DANISH MINISTRY OF THE ENVIRONMENT

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Total health assessment of chemicals in indoor climate from various consumer products

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Survey of Chemical Substances in Consumer Products, **No. 75** 2006

Table of Contents

Preface

In recent years the Danish Environmental Protection Agency (DEPA) has made special efforts surveying chemicals in consumer products/articles in order to assess the exposure of common people to such chemicals and potential risks in that regard. A large part of such consumer products are used indoor.

The indoor climate is important for the public health, because we reside far the greatest part of our life indoor. Taken together it is expected that Danes spend between 80 and 90 % of their life indoor. Therefore, stressors in the indoor climate may be very important for public health and comfort. Thus, in the Danish national strategy for environment and health indoor climate is a high priority area.

Most of the previous reports on consumer products published by DEPA conclude that the release of chemicals from one single product does not give rise to concern but the collective burden of chemicals from all products used indoor e.g. in the bed room, in the family room, the kitchen or the children's room, may be a problem.

The project had the aim of

- Mapping which chemicals could be released to the indoor climate from normal use of consumer products at home. Release is evaporation, wearing, migration, and primary and secondary formation.
- Assessing the importance of consumer products as source of chemical pollution indoor and the exposure of the residents.
- Describing the total chemical impacts from the indoor climate various places in the dwelling.
- Evaluating potential health impacts and nuisances from these exposures and advice how risks could be reduced.

The project group consisted of Frank Jensen (Chair) and Shima Dobel from DEPA and the two authors Allan Astrup Jensen, FORCE Technology and Henrik N. Knudsen, SBi-Danish Building Research Institute. Anders C. Schmidt, FORCE Technology, and Lars Gunnarsen, SBi-Danish Building Research Institute, were responsible for the quality control.

Summary and conclusions

The indoor climate is important for the public health, because we reside far the greatest part of our life's indoor. Taken together it is expected that Danes spend between 80 and 90 % of their life indoor. In addition, many studies show that the level of air pollution indoor is much higher than outdoor. Therefore, in the Danish National Strategy for Environment and Health indoor climate is a high-priority area.

1.1 The DEPA reports on chemicals in consumer products/articles

In the years 2002 to 2005 the Danish Environmental Protection Agency (DEPA) has published more than 60 reports on the study of chemicals in various consumer products. About half of these reports contain data and information relevant for the indoor climate but of different aim and character. In some report the focus is on the content of chemicals in the products, in others release to indoor air is included, which is most relevant for this project.

The DEPA-reports focus on each consumer product separately. It is more complex in the real dwelling, where many products may be used simultaneously.

Most of the reports on consumer products so far published by DEPA conclude that the release of chemicals from one single product does not give rise to concern. However, the collective burden of chemicals from all products used indoor e.g. in the bed room, in the living room, the kitchen or the children's room, may be a problem.

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- Evaluate potential health impacts and nuisances from these exposures and advice how risks could be reduced.

In phase 1 of the project all the DEPA reports on consumer products were reviewed, and a short summary in Danish was produced for each report relevant for the indoor environment.. In addition, Excel files containing a substance/product-matrice with indication, if quantitative emission data exist, and if the exposure is short or persistent, was developed, and it is available electronically on www.mst.dk.

Furthermore, selected relevant studies in the open literature on release of chemicals from consumer products and contamination of house dusts are reviewed in Appendix A (only in Danish). In this review the focus is on the less volatile brominated flame retardants (PBDE)often used in electronics, textiles and furniture foam, phthalate plasticizers (phthalates) occurring in vinyl floors, vinyl wallpaper and toys, and the water-oil-dirt repellant perfluoroalkylated compounds (PFAS) added to carpets, textiles and outdoor clothes. It is all substances, which have been included in only few of the DEPA reports.

Potential indoor concentrations of 8 selected volatile chemicals have been estimated in three model rooms: a hall/utility room, a kitchen/family room and a children’s room, based on pragmatic model calculations with some assumptions and simplifications. This is necessary, because the available data in the DEPA reports have different character and aim, and not necessarily produced with the purpose assessing indoor climate. Further, the determinations of the released chemicals were not always specific and reliable, since screening methods were applied. That could have been fine enough for the purpose of the particular report but if the aim from the start had been to look at the importance of indoor concentrations other procedures may have been selected.

It has been presumed that the studied consumer products were representative, adequate and relevant for indoor climate. However, data suggest a large variation within certain product groups. Thus the measured emissions may not be typical for all investigated products, especially if only one product was studied. The products are more likely indicators for the emission from the investigated product type.

1.2 Assumptions in model calculations

The background for model calculations based on the DEPA consumer product reports has also been that these reports represent the potential most important sources of pollution indoor from consumer products.

It should, however, be emphasized that in practice there may exist other important sources than the studied. It is not possible to predict human behavior at home. Situations may develop, where consumer products are used indoor, although others are recommended. Certain times of the year, e.g. at Christmas time, some activities differ from what is normal the rest of the year. I the dark time the use of candle lights increases, and in the cold time many dwellings will have less ventilation applied because of a wish to save energy. However, the opposite may be the case in older draughty buildings. Building technology may also have influence on the healthy conditions in a home, e.g. if water damage occurs and mould grows.

Indoor air quality depends on ventilation, temperature and other factors, besides which pollution sources are present.
In this report the focus is on the contribution from consumer products but it has to be kept in mind that there may be other sources of the same chemicals in the home, e.g. from tobacco smoking, food preparation and evaporations from building materials (paint and varnishes, integrated carpets etc.). There are a great number of potential sources.

The concentration (exposure) of pollutants in indoor air depends mainly on the balance between the pollution sources, and how much cleaner air is supplied to the building (ventilation) to dilute the pollution. Further, the concentration depends on how much pollution is deposited on surfaces (adsorption) or released from surfaces (desorption).

In addition, the concentration and composition depend on any secondary chemical reaction occurring in the air or at contact with material surfaces. In the reports from the DEPA, and in this report, the importance of such reactions is not taken into account. Where the focus earlier was solely on the so-called primary evaporation of chemicals from materials, the research focus is nowadays directed at the secondary evaporation. Primary evaporation is release of weakly bound substances, e.g. volatile organic compounds (VOC), used or formed in connection with the manufacture and the material or substances. The primary evaporation occurs mainly, when the material is new.

Secondary evaporation consists of VOC formed after the manufacture of the material. The origin may be degradation processes at oxidation of substances in the material surface by ozone. Newly research has shown that secondary evaporation particularly can diminish the quality of indoor air, an din this way have adverse health effects on building users. For some materials this type of evaporation seems to continue in the whole lifetime of the materials.

In spite of these reservations regards the performed model calculations, it is concluded that the highest concentrations in a home are likely to occur in the children's room. The reason is that that particular room normally is smaller than most other rooms in the home, and it contains many products, which may release chemicals to the air.

There is a clear tendency that new product release more chemicals to the air than older used products. The products also differ from each other by having different emission patterns. Some release substances over long time, others have a more brief release. Use of incense and some spray products indoor are the most polluting of the studied products and activities, and it emits considerable amounts of hazardous chemicals.

1.3 Assessment of prioritized chemicals

The maximal exposure to phenol from all sources is calculated to 62 µg/m^3. This concentration is much lower than an indoor limit value of 400 µg/m^3 based on odor nuisance. The calculated daily intake for a maximum exposed child is then 90 µg phenol/kg, or somewhat below the USEPA "Reference dose (RfD)" of 0.1 mg/kg bw/d, which has built-in safety factors. This shows that in a children's room, where a single pollution source may not be important, the total burden to phenol from all sources in the worst case may approach the highest tolerable for children.

Normally, formaldehyde levels in indoor air are estimated to 10-200 µg/m^3, depending on which sources exist. In this project the calculated maximum concentration of formaldehyde in indoor air was about 500 µg/m^3, however, typically the concentration will be below 50 µg/m^3. Thus, the recommended indoor air limit value for formaldehyde of 120 µg/m^3 is complied with at the typical concentration but not in the worst, however unlikely, case. A child will typically daily inhale 72 µg formaldehyde/kg bw but 0.7 mg/kg bw in the worst case. Thus, the "Reference dose" of 0.2 mg/kg bw/d will be easily complied with for a child in the typical case but not in the worst case adding up all sources working simultaneously in the children's room. Formaldehyde is a potent carcinogen, and since there is no complete safe limit for carcinogens, all unnecessary exposure to formaldehyde, e.g. from incense, should be avoided.

The worst case total exposure to acetaldehyde from many sources will be 265 µg/m^3- but normally it is lower than 10 µg/m^3; thus close to the USEPA Reference Concentration (RfC) of 9 µg/m^3. This RfC is based on the no-adverse-effect-level (NOAEL) for degeneration of the olfactory epithelium in animal studies and with a safety factor of 1000 applied. Since acetaldehyde is a carcinogen, and there is no complete safe limit for carcinogens, all unnecessary exposure to acetaldehyde, e.g. from incense, should be avoided

Only two products did release benzene to the indoor climate. The contribution of benzene from plasticine products investigated in the DEPA reports was <1 µg/m^3. This is less than the typical benzene concentrations measured indoor in Danish buildings. During use of incense extreme benzene concentrations up to 350 µg/m^3 may develop. The Reference concentration for benzene is reported to be between 9 and 30 µg/m^3, and an increased cancer risk is reported at concentrations above 20 µg/m^3. For plasticine alone the safety factor is sufficient but that is not the case regards use of incense that generates short-term benzene concentrations of 350 µg/m^3, which are a direct health hazard. The USEPA Reference Dose for benzene is 4 µg/kg bw/d. Normally, a child will inhale <1 µg benzene/kg bw during 24 hours, however, during use of incense alone the intake during one hours exposure account up to 21 µg benzene/kg bw/d. Such high exposure is completely unacceptable regards a substance proved to induce leukemia in humans.

The highest calculated concentrations of toluene were found in the children's room with a concentration of about 49 µg/m^3 for new electronic products and about 19 µg/m^3 for used products. The contribution mainly came from one particular PC monitor. To this should be added potential contributions from other consumer products of up to 900 µg/m^3, and about 2,980 µg/m^3 with printed matters and 39,000 µg/m^3 from spray paint included. Tolerable Daily Intake (TDI) and Reference Dose for toluene are 223 µg/kg bw/d, and the Reference Concentration is 0.4 mg/m^3. An indoor climate limit for toluene of 8 mg/m^3 has been suggested. With a toluene concentration of 50 µg/m^3 from a monitor working 6 hours a day a child will have a daily intake of 12 µg/kg bw/d, thus sufficient safety margin. However, this is certainly not the case, if the contributions from other sources are added on. Even without contributions from printed matters and spray paint the intake will be 1,800 µg/d or 180 µg/kg bw/d and very close to TDI.

The highest concentrations of xylenes occur also in the children's room, where the concentrations were 105 µg/m^3 for new electronic products and 44 µg/m^3 for used products. In the hall/utility room the concentration was 47 µg/m^3 for new products. To this should be added a possible contribution of up to 476 µg/m^3 (or 51,000 µg/m^3 with spray paint). The Reference Concentration (RfC) is 0.1 mg/m^3, which alone compare to the contribution from electronics in the children room. In case of spray painting the concentrations are so high that direct health damage may be possible. The Reference Dose for xylenes is 0.2 mg/kg bw/d. Six hours exposures to 100 µg/m^3 will correspond to a child intake of xylenes of 360 µg/kg bw/d. Thus, alone the electronics make too high exposure compared to Reference Dose. A further 10-100 times enhanced exposure, which is likely with contributions from other sources, may be seen as completely unacceptable.

In the children's room the calculated concentrations of styrene are 22 µg/m^3 for new electronic products and about 8 µg/m^3 for used products. To this should be added possible contributions of about 772 µg/m^3 from incense, tents to children and tubular pearls. The last figure is close to the WHO Air Quality value of 800 µg/m^3 but below the Reference Concentration of 1 mg/m^3, whish is based on effects on the central nervous system. The Reference dose is 0.2 mg/kg bw/d, which is somewhat above a Dutch Tolerable Daily Intake (TDI)of 120 µg/kg bw/d. Child exposure to a concentration of 20 µg/m^3 in 6 hours a day result in an intake of 7 µg styrene/kg bw/d. This is far below various danger limits and without health effects. However, in the worst scenario for the children room with use of incense etc. there will be a 20% excess of the Reference dose.

The highest concentrations of limonene were calculated for the children room, where the concentration will be around 4 µg/m^3 for new electronic products. Potential contributions from printed matters and incense of around 341 µg/m^3 in total should be added. By-exposure to limonene by storage and consumption of citrus fruits is also possible. Limonene has a Tolerable Daily Intake (TDI) of 0.1 mg/kg bw/d. A child exposed to a concentration of 4 µg/m^3 in 6 hours will have an intake of 1.5 µg/kg bw/d. This level of exposure is completely without health risks for a normal child. However, in the worst case scenario the intake may approach the TDI. In case of allergy or intolerance even very small concentrations of limonene may be of importance, however, this will not be a specific problem in relation to limonene in the indoor environment.

The available data in the Danish EPA's consumer product reports on the less volatile phthalates, brominated flame retardants and perfluoroalkylated compounds are very scattered, limited and insufficient to use for an exposure/risk assessment. Therefore, in order to estimate the exposure of the floor crawling children from various sources, these data is complemented with data from other Danish and foreign studies of these chemicals as contaminants in house dust.

The most abundant phthalate indoors is di(2-ethylhexyl)phthalate (DEHP). The typical daily child intake of DEHP from all indoor sources will be 10-20 µg/kg bw/d or 100-200 µg/day, however, in the worst case it likely will amount to 50-250 µg/kg bw/d or 0.5-2.5 mg/day for a very exposed child playing on a PVC floor. To be added is intake of DEHP with the food, which is estimated to 18 µg/kg bw/d or 180 µg/day for a child. That is in the same order of magnitude as the "normal" indoor exposure. This can be compared with the no-adverse-effect level of DEHP in animal feeding experiments with rats, which is 3.7 mg/kg bw/d or 37 mg/day for a child. If rats and crawling children do have a similar susceptibility for DEHP, the safety factor is rather narrow for the mostly exposed children, and that is even without including possible exposure to other phthalates.

