PentaBDE. Decabromodiphenyl ethane (DBDPE) is a replacement product of DecaBDE. DBDPE was placed on the market during the 1990s. These new replacement substances are also referred to as emerging flame retardants.

3.1.6 PFAS

Perfluoroalkyl substances (PFAS) belongs to a group of synthetic industrial produced chemicals used for many different purposes since the 1950s. The structure of PFAS are characterized by a fully fluorinated carbon skeleton with a hydrophilic head, a so-called functional group. This hydrophilic head may consist of a sulfonic acid, sulfonamide, sulfonate or a carboxylic acid. Thus, PFAS compounds have both hydrophilic and hydrophobic properties. The long chain PFAS, with a backbone consisting of more than eight carbons are very persistent i.e. their degradation rates are very slow in humans and in the environment. Amongst the most abundant and carefully studied PFAS compounds are PFOS (Perfluorooctanesulfonic acid) and PFOA (Perfluorooctanoic acid). They consist of an eight carbon-length long chain and a sulfonic and carboxylic acid head respectively. PFOS has been used as stain-repellant or impregnation agent on fabric and textiles because of its chemical properties. It was also used in food packaging material to repel grease and water. Another large application for PFOS has been in fire fighter foam. PFOS was adopted to the Stockholm Convention in 2009, due to its PBT properties, and is restricted globally. PFOS was replaced with PFAS analogues of shorter carbon length. In general, the eight-carbon PFAS industry shifted towards an industry of four-carbon. The desirable surfactant chemistry of the PFAS was achieved but without the negative bioaccumulative effects. FOSA, a metabolic precursor to PFOS commonly used in stain-repellant products prior to restriction PFOS, was not subject to a restriction but was phased out on voluntarily bases. PFBS (Perfluorobutanesulfonic acid), PFHxS (Perfluorohexanesulfonic acid), 6:2 FTS (6:2 fluorotelomer sulfonate) and PFDS (Perfluorodecane-sulfonic acid) have been used as replacement substances of PFOS. PFHxS, a six-carbon long sulfonic acid has been identified as SVHC due to its very persistent and very bioaccumulative properties. Further, PFHxS is a candidate proposed for listing under the Stockholm Convention.

PFOA has been used as surfactants or emulsifying agent in the production of e.g. fluoropolymers such as Teflon and is used in non-stick cookware. PFOA was identified as a substance of very high concern (SVHC) and was added to the Candidate list. As of 2020, the use of PFOA will be restricted. Any use of the substance will require authorization within REACH due to its reproductive toxic and bioaccumulative properties. PFOA is also a candidate proposed for listing under the Stockholm Convention.

PFPeA (Perfluoropentanoic acid), PFHxA (Perfluorohexanoic acid) and PFHpA (Perfluoroheptanoic acid) and PFNA (Perfluorononanoic acid) are PFOA analogues with a chain length of five, six, seven and nine carbons. PFNA have reproductive toxicity properties and is identified as a SVHC and included on the Candidate list for authorization.

The main pathways of human exposure to PFOS and PFOA are via food and water. However, they have also been recognized as indoor pollutants, prevalent in dust from indoor environments.

4 METHOD

4.1 SAMPLING

Indoor dust samples from five private homes (apartment/house) were collected within the Stockholm area. Sampling was conducted during 2017-09-06 to 2017-10-02. Maria Arwidsson from Kemikaliecentrum, Environment and Health Administration, City of Stockholm organized and carried out the dust sampling. Two samples from each home were collected: settled dust (50-200cm above the floor) from the living room and floor dust from the bedroom. The different types of flooring in the five homes were hardwood, linoleum, painted wood and hardwood parquet (Table 1.). Dust samples were collected on a cellulose filter (7 cm diameter) fixed in a styrene-acrylonitrile holder (Krim.Teknisk Materiel AB, Bålsta, Sweden), with a sieve placed on top of the filter for collecting dust for FR analysis. The filter holder was inserted in a nozzle made of polypropylene (Krim.Teknisk Materiel AB, Bålsta, Sweden) and mounted on the intake nozzle of a vacuum cleaner. In addition, information regarding flooring, renovations, area of rooms, ventilation system, electronic equipment, furniture's, textiles, children's toys present in each room were filled out in a questionnaire.

The analysis of BFR, PFR and chlorinated paraffin's in household dust were performed by the Department of Environmental Science and Analytical Chemistry (ACES) at Stockholm University in Stockholm. Phthalates, bisphenols and PFAS analysis were conducted by the Swedish Environmental Institute (IVL) in Stockholm.

Table 1. Overview over samples collected from five private homes in the Stockholm area of Sweden.

