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Survey and risk assessment of VOCs in PU foam products

Survey of chemical substances in consumer products No. 182

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Contents

Foreword

Emission of chemical substances from PU foam

This project studied the emission (off-gassing) of chemical substances from consumer products consisting of PU foam and evaluated the potential health risks caused by the substances emitted from selected PU foam products.

Control analyses were also performed on individual selected PU foam products on the Danish market to ensure that they comply with regulations. The control analyses focused on phthalates in childcare articles and flame retardant content.

The results of the survey, chemical analyses, and risk assessment are presented in this report.

This project was conducted by FORCE Technology together with Eurofins Product Testing A/S, as a subcontractor for chemical analyses.

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Summary and conclusions

Survey and risk assessment of VOCs in PU foam products

Polyurethane (PU) is a polymer; that is, a kind of plastic. PU foam is so-called "expanded polyurethane" and is a blanket term for a group of cellular plastic materials. PU foam is made from flexible polyurethane; i.e. the foam can be compressed. According to the Danish plastic industry, flexible PU comprises about 60% of the industry's PU production. The remaining portion is rigid PU. PU foam is used primarily in mattresses, pillows, seats, and cushions in the furniture industry.

Background
A previous Danish EPA survey project on PU foam products (squishy toys) showed that emissions of certain volatile organic compounds (VOCs) may constitute a health risk. For example, emissions of dimethylformamide (DMF) were identified, potentially capable of causing respiratory irritation and damage to the mucosa with long-term exposure. This substance may additionally damage fertility or the unborn child.

Previous surveys by the Danish EPA identified phthalates and flame retardants (chlorinated/phosphorus-based and brominated) in car seats and baby mattresses, and chlorinated/phosphorus-based flame retardants in furniture foam.

Purpose and scope
Despite the existence of previous surveys, there is a lack of specific knowledge regarding emissions from consumer PU foam products. The purpose of this project was therefore to examine the chemical substances that are emitted from consumer products made primarily of PU foam. The purpose was also to evaluate the extent to which users are exposed to health risks during realistic, foreseeable use of the products.

An additional purpose of this project was to analyse the extent to which certain limit values established by law for the content of chemical substances are exceeded. In this regard, it was decided to focus on flame retardants and phthalates. Lastly, one of the goals of the project was to examine whether there are differences in the emission and content of chemical substances present in products purchased in Denmark, purchased in the EU, and purchased outside the EU.

The primary focus for this project was the emission of chemical substances. For this reason, a decision was made to focus on larger PU foam products that could potentially emit substances into spaces in the home where we spend the most time; namely, nurseries, bedrooms, and living rooms. The products studied in this project are limited to so-called "rest products", which have long exposure times and are present in the immediate area where respiration takes place, such as mattresses and pillows.

Previous studies of VOCs in PU foam
The few previous studies identified in this area show that typically, a large number of distinct VOCs are emitted from PU foam. However, the studies do not necessarily identify the same VOCs. This may be due to the existence of different types of PU foam manufactured in different ways, even though the starting materials are typically the same. Another explanation may

be differences in the analysis methods used, and differences in when the analyses were performed; that is, at what point measurements are taken relative to the time when the product comes into use. Notably, some studies suggest that PU may serve as a kind of indoor climate VOC absorber, thereby accumulating VOCs if the concentration of VOCs in the indoor climate is greater than e.g. that of a mattress or sofa cushion. VOCs absorbed from the indoor climate can later be released back into the indoor climate when the concentration of VOCs in the surrounding air has decreased. This shows that complicated processes are involved. How relevant and significant this is in a residential situation is unknown, but this project has exclusively analysed emissions from newly purchased products that were first removed from their packaging immediately before cutting for analysis.

Survey and purchasing of products
An internet search was performed for different types of products containing PU foam. Based on this search, a gross list of examples of PU foam products was prepared. The gross list was divided into products from Denmark (Danish stores or online stores) (DK), products from the EU outside of Denmark (EU), and products purchased outside the EU (N-EU). For this reason, the internet search also included searches of foreign websites that ship products to Denmark (such as Amazon, eBay, AliExpress, GearBest, and Wish).

Products were purchased so as to represent purchases from different regions (DK, the EU, and N-EU), different types of products (e.g. mattresses and pillows), different price ranges, different manufacturers, and different target groups (babies, small children, adults / older children).
Primarily, products that clearly indicated that they consisted of PU foam were purchased. Products without such an indication were subjected to a material analysis to confirm their PU foam content prior to the chemical analyses.

In all, a total of 20 distinct consumer PU foam products were purchased, divided as follows:

- Target group: 10 products for babies or small children (i.e., ages 0-3) and 10 products for older children or adults.
- Region: 10 products purchased in Denmark, 5 products in the greater EU, and 5 products outside the EU.
- Product type:
    - 10 mattresses, 6 of which are mattresses for babies or small children
    - 2 folding mattresses
    - 1 tumbling mat
    - 5 pillows, 2 of which are pillows for small babies (to help with torticollis)
    - 2 cot bumpers

Compliance analyses
Certain analyses were performed to verify compliance with legal requirements for PU foam products. These were:

- Verification of phthalate levels in PU foam for all 20 products — analysis performed only on PU foam itself.
- Verification of brominated flame retardant content in the 10 Danish products — analysis performed only on the outer layer of the product, consisting primarily of fabric.

The results were as follows:

- Small quantities (between 5 and 65 mg/kg) of a few phthalates (DEHP, DIDIP, DBP, and/or DIBP) were identified in 6 out of 20 products. The allowed limit value is 500 or 1000 mg/kg, depending on which phthalate is identified. The low phthalate content is likely due to impurities from other added components.

- None of the products analysed contained any of the brominated flame retardants studied at concentrations above the level of detection. The level of detection varied across flame retardants but was never higher than 2.4 mg/kg, whereas the permitted limit values are 10, 100, or 1000 mg/kg, depending on the flame retardant.

Therefore, no violations of phthalate and flame retardant content regulations were found for any of the products studied.

Content analyses for chlorinated phosphorus-based flame retardants
No legislation exists regarding the content of chlorinated phosphorus-based flame retardants in the PU foam products purchased. These analyses were performed because the Danish EPA desired additional knowledge in this area.

The result of the analyses showed that out of nine chlorinated phosphorus-based flame retardants selected for analysis, only three were identified in four out of the 20 products analysed. No more than one flame retardant was identified in any product, and the identified levels are generally so low (< 0.003% or < 30 mg/kg) that they must be considered as impurities; these are hardly levels indicating deliberate addition to provide the PU foam with a flame retardant effect.

VOC emissions from PU foam: Emission chamber analyses
The 20 consumer PU foam products purchased were analysed for VOC emissions in a 119-litre emission chamber with air exchange. Analysis parameters set by existing certification programmes for PU foam products, including EuroPUR, CertiPUR, and TÜV Rheinland, were considered. However, it was decided to study VOC emission levels after 1 hour and after 3 days measurement intervals also chosen in the study on squishies (which are also made of PU foam).

The highest total emissions came from baby mattress N-EU 3 (which is certified by CertiPUR), with a total concentration of 1905 µg/m^3 after 1 hour and 410 µg/m^3 after 3 days. The lowest emissions came from cot bumper DK 3 (which bears the ÖekoTex mark), with a total concentration of 36 µg/m^3 after 1 hour; and from mattress DK 7, with a total concentration of emitted substances of 3 µg/m^3 after 3 days. Overall, it is clear that the concentration of emitted substances decreases from the first measurement after 1 hour until the second measurement after 3 days. On average, the concentration of emitted substances decreases by 58% from 1 hour to 3 days.

The combined VOC emission results show a tendency for N-EU products, on average, to emit slightly higher quantities of VOCs, compared to products purchased either in Denmark or the greater EU, which had roughly equal levels of emissions. However, the averages encompass large variations in emissions across products, so it is not an unambiguous depiction.

In general, there were large differences in how much of an odour came from the PU foam in the various PU foam products when they were removed from their packaging. The descriptions of the sample odours were compared with the quantities of emitted VOCs. There was generally a good correlation between the description of the odour and the total concentration of organic substances emitted from the PU foam samples.