The levels of brominated flame retardants (PBDE) in house dusts are very variable but, generally, PBDE occur in concentrations one order of magnitude lower than for phthalates. Maximum concentration may be >20,000 ng PBDE/g dust. The exposure to PBDE via house dust is in the same order of magnitude as in food. This is surprising for persistent organic pollutants, for which the food normally account for approximately 90% of human exposure. If the estimated intake of dust is 100 mg/day a child can have an intake of 30 and in seldom cases up to 2000 ng PBDE/day. This should be compared with an average intake from the food of 40-150 ng/day and about 2000 ng/day for nursing infants, because human milk contains relatively high levels of PBDE. Based hereupon the maximum child intake will be <5 µg/day. Comparison with the Reference Dose (RfD) of 2, 3 and 10 µg/kg bw/d for penta-, octa- and deca-BDEs, respectively, which includes sufficient safety factors, shows that only nursing infants may come close to the Reference dose. Therefore, with the present knowledge, the indoor exposure alone will have no health risks.

Perfluoroalkylated compounds (PFAS) are not lipophile. Thus intake of animal fat and food in general will not be so important an exposure source as for the lipophile persistent organic pollutants (POP). Indoor climate seems to be the major source of exposure to these substances. If the daily intakes of house dust are set to 100 mg/day, the daily average exposure of a child be 200-2,000 ng PFAS and the maximum 8-50 µg PFAS/day or 0.8-5 µg PFAS/kg bw/d. This corresponds very well to the exposure scenarios in DEPA consumer report no. 50 about impregnation agents. The acceptable daily intake for perfluoroalkylated compounds is 3 µg/kg bw/day; that corresponds to the no-effect level for reproductive effects with a safety factor of 1,000. Only in the case of maximum exposure the intake will be unacceptable. However, the present knowledge about the toxicology of PFAS is limited.

1.4 Mixed exposure

In a home there may be many different consumer products and e.g. building materials which altogether may release many different substances in a complex mixture. In the reports from the DEPA and in this report the health assessments are mainly based on one substance a time. The combined impacts of more/many substances present in the same time are not evaluated.

Children staying indoors are exposed to many substances simultaneously. That means possibility of additive effects, and formation of secondary pollutants. In the classical risk assessment paradigm both substances and group of substances are treated separately ignoring that these combined effects may change the picture completely. Knowledge of such cocktail effects is simply lacking.

In the DEPA reports the focus is on direct adverse health effects from degassing from particular products. In a broader health perspective issues such as comfort and well-being, including experience of air quality should be taken into account. According to the World Health Organization (WHO), health is not only absence of disease and weaknesses but also a state of complete physical, mental and social well-being. Many pollution sources indoors, including consumer products and building materials, contribute with bad-smelling substances and may affect the perceived air quality (PAQ).

Both from a health viewpoint and regards how the air quality is experienced indoor, it is important that adjust the amount of supplied outdoor air to the home, thus meet the demand of ventilation. Ventilation may be limited in many rooms in the dwelling. In some occasions in newer, well-insulated and sealed dwellings air flows less than 0.5 h^{-1}, which is required according to current building legislation, and is used in model calculations in this report. There are for instances found dwellings with an air flow of only 0.25 h^{-1}. If everything else was equal that would result in twice as high concentrations.

In this connection it is important to focus on source emission control, thus limit emissions from indoor pollution sources as much as possible. Thus it is important to take into account that placement of computers and other pollution sources in such rooms may introduce an increased need for ventilation. Then the need of ventilation will be less and energy be saved. That is especially relevant with the tighten energy requirements in the new building legislation. In a dwelling there will often be an exchange of air between rooms and between neighbors apartments, in this way a source may pollute the air inside other rooms than, where the source is located.

1.5 Recommendations

In order to establish a more true/credible basis for assessing the state of health in a Danish dwelling, the following studies are recommended:

- At a large number of randomly chosen occupied dwellings, actual measurements of selected indicator substances, released from consumer products into indoor air and dust, should be initiated; eventually, for a longer time period for determining the actual exposure level of the general population.
- Initiation of field measurements of indoor air in a dwelling, where a room is furnished as a realistic worst-case condition. An important situation to study could e.g. be a newly furnished children's room with a selection of new building materials, equipments and consumer products. It could be interesting to make the study at low ventilation rate, as occurring at winter time. The selected chemicals to be analyzed should have potential adverse effects on health or comfort, including substances originated from secondary chemical reactions.

In addition the following initiatives are recommended:

- Use of dangerous substances in consumer products, which may be released indoors and expose children for a risk, should be terminated by voluntary agreements or bans.
- If feasible, building materials and consumer products containing phthalate plasticizers, especially DEHP, should not be used in a children room.
- Indoor use of incense is the most polluting and dangerous of all studied activities, and it should be diminished or avoided.
- Use of spray products indoors is also an extreme pollution source, which should be avoided or at least be limited as much as possible. As a minimum breathing mask and extra ventilation should be applied.
- It is prudent to prevent children exposure to dangerous chemicals in the indoor climate by frequent cleaning and sufficient ventilation.

2 Introduction and background

The indoor climate is important for the public health, because we reside far the greatest part of our life indoors. In average Danes are spending more than 16 hours per workday indoors at home.[1] In addition, much time is spent indoors in offices, schools, institutions, etc. Taken together it is expected that Danes spend between 80 and 90 % of their life indoors. Therefore, stressors in the indoor climate may be very important for public health and comfort, including the total exposure to chemicals released from indoor sources. The danger is that this exposure is increased or intensified, because new materials and products are introduced. At the same time many buildings, because of wish of energy conservation, have been more sealed and have less ventilation. In addition, many studies show that the level of air pollution indoors is much higher than outdoors.

Indoor air is typically polluted by hundreds of chemicals in various concentrations. Traditionally, the focus has been on release of substances from building materials, including release of Volatile Organic Compounds (VOC) to the air. These substances may impact the health and comfort of building users.[2] Possible sources may be wood, paint and varnishers. The most important nuisance among VOCs is formaldehyde.

Many other substances may be released to the indoor climate from materials, e.g. fibres from insulation, PCB from sealing materials, formaldehyde from chip boards and phthalate plasticizers from PVC floors. In addition, pollutants are formed during various combustion processes in cigarettes, candle light, stoves, ovens, and boilers (particles, carbon monoxide, nitrogen dioxide, PAH, dioxin etc.). The formed pollutants may in some instances (e.g. ozone and terpenes) react and form secondary pollutants.

The indoor air quality also depends on:

- Release by degassing or dust generation of chemicals from furniture (formaldehyde, VOC, flame retardants etc.), carpets (perfluoroalkyl-based dust repellants and flame retardants etc.) and other furnishings, textiles, leather, paper and clothing.
- Degassing from TV, computer and other indoor electronic/electric apparatus (VOC, ozone, flame retardants, stabilisators, plasticizers, etc.). Flame retardants are used both in printed circuit boards and in chassis.
- Degassing of chemicals from children's toys etc. (plasticizers and flame retardants etc.) and hobby activities (VOC etc.). In addition direct exposure by migration.

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[1] Lis Keiding, Lars Gunnarsen, Nils Rosdal, Mette Machon, Ralf Møller og Ole Valbjørn: Environmental factors of everyday life in Denmark – with special focus on housing environment. Edited by Lis Keiding. (In Danish with summary in English). National Institute of Public Health. Copenhagen 2003.

[2] ECA-IAQ (European Collaborative Action "Indoor Air Quality and Its Impact on Man"), 1997. ”Evaluation of VOC emissions from building products - solid flooring materials”. Report 18. EUR 17334 EN. Luxembourg: Office for Official Publications of the European Community.

- Various everyday activities such as use of cleaning agents (perfume etc.), impregnation (VOC, PFOSA, organotin etc.), cosmetics (hair spray etc.) and air fresheners (perfume).

- The indoor air quality is, of course, also influenced by room size, temperature and air flow. Some apparatus to air purification indoors are marketed but a positive effect is doubtful[3] Further, such apparatus will like other electric apparatus release chemicals.

[3] Overgaard NS. Bedre luftrensere, men værdien stadig tvivlsom. Arbejdsmiljø 2003;3:51.

3 Review of DEPA reports on chemicals in consumer product and other studies

3.1 DEPA surveys

In the years 2002 to 2005 the Danish Environmental Protection Agency (DEPA) has published more than 60 reports on studies of chemicals in consumer products.[4] Around half of them contain information relevant for indoor climate considerations.

The particular reports do have different aim and character. In some reports the focus is on the content of chemicals in the products, in others release to indoor air is included, which is most relevant for this project. The DEPA-reports focus on each consumer product separately. It is more complex in the real dwelling, where many products may be used simultaneously.

Even those reports on products very relevant for the indoor climate may not contain sufficient data for an exposure assessment. Furthermore, the results of the chemical analysis are not always very specific and certain, because most are screening methods, and some use toluene-equivalents for quantification of VOCs.

The reports with indoor relevance are listed below with report no. The most relevant reports with emission data are marked with ”+”, while reports only with product composition data for products intended for indoor use are marked with ”(+)”.

3.1.1 Reports containing chemicals and indoor climate information:

(+)	1: Phthalates in PVC products
+	6: Candle (lights)
+	7: Mapping of compound discharge when ironing of beads
(+)	8: Contents of selected fragrance materials in cleaning products and other consumer products
+	14: Moulding wax
(+)	15: Carpets
(+)	16: Cleaning materials and polishers for metals
(+)	17: Analysis of perfluorooctanesulfonate compounds in impregnation agents, wax and floor polish products
(+)	18: Hair styling products
(+)	19: Christmas spray
(+)	21: Dry-cleaned clothes
(+)	23: Textile fabrics
(+)	29: Chemicals in glues
(+)	30: Air freshener and similar products

[4] www.mst.dk/kemi/02050100.htm

+	32: Electric and electronic products, Part 1
(+)	33: Natural toys
+	36: Survey, release and assessment of volatile chemicals in printed matters
(+)	38: Survey and release of chemicals from sealing materials
+	39: Chemicals released from incense
(+)	43: Stain removers
(+)	45: Spray paint
+	46: Tents and tunnels for children
(+)	48: Windows colours
+	49: Release of chemicals from products of exotic wood
+	50: Exposure to chemicals in impregnation agents
+	51: Release of chemicals from products of chloroprene
(+)	52: Chemicals in shoe care products
(+)	57: Screening of health effects from chemicals in textile colours
(+)	58: Survey of chemicals in textile colours
(+)	59: Survey and evaluation of chemicals in glass and porcelain colours
+	66: Electric and electronic products, Part 2.

For each of these reports a summary was made in a phase-1 report.

An Excel file was generated with a Substance-Product-Matrix for substances in various products with indication if quantitative emission data exists, and if the exposure is long-term or short-term.

3.2 Summaries of other relevant surveys

A review has been made of other selected published studies of release of chemicals from consumer products and into the indoor climate and exposure of people to chemicals indoors from house dusts originated from consumer products. These summaries are found in Appendix B (only in Danish).

In Appendix B the focus is on the newer problems with the less volatile brominated flame retardants, which are often used in electric products, textiles and furniture foam, phthalate plasticizers found in vinyl floor materials and wall paper, and toys, and the repellants used for carpets and clothes. These substances are only in few cases included in the DEPA reports.

4 Criteria for selection of substances, products and housing rooms for model calculations

4.1 Background for prioritization of substances, products/articles, housing rooms etc.

The major task in the project is to model the total exposure of chemicals which the dwellers may be exposed to from consumer products used different places in the house. Because it is impossible to calculate every possible scenario, it is essential to select the most critical situations and most important substances and products. The prioritization may be made from the following criteria:

1. The most important rooms in the dwelling to prioritize regards exposure are:
   - Rooms where the dwellers mostly stay,
   - Rooms found in all/many houses; thus most people are exposed,
   - Rooms where many household products are in operation,
   - Smaller rooms
   - Rooms with low air flow to the cleaner outdoor air (poor ventilation),
   - Rooms with other materials/processes, which could contribute to additional exposure (building materials, cooking, heating).

2. Those consumer products which potentially contribute most to the indoor pollution are:
   - Products found in many rooms,
   - Products used often and of many,
   - Products releasing or containing many dangerous substances.

3. The pollution by consumer products may evolve as:
   - Gaseous volatisation,
   - Formation of aerosols and particles, atomization,
   - Migration from articles,
   - Dust formation by wearing, house dust,
   - Sedimentation of airborne particles and house dust.

4. Regards exposure of people the following issues should be evaluated and prioritized:
   - Persistent, long-term exposure,
   - Exposure routes, inhalation, ingestion, skin contact,
   - Exposure in high concentrations,
   - Exposure to more substances with the same effect,
   - Exposure to the same substances from several product,

- Exposure which is significant compared to other sources,
- Exposure of more susceptible groups (sick, children, pregnant, seniors).

5. Among the substances the extremely dangerous persistent, bioaccumulative and toxic compounds should be prioritized:
    - Persistent organic pollutants (POPs),
    - Metals,
    - Highly acute toxic substances,
    - Carcinogens,
    - Reproductive hazards,
    - Endocrine disruptors,
    - Allergy/asthma causing substances,
    - Nervous system toxins.

4.2 Selection of substances

In consultation with DEPA 11 substances/groups were selected for model calculations and assessment. See Table 4.1:

Table 4.1: Prioritized substances.