Home	*House/ Apartment*	*Room*	*Type of dust collected*	*Height above floor (cm)*	*Type of surface*
A	*House*	*Living room*	*Settled dust*	50-200	Stone, Wood
A	*House*	*Bed room*	*Floor dust*		Hardwood flooring
B	*Apartment*	*Office space*	*Settled dust*	180-200	Wood
B	*Apartment*	*Bed room*	*Floor dust*		Linoleum flooring
C	*House*	*Living room*	*Settled dust*	50-200	Wood, Painted wood
C	*House*	*Bed room*	*Floor dust*		Hardwood flooring
D	*House*	*Living room*	*Settled dust*	100-200	Wood, Painted wood, Fabric, Hard plastic
D	*House*	*Bed room*	*Floor dust*		Painted wood flooring
E	*House*	*Living room*	*Settled dust*	50-170	Wood, Painted wood, Glass, Plaster
E	*House*	*Bed room*	*Floor dust*		Hardwood flooring, Parquet flooring

4.2 EXPOSURE ASSESSMENT

The ingestion of dust in indoor environments is estimated to be 60 mg per day (EPA 2011). For the exposure assessment calculations, maximum time spent indoors (24h) for an adult with a bodyweight of 70 kg, are assumed. Children's exposure to dust was not assessed within the scope of this study. However, the contribution from dust to the total exposure is of greater importance for children due to higher dust intake and lower bodyweights.

5 PARTICIPANTS

Following family homes took part in this study. The names stated below are randomly ordered and does not correspond to the order of the household denoted A-E.

Karin Wanngård, Mayor of Stockholm

Therese Zätterqvist, Youtuber

Karolina Skog, Swedish Minister for the Environment

Magnus Carlson, Singer (Weeping Willows)

Pamela Bellafesta, Stylist (Metro)

6 RESULTS AND DISCUSSION

6.1 PHTHALATES

Thirteen phthalates or replacement substances were analyzed in household dust in this study. Data for the five private homes is presented in Table 2. DEHP, with a median concentration of 81 (µg/g), was found in highest concentration followed by DEHT and DiNP (44 and 38 µg/g). The two latter have been used as replacement substances for DEHP with the same area of usage.

Table 2. Concentrations (µg/g) of restricted phthalates, phthalates and replacement substances in house dust from five private homes.

			Restricted phthalates						*Phthalates*			*Replacement substances*			
Home	*Room*	*Amount (mg)*	**DEHP**	**DiBP**	**DnBP**	**BBzP**	**DiNP**	**DiDP**	**DMP**	**DEP**	**DPHP**	**ATBC**	**DEHA**	**DEHT**	**DINCH**
A	*Living room*	28	90	3,1	3,8	3,6	128	28	2,9	2,4	8,0	374	4,5	262	24
A	*Bed room*	72	57	2,7	5,0	6,6	46	19	0,43	1,0	4,1	68	3,3	1336	17
B	*Office space*	58	107	4,5	11	4,2	14	15	0,04	1,4	2,5	5,5	3,4	8,8	1,7
B	*Bed room*	47	53	4,6	11	6,5	26	26	0,08	1,5	4,7	5,0	3,7	20	3,5
C	*Living room*	6	72	1,5	18	1,9	34	29	0,15	1,9	5,0	49	3,6	22	10
C	*Bed room*	72	305	1,7	11	1,5	39	16	0,05	0,9	7,2	8	3,2	50	18
D	*Living room*	81	49	5,1	12	2,6	38	14	0,13	3,1	5,5	22	23	35	8,6
D	*Bed room*	57	67	9,6	5,2	1,3	31	13	0,11	2,3	5,0	45	8,1	65	6,7
E	*Living room*	42	135	7,7	31	3,7	43	23	0,14	2,0	7,0	21	6,5	38	5,2
E	*Bed room*	77	215	4,0	5,9	5,0	198	47	0,14	1,5	11	38	7,5	191	14
A-E	***Median***		**81**	**4,3**	**11**	**3,7**	**38**	**21**	**0,14**	**1,7**	**5,3**	**30**	**4,1**	**44**	**9,5**
	Min		**49**	**2**	**4**	**1**	**14**	**13**	**0**	**1**	**3**	**5**	**3**	**9**	**2**
	Max		**305**	**10**	**31**	**7**	**198**	**47**	**3**	**3**	**11**	**374**	**23**	**1336**	**24**

The concentrations found in house dust reflects production volumes or usage of the compounds. In 1994, DEHP and DiNP constituted for 49% and 2% respectively of the total amount of phthalates used as plasticizers in Sweden. In 2008, as DEHP was added to the candidate list, the usage of DEHP decreased to 5% and DiNP increased to 45% (Luongo et al. 2016). Plasticizers as DiNP and DiDP replacing DEHP in PVC-carpets were in 2015 subjects for restriction in plastic materials used in children's toys and childcare products. DEHT has also been used as an alternative plasticizer to DEHP in PVC, and was put on the market in 2010 and have since then increased steadily. This is reflected in dust samples reported in different studies during 2008-2017 (Figure 3.). In bedroom, floor dust from House E, DEHP, DiNP and DEHT were found in higher concentrations than the median for this study. Reported flooring for the sampled room was hardwood. However, going through the pictures taking at sampling interestingly shows a pilates ball sitting on the bedroom floor. These types of plasticizers are commonly used in this type of plastic and is a suspect source of phthalates. The highest levels of ATBC and DEHT for this study were found in household A. It is difficult to point out a source of suspect here. The area of usage for ATBC also includes personal care/cosmetics products such as aerosol hair sprays and nail polishes. However, these compounds are not classified i.e. they are not considered to have harmful effects.