Selection of substances for risk assessment
Based on the VOCs emitted, a total of nine substances were selected for a risk assessment. The substances were chosen partially because of their emitted quantities, but also because of the concerning health-related properties of the substances, particularly in terms of inhalation. The nine substances chosen were:
- Dimethylformamide (DMF) (CAS no. 68-12-2)

- Octamethylcyclotetrasiloxane (D4) (CAS no. 556-67-2)
- Decamethylcyclopentasiloxane (D5) (CAS no. 541-02-6)
- Dodecamethylcyclohexasiloxane (D6) (CAS no. 540-97-6)
- 2-ethyl-1-hexanol (CAS no. 104-76-7)
- Toluene (CAS no. 108-88-3)
- α-Pinene (CAS no. 80-56-8)
- Formaldehyde (CAS no. 50-00-0)
- Phenol (CAS no. 108-95-2)

Risk assessment

Initially, a worst-case exposure calculation and risk assessment was performed individually for each of the 20 products studied. Here, we assumed a scenario in which a baby sleeps on the purchased product for 18 hours, regardless of whether the product was a pillow, adult mattress, baby mattress, or cot bumper. For this scenario, the concentration directly in the zone of respiration was used for calculations. The result was that for the majority of the 20 products, no risk of health effects exists. However, baby mattress N-EU 3 emitted such a high concentration of DMF that it constituted a risk of health effects in the form of mucous membrane irritation even after 3 days if a baby were to sleep on this mattress immediately after the product was removed from its packaging. This applies even if a shorter period of usage is considered, with a baby sleeping on this mattress only at night, sleeping in other places (e.g. in a pram) during the day.

Additionally, folding mattress N-EU 4 and adult mattress DK 9 may present a risk of health effects in the form of effects on the lungs, even after 3 days, due to the total emissions of siloxanes D4, D5, and D6. When using more realistic 9-hour periods of usage for these adult mattresses, there is still a risk of health effects based on the 1 hour measurement for both products, but not after 3 days. However, the risk calculations are based on effects on the lungs, a critical effect, which is first observed after long-term exposure to these substances. In light of the above, and in light of the fact that the calculations were performed assuming that emissions after 1 hour remain constant throughout the sleeping period, these products are not considered to constitute a risk to larger children or adults, since they sleep on these products for shorter times than babies.

Subsequently, exposure calculations and a risk assessment for the nine substances were performed with the following worst-case scenarios, using calculations with simultaneous exposure to multiple products, and with a deliberate focus on the two groups of users considered to be exposed to the highest amount of PU products for the longest periods of time. A stepwise approach was chosen for this evaluation, such that substances which did not result in a health risk were not considered further in other, more realistic scenarios.

1. Babies subjected to three different PU foam products in the zone of respiration (baby mattress, baby pillow, and cot bumper). The concentration measured in the emission chamber is used as a target for the concentration in the zone of respiration.
2. Babies that sleep / spend time in spaces with multiple PU foam products. Emitted substances from all products are considered to distribute themselves throughout the entire room. We assume that a baby may be exposed to a total of seven different products when sleeping in the parents' bedroom (two adult mattresses, two pillows, one baby mattress, one baby pillow, and one cot bumper) for 18 hours (sleeping time), and to one product (a tumbling mat) for 3 hours (awake time) in the living room.
3. Teenagers, who spend a significant portion of the day in their rooms. We assume the presence of five different PU foam products (a mattress, a folding mattress, two pillows, and a tumbling/play mat) in their rooms. Exposure occurs for a total of 18 hours (10 hours of sleep and 8 waking hours in the same room).

Conclusion

The conclusion of the risk assessment is that for the majority of substances in the most of scenarios, there will be no risk of health effects based on the worst-case scenarios presented for time spent in a space, even with multiple PU foam products. The exceptions, however, are baby mattress N-EU 3, which had high DMF emissions; and the substance formaldehyde, in the worst-case scenario with multiple products in the zone of respiration, where a baby sleeps with three products (baby mattress, baby pillow, and cot bumper) freshly removed from their packaging.

For a single product (baby mattress N-EU 3), DMF emissions were so high that even considering a situation where the emitted quantity is distributed evenly throughout the room, there may be a risk of health effects. After 1 hour, DMF emissions from this baby mattress (N-EU 3) were measured at a concentration 71 times greater than that of the product with the second greatest DMF emissions. The health effect which the DNEL value is based on is mucous membrane irritation.

Emissions of VOCs in general (including DMF) decrease between the 1-hour measurement and the 3-day measurement. Thus, emissions are not constant over the assumed period of sleep, and so the risk has been overestimated. Despite this, it appears that baby mattress N-EU 3 emits DMF at levels that may result in a health effect (mucous membrane irritation) during the first day of use. The amount of time that must pass before emission levels are low enough to no longer constitute the risk of mucous membrane irritation is unknown. This would have required longer analyses in the emission chamber than were performed in this project. There is thus no doubt that the high DMF emissions from baby mattress N-EU 3 are problematic and may result in health effects in the form of mucous membrane irritation. However, DMF emissions were problematic solely for this one product. 14 of the 20 products studied do not emit DMF above the limit of detection, and emissions for the five other products that emit DMF are not at levels that constitute a health risk.

Regarding formaldehyde, in the exposure scenario with a baby sleeping with multiple products in the zone of respiration, the PU foam products may constitute a health risk in the zone of respiration, even after 3 days. Therefore, there is a risk of health effects from formaldehyde emissions in this scenario, but only if a baby sleeps for 18 hours in close contact with three products (a baby mattress, a baby pillow, and a cot bumper) that have been newly purchased and recently removed from their packaging. None of the products will cause health effects individually after 3 days. However, it should be noted that the critical effect for formaldehyde is carcinogenicity, and this effect can occur in the event of exposure above the DNEL value for a long period. Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long formaldehyde emissions remain high enough to produce health effects.

It is, however, important to note that contributions to exposure from other sources, such as textiles, rugs, electronics, etc. that may emit these substances, must also be accounted for. This means that bedroom ventilation has a significant influence on the concentration of substances that are hazardous to health. Similarly, it may be appropriate to allow new products to release these substances outside for a few days before beginning to use them.

Abbreviations

BBP	Benzyl butyl phthalate (CAS 85-68-7)
BDE	Polybrominated diphenyl ethers (compounds used as flame retardants)
DBP	Dibutyl phthalate (CAS 84-74-2)
DEHP	Bis(2-ethylhexyl)phthalate (CAS 117-81-7)
Deca-BDE	Decabromodiphenyl ether, a flame retardant
DIBP	Diisobutyl phthalate (CAS 84-69-5)
DIDP	Diisodecyl phthalate (CAS 26761-40-0 and 68515-49-1)
DINP	Diisononyl phthalate (CAS 28553-12-0 and 68515-48-0)
DMF	Dimethylformamide (CAS 68-12-2)
DNEL	Derived No Effect Level; that is, the exposure considered to have no health effects in a risk analysis.
DNOP	Di-n-octyl phthalate (CAS 117-84-0)
HBCDD	Hexabromocyclododecane, a flame retardant; or more precisely, hexabromocyclododecane, 1,2,5,6,9,10-hexabromocyclododecane, and its key diastereoisomers: α-hexabromocyclododecane, β-hexabromocyclododecane, and γ-hexabromocyclododecane. (Encompasses several CAS numbers: 25637-99-4, 3194-55-6, 134237-50-6, 134237-51-7, 134237-52-8)
Hepta-BDE	Heptabromodiphenyl ether, a flame retardant
Hexa-BDE	Hexabromodiphenyl ether, a flame retardant
Octa-BDE	Octabromodiphenyl ether, a flame retardant
PBT	Environmentally hazardous substances; acronym of *persistent, bioaccumulative, toxic*.
Penda-BDE	Pentabromodiphenyl ether, a flame retardant
PU	Polyurethane, also sometimes abbreviated as PUR
RCR	Risk characterisation ratio. Used in risk analysis to establish whether something constitutes a risk.
SVOC	Semi-volatile organic compounds. Defined as all substances after n-hexadecane (n-C16) up to and including n-docosane (n-C22).
TCPP	Tris(2-chloroisopropyl)phosphate, a flame retardant (CAS 13674-84-5)
TCEP	Tris(2-chloroethyl)phosphate, a flame retardant (CAS 115-96-8)
TDCPP	Tris(1,3-dichloroisopropyl)phosphate, a flame retardant (CAS 13674-87-8)
Tetra-BDE	Tetrabromodiphenyl ether, a flame retardant
TVOC	Total volatile organic compounds
VOC	Volatile organic compounds. Defined as all substances from n-hexane (n-C6) to n-hexadecane (n-C16), inclusive.
vPvB	Substances that are highly persistent in the environment; acronym of *very persistent, very bioaccumulative.*
VVOC	Very volatile organic compounds. Defined as all substances before n-hexane (n-C6).