Substance	Effect	Occurrence/release in DEPA reports
Formaldehyde	Carcinogen, irritant	Computer, printer, monitor, playing console, household oven, decorative lamp, pressing iron, hair dryer, mobile phone, TV apparatus, chargers, El panel, El radiator, recharged batteries, floor carpets, textile fabrics, printed matters, incense, tents to children, products of exotic wood, agents to metal, glues
Acetaldehyde	Carcinogen, irritant	Computer, monitor, household oven, decorative lamp, pressing iron, hair dryer, mobile phone, TV apparatus, chargers, El radiator, recharged batteries, printed matters, incense, tents to children, glues
Phenol	Acute toxic, neurotoxic	Computer, monitor, playing console, household oven, pressing iron, TV apparatus, chargers, chloroprene products
Benzene	Cancinanden	Monitor, household oven, incense, moulding wax
Toluene	Neurotoxic	Monitor, pressing iron, decorative lamp, mobile phone, TV apparatus, recharged batteries, printed matters, incense, tents to children, products of exotic wood, beads
Xylenes	Neurotoxic	Computer, monitor, chargers, playing console, household oven, decorative lamp, hair dryer, mobile phone, TV apparatus, recharged batteries, printed matters, incense, tents to children, beads, Christmas spray
Styrene	Carcinogen, reprotoxic	Computer, monitor, playing console, household oven, decorative lamp, hair dryer, TV apparatus, recharged batteries, tents to children, beads
Limonene	Allergen	Printer, household oven, hair dryer, TV apparatus, recharged batteries, air freshener, printed matters, cleaning agents, stain remover
Phthalates	Endocrine disruptors	Household oven, hair dryer, TV apparatus, bath curtain, vinyl floors, carpet tiles, vinyl wall paper, textile fabrics, sealing agent, beads, Moulding wax, glues, stain remover
Brominated flame retardants	Persistent, some endocrine disruptors	Pressing iron
Perfluoroalkylated compounds	Persistent, some carcinogens	Impregnation agents, shoe care products

Worst-case model calculations could, however, only be made for the 8 volatile substances (VOC): Formaldehyde, acetaldehyde, phenol, benzene, toluene, xylenes, styrene and limonene, for which there were available and relevant emission data. Regards the less volatile substances (phthalates, brominated flame retardants and perfluoroalkylated substances) the exposures were evaluated based on content in house dust in a children's room scenario with infants playing on the floor. That is discussed in Chapter 6.

4.3 Prioritisation of housing room

The most relevant rooms in the house to be selected for exposure to VOC, are:

1. A children's room, where the most susceptible dwellers are mostly staying, and where many products are releasing substances,
2. A kitchen/family room in which many different activities occur, and
3. A utility room/hall in which the most polluting activities often occur, e.g. shoe polishing.

The model calculations are described in Chapter 5.

5 Model calculations of potential indoor concentrations of selected volatile substances and evaluation of its health importance

The purpose of this chapter is to estimate the total indoor concentrations of pollutants released from every consumer products that people may be exposed to various places in their homes, and make a preliminary health evaluation of such combined exposures.

5.1 Assumptions used in the calculations

The selection of which model rooms, which consumer products and which indoor chemicals should be included in the model calculation and health screening was made in consultation with DEPA and based on the developed substance-product matrix and the priority lists of substances and consumer products (see Chapter 4).

5.1.1 Model room

The model calculations are made for three types of rooms, where the exposure to VOC are supposed to be highest, thus a children's room, a kitchen/family room and utility room/hall.

5.1.1.1 Children's room

Infants, children and toddlers, who live in the children's room, are the most susceptible to chemical exposures. They stay there for long time when they sleep, play or make school homework. Furthermore, this room is often smaller than other rooms in the dwelling, and many consumer products able to release volatile chemicals to the air may be present.

The model room has a volume of 17.4 m^3 corresponding to a typical children's room in a well-insulated home. That size corresponds approximately to conditions in a standard room with a floor space of 7 m^2 and a ceiling height of 2.5 m, which normally is used to emission measurements.[5,6] The air flow is defined as 0.5 h^{-1}.

The size of the room and the air flow correspond to the conditions used for scenario calculations in several of the DEPA reports.

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[5] Anvisning for bestemmelse og vurdering af afgasning fra byggevarer. DS/INF 90. Dansk Standard, København, 1994.
[6] NT Building Materials 358: Emission of Volatile Compounds, Chamber Method. Espoo, Finland: Nordtest, 1990.

5.1.1.2 Kitchen/family room

In a kitchen/family room various hobby activities take place besides the cooking activities, which all may generate air pollution. The volume of the selected room is set to 52.2 m^3, corresponding to a room with a floor space of 21 m^2 (3 times the space of the children's room) and a ceiling height of 2.5 m. The air flow is 0.5 h^{-1}

5.1.1.3 Utility room/hall

In a utility room and in a hall many activities may pollute the air and it is those places dwellers and guests may carry dirt from outside. The volume of the room is set to 17.4 m^3, corresponding to a floor space of 7 m^2 and a ceiling height of 2.5 m. The air flow is again 0.5 h^{-1}

5.1.2 Consumer products

From DEPA's consumer product reports 46 consumer products with probable relevance for the indoor climate were selected. The three model rooms were equipped or decorated with these products, as indicated in Table 5.1.

Table 5.1: Consumer products with relevance for the indoor climate and included in DEPA reports. The figures indicate, how many specimen of a particular product are placed in the model rooms. "+" indicates that the particular product is in place, e.g. in amounts corresponding to scenario calculations in a relevant report, or that a product is used in the particular model room. It is mentioned, if one of the eight selected substances is found in the particular product, either as content or degassed.

Products	Model room			Substance(s) among the 8 selected?
	Children's room	Kitchen/family room	Utility room/hall	
Computer	1			yes
Printer	1			Yes
Monitor	1			yes
Playing console	1			yes
Household oven		1		yes
Hair dryer			1	yes
Pressing iron		1	1	yes
Decorative lamp	1			yes
Mobile phone – charger				yes
Mobile phone + charger	1	1	1	yes
TV apparatus	1	1		yes
Charger and transformer	1	1	1	yes
El panel	2	2	1	yes
El radiator	1	1	1	yes
Recharged batteries	1	1	1	yes
Vinyl floors		+	+	no
Carpet tiles	+	+	+	no
Vinyl wall paper	+	+	+	no
Candle lights		+	+	no
Floor carpets	+	+, partly	+	yes
Floor wax		+		no
Dry-cleaned clothes			+	no
Textile fabrics	+, curtain, bed linen	+, curtain, tablecloths	+, curtain	yes
Air fresheners		+	+	Yes
Printed matters	+	+	+	Yes
Sealing	+	+	+	yes
Incense	+	+	+	yes
Tents for children	1	1		Yes
Products of exotic wood	+	+	+	yes
Impregnation agent			+	no
Shoe care agents		+	+	Yes
Beads	+	+		Yes
Cleaning agents	+	+	+	Yes
Moulding wax	+ formed	+ heated		Yes
Agents to metal		+	+	Yes
Hair styling	+		+	no
Christmas spray	+	+	+	Yes
Glues	+	+	+	Yes
Natural toys	+	+		no
Stain removers		+	+	yes
Spray paint			+	yes
Windows colours	+	+	+	No
Chloroprene products			+	yes
Textile colours		+	+	no
Glass- and porcelain colours		+	+	no

5.1.3 Chemical substances

Model calculations are made for the eight selected volatile chemicals: Phenol, formaldehyde, acetaldehyde, benzene, toluene, xylenes, styrene and limonene.

Table 5.2 is an extract from the large substance-product-matrix on Excel sheet of those consumer products containing at least one out of eight selected chemicals. In the 33 products or product types the 8 substances are determined 107 times. In about 52 cases the substance is released continuously during a longer time, in about 34 cases the substance is released short-term, and in about 26 cases the substance is only determined as product content.

Table 5.2: Products, which may release or contain the selected chemical substances. RX shows the number of the relevant report from DEPA. "+" indicates if the substance is released continuously over longer time, and "(+)" indicates that the substance is released over shorter time. Absence of both "+" or "(+)" indicates that no release of the substance is measured, and typically substances were only detected as contents in the product.

	Phenol	Formaldehyde	Acetaldehyde	Benzene	Toluene	Xylenes	Styrene	Limonene
Computer	R66+	R66+	R66+			R66+	R66+	
Printer		R66+						R66 (+)
Monitor	R32+	R32+	R32+	R32+	R32+	R32+	R32+	
Playing console	R32+	R32+			R32+	R32(+)	R32+	
Household oven	R66(+)	R66+	R66+	R66 (+)		R66 (+)	R66 (+)	R66 (+)
Hair dryer		R66+				R66+	R66+	R66(+)
Pressing iron	R66+	R66+	R66(+)		R66+			
Decorative lamp		R66+	R66+		R66+	R66+	R66 (+)	
Mobile phone – charger					R66 (+)			
Mobile phone + charger		R66 (+)	R66 (+)		R66 (+)	R66 (+)		
TV apparatus	R66(+), R32+	R66(+), R32+	R66(+), R32+		R32+	R66(+), R32+	R66+, R32+	R66 (+)
Charger and transformer	R32+	R32+	R32+			R32+		
El panel		R66+	R66 (+)					
El radiator		R66+	R66 (+)					
Recharged batteries		R66+	R66 (+)		R66+	R66+	R66+	R66(+)
Vinyl floors		R15						
Carpet tiles		R23						
Vinyl wall paper								R30
Candle lights		R36+	R36+		R36+	R36+		R36+
Floor carpets					R38	R38		
Floor wax		R39	R39	R39	R39	R39	R39	
Dry-cleaned clothes	R46(+)	R46(+)	R46(+)		R46(+)	R46(+)	R46(+)	
Textile fabrics		R49+	R49+		R49+			
Air fresheners					R52	R52		R52
Printed matters					R7(+)	R7(+)	R7(+)	
Sealing								R8
Incense				R14(+)				
Tents for children		R16						
Products of exotic wood					R19	R19		
Impregnation agent		R29	R29					
Shoe care agents								R43(+)
Beads					R45	R45		
Cleaning agents	R51				R51			

5.1.4 Available data and assumptions for calculations

The review of DEPA's reports on chemicals and consumer products showed that data in the various reports had different character and goal. In some reports the focus is on substance contents in the products, instead of release of substances to the air, which is more relevant dealing with indoor climate. Even for some of the reports dealing with products very relevant for the indoor climate, there is often insufficient data for calculating indoor concentrations. In addition, the results of the chemical analysis are not always specific and certain, because screening methods are often used and quantification of VOCs may be with unspecific toluene-equivalents. For specific details reference is made to the DEPA reports.

Regards products, for which the release of substances to the air are measured and the source strength calculated, results are typically recalculated to potential indoor air concentrations in a standard room based on a simple model. Recalculations of results from climate chamber studies to concentrations in a standard room are typically based on the following standard conditions: It is assumed that the tested consumer products are used in a room with a volume of 17.4 m^3 and an air flow of 0.5^{-h}. This corresponds to a typically children's room in a well-insulated family house. At a certain air flow the highest concentration of pollutants, anything else equal, will occur in a children's room, because it is the smallest allowed room according to the building legislation.

In order to carry out the scenario and model calculations in the framework of this project with the given number of substances and products in the three types of model rooms, it has been necessary to use a pragmatic procedure, where the available data is applied in as simple and direct a way as possible. This means that the available and performed scenario calculations in the DEPA reports are used as far as possible. In those cases, where scenario calculations from the reports are not corresponding to the conditions for the three scenarios above, some simple calculations were undertaken, where it is assumed that there is proportionality between variations for ventilation and room size. That means e.g. that if the room is three times as large as in the original calculation, then the concentration is one third. A calculation example is given in Section 5.2.1.

Two types of source are distinguished between:

1. Sources that release substances during shorter time, and
2. Sources that release substances to the air continuously over long time.

Short-term and continuous sources are defined by the measurements available most extensively in the DEPA reports for electronics, after7 hours (new products) and 9 days (used products), respectively.

A "normal" worst-case situation is the basis of the calculations, and the focus is on indoor concentrations after 7 hours (new products) and 9 days (used products). The available indoor air concentrations for the particular products related to the three model rooms are listed in tables, and the concentrations are added in order to get the potential indoor air concentrations after 7 hours and 9 days, respectively.

Contrary to the more steady pollution sources, sources of a more extreme and brief character also appear, e.g. spray painting. These sources are treated separately and are assumed to impact the concentration with a contribution that has to be added to the more continuous (new or used) sources in order to estimate the highest short-term concentration.

For some products, e.g. TV apparatus and incense, measurements have been made on several different products. In such cases the product with the highest concentration is used in scenario calculations. For halogen lamp transformators an average figure of five transformators was used.

5.1.5 Special conditions for the single products

Regards printed matters the focus is that situation, in which the highest exposures are expected, that is watch and reading, when the consumer turns over the pages in the publication. In order to assess exposure in a standardized matter, theoretical exposure scenarios are defined. These shall illustrate worst-case but realistic exposures. The direct exposure of the consumers is supposed to take place, when the printed matter reaches the consumer after 2-15 days (3^{rd} measurement period), and the consumer turns the pages. The potential concentrations are calculated in a model room of a volume of 10 m^3 with an air flow of 0.5 times an hour. These results are used to calculate potential concentrations in the 2 smallest of the 3 scenarios. Thus a "worst-case" scenario was selected, in which pages are turned in three photogravure papers (e.g. sales catalogues) arriving at the same time, thus 498 gram photogravure and 677 gram offset, in total 1,175 kg printed matters in children's room and in utility room/hall. The release of chemicals is considerably lower, when the pages are not turned.

For incense there is used a consumption scenario, in which one incense pin is burned continuously in one hour in a room of a volume of 20 m^3 and an air flow of 0.5 h^{-1}. The combustion time of one pin varies between 25 -50 minutes. In order to estimate the indoor air levels several scenarios were put forward with the help of a box model and based on measured concentrations. It was chosen to use results from ventilated rooms instead of closed unventilated rooms, since it is more realistic. The room size was deliberately assumed small for the sake of a realistic worst-case with an air flow of 0.5 h^{-1}**.**

Regards the study of children's tents, the product under investigation was placed in a climate chamber at standard test conditions. An evaluation is undertaken based on the highest measured concentration (not recalculated for a model scenario), which occurs 3 hours after unpacking of the product. If that concentration is a matter of concern, the rest of the analytical results measured after 3, 10 and 28 days after outpacking of the product are taken into account.

For products of exotic wood the concentration of the substances was measured in a climate chamber and recalculated to what was relevant in indoor climate connections. The calculations were made for a standard room with a volume of 17.4 m^3 and an air flow of 0.5 h^{-1}. For all products a material load of 0.4 m^2/m^3 (0.4 m^2 material per m^3 air) was used, which is believed to correspond to e.g. one table and 6 chairs or a floor area of 7 m^2. By using the same material load for all products it mostly will be worst-case calculations. For every identified substance in the climate chamber measurements, calculations were made for days 3, 10 and 28.

For Christmas spray there was gathered information about product composition from safety data sheets and recipes, thus information exists about the content of the products. In order to evaluate the inhalation exposure of people, the report defines some standard conditions. These conditions are based on the various ways, the products are applied.