The generally higher concentrations of phthalates found in the living rooms reflects the type of dust analyzed here. Settled dust, vacuumed above floor level, have been build up over a longer time. Thus, with time, higher concentrations of indoor pollutants will accumulate.

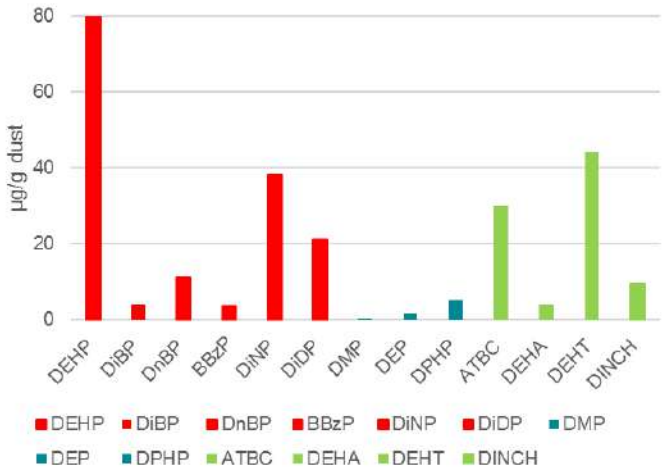

Figure 1. Median concentrations (µg/g) of restricted phthalates (red bars), non-restricted phthalates (blue bars) and replacement substances (green bars) in household dust from five private homes in Stockholm, Sweden.

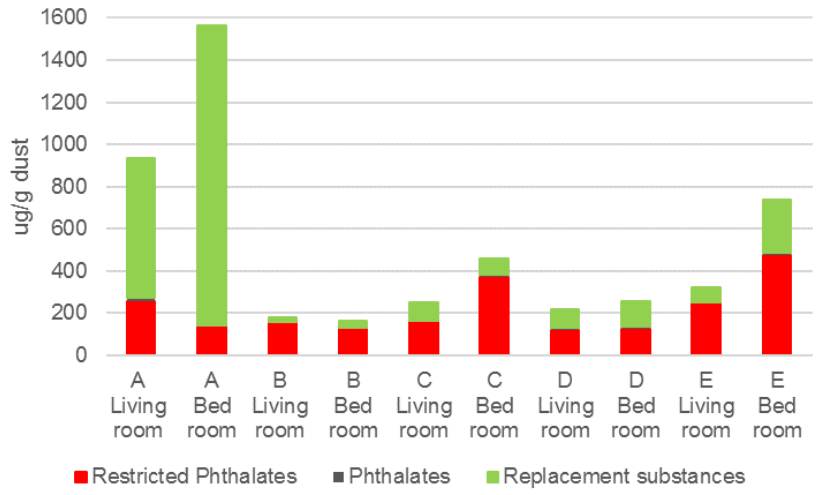

Figure 2. Total sum (µg/g) of restricted phthalates (red bars), non-restricted phthalates (blue bars) and replacement substances (green bars) in individual dust samples from five homes in Stockholm, Sweden.

TDI for DEHP is 50 µg/kg bw and day (EFSA 2005). The measured median and maximum value for DEHP for this study was 81 and 305 µg/g dust respectively. The calculate exposure of DEHP from dust ingestion for an adult, is 0,07 and 0,26 µg/kg bw per day respectively using the median and maximum values from this study. This exposure is around 100 times lower than the TDI value set by EFSA.

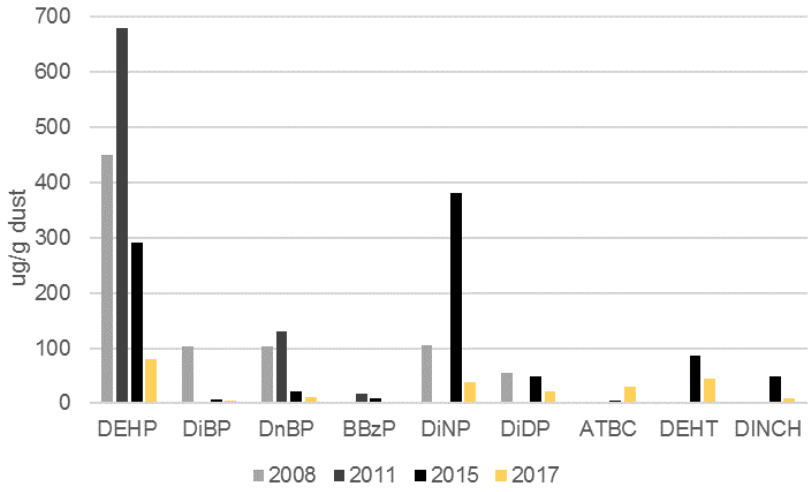

Figure 3. Median concentrations of plasticizers (phthalates and replacement substances) in dust from homes in 2008 and 2011 (grey bars) and daycare facilities in 2015 (black bars) in Stockholm compared to this present study (yellow bars).