1. Introduction

Polyurethane (PU) foam is a common designation for a group of cellular plastic materials; that is, a type of polymeric foam (Danish Plastics Federation, 2019). PU foam is made from flexible polyurethane; the foam can be compressed. According to the Danish Plastics Federation, flexible PU comprises about 60% of the industry's PU production. The remaining portion is rigid PU. PU foam is used primarily in mattresses, pillows, seats, and cushions in the furniture industry.

1.1 Background

In 2018, the Danish EPA conducted a survey titled "Study and risk assessment of perfume and other organic substances in squishy toys" (Klinke et al., 2018). All the squishies studied in this project were made of PU foam. This project suggests that emission of various chemical substances from PU foam may constitute a health risk. The earlier survey of squishies identified such substances as amines, dimethylformamide (DMF), and other (semi-)volatile organic compounds ((S)VOCs) that do not bond to the PU material and are thus emitted over time, or when the material is mechanically manipulated. Common to the identified substances is their potential to cause respiratory irritation and, in the case of prolonged exposure, damage to the mucosa. Some of the substances are additionally reprotoxic and/or carcinogenic.

Previous surveys by the Danish EPA identified phthalates and flame retardants (chlorinated/phosphorus-based and brominated) in car seats and baby mattresses, and chlorinated/phosphorus-based flame retardants in furniture foam. The Ecological Council's published project from March 2019, titled "Indoor climate in childcare centres", also identified phosphorus-based flame retardants in dust in childcare centres, considered to come from furniture foam in the centres, among other sources.

Despite the existence of previous surveys, there is a lack of specific knowledge regarding emitted from consumer PU foam products.

The Danish EPA has additionally received inquiries from concerned consumers, possibly indicating that (S)VOCs can be emitted from adult mattresses. Consumers — both children and adults — are in close contact with PU foam materials for prolonged periods every day and may thus be exposed to (S)VOCs emitted from the PU foam.

1.2 Purpose

The purpose of this project is, first and foremost, to examine the chemical substances that are emitted from consumer products made primarily of PU foam. The purpose of the project is thus to analyse numerous types of PU foam products to determine which substances are released and at what concentrations. The purpose is also to evaluate the extent to which users are exposed to health risks during realistic, foreseeable use of the products.

An additional purpose of this project is to analyse the extent to which certain limit values established by law for the content of chemical substances are exceeded.

Lastly, one of the goals of the project is to examine whether there are differences in the emission and content of chemical substances present in products purchased in Denmark, purchased in the EU, and purchased outside the EU.

1.3 Scope and limitations

The consumer products on which this project focuses are products that consist primarily of soft, flexible PU foam; that is, elastic foam products. The project consists of both a survey part and a testing part.

- The survey part focuses primarily on off-gassing (emission of chemical substances). Additionally, chemical analyses were performed to determine the content of chlorinated/phosphorus-based flame retardants, since the Danish EPA wishes to acquire more knowledge regarding the use of these substances in consumer products of PU foam.
- The testing part focuses on compliance with limit values for certain ingredients. It was decided that this part would focus on testing regulatory compliance as regards to the content of phthalates and brominated flame retardants.

Because the primary focus is on emission of chemical substances, a conscious choice was made to focus on larger PU foam products (or products composed largely of PU foam) which may emit chemical substances into spaces in our homes where we spend the most time; namely, nurseries, bedrooms, and living rooms. The products studied in this project are limited to so-called "products for resting", which have long exposure times and are present in the immediate surroundings where respiration takes place (breathing zone). Products for small children (i.e., under 3 years) also constitute a large proportion of the products examined. A decision was made to focus on the following types of products:

- Mattresses (for children and adults)
- Children's play/tumbling furniture
- Furniture (for children and adults)
- Folding mattresses
- Changing pads
- Pillows (for adults)
- Other large products with "memory foam"

Small consumer products made of PU foam, such as sponges, foam towels/cloths, etc. were thus deliberately excluded from this project. Car seats were also deliberately excluded from this project. This is partially because car seats were examined in a previous project, and partially because the product is used in cars, not in homes. Similarly, office chairs were deliberately excluded from the project because the total amount of foam and the degree of exposure from these products are considered to be limited relative to that of the chosen products for resting.

2. Polyurethane (PU)

This chapter provides a short description of what polyurethane (PU) is and how it is made.

2.1 What is PU?

Polyurethane (PU or PUR) is a polymer characterised by the presence of urethanes and their derivatives; that is, compounds with the structure $[-R_1\text{-NH-CO-O-}R_2\text{-}]_n$.

Polyurethane is typically made by reacting a multifunctional isocyanate, most commonly a di-isocyanate, with a polyol containing several alcohol groups in a urethane polymerisation (see FIGURE 1 below).

In practice, there are two diisocyanates that are most commonly used; namely, toluene diisocyanate (TDI) and 4,4-diphenylmethane-diisocyanate (MDI), but there is a variety of compounds available for this purpose.

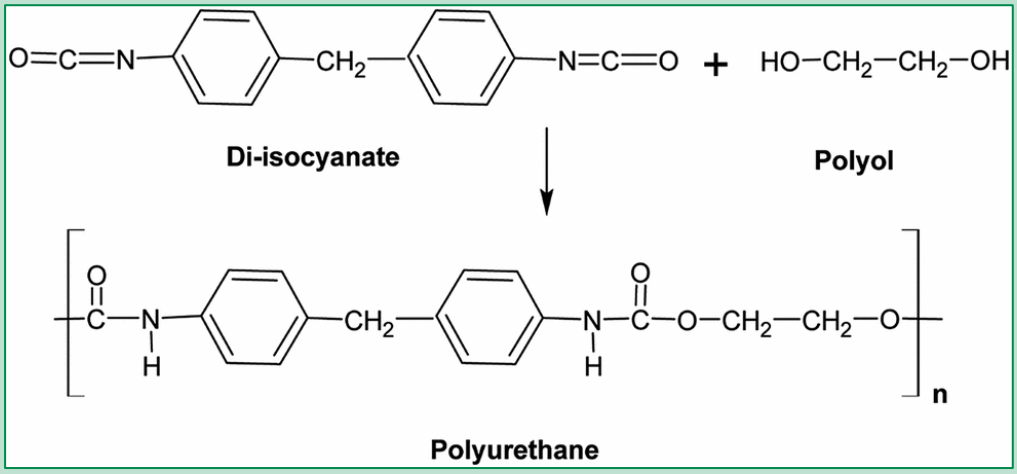

FIGURE 1. Polyurethane[1] produced by polymerising a diisocyanate and a polyol

2.2 Different types of PU foam

Both polyester polyols, on which the first flexible polyurethane foam was based, and (more widespread) polyether polyols exist, which produce different material qualities depending on their use. The raw polyols (i.e., both polyether and polyester polyols) used to produce polyurethane are typically already high-molecular-weight components produced from monomers.

PU foams based on polyester polyol and polyether polyol are also referred to as polyester foam and polyether foam, respectively.

[1] https://pubs.rsc.org/en/content/articlelanding/2016/ra/c6ra14525f#!divAbstract

In general, there is a very wide range of usable polyisocyanates, polyols, and other reactive additives that make a great variety of material characteristics possible, such as density, flexibility, cellular structure, etc.