Therefore, the calculations are made for two scenarios, namely use of a full spray can in a relatively short time period and secondly use of smaller doses.

In the report a small dose is defined as 1/25 of a 150 ml can. When spray products are used, it may happen in different types of rooms. Since some of the products are not supposed to be used indoors, two different conditions, where the products can be used, are included: Garage or similar (3 m x 6 m x 2.5 m) with an air flow of 2 h^{-1}, and indoors e.g. in a kitchen (3 m x 4 m x 2.5 m) with an air flow of 0.5 h^{-1}. It is assumed that there is sprayed only once in a period and that all solvents evaporate instantly. The normal equation for decay is used to follow concentrations in air during time. In this way it is possible to get a feeling for, how the circumstances will be during various use conditions.

The exposure calculations for spray paint include some imaginary situations, in which a consumer or his family could be exposed to contents in spray paint. The calculations are built on the following scenario: An adult spray paints an item in an enclosed space at room temperature. The content of the can is sprayed against the item. Parts of the contents hit the item but the rest is released to the air. During this process the user of the can has a great risk of inhale these gaseous or particle-bound pollutants. It is assumed that an applicant uses a simple disposable particle filter to protect mouth and nose, thus only inhalation of gasses and vapors are included in the calculations (and in the present project). Exposures by inhalation are calculated as scenarios for application and drying. The scenario for application is based on substance concentrations determined by chemical analysis, while the scenario for drying is based on the determined amounts of substances. For each of the focus chemicals the highest concentration/amount determined by the chemical analyses was selected to the exposure scenario. These scenarios will, therefore, reflect the realistic worst-case exposures to each focus chemical.

For some products unusual or ”illegal” situations may develop, which may be hazardous to health, e.g. wrongly use of spray products indoors. These products are discussed separately as a problem but should be assessed with other products and other sources contributing the same chemical, e.g. building materials.

If there is data from more than one product from the same product group, the highest release of a chemical is used in the calculations.

5.2 Modelling of indoor concentrations

In the following the results are presented of worst case model calculations of indoor concentrations, based on above mentioned preconditions, for each of the eight selected volatile substances at occurrence of each product, and when the products are present at the same time in the three model room scenarios.

5.2.1 Phenol

The calculated concentrations for phenol are shown in Table 5.3.

An example of the calculations:
The emissions measured in the DEPA reports are transformed to potential indoor air concentrations in a room of 17.4 m^2 and an air flow of 0.5 h^{-1}. Regards phenol and pressing iron the concentrations are 1.4 µg/m^3 (after 7 hrs) and 0.2 µg/m^3 (after 9 days) in Children’s room and Utility room/hall but only a third in the Kitchen/family room.

Table 5.3: The concentration of phenol in a model room with one or more products.

Product	Model room					
	Children's room		Kitchen/family room		Utility room/hall	
	New products µg/m³	Used products µg/m³	New products µg/m³	Used products µg/m³	New products µg/m³	Used products µg/m³
Computer	16.1	16.1				
Monitor, obs uncertain data	22.6	18.7				
Playing console	1.5	0.5				
Household oven			0.3	<0.3		
Pressing iron			0.5	0.1	1.4	0.2
TV apparatus	3.4	3.0	1.1	1.0		
Chargers and transformers, obs	0.0	4.2	0.0	1.4	0.0	4.2
Tents for children	X	X	X	X		
Chloroprene products					X	X
Concentration in model room	43.6	42.5	1.9	2.5	1.4	4.4

Note: For monitor: Phenol + trimethylbenzene, Tenax-tubes are somewhat oversaturated. Given concentrations are minimum concentrations. The error is in all cases less than a factor 2. For Chargers and transformers: Tenax-tubes are somewhat oversaturated, because of unexpected high emissions, which are seen from the analytical results from the tubes with the two different sampling volumes. Reported concentrations are minimum concentrations. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As seen in Table 5.3, the highest concentrations of phenol are in the children's room, where the concentration is about 43 µg/m³ for both new and used products.

To this shall be added a potential contribution of 18.6 µg/m³ from tents for children and chloroprene products, for which the following can be stated:

- Regards tents for children the highest concentration of phenol was 18 µg/m³ (in climate chamber) after three hours. This value decreased to 15 µg/m³ after three days and to 7 µg/m³ after 10 days.

- Regards chloroprene products, phenol was determined in gloves of chloroprene in a concentration of 0.9 µg/gram. No information was available about release of phenol to the air, thus it is necessary to make some assumptions for estimating a potential worst-case concentration of phenol in the air. It is assumed that the gloves have a weight/volume 1/20 of the waders releasing most toluene, see below. A simple calculation based on the calculations for waders and toluene (0.12 µg/g and a total content of toluene of 0.029 mg) and with this assumption the total amount of phenol in a pair of gloves: 0.9/0.12 x 0.029 mg/20 = 0.011 mg. If it is assumed that this amount evaporates momentarily (unrealistic worst-case) in a hall with a volume of 17.4 m³ it would generate a concentration of 0.63 µg/m³.

It should naturally be emphasized that other sources exist than the mentioned.

5.2.1.1 Health assessment

Above it is mentioned that the maximal worst-case phenol exposure, which is in a children's room, is calculated to 62 µg/m³. This concentration is much lower than an indoor limit value of 400 µg/m^3 based on odour recognition (see Appendix B).

If a child weighing 10 kg inhales the worst-case concentration of 62 µg/m^3 the whole day with an inhalation rate of 0.6 m^3/time, it receives a total dose of about 900 µg/day or 90 µg/kg bw/day; or a little below the USEPA Reference Dose (RfD) for phenol of 100 µg/kg bw/day developed with a built-in safety factor. This shows that in a children's room, where every single pollution source alone counts insignificantly, the total chemical intake can in worst case approach or may be exceed the highest tolerable for a child.

5.2.2 Formaldehyde

The calculated concentrations of formaldehyde are shown in Table 5.4.

Table 5.4: The concentration of formaldehyde in a model room with one or more products.

Products	Model room					
	Children's room		Kitchen/family room		Utility room/hall	
	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3
Computer	3.3	3.7				
Printer	0.4	0.9				
Monitor	3.0	2.8				
Playing console	0.8	0.5				
Household oven			6.0	8.0		
Hair dryer					0.5	0.7
Pressing iron			1.1	0.0	3.3	0.0
Decorative lamp	19.5	4.9				
Mobile phone with charger	<0.1	<0.1	<0.03	<0.03	<0.1	<o.1
TV apparatus	1.5	0.3	0.5	0.1		
Chargers and transformers	11.1	4.3	3.7	1.4	11.1	4.3
El panel	<0.1	0.2	<0.03	0.1	<0.1	0.1
El radiator	0.4	0.4	0.1	0.1	0.4	0.4
Recharged batteries	<0.1	<0.1	<0.03	<0.03	<0.1	<0.1
Carpets	Content	Content	Content	Content	Content	Content
Textile fabrics	X	X	X	X	X	X
Printed matters	X	X	X	X	X	X
Incense	X	X	X	X	X	X
Tents for children	X	X	X	X		
Products of exotic wood	X	X	X	X	X	X
Agents for metals			Content	Content	Content	Content
Christmas spray						
Hobby glues	Content	Content	Content	Content	Content	Content
Concentration in model room	40.0	18.0	11.4	9.7	15.3	5.5

Reported concentrations are minimum concentrations. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As indicated in Table 5.4 the highest concentrations of formaldehyde are found in children's room, where the concentration is about 40 µg/m^3 for new products and around 18 µg/m^3 for used products.

To this shall be added a potential contribution of 515 µg/m^3 from textile fabrics, printed matters, incense, tents for children and products of exotic wood, for which the following can be stated:

- For a textile fabric made of 100% viscose, contents of formaldehyde of 43 mg/kg textile have been determined. The theoretical maximum concentration of formaldehyde in air was calculated by using the law on ideal gasses in an approximate form and assumptions that the substance is released instantly to the whole room and is homogenous distributed. The room scenario was selected to a volume of 20 m^3, and there are 30 m^2 textiles, corresponding to 10 kg in the room. Included in the weight is among others bed linen, curtains and clothes. On that basis the theoretical maximum concentration of formaldehyde in air was calculated to 57.6 µg/m^3. As mentioned it is a calculated theoretical maximum concentration of formaldehyd, which is not directly comparable with other more realistic determined concentrations. It should also be considered that formaldehyde after a trial wash only was found in one out of three textiles, and that a considerable reduction in the amount of free formaldehyde released from the textiles after one washing.

- For printed matters the concentration was calculated based on a scenario illustrating the worst case but still realistic exposures, in which the person turns pages in freshly printed matters in the hall. The potential concentrations were calculated in a model room of a volume of 10 m^3 and an air flow of 0.5 h^{-1}. If this result is recalculated to scenario for a children's room and a utility room/hall, the potential indoor concentration of formaldehyde becomes 1 µg/m^3.

- For incense the highest concentration of formaldehyde was calculated to 235 µg/m^3 after one hour of constant combustion of one pin of incense in a room with a volume of 20 m^3 and with an air flow of 0.5 h^{-1}(based on a box model). It was calculated that it would take at least 4 hours before the levels of formaldehyde were decreased to typically indoor levels.

- Regards tents for children the highest determined concentration of formaldehyde was 163 µg/m^3 (in a climate chamber) after three hours. This value was decreased to the half after three days. Since the measured formaldehyde concentrations decreased with time, it will be early hour's use of the tents where the largest release will take place.

- For products of exotic wood calculations were made for a standard room of a volume of 17.4 m^3 and an air flow of 0.5 h^{-1}. For every product was used a material load of 0.4 m^2/m^3 (0.4 m^2 material per m^3 air). The maximal concentration of formaldehyde in the standard room was calculated to 58 µg/m^3(rubber tree), and that is supposed to correspond to worst case.

Some cleaning agents and polishers for metals contain small amounts preservatives, including formaldehyde releasing compounds.

For carpets and hobby glues, formaldehyde was only found as a constituent without emission data.

It should be underlined that other sources than the mentioned may be present. Typical concentration levels of formaldehyde measured indoors in Danish dwellings are around 30 – 50 µg/m³. Sources to formaldehyde in indoor air include some adhesives and glued woodwork such as chip boards, combustion processes, and tobacco smoking. Under normal circumstances the formaldehyde levels in dwellings are estimated to 10-200 µg/m³, depending on which sources are present.

5.2.2.1 Health assessment

The maximal calculated concentration of formaldehyde in indoor air is around 500 µg/m³ but it will typically be below 50 µg/m³. The recommended indoor air limit value of 120 µg/m³ for formaldehyde is complied with at the typical concentration but not in the worst but unlikely case.

A child will normally inhale 720 µg formaldehyde/day at the typical value and 7 mg/day at the worst case. The Reference Dose (RfD) of 0.2 mg/kg bw/day will be complied with in the common case but not in worst case with all sources in operation simultaneously. Because formaldehyde is a recognized carcinogen and a safe limit is impossible to determine, all unnecessary exposure to formaldehyde should be prevented.

5.2.3 Acetaldehyd

The calculated concentrations for acetaldehyde are shown in Table 5.5.

Table 5.5: The concentration of acetaldehyd in a model room with one or more products

Products	Model room					
	Children's room		Kitchen/family room		Utility room/hall	
	New products µg/m³	Used products µg/m³	New products µg/m³	Used products µg/m³	New products µg/m³	Used products µg/m³
Computer	0.9	1.0				
Monitor	1.0	1.3				
Household oven			<0.3	4.7		
Pressing iron			0.7	<0.07	2.1	<0.2
Decorative lamp	1.1	0.2				
Mobile phone with charger	<0.1	<0.1	<0.03	<0.03	<0.1	<0.1
TV apparatus	0.6	0.3	0.2	0.1		
Chargers and transformers	1.2	0.5	0.4	0.2	1.2	0.5
El panel	<0.1	<0.1	<0.03	<0.03	<0.1	<0.1
El radiator	0.4	<0.2	0.1	<0.07	0.4	<0.2
Recharged batteries	<0.1	<0.1	<0.03	<0.03	<0.1	<0.1
Printed matters	X	X	X	X	X	X
Incense	X	X	X	X	X	X
Tents for children	X	X	X	X		
Products of exotic wood	X	X	X	X	X	X
Hobby glues	Content	Content	Content	Content	Content	Content
Concentration in model room	5.2	3.3	1.4	4.9	3.7	0.5

Reported concentrations are minimum concentrations. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As it is seen in Table 5.5 the highest concentrations of acetaldehyd are found in the children's room for new products and in kitchen/family room for used products. The concentrations are around 5 µg/m^3.

To this should be added potential contributions of up to 260 µg/m^3 from printed matters, incense, tents for children, and products of exotic wood, for which the following estimate is given:

- For printed matters the concentrations are calculated from a scenario, which is supposed to illustrate the worst but still realistic case, in which the consumer turns the pages in printed matter. The potential concentrations are calculated in a model room with a volume of 10 m^3 and an air flow of 0.5 h^{-1}. If the result is recalculated to scenarios for a children's room and a utility room/hall, the potential indoor concentration of acetaldehyde is 7.5 µg/m^3.

- For incense the highest concentration of acetaldehyde was calculated to 198 µg/m^3 after one hours continuous burning of one pin of incense in a room of a volume of 20 m^3 and an air flow of 0.5 h^{-1}(based on a box model).

- Regards tents for children the highest concentration of acetaldehyde is 12 µg/m^3 after three hours (in climate chamber). This value decreases to 2 µg/m^3 after three days.

- For products of exotic wood calculations are made for a standard room with a volume of 17.4 m^3 and an air flow of 0.5 h^{-1}. For all products were used a material load of 0.4 m^2 material pr. m^3 air. The maximum concentration of acetaldehyde in the standard room was calculated to 43 µg/m^3 (rubber tree), and it is supposed to correspond to worst case.

Regards hobby glues, acetaldehyde is found as constituent of products but no emission data exists.

It should be underlined that other sources than the mentioned may occur.