The measured levels of traditional phthalates and replacement substances in this present study are much lower than reported previously in dust from Sweden. Of importance is also that the extreme values for DEHP are much lower in this study compared to the others. For the studies conducted in 2008 (Luongo et al. 2016), 2011 (Bergh et al. 2011) and 2015 (Utvärdering av barns exponering i förskolan, 2015) the maximum measure value was 4843, 3200 and 4500 µg/g dust respectively whereas the highest concentration in this present study was 305 µg/g dust for DEHP. In general, higher concentrations of plasticizers are found at daycare facilities compared to private homes reflecting the higher use of plastic flooring, materials and toys.

6.2 ORGANOPHOSPHATE ESTERS

Three halogenated phosphorous FR and two non-halogenated OPE were analyzed in household dust in this study. Data for the five private homes is presented in Table 3. For several of the analyzed compounds measured values were below limit of quantification (LOQ) which implies that the compound is detected but not quantified in the sample and denoted with < (value for LOQ). TBEP with a median concentration of 3.9 µg/g dust, was found in highest concentration followed by TPP 0.72 µg/g dust.

Table 3. Concentrations (µg/g) of organophosphate esters in house dust from five private homes.

			Restricted	*OPE*			
Home	*Room*	*Amount (mg)*	**TCEP**	**TCPP**	**TDCPP**	**TPP**	**TBEP**
A	*Living room*	26	*<0.81*	*<1.5*	0,60	0,56	4,8
A	*Bed room*	52	*0.40-0.66*	*<0.74*	0,43	0,76	7,4
B	*Office space*	29	*0.72-1.2*	*1.3-2.2*	0,16	*0.070-0.21*	*0.23-0.70*
B	*Bed room*	40	*<0.52*	*<0.97*	0,09	0,16	3,3
C	*Living room*	23	2,8	*<1.7*	0,34	0,99	2,3
C	*Bed room*	59	1,1	1,1	0,53	1,7	5,3
D	*Living room*	57	*<0.37*	1,3	0,58	0,72	1,5
D	*Bed room*	62	*<0.33*	*0.62-1.0*	0,44	2,4	1,3
E	*Living room*	26	*<0.79*	*<1.5*	0,36	0,71	3,9
E	*Bed room*	51	*0.41-0.68*	*<0.76*	0,27	0,42	5,7
A-E	***Median***		**0,9**	**1,2**	**0,40**	**0,72**	**3,6**
	Min		**<LOQ**	**<LOQ**	**0,1**	**0.070-0.21**	**0.23-0.70**
	Max		**2,8**	**1,5**	**0,6**	**2,4**	**7,4**

The dominating OPEs measured in this study was TBEP. This chemical is used as a multifunctional additive, primarily as a plasticizer but also as a flame retardant. The wide area of application may explain the dominating occurrence of this compound in this study. However, the measured levels is usually a result of several different sources. The low detection frequency and a median concentration below LOQ for TCEP indicate longtime low usage. TCEP was voluntarily phased out in the 1980th prior to affective of legislation.

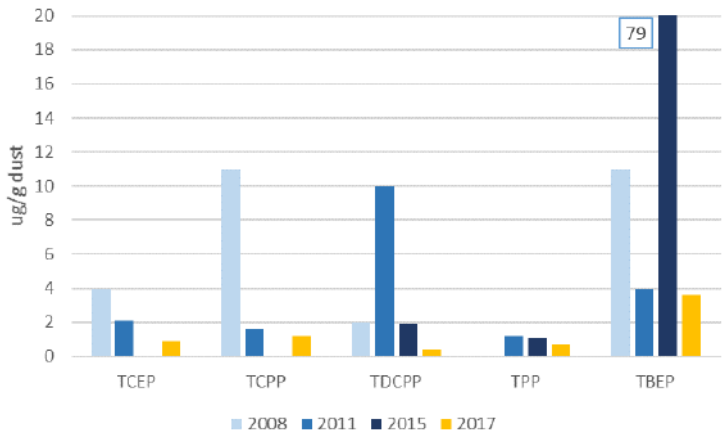

Figure 4. Median concentrations of organophosphate esters (OPEs) in dust from private homes in 2008 and 2011 (blue bars) and day care facilities in 2015 (dark blue bars) and present study (yellow bars) from Stockholm, Sweden.

Provisionally TDI (p-TDI) for TCEP is 13 µg /kg bw/day (SCHEER 2009). The measured maximum value for TCEP for this study was 2.8 µg/g dust. The calculate exposure of TECP from dust is 0.0024 µg/kg bw per day for the highest measured value in this study. This exposure is around 10 000 times lower than the p-TDI value set by EFSA.

6.3 BISPHENOLS

BPA and three replacement BPF, BPAF and BPS were analysed in household dust in this study. Data for the five private homes is presented in Table 4. BPA was detected in all samples with a median concentration of 0.59 µg/g and was found in highest concentration followed by BPF and BPAF (0.08 and 0.01 µg/g). Levels of BFS was below limit of detection (LOD).

Table 4. Concentrations (µg/g) of bisphenols in house dust.