The advantage of polyurethane is that it can be produced as a foam — or more properly, a cellular plastic. "Cellular plastic" is a common designation for porous plastic foams. The production of plastic foams requires the creation of a gas at the same time as urethane polymerisation is occurring. The foam production may occur chemically, as when the reagents emit CO_2 as a propellant; or physically, as when a liquid propellant is added that evaporates due to heat generated in the reaction. Traditionally, various chlorofluorohydrocarbons (CFCs) were used. As these are prohibited to use today, substances such as HFC's (hydrofluorocarbons) or different hydrocarbons (HC's) like cyclopentane or isopentane, are used today (Singh, 2002).

Polyurethane can be divided into rigid and flexible/soft types[2], and further into subtypes based on density:

Rigid polyurethanes

- Solid types 1200 kg/m^3
- Rigid integral skin foam 100-800 kg/m^3
- Insulating foam 32-100 kg/m^3
- Ultralight foam 8-30 kg/m^3

Flexible polyurethanes

- Solid, flexible 1100-1250 kg/m^3
- Microcellular, flexible 100-1100 kg/m^3
- Integral skin foam, flexible 100-800 kg/m^3
- Light 15-60 kg/m^3

An internet search for items like mattresses reveals many different terms/materials for foam mattresses, including:

- Foam
- Cold foam
- Viscoelastic foam
- Polyether foam
- Polyester foam
- Memory foam

According to a Danish producer of PU foam, the terms above all represent variants of PU foam, and are defined as[3]:

- PU foam is also referred to as PUR foam, polyurethane foam, or simply polyurethane. PU foam is a flexible material with an open cellular structure.
- Cold foam (or high resilience (HR) foam) is a special variant of polyurethane foam distinguished primarily by its high elasticity. It is also often referred to as high-elasticity foam.
- Polyether foam is a special variant of polyurethane foam distinguished by its high resistance to tearing and humidity, making it particularly durable.
- Polyester foam is a variant of polyurethane foam that is appropriate for more technical uses than polyether foam because of its higher durability.

[2] https://plast.dk/det-store-plastleksikon/polyurethan-pur-plast/

[3] https://arbi-skum.dk/skummaterialer/polyurethanskum

- "Memory foam" is a relatively soft material that is shaped by the heat and weight of one's body[4]. The history of "memory foam" can be traced to 1966, when the material was developed by NASA. For this reason, this type of foam is also known as "NASA foam". "Memory foam" is PU foam to which chemical substances have been added to change the "experience" of the foam[5].

Mattress products made from latex foam or foam latex, based on natural rubber (i.e., not PU) also exist. Because they are not made of PU, they were not prioritised in this survey.

2.3 Additives used in PU foam

In general, a variety of raw materials, additives, and processing agents may be used, both to control the production process and to give the finished product the correct characteristics; among them are catalysts, additives, and solvents (Oertel, 1993). For example, BASF has listed a number of products that can be used in the production of PU foam[6].

2.4 Unpleasant odours from PU foam

Numerous internet forums and the like contain posts about unpleasant odours coming from recently purchased foam mattresses,[7] and in some cases, reports of consumers who report feeling markedly worse after sleeping on their foam mattresses.

In a study of VOC emissions from PU foam (Hillier et al., 2003), EUROPUR (the European Association of Flexible Polyurethane Foam Block Manufacturers) states that odours from PU foam are rarely problematic in practice, and that the unpleasant odours are due to the fact that many impurities contained in the materials used to produce PU foam have extremely low odour detection thresholds; i.e. they can be smelled even at very low concentrations. This is true for such substances as toluene and xylene, with an odour detection threshold of about 0.1 ppm; and styrene, with an even lower odour detection threshold under 0.03 ppm (Hillier et al., 2003).

[4] https://www.sengefabriksudsalg.dk/pages/topmadras-guide

[5] https://sleeponlatex.com/blogs/news/8948719-choosing-between-polyurethane-foam-memory-foam-and-latex-foam

[6] http://www.intermediates.basf.com/chemicals/web/en/function/conversions:/publish/content/news-and-publications/brochures/download/BASF_PUR_Brochure.pdf

[7] https://chem-tox.com/beds/toxicbeds.htm

3. Regulations

Regulations exist in both Denmark and the EU that restrict the content of various chemical substances in consumer products. The applicable legislation depends partially on the material chosen, but also on the type of product; for example, there are special requirements for childcare articles, defined in Danish Statutory Order as "any product which is intended to be, or can reasonably be expected to be, placed in the mouth by children aged 0-3 years" (Danish Statutory Order Prohibiting Phthalates in Toys and Childcare Articles, Stat. Ord. no. 855, 2009).

There also exists legislation limiting the content of chemical substances in consumer products that is relevant to PU foam products. In some cases, the regulation distinguishes between different types of products (e.g., childcare articles) and how the products are used (e.g., products which come into direct contact with skin). The relevant regulations, divided according to groups of chemical substances, are:

- Phthalates:
  - Regulated for childcare articles[8] via REACH (EU Regulation no. 1907/2006[9]), Annex XVII; and in the Danish Statutory Order Prohibiting Phthalates in Toys and Childcare Articles (Stat. Ord. no. 855, 2009[10])
- Dimethyl fumarate:
  - Regulated in all articles via REACH (EU Regulation no. 1907/2006), Annex XVII
- Flame retardants:
  - Certain brominated flame retardants are regulated in all articles by the POP regulation (EU Regulation no. 850, 2004[11]) and REACH (EU Regulation no. 1907/2006), Annex XVII
- Organostannic tin compounds:
  - Certain organostannic tin compounds are regulated in all articles by REACH (EU Regulation no. 1907/2006), Annex XVII
- PAHs (polyaromatic hydrocarbons):
  - Certain PAHs are regulated in all articles made of plastic or rubber that come into direct as well as prolonged or short-term contact with the human skin or the oral cavity via REACH (EU Regulation no. 1907/2006), Annex XVII

This project chooses to focus on phthalates and flame retardants, for which specific legislation exists; and on the release of VOCs, where specific legislation for chemical substances does not exist. In the latter case, the Danish Statutory Order on Product Safety applies. For this reason, only these regulations are described in greater detail below.

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[8] It should be noted that the Danish translation of the law uses the term "*småbørnsartikler*" (lit. "articles for small children "), while the English original uses the term "childcare articles". See section for further details.

[9] Regulation (EC) no. 1907/2006 of the European Parliament and Council, of 18 December 2006, on the registration, evaluation, authorisation and restriction of chemicals (REACH); establishing a European chemicals agency, and amending directive 1999/45/EF

[10] Stat. Ord. no. 855 of 5/9/2009. Danish Statutory Order Prohibiting Phthalates in Toys and Childcare Articles.

[11] Regulation (EC) no. 850/2004 of the European Parliament and Council, of 29 April 2004, on persistent organic pollutants; and amending directive 79/117/EEC.

3.1 Phthalates in childcare articles

Phthalates in childcare articles are regulated by both Annex XVII of REACH and by the Danish Statutory Order Prohibiting Phthalates in Childcare Articles (Stat. Ord. no. 855, 2009). In both regulations, restrictions on the use of phthalates apply exclusively to items referred to as "childcare articles" *("småbørnsartikler"* in Danish). However, it must be noted that there are differences in their definitions. The original English text of REACH uses the phrase "childcare articles", but the corresponding term in the Danish translation, "*småbørnsartikler",* literally means "articles for small children ". The definitions of childcare articles are different in REACH and in the Danish Statutory Order on phthalates: the REACH definition is concerned primarily with the use of the articles, whereas the definition in the Danish phthalate order is concerned additionally with age (children under 3 years). This report uses the term "childcare articles", found in the original English text of REACH. The precise definitions of the term are given below, in each of the respective sections of the regulations.

3.1.1 REACH Annex XVII (EU)

Entries 51 and 52 in Annex XVII of REACH restrict certain phthalates in toys and childcare articles. REACH does not define childcare articles in terms of the age group for which they are designed, but in terms of their use. According to the questions and answers on the ECHA website[12] and REACH Annex XVII, entry 52, childcare articles are defined as "any product intended to facilitate sleep, relaxation, hygiene, the feeding of children or sucking on the part of children". Thus, products like pillows, mattresses, cot bumpers, changing pads, etc. are encompassed by this definition.