5.2.3.1 Health assessment

In the worst case the total exposure from many sources will be 265 µg/m^3 but normally it will be lower than 10 µg/m^3, thus close to the Reference Concentration (RfC) of 9 µg/m^3 determined by USEPA. In a 4-week animal study the no-adverse-effect-level (NOAEL) was 273 mg/m^3. With an uncertainty factor of 1000 the tolerable concentration is 0.3 mg/m^3 = 300 µg/m^3. This is higher than worst-case exposure but because acetaldehyde is a recognized carcinogen, and because a safe limit is impossible to determine for this effect, all unnecessary exposure, e.g. from use of incense, should be prevented.

5.2.4 Benzene

The calculated concentrations of benzene are shown in Table 5.6.

Table 5.6: The concentration of benzene in a model room with one or more products

Products	Model room					
	Children's room		Kitchen/family room		Utility room/hall	
	New products	Used products	New products	Used products	New products	Used products
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Monitor, obs	0.8	0.7				
Household oven			0.7	<0.3		
Hair dryer					0.0	0.0
Incense	X	X	X	X	X	X
Moulding wax			X	X		
Concentration in model room	0.8	0.7	0.7	0.0	0.0	0.0

Note: For monitor the Tenax- tubes are somewhat over saturated. Given concentrations are minimum concentrations. In all cases the errors are estimated to less than a factor 2. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As indicated in Table 5.6 the highest concentrations of benzene are found in children's room for both new and used monitors and in kitchen/family room for new household ovens. The concentration is about 0.8 µg/m^3.

To this should be added potential contributions from incense and oven-harded moulding wax, for which the following estimate is given:

- For incense the highest concentration of benzene was calculated to 353 µg/m^3 after one hour continuous combustion of a pin of incense in a room with a volume of 20 m^3 and with an air flow of 0.5 h^{-1} (based on a box model). It was calculated that it would take up to 8 hours, before the concentration level of benzene has decreased to a typical indoor level.

- For oven-hardened moulding wax release of benzene was measured at 200°C, which corresponds to wrong application of the product (worst-case), because in the guideline it is recommended to harden the product at 130°C. At 130°C no release of benzene was measured. At 200°C and after 30 minutes exposure the report mentions that 170 mg benzene was emitted pr. kg sample. It is unclear, if the 170 mg benzene pr. kg sample is released over 30 minutes or is the total long-term release for the product. Therefore, no scenario calculation of indoor levels was undertaken. There could be a relatively short-term and high release of benzene, when the oven is opened.

It should be underlined that other sources than the mentioned may occur. For instance, benzene could be expected to origin from sources as gasoline products used indoors and from car exhaust gasses, which are moved indoors with ventilation air from garages and repair shops.

5.2.4.1 Health assessment

Contribution of benzene to the indoor climate from the few products, which are investigated in the DEPA reports, is <1 µg/m^3. That is less than the typical concentration levels of benzene of 3 – 10 µg/m^3 measured indoors in dwellings of among others Danish Technological Institute. By using incense, extreme concentrations of up to 350 µg/m^3 may develop.

The Reference concentration (RfC) for benzene is 9-30 µg/m^3, and an increased risk of cancer is likely at concentrations above 20 µg/m^3. In EU a quality value of 5 µg benzene/m^3 for outdoor air has to be in force in January 2010. For moulding wax alone there is sufficient safety factor, but this is not the case for a total assessment. In addition, use of incense will generate for short time direct unhealthy benzene concentrations of 350 µg/m^3.

The Reference dose (RfD) for benzene is 4 µg/kg bw/day. Normally, a child will inhale < 1 µg benzene/kg bw during 24 hours, however, by using incense the intake during one hour exposure will be up to 21 µg benzene/kg bw/day. Such an intake of a chemical known to cause leukemia in humans must be looked on as completely unacceptable from a health viewpoint.

5.2.5 Toluene

The calculated concentrations of toluene are shown in Table 5.7.

Table 5.7: The concentration of toluene in a model room with one or more products

Products	Model room					
	Children' s room		Kitchen/family room		Utility room/hall	
	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3
Monitor, obs	38.3	16.0				
Playing console	0.2	0.2				
Pressing iron			1.0	0.0	2.9	0.1
Decorative lamp	6.7	1.0				
Mobile phone with charger	2.0	<0.1	0.7	<0.03	2.0	<0.1
TV apparatus	2.0	2.2	0.7	0.7		
Recharged batteries	<0.1	<0.1	<0.03	<0.03	<0.1	<0.1
Printed matters	X	X	X	X	X	X
Sealings	content	content	content	Content	content	content
Incense	X	X	X	X	X	X
Tents for children	X	X	X	X		
Products of exotic wood	X	X	X	X	X	X
Shoe care agents			content	Content	content	content
Beads	X	X	X	X	X	X
Christmas spray	X	X	X	X	X	X
Spray paint					X	X
Chloroprene products					X	X
Concentration in model room	49.2	19.4	2.3	0.8	4.9	0.1

Note: For monitor the Tenax- tubes are somewhat over saturated. Given concentrations are minimum concentrations. In all cases the errors are estimated to less than a factor 2. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As seen from Table 5.7 the highest concentrations of toluene are found in children's room, where the concentration was about 49 µg/m^3 for new products and about 19 µg/m^3 for used products.

To this should be added potential contributions of up to in total 2,980 µg/m^3 (or 39,000 µg/m^3 with spray paint) from printed matters, incense, tents for children, products of exotic wood, beads, Christmas spray, spray paint and chloroprene products, for which the following estimate may be given:

- For printed matters the concentration of toluene is calculated based on a scenario, which shall illustrate the worst case but still with realistic exposures, where the consumer turns the pages of printed matters. Possible concentrations are calculated in a model room of a volume of 10 m^3 and with an air flow of 0.5 h^{-1}. If the obtained results are converted to scenarios for children's room and utility room/hall the potential indoor concentration of toluene will be 2,097 µg/m^3.

- For incense the highest concentration of toluene was calculated to 59 µg/m^3 after one hour continuous combustion of one pin of incense in a room with a volume of 20 m^3 and an air flow of 0.5 h^{-1} (based on a box model).

- For tents to children the highest concentration of toluene was determined to 27 µg/m^3 after three hours in climate chamber. However, the blind values are about 10 µg/m^3, so the measurements must be seen as relatively uncertain.

- For products of exotic wood the calculations were made for a standard room with a volume of 17.4 m^3 and an air flow of 0.5 h^{-1}. For all products were used a material load of 0.4 m^2/m^3 (0.4 m^2 material pr. m^3 air). The maximum concentration of toluene in the standard room was calculated to 74 µg/m^3 (caoutchouc tree) and is assumed to correspond to worst case.

- For beads concentrations of toluene of 720 µg/m^3 may occur. This concentration will only appear as long bead boards are ironed, and it will decrease as soon as the activity is stopped, because there will be a dilution with the other room air.

- For Christmas spray the report from DEPA gives concentration in the air of organic solvents and propellants. Products are selected randomly, and in individual cases are used the most precise information, which is recipe information, if it is available. Actual concentrations of toluene are not available.

- For spray paint the highest concentration of toluene is determined to 36,000 µg/m^3 around the applicant during application of paint. During the following drying period the concentration will be considerably lower.

- For chloroprene products, toluene was found in waders in a concentration of 0.12 µg/g. Toluene occurs in concentrations of 0.0046 µg/cm^3 in the product, which end up in a total toluene content of 0.029 mg. This amount may in theory evaporate, because toluene is very volatile. Instant evaporation of this amount (unrealistic worst-case) in a hall of a volume of 17.4 m^3 might result in a concentration of 1.7 µg/m^3.

Regards sealing and shoe care agents toluene was found as constituent but no emission data was available.

It should naturally be emphasized that other sources exist than the mentioned.

5.2.5.1 Health assessment

The highest concentrations of toluene were calculated to be in a children's room with a concentration of about 49 µg/m^3 for new electronics and about 19 µg/m^3 for used products. The contribution came mainly from a PC monitor. Moreover to be added is potential contribution from other consumer products of up to 900 µg/m^3; however, in total about 2,980 µg/m^3 with printed matters and 39,000 µg/m^3 including spray paint.

The Reference Dose (RfD) is reported to be 223 µg/kg bw/day and the Reference Concentration (RfC) to be 0.4 mg/m^3.

If the toluene concentration generated from en monitor, that is working 6 hours/day, is 50 µg/m^3, then a child will have an intake of 120 µg/day or 12 µg/kg bw/day, thus a sufficient safety margin. This is, however, not the case, if contributions from other sources are added. Even without contributions from printed matters and spray paint, the intakes of 1,800 µg/day or 180 µg/kg bw/day are very close to the highest tolerable.

5.2.6 Xylen(es)

The calculated concentrations of xylenes are shown in Table 5.8.

Table 5.8 Concentration of xylenes in a model room with one or more products

Products	Model room					
	Children' s room		Kitchen/family room		Utility room/hall	
	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3
Computer	10.5	8.6				
Monitor. obs	24.2	7.9				
Playing console	0.7	0.0				
Household oven			0.3	<0.33		
Hair dryer					1.3	1.7
Decorative lamp	23.0	4.7				
Mobile phone with charger	0.1	<0.1	0.0	<0.03	0.1	<0.1
TV apparatus, obs	1.8	2.0	0.6	0,7		
Chargers and transformers, obs	25.6	15.2	8.5	5.1	25.6	15.2
Recharged batteries	19.5	5.3	6.5	1.8	19.5	5.3
Printed matters	X	X	X	X	X	X
Sealings	content	Content	content	content	content	content
Incense	X	X	X	X	X	X
Tents for children	X	X	X	X		
Shoe care agents			content	content	content	content
Beads	X	X	X	X		
Christmas spray	X	X	X	X	X	X
Spray paint					X	X
Concentration in model room	105.4	43.7	16.0	7.5	46.5	22.2

Notes: For monitor, TV apparatus and chargers and transformers the concentrations are measured combined for a mixture of o-xylene and styrene. The total value is used (worst-case) and the concentrations for the three xylenes: *o*-, *m*- and *p*-xylene are added. For chargers and transformers Tenax-tubes are somewhat oversaturated because of unexpected high emissions. It is seen of the analytical results from the tubes with the two different sample volumes applied. Reported concentrations are minimum concentrations. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As seen in Table 5.8, the highest concentrations of xylenes are found in children's room with a concentration of about 105 µg/m^3 for new products and about 44 µg/m^3 for used products. In the utility room/hall the concentration is about 47 µg/m^3 for new products.

To this may be added potential contributions of in total about 476 µg/m^3 (or 51,476 µg/m^3 with spray paint) from printed matters, incense, tents for children, beads and spray paint, for which the following estimate may be given:

- For printed matters the concentrations of xylenes are calculated from a scenario illustrating the worst cases but realistic exposures, when a person turns the pages of printed matters. The potential concentrations are calculated in a model room of a volume of 10 m^3 and an air flow of 0.5 h^{-1}. If the results from here are converted to scenarios for children's room and utility room/hall the potential indoor concentration of xylenes is 17 µg/m^3.

- For incense the highest concentration of xylenes was calculated to 20 µg/m^3 after one hour continuous combustion of a pin of incense in a room with a volume of 20 m^3 and with an air flow of 0.5 h^{-1}(based on a box model).

- Regards tents to children small amounts of xylenes were found in all samples. After three hours concentrations were measured to be between 3 µg/m^3 and 9 µg/m^3. Measurements made after 3 and 10 days resulted in concentrations at the same level or decreasing.

- For beads concentrations of xylenes of 430 µg/m^3 may occur. Such concentration will only be present as long bead plates are ironed, and it will decrease as soon as the activity ceases, because then it will be blended with the room air.

- For spray paint the highest concentration of xylenes is determined to be 51,000 µg/m^3 around the applicant. During the subsequently drying the concentration will be considerable lower.

- For Christmas spray the report from DEPA gives concentration in the air of organic solvents and propellants. Products are selected randomly, and in individual cases the most precise information is used, which is recipe information, if it is available. Actual concentrations of xylenes are not available.

- For sealing and shoe care agents, xylenes were found as constituent, and there is no emission data.

It should be underlined that other sources, than these mentioned, may occur.

5.2.6.1 Health assessment

The highest concentrations of xylenes were found to be in a children's room with a concentration of about 105 µg/m^3 for new electronics and about 44 µg/m^3 for used products.

In the utility room/hall the concentrations are about 47 µg/m^3 for new products. To this may be added potential contribution of up to 476 µg/m^3 (or 51,000 µg/m^3 with spray paint).

The Reference Concentration (RfC) for xylenes is 100 µg/m^3. The contributions from the electronic products in children's room alone correspond to that. In case of spray paint the concentrations are so high that there is a possibility of direct health damages, because the exposure then is >10 times the occupational health limit value.

The Reference Dose (RfD) for xylenes is 200 µg/kg bw/day. Exposure to 100 µg/m^3 for 6 hours results in a child intake of xylenes at 3,600 µg/day or 360 µg/kg bw/day. That means that alone the electronics cause too high exposures compared to RfD. A further 10-100 times increased exposure, which can be obtained from other sources, might be unacceptable.

5.2.7 Styrene

The calculated concentrations for styrene are shown in Table 5.9.

Table 5.9 Concentration of styrene in a model room with one or more products.

Products	Model room					
	Children' s room		Kitchen/family room		Utility room/hall	
	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3	New products µg/m^3	Used products µg/m^3
Computer	2.5	1.8				
Monitor, obs	14.8	4.1				
Playing console	1.8	0.2				
Household oven			0.3	<0.3		
Hair dryer					<0.3	0.2
Decorative lamp	0.3	<0.2				
TV apparatus, obs	1.5	1.4	0.5	0.5		
Recharged batteries	0.8	0.2	0.3	0.1	0.8	0.2
Incense	X	X	X	X	X	X
Tents for children	X	X	X	X		
Beads	X	X	X	obs		
Concentration in model room	21.7	7.7	1.1	0.5	0.8	0.4

Note: For monitor and TV apparatus the concentrations are measured combined for a mixture of *o*-xylene and styrene. Reported concentrations are minimum concentrations. The total values are given (worst case). An "X" means here and in the following tables that special conditions are present and discussed below the table.

As seen in Table 5.9 the highest concentrations of styrene are found in children's room with concentrations of about 22 µg/m^3 for new products and about 8 µg/m^3 for used products.