				Replacement substances of BPA		
Home	*Room*	*Amount (mg)*	**BPA**	**BPF**	**BPAF**	**BPS**
A	*Living room*	28	0,93	0,03	0,010	<LOD
A	*Bed room*	72	0,30	0,03	0,008	<LOD
B	*Office space*	58	0,55	0,02	<LOD	<LOD
B	*Bed room*	47	0,56	0,05	<LOD	<LOD
C	*Living room*	6	0,34	0,53	<LOD	<LOD
C	*Bed room*	72	0,21	0,37	0,004	<LOD
D	*Living room*	81	1,7	0,25	0,002	<LOD
D	*Bed room*	57	1,1	0,08	<LOD	<LOD
E	*Living room*	42	0,98	0,11	<LOD	<LOD
E	*Bed room*	77	0,61	0,08	0,005	<LOD
A-E	***Median***		**0,59**	**0,08**	**0,01**	**<LOD**
	Min		**0,21**	**0,02**	**<LOD**	**<LOD**
	Max		**1,7**	**0,53**	**0,01**	**<LOD**

Median concentrations of BPA in Swedish homes from this study were 0.59 (0.21- 1.7) µg/g dust which is lower than was reported from Swedish pre-schools in 2015 (geometric mean 1.2 (<LOD-15) µg/g dust).

Temporary TDI (t-TDI) for BPA is 4 µg/bw per day (EFSA 2015). The calculated exposure of BPA from dust ingestion for an adult, using the measured median and maximum values from this study, was 0,0005 and 0,0015 µg/kg bw per day respectively. This exposure is around 1000 times lower than the t-TDI value set by EFSA. However, exposure of BPA through dust is not considered the main pathway of exposure for humans. Food that comes in contact to plastic packaging or canned food is of greater importance for the total exposure.

6.4 CHLORINATED PARAFFINS

Short-chain, medium-chain and long-chain chlorinated paraffins were analyzed in household dust in this study. Data for the five private homes is presented in Table 5. MCCPs with a median concentration of 31 ng/g dust, was found in highest concentration followed by LCCPs and SCCPs (20 and 13 µg/g dust). MCCPs are classified with reproductive hazards as cause harm to breast-fed children but no legal restriction applies for them. The LCCP have no classification i.e. no hazards are identified. The regulated SCCPs constituted for 20% of the total concentration of CP found in dust in this study.

Table 5. Concentrations (µg/g) of chlorinated paraffins in house dust.

Home	*Room*	*Amount (mg)*	*Regulated* **SCCPs**	**MCCPs**	**LCCPs**	**Total**
A	*Living room*	26	*10*	*29*	23	62
A	*Bed room*	52	*15*	*48*	45	110
B	*Office space*	29	*24*	*40*	17	*81*
B	*Bed room*	40	*11*	*34*	23	68
C	*Living room*	23	8.6	*18*	8.9	36
C	*Bed room*	59	3.4	12	4.1	19
D	*Living room*	57	*7.9*	30	15	53
D	*Bed room*	62	*3.8*	*14*	10	28
E	*Living room*	26	*14*	*32*	26	72
E	*Bed room*	51	*12*	*54*	17	83
A-E	***Median***		**13**	**31**	**20**	**65**
	Min		**10**	**12**	**10**	**19**
	Max		**24**	**54**	**45**	**110**

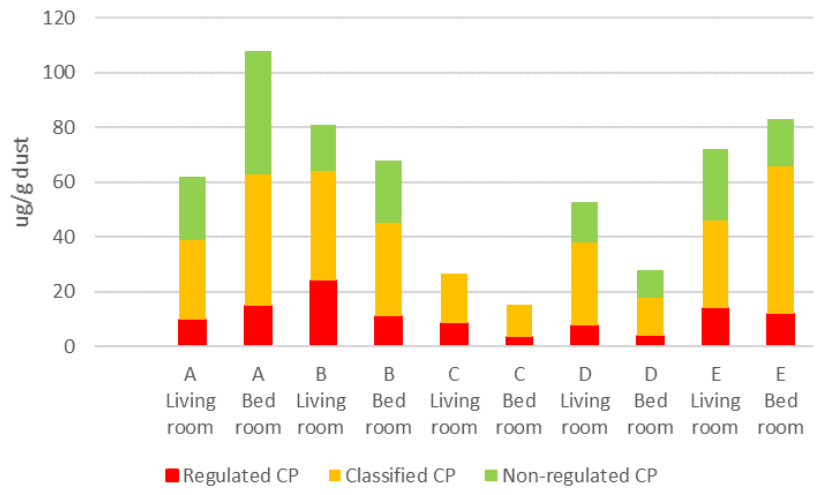

Figure 5. Sum of total concentrations (µg/g) of regulated CP (red bars), classified, non-restricted CP (orange bars) and non-regulated CP (green bars) in individual dust samples in homes of Stockholm, Sweden.