According to REACH Annex XVII, entry 51, the following phthalates may not be used in toys and childcare articles, whether individually or in combination:

- DEHP
- DBP
- BBP
- DIBP — however, this requirement does not take effect until 7 June 2020

The limit value is 0.1% (w/w) and applies to the four phthalates above both individually and in total (however, DIBP is not included until 7 June 2020).

According to REACH Annex XVII, entry 52, the following phthalates may not be used in toys and childcare articles that may be placed in the mouth by children, whether individually or in combination:

- DINP
- DIDP
- DNOP

The limit value is 0.1% (w/w) and applies to the three phthalates above both individually and in total.

According to the ECHA website[13] and the ECHA's guidance on the definition of "may be placed in the mouth by children" (ECHA, year unknown), articles that children can suck on or put in their mouths are defined as products measuring under 5 cm in any dimension. According to the ECHA's guidance, this means that e.g. cot bumpers are a product that may be placed in the mouth by children, since the corners can fit in their mouths. However, the corners

[12] https://echa.europa.eu/da/support/qas-support/browse/-/qa/70Qx/view/scope/REACH/Restrictions. Childcare articles are defined here as "any product intended to facilitate sleep, relaxation, hygiene, the feeding of children or sucking on the part of children".

[13] https://echa.europa.eu/da/support/qas-support/browse/-/qa/70Qx/view/scope/REACH/Restrictions

of mattresses are not considered products that may be placed in the mouth (with the exception of very thin mattress products, such as mattress toppers). Both mattresses and changing pads are covered by REACH Annex XVII, entry 51, as they are products whose purpose is to facilitate sleep, or which are used for children's hygiene. Using the example of mattresses and changing pads, mattresses are covered only by entry 51, whereas changing pads are covered by both entry 51 and entry 52.

3.1.2 Danish legislation on phthalates in childcare articles (DK)

Danish order no. 855 of 5/9/2009, "Statutory Order Prohibiting Phthalates in Toys and Childcare Articles", restricts the content of phthalates in toys and childcare articles (Danish: "*småbørnsartkler*"). In the regulation, childcare articles (Danish: "*småbørnsartkler*") are defined as "any product intended for, or which can reasonably be expected to be placed in the mouth by, children aged 0-3 years (0-36 months), including dummies, bibs, jewellery, bathing equipment, etc." (Stat. Ord. no. 855, 2009).

The Danish order specifies that it is forbidden to import or sell toys, childcare articles (Danish: "*småbørnsartkler*"), or components thereof containing phthalates at a concentration above 0.05% (w/w). Phthalates are here defined as all phthalates; that is, esters of *ortho*-phthalic acid. However, the Danish order does not encompass the phthalates described above which are regulated by REACH Annex XVII; namely, DEHP, DBP, BBP, DINP, DIDP, and DNOP.

Thus, the Danish legislation on phthalates in childcare articles (Danish: "*småbørnsartkler*") applies to e.g. cot bumpers, pillows for babies, and changing pads, all of which measure less than 5 cm in one dimension and are thereby able to be placed in the mouth by small children.

3.2 Flame retardants (EU)

Certain brominated flame retardants are regulated by both the POP regulation (EU Regulation no. 850, 2004) and REACH (EU Regulation no. 1907, 2006), Annex XVII. These are described in greater detail below.

3.2.1 The POP regulation (EU)

The POP regulation[14] (EU Regulation no. 850, 2004) regarding persistent organic pollutants, restricts the following brominated flame retardants in all articles:

- Tetra-BDE: limit value 10 mg/kg
- Penta-BDE: limit value 10 mg/kg
- Hexa-BDE: limit value 10 mg/kg
- Hepta-BDE: limit value 10 mg/kg
- HBCDD: limit value 100 mg/kg

The restriction on these brominated flame retardants applies to all articles, and to the flame-resistant portion of the article. That is, the regulation applies to all PU foam products studied in this project.

3.2.2 REACH Annex XVII (EU)

REACH (EU Regulation no. 1907, 2006) Annex XVII restricts the presence of the following brominated flame retardants in articles:

- Octa-BDE (entry no. 45): limit value 1000 mg/kg
- Deca-BDE (entry no. 67): limit value 1000 mg/kg — took effect on 2 March 2019

[14] Directive (EC) no. 850/2004 of the European Parliament and Council, of 29 April 2004, on persistent organic pollutants; and to amend directive 79/117/EEC

The restriction on these brominated flame retardants applies to all articles. That is, the regulation applies to all PU foam products studied in this project.

3.3 The Danish Statutory Order on Product Safety (DK)

The Danish Statutory Order on Product Safety[15] (LBK no. 3, 2019) is based on provisions in EU Directive no. 95/2001 on general product safety. According to the Danish Statutory Order on Product Safety, only safe products may be made available on the domestic market. The term "safe products" means (as defined in LBK no. 3 (2019)):

"Any product which presents no risk, or which presents only a limited and acceptable risk, to the health and safety of consumers when the product is used under normal or reasonably foreseeable conditions and within the expected lifetime of the product. When evaluating whether a risk is limited and acceptable, the following shall be taken into account:

a) The characteristics of the product, including its composition, packaging, instructions for assembly and, where applicable, for installation and maintenance.
b) The effect on other products, where it is reasonably foreseeable that it will be used with other products.
c) The presentation of the product, the labelling, any warnings and instructions for its use and disposal, and any other indication or information regarding the product.
d) The categories of consumers at risk when using the product."

It is thus important to note that the composition of a product and (by extension) its chemical substance content also play a role in evaluating whether or not it is safe. If a risk assessment performed on an ingredient in a product shows a risk to consumers during use, this means that the product cannot be legally marketed under the Danish Statutory Order on Product Safety. The same applies to substances that are emitted from products.

The Danish Statutory Order on Product Safety does not apply to those aspects of safety already accounted for by other legislation.

[15]Danish Product Safety Act. LBK no. 3 of 3/1/2019. https://www.retsinformation.dk/Forms/R0710.aspx?id=206230

4. Certification programmes for PU foam

Various certification programmes for PU foam products exist today. These programmes restrict the levels and emission of chemical substances in the material. In a search for PU foam certification programmes, this project identified the following programmes:

- CertiPUR: certification programme from Europe's EUROPUR (European Association of Flexible Polyurethane Foam Block Manufacturers) for PU foam
- CertiPUR-US: American certification programme for PU foam
- TÜV Rheinland: certification programme for mattresses, administered by Germany's TÜV Rheinland LGA Products GmbH
- IKEA has its own requirements for PU foam products that are not made public[16]
- Oeko-Tex Standard 100 "Confidence in Textile", which also applies to mattresses[17]

The comprehensiveness of the various certification programmes for PU foam products differs. Some of the most comprehensive certification programmes are described in greater detail below — specifically, the two CertiPUR certification programmes and TÜV Rheinland's mattress certification programme. IKEA's standards are not described in greater detail because their requirements are not made public. Additionally, the Oeko-Tex 100 standard is not described in greater detail because it was created as a textile marking. Today, the standard also applies to mattresses, in which case both the textile (exterior) and foam (interior) portions must be tested against the criteria[18]. Oeko-Tex 100 focuses primarily on chemical substance content, and not nearly as much on emission. For example, the Oeko-Tex 100 standard restricts the emission of the following substances: formaldehyde, toluene, styrene, 4-vinylcyclohexene, 4-phenylcyclohexene, butadiene, vinyl chloride, and the sum total of aromatic hydrocarbons and VOCs.

4.1 CertiPUR-US and CertiPUR in general

The official explanation for the origin of CertiPUR, according to the American CertiPUR website, is that American PU foam manufacturers were concerned that imported PU foam products contained chemicals that were prohibited in the USA. For this reason, the CertiPUR-US certification programme was created. The programme began in the USA in 2008, but foam producers from around the world can use the programme and the CertiPUR mark if they meet the requirements[19].