To this may be added potential contribution of up to 772 µg/m^3 from incense, tents for children and beads, for which the following estimate can be given:

- For incense the highest concentration of styrene is calculated to 34 µg/m^3 after one hour continuous combustion of a pin of incense in a room with a volume of 20 m^3 and an air flow of 0.5 h^{-1}(based on a box model).

- For tents to children the highest concentration of styrene is 18 µg/m^3 after three hours in climate chamber. Styrene is not treated as a potentially problematic substance.

- For beads the figures are uncertain. Bearing that in mind, there may be generated concentrations of styrene of 720 μg/m^3. Such concentration will only be present as long bead plates are ironed, and it will decrease as soon as the activity ceases, because then it will be blended with the room air.

It should be underlined that other sources, than these mentioned, may occur.

5.2.7.1 Health assessment

The highest concentrations of styrene were calculated to be in a children's room with a concentration of about 22 μg/m^3 for new electronics and about 8 μg/m^3 for used products. In addition, potential contributions of up to about 772 μg/m^3 from incense, tents for children, and beads. The latter value is very close to the WHO air quality guideline value of 800 μg/m^3 but below the Reference concentration (RfC) of 1 mg/m^3 based on effects on the central nervous system.

The Reference dose (RfD) is 200 μg/kg bw/day, which is a little larger than a Dutch TDI of 120 μg/kg lgv/day. At exposure to a concentration of 20 μg/m^3 in 6 hours/day, the child intake of styrene is about 72 μg/day or 7 μg/kg bw/day. This is far below any risk level and without health effects. However, in the worst-case scenario for children's room with incense etc., there will be a 20% excess of RfD.

5.2.8 Limonene

The calculated concentrations of limonene are shown in Table 5.10.

Table 5.10 Concentrations of limonene in a model room with one or more products

Products	Model room					
	Children' s room		Kitchen/family room		Utility room/hall	
	New products	Used products	New products	Used products	New products	Used products
	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Printer, obs	3.1	<0.5				
Household oven			1.0	<0.3		
Hair dryer					0.6	<0.4
TV apparatus	1.1	<0.3	0.4	<0.1		
Recharged batteries	0.1	<0.1	0.0	<0.03	0.1	<0.1
Air fresheners			content	content	content	content
Printed matters	X	X	X	X	X	X
Shoe care agents			content	content	content	content
Cleaning agents	content	Content	content	content	content	content
Stain removers			X	X	X	X
Concentration in model room	4.3	0.0	1.4	0.0	0.7	0.0

Note: For printer measured as toluene equivalents. Reported concentrations are minimum concentrations. An "X" means here and in the following tables that special conditions are present and discussed below the table.

As seen in Table 5.10 the highest concentrations of limonene are found in children's room, where the concentration is about 4 μg/m^3 for new products.

To this may be added possible contributions of up to 341 μg/m^3 from printed matters and incense, among others, for which the following may be estimated:

- For printed matters the concentrations of limonene are calculated from a scenario illustrating the worst cases but realistic exposures, when a person turns the pages of printed matters. The potential concentrations are calculated in a model room of a volume of 10 m^3 and an air flow of 0.5 h^{-1}. If the results from here are converted to scenarios for children's room and utility room/hall the potential indoor concentration of limonene 16 µg/m^3.

- For stain removers the maximum content of limonene in a liquid product is determined to 0.44%. A worst-case calculation has been made, where a person uses a stain remover in a spray can which is used once a week. Every time the person stayed 5 minutes inside the room, where the application was made. Investigations with three different types of spray cans without propellant but with a hand pump gave an average consumption of 1.3 g at application on a spot of average size. The model room, in which the stain removal takes place, has a volume of 15 m^3 without ventilation. It is assumed that after the injection a complete mixing of substances in the air is seen. The concentration in a person's inhalations zone may be calculated by an equation. This gave a concentration of limonene of 325 µg/m^3.

- For air fresheners, shoe care agents, and cleaning agents, limonene was found as constituent without emission data.

It should be remembered that other sources than those mentioned may be present. Average concentrations for limonene of 5-15 µg/m^3 in indoor air are reported in some studies but concentrations may reach several hundreds µg/m^3 during or just after use of various consumer products.[7,8,9,10]

5.2.8.1 Health assessment
The highest concentrations of limonene are in children's room, where the concentration is about 4 µg/m^3 for new electronics. To this may be added possible contribution of up to about 341 µg/m^3 from printed matters and incense among others. Exposure to limonene may also occur by storage and consuming of citrus fruits.

Limonene has a low toxicity and the tolerable daily intake (TDI) is 100 µg/kg bw/day. If a child is exposed to a concentration of 4 µg/m^3 for 6 hours the intake will be 15 µg/day or 1.5 µg/kg bw/day. Such an intake is completely without health concerns to a normal child. In a worst case scenario, however, the intake may approach the TDI. In case of allergy or intolerance even small amounts may have importance; however, this will not be a specific indoor problem in relation to limonene.

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[7] Seifert B, Mailahn W, Schulz C, Ullrich D. Seasonal variation of concentrations of volatile organic compounds in selected German homes. Environ Int 1989;15:397-408.

[8] Fellin P, Otson R. Assessment of the influence of climatic factors on concentration levels of volatile organic compounds (VOCs) in Canadian homes. Atmospheric Environment 1994;28 (22):3581-3586.

[9] Wainman T, Zhang J, Weschler CJ, Lioy P. Ozone and limonene in indoor air: a source of submicron particle exposure. Environ Health Perspec 2000;108 (12):1139-1145.

[10] Singer BC, Destaillats H, Hodgson AT, Nazaroff WW. Cleaning Products and Air Fresheners: Emissions and Resulting Concentrations of Glycol Ethers and Terpenoids. Submitted for publication, 2005.

6 Exposure assessment to less volatile substances

Most of the substances studied in DEPA's consumer reports are volatile substances (VOC) released from consumer products to indoor air. Inhalation of vapors is the most important exposure route for volatile substances. Even the less volatile substances with a low vapor pressure generate small concentration of vapors but these will easily condense on air particles that fall down as dust of various composition. Activities inside a room, inclusive vacuum cleaning, mean a potential for reentrance of airborne dust with a diameter of 5-25 µm.

Evaporation increases with temperature and it will normally be highest in summertime. The dust may in addition receive substances from normal wearing of products or migration from products by contact with dirts. Depending on house cleaning quality, dust may accumulate substances during longer time, thus dust may be seen as a passive sampling device.

Individuals may also be exposed to migrated substances from consumer products, e.g. toys and clothes, by skin contact. Ingestion of dust will probably still be the most important exposure route indoors for less volatile substances such as phthalate plasticizers, brominated flame retardants, and perfluoroalkylated compounds.

House dust may be absorbed in the body from inhalation of airborne dust and intake of dust deposited on foodstuff and surfaces. Direct absorption of dirt through the skin is also possible. The issue of pollution of house dust has been reviewed thoroughly by Butte and Heinzow.[11]

6.1 Exposure of children to dust

Small children do have a special high intake of dust with less volatile chemicals, because they are crawling around on the floor, putting dirty fingers in the mouth and sucking toys and other items. However, everything depends on behavior, hygiene and actual conditions. A crawling toddler is special exposed to dust, and in special cases such a child may have a daily intake of up to 10 gram dust or soil. USEPA estimates, however, that a 2½ years old child normally only has a daily intake of 100 mg house dust in wintertime and 50 mg in the summer, where the child is more outdoor. In Germany daily dust intake estimations of 20-100 mg for 1-6 years old children, 5-25 mg for 7-14 years old children and 2-10 mg for adults are used. It is estimated that children daily alone have an intake of 100 µg wall paper dust.

[11] Butte W, Heinzow B. Pollutants in house dust as indicators of indoor contamination. Rev Environ Contam Toxicol 2002;175:1-46.

6.2 Exposure to phthalates from consumer goods

Phthalates are used as plasticizers in many consumer goods, especially goods manufactured in PVC-plastic. The most used plasticizer is di(2-ethylhexyl) phthalate (DEHP). The plasticizer is not bound especially firmly to the polymer, and is able to leach and migrate relatively easily. The short chain dialkyl phthalates are released most easily.

There is information about phthalates in DEPA consumer reports no. 1, 7, 14, 23, 29, 38 and 43, however, only exposure- and risk assessment in report no. 23 and 43.

6.2.1 Phthalates in PVC products (Report no. 1)

Consumer goods made of PVC, such as bathing curtain, bags, gloves, vinyl floor, carpet tiles and vinyl wall paper were studied. At least one type of phthalates was found in all samples in concentrations from 2 to 63%. The most abundant was DEHP in 10 out of 12 goods followed by DINP/DIDP in half of the goods, DBP in a third and BBP in two products.

6.2.2 Phthalates in Beads (Report no. 7)

Some phthalates were found in every bead and bead plates.

6.2.3 Phthalates in moulding wax (Report no. 14)

In all products meant for heating a high content (16-22%) of phthalate plasticizers was determined.

6.2.4 DEHP in textile fabrics (Report no. 23)

The content of DEHP was determined to 2-8 mg/kg in 20 spot samples of textiles of cotton, wool, flax, PET and viscose.

Regards textiles a 100% dermal uptake corresponds to an uptake of 55 µg/kg bw/day for adults and 195 µg/kg bw/day for children. However, a dermal uptake of 5% for DEHP is estimated for both children and adults. The maximum dermal uptake of DEHP is thereafter calculated to 0.00275 mg/kg bw for an adult and 0.0096 mg/kg bw for a child.

In the report the oral uptake of DEHP is estimated to about 50% for adults and 100% for children. The evaluation of intake was based on a child, who is sucking/chewing a textile piece corresponding to 400 cm^2 or 20 gram. The weight of the child is set to 10 kg and absorption to 100%. Then the intake every time will be 15.4 µg/kg bw.

Regards inhalation it is estimated that the compound evaporates to the maximal concentration (saturated) and is distributed uniformly in the whole room. In addition it was assumed, that there was 10 kg clothes in the room, that the room had a volume of 20 m^3, and that inhalation for an adult had duration of 24 hours. Exposure by inhalation was as expected very small and insignificant: 6.44×10^{-6} µg DEHP/kg bw/day.

6.2.5 Phthalates in hobby glues (Report no. 29)

In some wood glues, in one vinyl glue and in one school glue the analysis found a content of phthalate plasticizers. Only the content of diisobutyl phthalate (DIBP) in the school glue was declared.

6.2.6 Phthalates in sealings (Report no. 38)

Two acryl based sealings had a content of phthalate plasticizers, repectively 3 % dibutyl phthalate (DBP) and 16 % diisononyl phthalate (DINP). In a MS-polymer sealing contents of 32 % diisodecyl phthalate (DIDP) and 4 % di(2-ethylhexyl) phthalate (DEHP) were determined.

6.2.7 Dibutyl phthalate (DBP) in stain remover (Report no. 43)

The air concentration of DBP was calculated to 22.5 µg/m^3, using the EUSES model, and the uptake via the airways was calculated to 3.19 x 10^{-6} mg/kg bw/day, which was far below the no-effect level (NOAEL) of 583 mg/m^3 or 125 mg/kg bw/day. This indicated a minimal risk by application of DBP in stain remover.

6.3 Brominated flame retardants

Brominated diphenyl ethers may be used as flame retardant in many consumer products. Brominated flame retardants are only investigated in the latest report 66 about electronics. Only one single product (a pressing iron) did release brominated flame retardants in the form of nonaBDE and decaBDE. The source strength was less than 0.05 µg/unit/h for both substances.

6.4 Perfluoroalkylated substances

Perfluoroalkylated substances (PFAS) are studied in DEPA consumer reports no. 17, 50, 52 and 66 about electronics. These substances are also evaluated in other reports from DEPA.[12,13]

6.4.1 PFAS in impregnation agents and floor wax/polish (Report no. 17)

In 2001, 21 different consumer products were purchased and analysed for 6 perfluorinated compounds. In 2 out of 11 investigated spray products a content of these compounds were detected.

In a spray product mend for impregnation of leather, hide and textiles a content of 3.5 µg/mL perfluorooctane sulfonamide (PFOSA) was determined. This result was in accordance with the declaration of the product stating that the impregnation agent was a fluorocarbon.

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[12] Havelund S. Kortlægning af perfluoroktanylsulfonat og lignende stoffer i forbrugerprodukter – fase 2, COWI Rådgivende Ingeniører A/S. Miljøprojekt nr. 691, 2002. Miljøstyrelsen.

[13] Poulsen PB, Jensen AA, Wallström E. More environmentally friendly alternatives to PFOS-compounds and PFOA. Environmental Project No. 1013. Danish Environmental Protection Agency, 2005.

In a spray product to tents, sleeping bags etc. the content of perfluorooctane sulfonate (PFOS) was 212 µg/mL.

In one out of five liquid floor polishers to vinyl, cork, linoleum etc. a concentration of 10 µg/mL of ***N***-ethyl perfluorooctane sulfonamide (EtFOSA) was determined.

The analysed substances are under phasing out but are probably substituted by other perfluorinated substances.

6.4.2 PFAS in impregnation agents (Report no. 50)

The substances perfluoroheptanoic acid (PFHpA) and perfluorooctanoic acid (PFOA) were identified in a migration test of the impregnation agent IM-05. IM-05 is a product used as a liquid in a.o. dry-cleaning shops. These two substances do have similar properties, similar effects and are released from the same impregnation agent. It was concluded that the uptake of the two substances may be added.

The exposure scenarios for use of impregnated products show that the two PFAS are taken up in amounts from 0.2 to 0.6 µg/kg bw/day. That means that a child can have a total uptake of about 0.9 µg/kg bw/day. The acceptable daily intake (ADI) is 3 µg/kg bw/day corresponding to the no-effect level (NOAEL) for reproductive effects and with a safety factor of 1,000.

There is a risk that the total exposure to these substances can reach levels, where adverse health effect may develop. If children are exposed to such substances from other sources, the report concludes that there is a risk of adverse effects such as damaged organs. However, it must be presumed that use of impregnated clothes occurs with another clothing under, and then the risk is further minimized.

6.4.3 Shoe care agents (Report no. 52)

These products were analysed for 8 different PFAS compounds. In one out of the four analysed products very low concentrations of perfluoroheptanoic acid (PFHpA) and perfluorooctanoic acid (PFOA) were determined, respectively 1.1 and 0.36 mg/kg.