The measured concentrations of CP in household dust are in the µg/g range due to large production volumes and a wide area of usage for CPs. Potential emission sources are several including flame retardant use in furniture, floor polish, paints, sealants in window seals, adhesives in wallpaper, plasticizers and/or lubricants in household appliances. The production of SCCPs peaked in mid-1990th and decreased drastically from 2010 and forward. Although the use of SCCP was recently restricted, the measured levels in house dust is still high in comparison to other indoor pollutants due to their persistent properties. TDI for SCCP is 100 µg/kg bw/day. The measured median and maximum values for SCCP for this study were 13 and 24 µg/g dust respectively. The calculated exposure of SCCP from dust ingestion for an adult, for the median and highest measured value in this study is 0.011 and 0.020 µg/kg bw per day respectively. The exposure from house dust in this study is 1000 to 10 000 times lower than the TDI value set by EFSA.

6.5 BROMINATED FLAME RETARDANTS

Eight regulated BFR and five replacement substances and TBBPA were analyzed in household dust in this study. Data for the five private homes is presented in Table 6. DBDPE with a median concentration of 241 ng/g dust, was found in highest concentration followed by BEH-TEBP and BDE-209 (205 and 107 ng/g dust). For several of the analyzed compounds measured values were below limit of quantification (LOQ) which implies that the compound is detected but not quantified in the sample and denoted with < (value for LOQ). For some of the analyst these were troublesome issues with the analysis and there is missing data (m.d.).

Table 6. Concentrations (ng/g) of brominated flame retardants in house dust.

			Regulated BFR								*BFR*	*Replacement BFR*				
Home	*Room*	*Amount (mg)*	**BDE-47**	**BDE-99**	**BDE-100**	**BDE-153**	**α-HBCDD**	**β-HBCDD**	**γ-HBCDD**	**BDE-209**	**TBBPA**	**α-DBE-DBCH**	**β-DBE-DBCH**	**EH-TBB**	**BEH-TEBP**	**DBDPE**
A	*Living room*	26	5,7	11,0	<1.3	<2.0	m.d.	460	220	*85*	31-52	<7.8	<7.8	10	730	220
A	*Bed room*	52	4,7	5,6	<0.64	<1.0	m.d.	94	27	*31*	m.d.	*<3.9*	*<3.9*	13	540	170
B	*Office space*	29	12	8,8	1.2-3.5	<1.7	m.d.	m.d.	m.d.	140	<28	*13*	*9,4*	<17	140	260
B	*Bed room*	40	6,1	5,6	0.84-2.5	<1.3	m.d.	<15	<16	26	<20	12	7,2	<13	190	320
C	*Living room*	23	6,0	1.4-4.3	<1.4	<2.2	66	8,4	<6.2	16	34-57	<8.6	<8.6	<22	220	29
C	*Bed room*	59	2,7	0.56-1.7	<0.56	<0.85	m.d.	m.d.	m.d.	140	77	<3.4	<3.4	16	1200	77
D	*Living room*	57	10	3,4	0.59-1.8	<0.88	m.d.	28	11-32	460	*m.d.*	<3.5	<3.5	<8.8	150	560
D	*Bed room*	62	3,9	2,2	<0.54	<0.81	m.d.	25	300	1100	59	<3.2	<3.2	<8.1	80	350
E	*Living room*	26	16	5,9	<1.3	<1.9	120	110	430	130	30-51	<7.7	<7.7	<19	320	110
E	*Bed room*	51	18	7,8	0.65-2.0	<1.0	m.d.	13	71	57	180	<3.9	<3.9	5,9	190	430
A-E	***Median***		**6,1**	**5,6**	**1,2**	**<LOQ**	**94**	**27**	**49**	**107**	**7**	**<LOQ**	**<LOQ**	**<LOQ**	**205**	**241**
	Min		**2,7**	**0.56-1.7**	**<LOQ**	**<LOQ**	**66**	**<LOQ**	**<LOQ**	**16**	**<LOQ**	**<LOQ**	**<LOQ**	**<LOQ**	**80**	**29**
	Max		**18**	**11**	**2**	**<LOQ**	**120**	**460**	**430**	**1100**	**180**	**13**	**9**	**16**	**1200**	**560**

In general, the legacy POPs that have been subject for regulation, the longest (BDE-47, BDE-99, BDE-100, BDE-153), are found in the lowest concentrations (Figure 6). The use of these compounds have been regulated in the EU since 2004. BDE-209 and HBCDD were added to the Stockholm convention rather recently, in late 2015 and 2013 respectively. However, BDE-209 was regulated in electronics under the EU Restriction of Hazardous Substances (RoHS) directive since 2008 allowing maximum weight of 0.1 % by weight in products. The time aspect of restriction and production volumes are reflected in the measured values of BDE-209 and HBCDD. The highest concentrations of BFR in dust are found amongst the replacement substances BEH-TEBP and DBDPE. The higher concentrations and higher detection rate demonstrate a more recent and widespread use.