FIGURE 2 below shows the official CertiPUR marks. CertiPUR-US is the American certification programme, and EuroPUR is responsible for the European certification programme, which is called CertiPUR. The principles behind these markings are relatively similar. Both are voluntary schemes involving emission tests and tests for the content of specific chemical substances performed by independent laboratories, but there are differences between the requirements set by each scheme for emissions and content of chemical substances.

[16] Information received from Dan Foam via personal communication in this project.

[17] https://www.oeko-tex.com/media/init_data/downloads/STANDARD%20100%20by%20OEKO-TEX®%20-%20Standard.pdf

[18] https://www.oeko-tex.com/media/downloads/Customer_Information_Certification_of_Mattresses_and_Bedding_EN.pdf

[19] https://certipur.us/about-the-seal/about-certipur-us/

FIGURE 2. The mark for the CertiPUR-US certification programme (the American edition of CertiPUR) and CertiPUR (the European version of CertiPUR, managed by EuroPUR)

4.1.1 CertiPUR-US

On its website, the American certification programme CertiPUR-US writes that the requirements for the CertiPUR-US programme were developed in co-operation with the PU foam industry and leading environmental experts, chemists, and researchers from accredited laboratories, as well as the bedding and furniture industries.

The following is required for a company to make use of the CertiPUR-US programme:

- A form regarding the rules of the CertiPUR-US programme must be signed (CertiPUR-US, 2019b)
- The products which the company produces must be tested by one of the approved, independent CertiPUR laboratories. The tests performed are described in their technical guidelines (CertiPUR-US, 2019a) — both physical and analytical tests for chemical substance content and emission must be performed
- The CertiPUR-US logo must be used properly, in accordance with the provided guidelines, and marketing materials must be approved in advance by CertiPUR-US (CertiPUR-US, 2019b)
- CertiPUR-US performs sample verification for selected CertiPUR-US products on the market[20]

Relevant chemical substance content and emission requirements are described in detail below and presented in the tables together with the requirements for the European CertiPUR programme managed by EuroPUR (see TABLE 1 through TABLE 8).

4.1.1.1 Requirements for sampling and emission chamber test

CertiPUR-US sets the following requirements on product sampling and the emission chamber test that must be performed.

The product selected for chemical substance content and emission tests must be a product manufactured frequently and which is expected to have the greatest emission levels.

[20] https://certipur.us/about-the-seal/about-certipur-us/

Central samples (i.e., not from sides or corners) must be cut from PU foam products, at least 35 cm from the edges. If this is not possible, then the central portion of the product must be used as a sample. The sample must be taken no later than 7 days after the foam was manufactured, it must reach the testing laboratory within 14 days, and it must be tested for VOC emission in the emission chamber within 35 days of receipt of the sample.

Two identical samples (taken adjacently) measuring 25 x 20 x 15 cm must be cut. Phthalate-free gloves must be used when taking samples, and the cutting tool used must be free of oil, silicones, and other volatile substances. The samples must be individually packaged in aluminium foil or Mylar bags (metallised polyester bags).

The emission chamber test must be performed according to the testing method of ISO 16000 parts 3, 6, 9, and 11, with an emission chamber volume of 0.5 or 1 m^3. The foam sample must be placed at the bottom of the emission chamber. The sample in the emission chamber must be held at a temperature of 23°C, 50% relative air humidity, with an air exchange rate of 0.5 per hour and a chamber loading rate of 0.4 m^2/m^3. (CertiPUR-US, 2019a)

4.1.2 CertiPUR (EuroPUR)

The European CertiPUR certification programme is managed by EuroPUR, the European Association of Flexible Polyurethane Foam Block Manufacturers[21].

The following is required for a company to make use of the CertiPUR programme:

- An application must be filled out and submitted, including descriptions of the products to be covered (CertiPUR, 2019)
- A signature is required on the application, acknowledging that substances prohibited by the CertiPUR requirements, such as phthalates, have not been intentionally added
- The products which the company produces must be tested at one of the approved, independent CertiPUR laboratories. The tests to be performed are described in their technical guidelines (CertiPUR, 2019) — only analytical tests for chemical substance content and emission must be performed
- The CertiPUR logo must be used properly, in accordance with the provided guidelines (CertiPUR, 2019)
- Payment is required to participate in the CertiPUR programme, and certification is valid for 3 years
- Yearly testing of CertiPUR certified products is required (CertiPUR, 2019)

Relevant chemical substance content and emission requirements are described in detail below and presented in the tables together with the requirements for the European CertiPUR programme managed by EuroPUR (seeTABLE 1 through TABLE 8).

4.1.2.1 Requirements for sampling and emission chamber test

CertiPUR sets the following requirements on product sampling and the emission chamber test that must be performed.

Central pieces of the PU foam products must be extracted (central pieces of a block with minimum dimensions of 2 metres). The product must either be representative of or actually from normal production. The samples must be cut out of the block within one week from when the block was produced and must then be immediately packed and shipped.

[21] https://www.europur.org/

Several identical samples (as many as required by the testing laboratory) must be taken, plus one extra control sample to be stored at the company for 6 months. The samples must measure 25 x 20 x 15 cm. Phthalate-free gloves (such as PU or latex gloves) must be used when extracting the sample. The samples must be individually packed in aluminium foil and then in PE foil immediately after cutting. The samples must be placed in a cardboard box and shipped to the chosen accredited laboratory.

The emission chamber test must be performed according to the testing method of ISO 16000 parts 3, 6, 9, and 11, with an emission chamber volume of 0.5 or 1 m^3. The foam sample must be placed at the bottom of the emission chamber. It is also required that the sample must be placed on one of its smallest sides (in terms of surface area). The sample in the emission chamber must be held at a temperature of 23°C, 50% relative air humidity, with an air exchange rate of 0.5 per hour and a chamber loading rate of 0.4 m^2/m^3. (CertiPUR, 2019)

4.1.3 TÜV Rheinland

TÜV Rheinland is an international service organisation that provides independent inspection services. It has also developed criteria for emissions, odours, and chemical substance content for mattresses (made of PU foam). TÜV Rheinland LGA Products GmbH is the organisation responsible for testing and evaluating companies' products. If the requirements are met, TÜV Rheinland's certification mark may be used.

TÜV Rheinland's requirements for mattresses are designated "2 PfG S 0135/03.14". Rather than a simple set of criteria that must be followed, there are several modules that one can choose to follow. For example, depending on the requirements met, it may be possible to use the TÜV Rheinland certification mark together with one of the following phrases:

- "LGA-tested for contaminants"
- "Tested for harmful substances"
- "Emission tested"
- "Low odour"

Figure 1 from TÜV Rheinland's criteria document, which explains the relationships indicated by these phrases, is shown below in FIGURE 3. For example, the phrase "LGA-tested for contaminants" together with the TÜV Rheinland mark indicates that all requirements have been met.

In addition to requirements set for the PU material itself, TÜV Rheinland also sets requirements for the textile surrounding the mattress. If the textile is already certified under the Oeko-Tex 100 standard, however, then fewer tests are required for the textile surrounding the mattress.

As with the CertiPUR programmes, TÜV Rheinland also specifies the use of a 1-3 m^3 emission chamber, a temperature of 23°C and a relative humidity of 50%. The required air exchange rate is slightly lower, at 0.3 per hour. TÜV Rheinland requires 3- and 7-day measurements, as with the CertiPUR programmes. The methods of the ISO 16000-9 standard are also prescribed, once again as with the CertiPUR programmes.

The requirements TÜV Rheinland sets for PU foam are given in TABLE 1 through TABLE 8. These are exclusively the PU foam requirements, not the textile requirements.