6.4.4 Electronic products (Report no. 66)

From the household oven was detected a release of a fluorinated compound. Probably, it was evaporation of substance from the self cleaning coating at the inner side of the oven.

6.5 Assessment of a crawling children's intake of phthalates, PBDE and PFAS in house dust

The available data on phthalates, brominated flame retardants and perfluoroalkylated compounds in DEPAs consumer product reports are as seen above very scarce, limited and difficult to use for an exposure and risk assessment. Instead, Danish and foreign studies of house dust content can be used for estimating children exposures for these less volatile substances from various indoor sources. More information and references in Annex A and B (only in Danish).

6.5.1 Phthalates

The content of phthalates in house dust is typically about 1,000 mg/kg (0.1%), of which DEHP amounts to 60-70%. In rooms with vinyl flooring or vinyl wall paper and with poor cleaning the content may be ten times higher.

An intake of 100 mg dust daily implies an average child intake of about 100 µg phthalates/day or 10 µg/kg bw/day, if the body weight of the child is 10 kg. There is assumed a 100% absorption.

In addition there may be direct migration from contact with and suckling of toys (sold before the phthalate ban), textiles etc. Regards skin contact to DEHP-treated textiles it was calculated in DEPA Consumer Report no. 23 that a child with, respectively, 5% and 100% absorption through the skin, absorbe 9.6 to 195 µg DEHP/kg bw/day. It was also calculated that a child weighing 10 kg, who sucks/chews a impregnated textile of 400 cm^2 or 20 gram will absorb 15.4 µg DEHP/kg bw each time.

As expected, exposure by inhalation was small and insignificant at 6.4×10^{-6} µg DEHP/kg bw/day.

In all, a typical daily child absorption of DEHP from all indoor sources will normally amount 10-20 µg/kg bw/d or 100-200 µg/d, but in worst case probably as much as 50-250 µg/kg bw or 0.5-2.5 mg/day for a much exposed crawling child on a PVC-floor. In addition to the indoor exposure, there is an intake of DEHP in foods, which in Germany is estimated to 18 µg/kg bw/d for a child or 180 µg/day, thus in the same order of magnitude as the usual indoor exposure.

The highest oral exposure to DEHP in long-term rat experiments without adverse effects (NOAEL) is 3.7 mg/kg bw/day or 37 mg/day. If rats and humans do have the same sensitivity, there seems to be a very small safety factor for the most exposed children. To this comes the possible exposure to the other phthalates.

6.5.2 Polybrominated diphenyl ethers (PBDE)

No Danish studies of brominated flame retardants in the indoor environment are available, thus the assessment has to be based on international experience. Measured concentrations of brominated flame retardants in human tissues are higher than expected from the intake by foods, thus there must be other exposures and sources. It is likely to be the indoor environment and car driving.[14,15,16]

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[14] Jones-Otazo HA, Clarke JP, Diamond ML et al. Is house dust the missing exposure pathway for PBDE? An analysis of the urban fate and human exposure to PBDEs. Environ Sci Technol 2005;39:5121-5130.

[15] Wilford BH, Shoeib M, Harner T, Zhu J, Jones KC.. Passive sampling survey of polybrominated diphenyl ether flame retardants in indoor and outdoor air in Ottawa, Canada: Implication for source and exposure. ES&T 2004;38:5312-5318.

[16] Shoeib M, Harner T, Wilford BH, Jones KC, Zhu J. Indoor and outdoor air concentrations and phase partitioning of perfluoralkyl sulfonamides and polybrominated diphenyl ethers. ES&T 2004;38:1313-1320.

6.5.2.1 PBDE in air

In existing surveys there has been a correlation between PBDE concentration in indoor air and the number of electrical apparatus and the number of upholstered furniture in the home. Soft polyurethane foam applied to office chairs, car seats and furniture may release several hundred microgram PBDE per day. Concentrations of PBDE in indoor air are typical 20-50 times higher than in outdoor air. However, in air measurements the less volatile congener BDE209 is not measured and excluded.

Median concentrations are often 100-200 pg PBDE/m^3 with maximum concentrations of >15.000 pg PBDE/m^3. If the inhalation rate of a child is set to 1 m^3/h, the inhaled amount will be up to 36 ng PBDE a day but, typically, the amount will be below 1 ng and thus not significant.

6.5.2.2 PBDE in house dust

There are large variations in content of PBDE in dust from the various homes investigated. Maximum concentrations may be >20.000 ng PBDE/g dust. BDE 47, BDE99 and BDE209 are the most abundant congeners in house dust with common median concentrations of 17, 24 and 265 ng/g for these three congeners, which typically amount to 95% of the content.

If the dust intake is 100 mg/day, then a child may have an intake of 30 and in few cases up to 2000 ng PBDE/day. This should be compared with an average intake from foods of 40-150 ng/day,[17] and about 2000 ng/day for breastfed children, because human milk contains very high concentrations of PBDE. On that background the maximal amount a child may be exposed to will be <5 µg/day.

For PBDE as a group, a no-adverse-effect-level (NOAEL) of 1 mg/kg bw/day can be used. It is based on classical toxicological effects and do not take into account e.g. endocrine disrupting effects and bioaccumulation. Compared with this NOAEL there is a sufficient safety factor at present pollution levels. A comparison with the USEPA's Reference Doses (RfD) of 2-10 µg/kg bw/day, which includes safety factors shows that only breastfed infants may reach near of the Reference Dose.

Exposure via house dust is in the same order of magnitude as in foods. This is surprising, because 90% of people's exposure to persistent organic pollutants normally is through food intake.

6.5.3 PFAS

The concentration of perfluoroalkylated compounds (PFAS) in indoor air is commonly 25-100 times higher than outdoors. Average levels are typically >3,000 ng/m^3 with maximum concentrations of >16,000 ng/m^3. This means a potential inhalation of 60-300 µg/day.[16]

The PFAS content in house dust varies extremely much. Up to 13 different derivatives have been measured but, normally, there are most of perfluorohexane sulfonate (PFHxS) and perfluorooctane sulfonate (PFOS). Average concentrations of >2,000 to 20,000 ng/g and maximum concentrations of >80,000 to 500,000 ng/g have been determined. With a

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[17] Data from Denmark is missing but Denmark might be in the lower part as the mean ingestion in Sweden is 41 ng/day with a maximum value of 666 ng/day (Lind Y et al. Organohalogen Compounds 2002;58:181-184).

dust intake of 100 mg/day the daily average exposure will be 200-2,000 ng PFAS with a maximum of 8-50 µg PFAS.

In DEPA Consumer Report no. 50 about impregnation agents, exposure scenarios for PFAS were presented showing that an exposed child in total may have an intake of 0,9 µg/kg bw/day or 9 µg PFAS/day; thus, in the high end of the assessment above.

Because these PFAS derivatives are not lipophile, intake of animal fat and foods in general will not be as important a source, as it is for the lipophile persistent organic pollutants (POPs). The indoor climate seems to be the most important source of these substances.

Inhalation seems to be more important than dust intake but even combined there is a very large safety factor, because the acceptable daily intake (ADI) for perfluoroalkylated compounds is not exceeded. The ADI is 3 µg/kg bw/day, corresponding to no-effect-level (NOAEL) for reproductive effects with a safety factor of 1,000.

However, the present knowledge about the toxicological properties of the PFAS substances is limited.

7 Discussion, conclusions and recommendations

7.1 Discussion and conclusions

7.1.1 Assumptions in model calculations

Potential indoor concentrations of 8 selected volatile chemicals have been estimated based on pragmatic model calculations with some assumptions and simplifications. This is necessary, because the available data in the DEPA reports have different character and aim, and not necessarily produced with the purpose assessing indoor climate. Further, the determinations of the released chemicals were not always specific and reliable, since screening methods were applied. These have served the purpose of the particular report but if the aim from the start had been to look at the importance of indoor concentrations other procedures may have been selected.

It has implicit been presumed that the studied consumer products were representative, adequate and relevant for indoor climate. However, data suggests a large variation within certain product groups. Thus the measured emissions may not be typical for all investigated products, especially if only one product was studied. The products are more likely indicators for the emission from the investigated product type.

The background for model calculations based on the DEPA consumer product reports has been that these reports represent the potential most important sources of pollution indoor from consumer products.

It should, however, be emphasized that in practice there may exist other important and unpredictable sources than the studied. It is not possible to predict human behavior at home. Situations may develop, where consumer products are used indoors, although others are recommended. Certain times of the year, e.g. at Christmas time, some activities differ from what is normal the rest of the year. In the dark time the use of candle lights increases, and in the cold time many dwellings will have less ventilation because of a wish to save energy. Building technology may also have influence on the healthy conditions in a home, e.g. if water damage occurs and mould grows.

Indoor air quality depends on ventilation, temperature and other factors, besides the pollution sources being present. In this report the focus is on the contribution from consumer products but it has to be kept in mind that there may be other sources of the same chemicals in the home, e.g. from tobacco smoking, food preparation and evaporations from building materials (paint and varnishes, integrated carpets etc.). There are a great number of potential sources.

The concentration (exposure) of pollutants in indoor air depends mainly on the balance between the pollution sources, and how much clean air is supplied to the building (ventilation) to dilute the pollution. Further, the concentration depends on how much pollution is deposited on surfaces (adsorption) or released from surfaces (desorption).

In addition, the concentration and composition depend on any secondary chemical reaction occurring in the air or at contact with material surfaces. In the reports from the DEPA and in this report the importance of such reactions is not taken into account. Where the focus earlier was solely on the so-called primary evaporation of chemicals from materials, the research focus is nowadays directed at the secondary evaporation. Primary evaporation is release of weakly bound substances, e.g. volatile organic compounds (VOC), used or formed in connection with the manufacture and the material or substances. The primary evaporation occurs mainly, when the material is new.

Secondary evaporation consists of VOC formed after the manufacture of the material. The origin may be degradation processes at oxidation of the material surface by ozone. Newly research has shown that secondary evaporation particularly can diminish the quality of indoor air and in this way have adverse health effects on building users.[18] For some materials this type of evaporation seems to continue in the whole lifetime of the materials.[19]

In spite of these reservations regards the performed model calculations, it is concluded that for the eight selected volatile compounds, the highest concentrations in a home are likely to occur in the children's room. The reason is that this particular room normally is smaller than most other rooms in the home, and it contains many products, which may release chemicals to the air.

There is a clear tendency that new products release more chemicals to the air than older used products. The products also differ from each other by having different emission patterns. Some release substances over long time, others have a more extreme and brief character. Use of incense and spray products indoors are the most polluting of the studied products/activities and emit considerable amounts of hazardous chemicals.

7.1.2 Assessment of prioritized chemicals

The maximal exposure to phenol from all sources is calculated to 62 µg/m^3. This concentration is much lower than an indoor limit value of 400 µg/m^3 based on odor nuisance. The calculated daily intake for a maximum exposed child is then 90 µg phenol/kg, or somewhat below the USEPA Reference Dose (RfD) of 0.1 mg/kg bw/d, which has built-in safety factors. This shows that in a children's room, where a single pollution source may not be important, the total burden to phenol from all sources in the worst case may approach the highest tolerable for children.

Normally, formaldehyde levels in indoor air are estimated to 0.01-0.20 mg/m^3, depending on which sources exist. In this project the calculated maximum concentration of formaldehyde in indoor air was about 500 µg/m^3, however, typically the concentration will be below 50 µg/m^3. Thus, the recommended

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[18]Knudsen HN, Nielsen PA, Clausen PA, Wilkins CK, Wolkoff P. Sensory evaluation of emissions from selected building products exposed to ozone. Indoor Air 2003;13:223-231.
[19]Knudsen HN, Clausen PA, Shibuya H, Wilkins K, Wolkoff P. Indeklimavurdering af linolieholdige building materials. By og Byg Dokumentation 054. Hørsholm: Statens Bygge-forskningsinstitut, 2004.

indoor air limit value for formaldehyde of 0.12 mg/m^3 is complied with at the typical concentration but not in the worst, however unlikely, case.

A child will typically daily inhale 72 µg formaldehyde/kg bw but 0.7 mg/kg bw in the worst case. Thus, the Reference Dose of 0.2 mg/kg bw/d will be easily complied with for a child in the typical case but not in the worst case adding up all sources working simultaneously. Formaldehyde is a potent carcinogen, and since there is no complete safe limit for carcinogens, all unnecessary exposure to formaldehyde, e.g. from incense, should be avoided.

The worst case total exposure to acetaldehyde from many sources will be 265 $µg/m^3$ - but normally lower than 10 $µg/m^3$; thus close to the USEPA Reference Concentration (RfC) of 9 $µg/m^3$. This RfC is based on the no-adverse-effect-level (NOAEL) in animal studies and with a safe factor of 1000 applied. Since acetaldehyde is a carcinogen, and there is no complete safe limit for carcinogens, all unnecessary exposure to acetaldehyde, e.g. from incense, should be avoided

The contribution of benzene to the indoor climate from the few products investigated in the DEPA reports is <1 $µg/m^3$. This is less than the typical benzene concentrations measured indoors in Danish buildings. During use of incense extreme benzene concentrations up to 350 $µg/m^3$ may develop. The Reference concentration for benzene is reported to 9-30 $µg/m^3$, and an increased cancer risk is possible at concentrations over 20 $µg/m^3$. For plasticine alone the safety factor is sufficient but that is not the case regards a total assessment. Furthermore, use of incense generates short-term benzene concentrations of 350 $µg/m^3$, which are a direct health hazard. The Reference Dose for benzene is 4 µg/kg bw/d. Normally, a child will inhale <1 µg benzene/kg bw during 24 hours, however, during use of incense alone the intake during one hours exposure accounts up to 21 µg benzene/kg bw/d. Such high exposure is completely unacceptable regards a substance proved to induce leukemia in humans.

The highest calculated concentrations of toluene were found in the children's room with a concentration of about 49 $µg/m^3$ for new electronic products and about 19 $µg/m^3$ for used products. The contribution mainly came from one particular PC monitor. To this should be added potential contributions from other consumer products of up to 900 $µg/m^3$; however, totally about 2,980 $µg/m^3$ with printed matters and 39,000 $µg/m^3$ from spray paint. The Reference Dose for toluene is 223 µg/kg bw/d, and the Reference Concentration is 0.4 mg/m^3. An indoor climate limit for toluene of 8 mg/m^3 has been suggested. With a toluene concentration of 50 $µg/m^3$ emitted from a monitor working 6 hours a day a child will have a daily intake of 12 µg/kg bw/d, thus sufficient safety margin. However, this is certainly not the case, if the contributions from other sources are added on. Even without contributions from printed matters spray paint the intake of 1,800 µg/d or 180 µg/kg bw/d is very close to the highest tolerable.