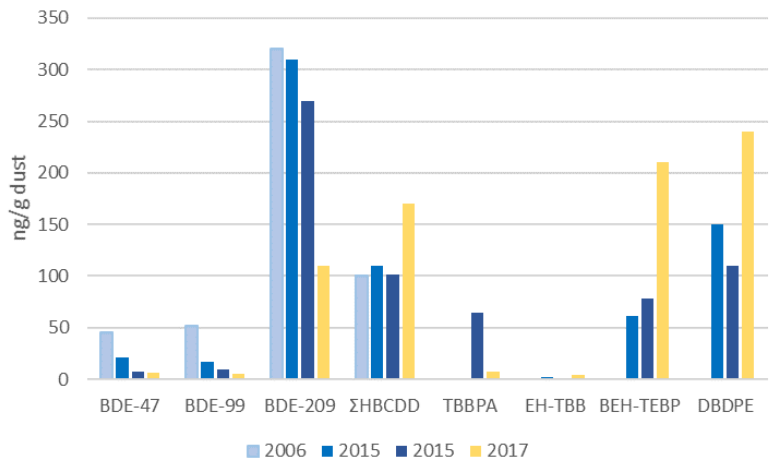

Figure 6. Comparison of median concentrations (ng/g) of BFRs in dust from private homes in 2006 and 2015 (blue bars), daycare facilities in 2015 (dark blue bars) and present study (yellow bars) in Stockholm, Sweden.

Instead of TDI, reference dose (RfD) for PBDEs was used for comparing the level of exposure measured in this study. RfD for BDE-47 is 100 ng/kg bw per day (US EPA IRIS 2016). The calculated exposure of BDE-47 from dust ingestion for an adult is 0.005 and 0.015 ng/kg bw per day for the median and maximum measured value in this study. This exposure is around 10 000 times lower than the maximum acceptable oral dose value set by US EPA.

The RfD for BDE-209 is 7000 ng/kg bw/day. The calculated exposure from dust for BDE-209 is 0.09 and 0.94 ng/kg bw per day for the median and maximum measured value in this study. The exposure of the highest concentration of BDE-209 is around 10 000 times lower than the maximum acceptable oral dose value set by US EPA.

The DNEL for DBDPE is 5 000 000 ng/kg bw/day. The calculated exposure from dust for DBDPE is 0.21 and 0.48 ng/kg bw per day for the median and maximum measured value in this study. This corresponds to an exposure level in 10 000 000 times lower than the DNEL value.

6.6 PFAS

Eleven perfluoroalkyl substances, PFOS and five other perfluorinated alkylsulfonic acids, PFOA and four other perfluorinated alkylcarboxylic acids were analysed in household dust in this study. Data for the five private homes is presented in Table 7. PFOA with a median concentration of 13 ng/g dust, was found in highest concentration followed by PFHxA and PFDS (5.0 and 4.8 ng/g dust). PFHxA has been used to replace PFOA is now identified as an SVHC and added to the Candidate list. The low levels of PFOS and PFOS-analogues found in household dust most likely reflects the consequences of the restricting the use of these chemicals.

Table 7. Concentrations (ng/g) of PFAS in house dust.

			Restricted	PFOS Analogues						PFOA Analogues			
Home	Room	Amount (mg)	PFOS	FOSA	PFBS	PFHxS	6:2 FTS	PFDS	PFOA	PFPeA	PFHxA	PFHpA	PFNA
A	Living room	28	<LOD	<LOD	<LOD	<LOD	2,2	6,4	34	5,8	15	<LOD	6,5
A	Bed room	72	<LOD	<LOD	<LOD	<LOD	0,32	3,5	26	0,60	3,6	<LOD	1,0
B	Office space	58	<LOD	<LOD	<LOD	<LOD	0,45	4,9	19	0,70	<LOD	<LOD	1,4
B	Bed room	47	<LOD	<LOD	<LOD	<LOD	0,54	5,8	6,2	0,85	6,9	<LOD	0,22
C	Living room	6	<LOD	<LOD	<LOD	8,7	3,0	<LOD	<LOD	1,5	<LOD	<LOD	0,28
C	Bed room	72	<LOD	<LOD	1,7	2,2	0,45	3,5	<LOD	0,71	7,4	<LOD	0,61
D	Living room	81	12	<LOD	<LOD	<LOD	5,9	4,4	13	<LOD	6,2	<LOD	1,9
D	Bed room	57	6,6	<LOD	0,8	0,7	15	4,8	<LOD	<LOD	3,8	<LOD	0,40
E	Living room	42	<LOD	<LOD	<LOD	<LOD	1,7	7,2	11	<LOD	3,5	<LOD	1,4
E	Bed room	77	5,2	<LOD	<LOD	<LOD	0,76	2,1	11	<LOD	3,5	<LOD	7,8
A-E	**Median**		**<LOD**	**<LOD**	**<LOD**	**<LOD**	**1,2**	**4,8**	**13**	**0,8**	**5,0**	**<LOD**	**1,2**
	Min		**<LOD**	**<LOD**	**<LOD**	**<LOD**	**0,3**	**<LOD**	**<LOD**	**<LOD**	**3,5**	**<LOD**	**0,2**
	Max		**12**	**<LOD**	**1,7**	**8,7**	**15**	**7,2**	**34**	**5,8**	**15**	**<LOD**	**7,8**

For PFOS and PFOA, a TDI of 150 ng/kg bw per day and 1500 ng/kg bw per day is established. The calculate exposure of PFOS from dust ingestion for an adult, is 0,010 ng/kg bw per day for the highest measured value in this study. This exposure is around 10 000 times lower than the TDI value set by EFSA. The calculate exposure of PFOA from dust ingestion for an adult, is 0.011 and 0.030 ng/kg bw per day respectively using the median and maximum values in this study. This exposure is around 100 000 times lower than the TDI value set by EFSA. However, diet (food and drinking water) has been shown to be the major human exposure pathway of PFOA and PFOS for Swedes, constituting for about 70% of the total exposure (Vestergren et al. 2012).