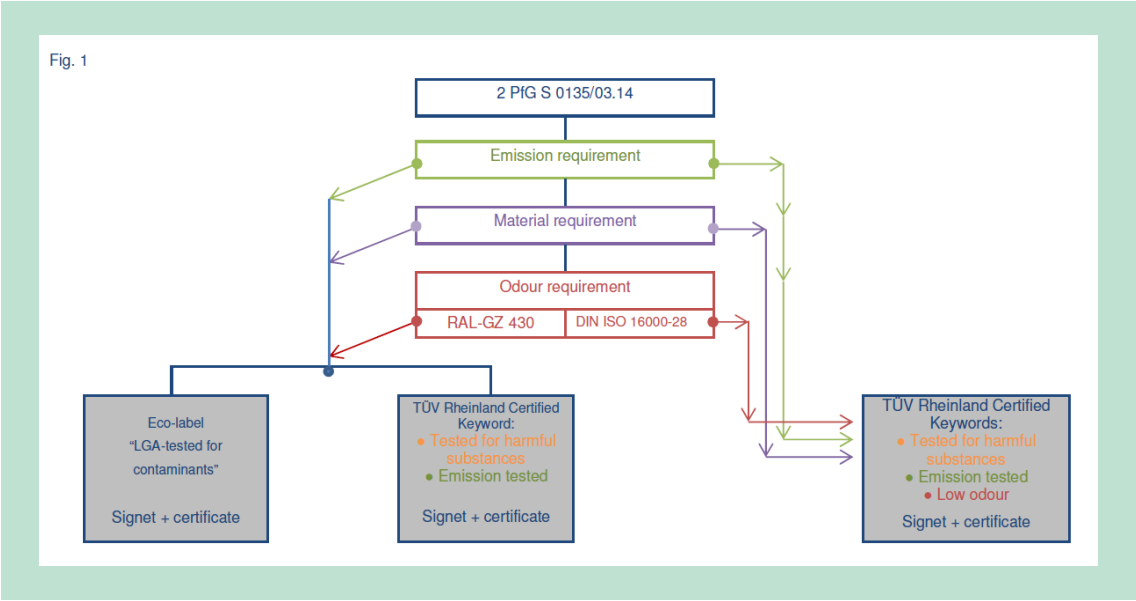

FIGURE 3. Overview of requirements in TÜV Rheinland's mattress criteria. It is possible to achieve TÜV Rheinland certification if e.g. only the odour or emission requirements are met (TÜV Rheinland, 2014)

4.2 Overview of chemical substance content and emission requirements

The table below summarises the requirements set by each of the CertiPUR-US, CertiPUR (EuroPUR), and TÜV Rheinland certification programmes. It should be noted that the requirements listed for TÜV Rheinland are 3-day requirements. Similar requirements are set for after 7 days, and in some cases, these requirements are slightly lower. For some substances, only emission requirements are set for after 7 days. A note has been added to such requirements.

TABLE 1. Emission requirements for VOCs from PU foam after 3 days — emission chamber test

Substance name	CAS no.	CertiPUR-US (mg/m^3)	CertiPUR (mg/m^3)	TÜV Rheinland (mg/m^3)
Formaldehyde (Carc. 1B, Muta. 2)	50-00-0	< 0.1	0.01	< 0.01
Benzene (Carc. 1A, Muta. 1B)	71-43-2	< 0.5	*	*
Toluene (Repr. 2)	108-88-3	< 0.5	0.1	*
Styrene (Repr. 2)	100-42-5	< 0.3	0.005	< 0.0065***
Vinylcyclohexene (Carc. 2)	100-40-3	< LOD	-	
4-Phenylcyclohexene (classification unknown)	4994-16-5	< LOD	-	
Butadiene (Carc. 1A, Muta. 1B)	106-99-0	< LOD	*	
Vinyl chloride (Carc. 1A)	75-01-4	< LOD	*	
Tetramethylsuccinodinitrile (TMSN) (not CMR, but toxic, Acute Tox. 1)	3333-52-6	-	-	0.0025***

Substance name	CAS no.	CertiPUR-US (mg/m^3)	CertiPUR (mg/m^3)	TÜV Rheinland (mg/m^3)
All other CMR substances (1A or 1B)		x **	0.005	*
Total of all CMR substances (1A and 1B)		x **	0.04	C 1A: 0.001 C 1B: 0.0015 MR 1A/1B: 0.0025
Total of all CMR substances (2)		-	-	< 0.0035
Aromatic hydrocarbons		< 0.5	0.5	Halogenated: 0.0025***
Substances classified as: Acute Tox. 1, 2, or 3 STOT SE 1 STOT RE 1		-	-	< 0.0035***
Substances classified as: Skin Sens. 1 Resp. Sens. 1		-	-	< 0.0035***
TVOC emissions		< 0.5	0.5	< 0.015***

LOD = limit of detection
* These CMR substances are generally restricted because they fall under CMR category 1A or 1B
** CMR substances in categories 1A and 1B are prohibited in the CertiPUR-US programme
*** Requirement applies only after 7 days, not after 3 days
x indicates that the programme restricts these substances by use of a ban, but there is no specific limit value listed for the substance
- indicates that the programme does not restrict these substances

TABLE 2. Content requirements for metals in PU foam

Substance name	CAS no.	CertiPUR-US (mg/kg - ppm)	CertiPUR (mg/kg - ppm)	TÜV Rheinland (mg/kg - ppm)
Antimony (Sb)	7440-36-0	0.5	0.5	< 5
Arsenic (As)	7440-38-2	0.2	0.2	< 1
Cadmium (Cd)	7440-43-9	0.1	0.1	< 0.1
Chromium, total (Cr)	7440-47-3	1.0	1.0	< 2
Chromium, hexavalent (Cr(VI))	18540-29-9	< LOD	0.01	-
Cobalt (Co)	7440-48-4	0.5	0.5	-
Copper (Cu)	7440-50-8	2.0	2.0	-
Lead (Pb)	7439-92-1	0.2	0.2	< 1
Nickel (Ni)	7440-20-0	1.0	1.0	< 4
Mercury (Hg)	7439-97-6	0.02	0.02	< 0.02
Selenium (Se)	7782-49-2	0.5	0.5	-

LOD = limit of detection

TABLE 3. Content requirements for organotin compounds in PU foam

Substance name	CAS no.	CertiPUR-US (µg/kg - ppb)	CertiPUR (µg/kg - ppb)	TÜV Rheinland (µg/kg - ppb)
Tributyltin (TBT)		500	< 50	< 100
Dibutyltin (DBT)		-	< 100	
Monobutyltin (MBT)		-	< 100	
Tetrabutyltin (TeBT)		-		
Monooctyltin (MOT)		-		
Dioctyltin (DOT)		-		
Tricyclohexyltin (TcyT)		-		
Triphenyltin (TPhT)		-		
Total of all organotin compounds		-	< 500	< 500

- indicates that the programme does not set restrictions on these substances

TABLE 4. Content requirements for phthalates in PU foam

Substance name	CAS no.	CertiPUR-US (mg/kg - ppm)	CertiPUR (mg/kg - ppm)	TÜV Rheinland (mg/kg – ppm)
Diisononyl phthalate (DINP)	28553-12-0	x	x	< 1000
Diisodecyl phthalate (DIDP)	26761-40-0	-	x	
Di-n-octyl phthalate (DNOP)	117-84-0	-	x	
Di-n-hexyl phthalate (DHEXP)	84-75-3	x	x	x
Di-(2-ethylhexyl) phthalate (DEHP)	117-81-7	x	x	< 1000
Butyl benzyl phthalate (BBP)	85-68-7	x	x	
Dibutyl phthalate (DBP)	84-74-2	x	x	
Diisobutyl phthalate (DIBP)	84-69-5	x	-	< 1000
Di-n-pentyl phthalate (DPENP)	131-18-0	x	-	x
Dicyclohexyl phthalate (DCHP)	84-61-7	x	-	
Bis(2-methoxyethyl) phthalate (DMEP)	117-82-8	-	-	< 1000
Total of all phthalates marked with "x"		100	100	-
Other phthalates ((C_6-C_{11}-di-n/iso-phthalates)		-	-	< 1000

x indicates that the programme restricts these substances by use of a ban, but there is no specific limit value listed for the substance
- indicates that the programme does not restrict these substances

TABLE 5. Content requirements for TDA/MDA in PU foam

Substance name	CAS no.	CertiPUR-US (mg/kg - ppm)	CertiPUR (mg/kg - ppm)	TÜV Rheinland (mg/kg – ppm)
2,4-toluenediamine (2,4-TDA)	95-80-7	< 5	< 5	< 3
4,4'-diaminodiphenylmethane (MDA)	101-77-9	< 5	< 5	< 3
Total of both substances		< 5	-	-