The highest concentrations of xylenes occur also in the children's room, where the concentration is 105 $µg/m^3$ for new electronic products and 44 $µg/m^3$ for used products. In the utility room/hall the concentration is 47$µg/m^3$ for new products. To this should be added a possible contribution of up to 476$µg/m^3$ (or 51,000 $µg/m^3$ with spray paint). The Reference Concentration is 0.1 mg/m^3, which alone compares to the contribution from electronics in the children room. In case of spray painting the concentrations are so high that direct health damage may be possible, because the exposure is >10 times the occupational limit value. The Reference Dose for xylenes is 0.2 mg/kg bw/d. Six hours exposure for 100 µg/m^3 makes a child intake of xylenes of 360 µg/kg bw/d. Thus, alone the electronics make too high exposure compared to Reference dose. A further 10-100 times enhanced exposure, which is likely with contributions from other sources, may be seen as completely unacceptable.

In the children's room the calculated concentrations of styrene are 22 µg/m^3 for new electronic products and about 8 µg/m^3 for used products. To this should be added possible contributions of about 772 µg/m^3 in total from incense, tents to children and tubular pearls. The last figure is close to the WHO air quality value of 800 µg/m^3 but below the Reference Concentration of 1 mg/m^3, which is based on effects on the central nervous system. The Reference Dose is 0.2 mg/kg bw/d, which is somewhat above a Dutch Tolerable Daily Intake of 120 µg/kg bw/d. Child exposures to a concentration of 20 µg/m^3 in 6 hours a day results in an intake of 7 µg styrene/kg bw/d. This is far below various danger limits and without health effects. However, in the worst scenario for the children's room with use of incense etc. there will be a 20% excess of the Reference dose.

The highest concentrations of limonene are also calculated in the children's room, where the concentration will be around 4 µg/m^3 for new electronic products. Potential contributions from, for instance, printed matters and incense of around 341 µg/m^3 in total should be added. By-exposure to limonene by storage and consumption of citrus fruits is also possible. Limonene has a tolerable daily intake of 0.1 mg/kg bw/d. A child exposed to a concentration of 4 µg/m^3 in 6 hours will have an intake of 1.5 µg/kg bw/d. This level of exposure is completely without health risks for a normal child. However, in the worst case scenario the intake may approach the tolerable. In case of allergy or intolerance even very small concentrations of limonene may be of importance, however, but this will not be a specific problem in relation to limonene in the indoor climate.

The available data on the less volatile phthalates, brominated flame retardants and perfluoroalkylated compounds in DEPA's Consumer Product Reports are very scattered, limited and insufficient to use for an exposure/risk assessment. Therefore, in order to estimate the exposure of the floor crawling children from various sources, this data is complemented with data from other Danish and foreign studies of these chemicals as contaminants in house dust.

The most abundant phthalate indoor is di(2-ethylhexyl)phthalate (DEHP). The typical daily child intake of DEHP from all indoor sources will be 10-20 µg/kg bw/d or 100-200 µg/day, however in worst case likely amount to 50-250 µg/kg bw/d or 0.5-2.5 mg/day for a very exposed child playing on a PVC floor. To be added is intake of DEHP with the food, which is estimated to 18 µg/kg bw/d or 180 µg/day for a child, thus, in the same order of magnitude as the ”normal” indoor exposure. This can be compared with the no-adverse-effect level of DEHP in animal feeding experiments with rats, which is 3.7 mg/kg bw/d or 37 mg/day for a child. If rats and crawling children do have a similar susceptibility for DEHP, the safety factor is rather narrow for the mostly exposed children, and that is even without including exposure to other phthalates.

The levels of brominated flame retardants (PBDE) in house dusts are very variable but, generally, PBDE occur in concentrations one order of magnitude lower than for phthalates. Maximum concentration may be >20,000 ng PBDE/g dust. The exposure to PBDE via house dust is in the same order of magnitude as in food. This is surprising for persistent organic pollutants, for which the food normally accounts for approximately 90% of human exposure. If the estimated intake of dust is 100 mg/day a child can have an intake of 30 and in seldom cases up to 2,000 ng PBDE/day. This should be compared with an average intake from the food of 40-150 ng/day and about 2000 ng/day for nursing infants, because human milk contains relatively high levels of PBDE. Based hereupon the maximum child intake will be <5 µg/day. Comparison with the Reference Dose (RfD) of 2-10 µg/kg bw/d, which includes sufficient safety factors, shows that only nursing infants may come close to the Reference Dose. Therefore, with the present knowledge, the indoor exposure alone will have no immediate health risks.

Perfluoroalkylated compounds (PFAS) are not lipophile. Thus intake of animal fat and food in general will not be so important an exposure source as for the lipophile persistent organic pollutants (POP). Indoor climate seems to be the major source of exposure to these substances. If the daily intakes of house dust are set to 100 mg/day, the daily average exposure of a child will be 200-2,000 ng PFAS and the maximum 8-50 µg PFAS/day or 0.8-5 µg PFAS/kg bw/d. This corresponds very well to the exposure scenarios in DEPA consumer report no. 50 about impregnation agents. The acceptable daily intake for perfluoroalkylated compounds is 3 µg/kg bw/day, which corresponds to the no-effect level for reproductive effects with a safety factor of 1,000. Only in the case of maximum exposure the intake will be unacceptable. However, the present knowledge about the toxicology of PFAS is limited, and these substances may appear to be more dangerous, than the investigations until now have indicated.

7.1.3 Mixed exposure

In a home there may be many different consumer products and e.g. building materials which altogether may release many different substances in a complex mixture. In the reports from the DEPA and in this report the health assessments are mainly based on one substance a time. The combined impacts of more/many substances present in the same time are not evaluated.

Children staying indoors are exposed to many substances simultaneously. That means possibility of additive effects, and formation of secondary pollutants. In the classical risk assessment paradigm both substances and group of substances are treated separately ignoring that these combined effects may change the picture completely. Knowledge of such cocktail effects is simply lacking. Therefore, exposures should be reduced, even if there are sufficient safety factors for exposure to single substances.

In the DEPA reports the focus is on direct adverse health effects from degassing from particular products. In a broader health perspective issues such as comfort and well-being, including experience of air quality should be taken into account. According to the WHO definition: “Health is not only absence of disease and weaknesses but also a state of complete physical, mental and social well-being”. Many pollution sources indoors, including consumer products and building materials, contribute with bad-smelling substances and impact then the experienced air quality.

Both from a health viewpoint and regards how the air quality is experienced indoors, it is important to adjust the amount of supplied outdoor air to the home, thus meeting the demand of ventilation. It is important to take into account that placement of computers and other consumer articles in a room may require increased ventilation.

In some occasions in newer, well-insulated and sealed dwellings air flows less than 0.5 h^{-1}, which is required according to current building legislation, and is used in model calculations in this report. There are for instances found dwellings with an air flow of only 0.25 h^{-1}. If everything else was equal that would result in twice as high concentrations.

In this connection it is important to focus on source emission control, thus limit emissions from indoor pollution sources as much as possible. Then the need of ventilation will be less and energy be saved. That is especially relevant with the tighten energy requirements in the new building legislation. In a dwelling there will often be an exchange of air between rooms and between neighbours apartments, in this way a source may pollute the air inside other rooms than where the source is located.

Thus, many things are determining the healthy status of a dwelling, and there will often be insufficient/lacking data for a total and certain assessment. On this background the following recommendations are stated.

7.2 Recommendations of further studies and actions

In order to establish a more true/credible basis for assessing the state of health in a Danish dwelling with many consumer articles, the following are recommended:

- Actual measurements of selected indicator substances, released from consumer products into indoor air and dust, should be initiated at a large number of randomly chosen occupied dwellings, potentially, for a longer time period for determining the actual exposure level of the general population.
- Field measurements of indoor air in a dwelling, where a room, e.g. the children’s room, is furnished as a realistic worst-case condition. An important situation to study could e.g. be a newly furnished children’s room with a selection of new building materials, equipments and consumer products. It could be interesting to make the study at low ventilation rate, as occurring at winter time. The selected chemicals to be analyzed should have potential adverse effects on health or comfort, including substances originated from secondary chemical reactions.

In addition following actions are recommended:

- Use of dangerous substances in consumer products, substances which may be released indoors and expose children for a risk, should be terminated by voluntary agreements or bans.
- Building materials and consumer products containing phthalate plasticizers should not be used in or furnish a children room.
- Use of incense indoor should be avoided, because this activity is the most polluting of all studied activities, and it is likely to be a direct health hazard.

- Use of spray products, e.g. spray paint, indoors is also an extreme pollution source, which should be avoided or at least be limited as much as possible. As a minimum breathing mask and extra ventilation should be used.
- Children's exposure to dangerous substances indoors should be reduced as much as possible by frequent and sufficient cleaning and ventilation.

8 Practical advice about how risks may be reduced

In the DEPA reports about chemicals in consumer products, various specific advices were stated about how potential health risks from consumer products may be handled, including special conditions related to the indoor climate; see www.mst.dk. In the following, firstly, various general advices are stated about what you as a consumer could do to reduce risks and improve comfort indoors.

A consumer and dweller can do a lot to reduce health risks, there may be in a home and which are related to the indoor climate. In many occasions you even share the responsibility for the quality of the indoor climate, and the behaviour of both yourself and your family is important.

As indicated by the results in this report, there is a great risk for high levels of pollution and thus undesirable health effects specifically in children's rooms. The reason is that such a room often is small and with limited ventilation in relation to the many products present, which may release chemicals into the air. Furthermore, children are a special susceptible group. An important scenario to be aware of is, therefore, a newly furnished children's room, which besides a number of consumer products also has impacts from a number of new building materials and fixtures. Especially at winter time, where there is a tendency to reduce the ventilation in order to reduce the heating bill, it is important to ensure that the ventilation still is sufficient in children's room.

As a normal consumer it is difficult to assess concentrations of undesirable substances in the air and the ventilation conditions. However, it is possible to use the sense of smell, which is a sensitive indicator of odorous substances. By this it is possible to get a warning that something is wrong. Bad smell may be a warning of too less ventilation or too many pollution sources. It has to be underlined that even if bad smell is lacking, there is no guarantee that the air is free of health-problematic substances. For example, if there is a smell of hot electronics, or there is a smell of stuffy in a children's room, then it may be a sign of a need for more airing of the room. It is recommended to shot down electrical apparatus not in use.

As a dweller you may generally be aware of the following:

- Sources, which may pollute the air
- Ventilation
- Correct and reasonable use of products
- Cleaning

8.1 Sources which may pollute the air

A large number of consumer products investigated by DEPA may contribute to pollution of the indoor climate. It includes the following products:

Electrical products and electronics, for example computer, printer, monitor, playing console, household oven, hair dryer, pressing iron, decorative lamp, mobile phone with charger, TV apparatus, chargers and transformers, el panel, el radiator, and recharged batteries.

Bathing curtains, vinyl floors, carpet tiles, vinyl wall paper, candle lights, carpets, floor wax, dry-cleaned clothes, textile fabrics, air fresheners, printed matters, sealing, incense, tents for children, products of exotic wood, impregnation agents, shoe care agents, beads to bead plates, cleaning agents, moulding wax, agents for metals, hair styling, Christmas spray, hobby glues, natural toys, stain removers, spray paint, windows paint, chloroprene products, textile colours, glass and porcelain colours.

Of course, this list is not complete, among others, because all the time new products are introduced to the market. To this may be added that pollution, having its origin from building materials, e.g. from paint, varnish, carpets, furniture and fixtures. Damp may also cause increased pollution, e.g. by mould fungus.

For many products there exist less polluting alternatives. Therefore, as a conscientious consumer you should consider the possibilities of substituting one product with another less polluting. As consumer you have the opportunity to influence the development of more indoor climate friendly products by demanding the less polluting products, e.g. by preferring products, which are labeled somehow reflecting their capacity to pollute the indoor environment. It is also recommended to look carefully on the products informative declaration.

8.2 Ventilation

The dwelling should be ventilated with fresh out door air in order to dilute that pollution, which enters indoor air from consumer products, humans, materials and fixtures. In order to decrease the need for ventilation and the consequently increase in energy expenses; it is important, as mentioned above, to reduce pollution as much as possible. However, a complete phase out of pollution is not feasible, and in some situations it could be useful to increase the ventilation during some periods.

Since release of pollution from consumer products, building materials and fixtures often is greatest at purchasing, and the release thereafter is decreasing over time, it is recommended to ventilate extra in the first hours or days after the products are taken into use.

8.3 Correct and reasonable use of products

Wrongly use of some products may cause health risks. Therefore, it is important to follow the producers’ guide in correct use of their products. It could e.g. be an advice about only use of the product outdoors in order to prevent problems indoors. This may be the case for products, which are preserved against microbial growth with e.g. formaldehyde.

Uses of spray products indoors are advised against generally, because such products often pollute indoor air more than alternatives. It could e.g. be recommended to use liquid cleaning products on a cloth, instead of using a spray flask and apply paint with a brush instead of a spray can.

During use of some products combustion products are generated as a result of an incomplete combustion of organic material. These combustion products may be dangerous to health. This may be the case by burning e.g. ***incense and candle lights.*** Therefore, it is recommended against use of these products in small and poor ventilated rooms. If such products have to be used, it should be done in large rooms and with efficient ventilation both under and after the burning process.

8.4 Cleaning

In a home dusts are formed all the time. Dust consists of many different constituents. It may consist of pollution from the activities going on, including use of a number of consumer products, from residues of worn-off material, from house dust mites, furred animals, pollen, moulding fungus, bacteria and phthalates.

Therefore, it is important at regular intervals to clean the home in order to reduce the amount of dust. Otherwise, the dusts may cause health problems for special exposed groups such as allergy suffers and children. Small children stay more and closer to the floor, where they are more exposed to whirled dust than adults.