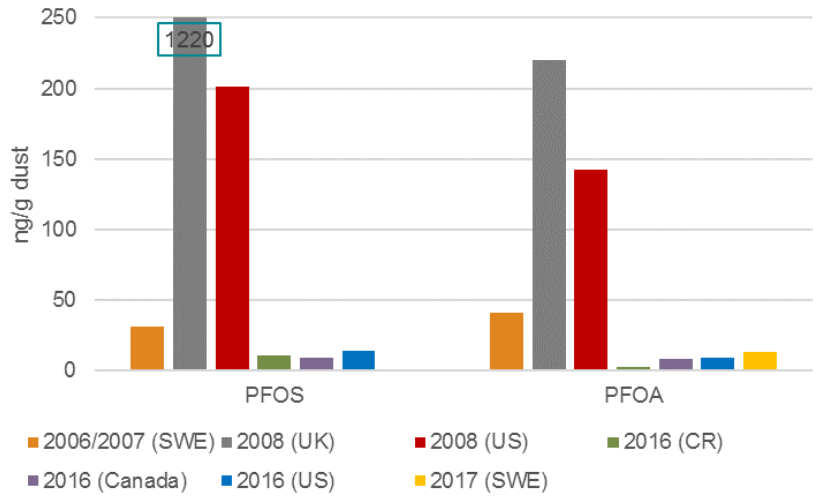

Figure 7. Median concentrations (ng/g) of PFOS and PFOA in dust from Sweden in 2006/2007 (orange bars), UK and US in 2008 (grey and red bar), Czech Republic in 2016 (green bars), Canada and US in 2016 (purple and blue bars) and present study 2017 (yellow bar).

The concentrations of PFOS and PFOA found in this study of private households were compared to dust samples from Canada, US and the Czech Republic in 2016 from daycare centers or households. The reported concentration of PFOS and PFOA from Swedish households are generally low. The trend for levels of PFOS and PFOA is declining and the under the detection of limit (<LOD) in this present study.

7 CONCLUSIONS

The general concentrations of indoor pollutants reported from this present study is low in comparison to earlier published studies of homes and day cares in the Stockholm area. Nevertheless, this study points out that environmental pollutants still are present in dust from these five households with chemical awareness who have made active choices on materials and products in their homes.

The most abundant indoor pollutants present in indoor dust are phthalates, organophosphorous esters (OPEs), bisphenols and chlorinated paraffins (CPs) present in µg/g concentrations. Brominated flame retardants (BFRs) and perfluoroalkyl substances (PFAS) are present in 1000 times lower concentration in ng/g concentrations. Classified harmful chemicals, whom are legally regulated or restricted, were demonstrated within this study. Calculating the total daily exposure from these compounds from dust and comparing to a risk number such as tolerable daily intake (TDI) indicates exposure levels 100 – 10 000 times lower than the set value for the chemical. However, dust alone seldom make up for the entire exposure, thus other sources such as dermal uptake and dietry sources are of importance.

Traditionally used OPEs and BFRs, now subject for restriction, are declining over time. For the BFRs replacement substances such as DBDPE and BEH-TEBP was the prominent compounds present in dust.

The median-chain chlorinated paraffins (MCCPs) were found in the highest concentrations followed by LCCPs and SCCPs. The restricted SCCPs constitute for 20% of the total concentration of CP in dust.

Amongst the perfluoroalkyl substances, PFOA was found in highest concentration in house dust of which is a candidate proposed for listing under the Stockholm Convention.

The use of hard flooring instead of PVC-flooring may explain the generally low levels of phthalates measured in dust from these family homes.

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VI ÄR WSP

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ABOUT THE PROJECT

The project “Innovative Management Solutions for Minimizing emissions of hazardous substances from urban areas in the Baltic Sea Region” (NonHazCity) is financed by the European regional development fund within the Interreg Baltic Sea Region program, from March 2016 to February 2019. The project involves 18 partners from Sweden, Finland, Estonia, Latvia, Lithuania, Poland and Germany and 23 associated partners.

NonHazCity wants to demonstrate possibilities of municipalities and WWTPs to reduce emissions of priority hazardous substances (HS) from small scale emitters in urban areas that cannot be reached by traditional enforcement techniques. Substances of concern will be identified and prioritised, sources tracked and ranked, individual HS Source Maps and Chemicals Action Plans developed by each partner municipality.

Municipal entities will implement own substance reduction measures at their premises. Private small scale businesses will pilot substitution actions and improve their assortment. Inhabitants will be shown their HS emission share and test the use of less HS in every-days household management to help to protect the Baltic Sea environment but also their own health.

If you are interested to follow the project this newsletter will be produced about twice a year. It is also possible to read about activities at the project website www.nonhazcity.eu and at partner websites.

IMPRINT

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