- indicates that the programme does not set requirements for the total of these substances

TABLE 6. Prohibited foaming agents for PU foam

Substance name	CAS no.	CertiPUR-US	CertiPUR	TÜV Rheinland
CFC		x	x *	-
HCFC		x	x *	-
Halons		-	x	-
Dichloromethane (methylene chloride)		x	-	-

x indicates that the programme restricts these substances by use of a ban, but there is no specific limit value listed for the substance
- indicates that the programme does not restrict these substances
* indicates that the substances are generally prohibited in the EU

TABLE 7. Prohibited substances in PU foam: flame retardant additives

Substance name	CAS no.	CertiPUR-US	CertiPUR	TÜV Rheinland
Chlorinated and brominated dioxins or furanes		x	x	-
Chlorinated hydrocarbons (1,1,2,2-Tetrachloroethane, Pentachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethylene)		x	x	-
Nitrites		x	x	-
Polybrominated biphenyls (PBB)		x	x	-
Pentabromodiphenyl ether (PeBDE)	32534-81-9	x	x	-
Octabromodiphenyl ether (OBDE)[1]	32536-52-0	x	x	-
Decabromodiphenyl ether (DBDE)[1]	1163-19-5	x	- *	-
Polychlorinated biphenyls (PCB)	1336-36-3	x	x	-
Polychlorinated terphenyls (PCT)	61788-33-8	x	x	-
Tris-(2,3-dibromopropyl) phosphate (TRIS)	126-72-7	x	x	-
Tris-(aziridinyl)-phosphine oxide (TEPA)	5455-55-1	x	x	-
Tris(2-chloroethyl) phosphate (TCEP)	115-96-8	x	x	< 10

Substance name	CAS no.	CertiPUR-US	CertiPUR	TÜV Rheinland
Tris(1,3-dichloro-2-propyl) phosphate (TDCPP)	13674-87-8	x	-	< 50
Tris(2-chloropropyl) phosphate (TCPP)	115-96-8	-	-	< 50
Dimethyl methylphosphonate (DMMP)	756-79-6	x	x	-
Hexabromocyclododecane (HBCDD)[1]	3194-55-6	x	x	-

* Not directly specified in CertiPUR, but generally prohibited in the EU by EU legislation
x indicates that the programme restricts these substances by use of a ban, but there is no specific limit value listed for the substance
- indicates that the programme does not restrict these substances
1. Prohibited in the EU by REACH Annex XVII

TABLE 8. Other prohibited substances in PU foam

Substance name	CAS no.	CertiPUR-US	CertiPUR	TÜV Rheinland
Chlorinated phenols (PCP, TeCP)	87-65-5	x	x	-
Hexachlorocyclohexane	58-89-9	x	x	-
Monomethyl-dibromo-diphenyl methane	99688-47-8	x	x	-
Monomethyl-dichloro-diphenyl methane	81161-70-8	x	x	-
Trimethyl phosphate	5455-55-1	x	x	-
Biocides		-	Excluding those approved by EU regulation 528, 2012	-
Total chlorine content from use of isocyanates			< 0.07 %	-
Raw materials classified with the following H-statements: H340 May cause genetic defects H350 May cause cancer H360 May damage fertility or the unborn child H370 Causes damage to organs		H340, H350, and H360 are directly covered by the general prohibition of CMR substances in categories 1A and 1B H370 is not covered	x	-
Azo dyes and dispersion colourants		-	-	Not detectable

x indicates that the programme restricts these substances by use of a ban, but there is no specific limit value listed for the substance
- indicates that the programme does not restrict these substances

4.3 Discussion and comparison of requirements

It can be seen from the descriptions above that the requirements for sample cutting and the test conditions for the emission chamber analyses are more or less identical in the two CertiPUR programmes. TÜV Rheinland (2014) does not state any specific cutting requirements.

Only minor, nuanced differences exist in the descriptions of the cutting procedures for the products.

Regarding the PU foam VOC emission requirements, CertiPUR-US and CertiPUR (EuroPUR) have roughly the same requirements; while requirements are set for different particular substances, common to them is a general requirement to restrict CMR substances in categories 1A and 1B. However, CertiPUR-US sets specific requirements for vinylcyclohexene (classified as Carc. 2) and 4-phenylcyclohexene (classification unknown; not present in the ECHA's C&L database[22]), while these two substances in particular are not covered by the European CertiPUR programme. The general requirement of no more than 0.5 mg/m^3 TVOCs is the same in both programmes. As for specific limit values for specific substances (formaldehyde, toluene, and styrene), the requirements in the European CertiPUR programme are generally somewhat lower than those in the CertiPUR-US programme.

Not many specific substances have limit values set in the TÜV Rheinland certification programme. On the other hand, it sets more stringent requirements for substances in CMR categories 1A and 1B, compared to the two CertiPUR programmes. TÜV Rheinland additionally sets requirements for CMR 2 substances.

The remaining chemical substance content requirements for PU foam are relatively identical. For example, the content limit values for certain metals are identical in the two CertiPUR programmes, though TÜV Rheinland sets slightly fewer metal requirements. There are nonetheless minor differences in other content requirements. These are as follows:

- The European CertiPUR programme and TÜV Rheinland restrict a number of organotin compounds (TBT, DBT, and MBT) and set a limit value for the total amount of organotin compounds. CertiPUR-US establishes a content requirement for only tributyltin (TBT).
- The CertiPUR-US, CertiPUR, and TÜV Rheinland programmes restrict 8, 7, and 8 specific pthalates, respectively; 5 of the restricted phthalates are identical. An identical limit of 100 ppm is established for the total amount of restricted phthalates for the two CertiPUR programmes, while TÜV Rheinland uses a limit value of 1000 ppm.
- Content requirements for TDA and MDA are identical in the two CertiPUR programmes, but CertiPUR-US additionally has established a limit value for the total amount of the two substances. TÜV Rheinland's limit value for TDA and MDA, however, is slightly lower.
- Regarding foaming agents, CertiPUR-US prohibits the use of dichloromethane, while the European CertiPUR programme prohibits the use of halons in general. TÜV Rheinland sets no requirements in this regard.
- Both CertiPUR programmes prohibit a long list of flame retardant additives, and the programmes lists of prohibited substances are essentially identical, with the exception that CertiPUR-US prohibits the flame retardant TDCPP in addition to the same substances prohibited in the European CertiPUR programme. Here, TÜV Rheinland restricts only the three chlorinated phosphorus-based flame retardants, TCPP, TCEP, and TDCPP.
- There are also minor differences concerning other prohibited substances. For example, the European CertiPUR programme has a number of additional prohibitions that CertiPUR-US and TÜV Rheinland lack:
    - Biocides not approved in the European biocide regulation are prohibited; that is, it is simply indicated that products must follow European rules in this area.
    - A limit value for the total chlorine content due to the use of isocyanates.
    - A prohibition on raw materials classified under H370 "Causes damage to organs".

One of the areas of focus of this project is the chlorinated phosphorus-based flame retardants listed below:

[22] https://echa.europa.eu/da/information-on-chemicals/cl-inventory-database

- TCPP: Tris(2-chloroisopropyl)phosphate (CAS 13674-84-5)
- TCEP: Tris(2-chloroethyl)phosphate (CAS 115-96-8)
- TDCPP: Tris(1,3-dichloroisopropyl)phosphate (CAS 13674-87-8)

It can be seen from the requirements above that both CertiPUR certification programmes prohibit TCEP, neither of the certification programmes prohibit TCPP, and CertiPUR-US is the only programme that prohibits TDCPP. TÜV Rheinland's certification programme, however, prohibits all three of these chlorinated phosphorus-based flame retardants. In light of this, certain CertiPUR-US or CertiPUR certified products were specifically purchased for this project because some of these flame retardants may be present in the certified products.

5. Survey: method

This chapter describes the approach taken to the survey of PU foam products in this project. The following activities were carried out:

- Contact with the industry through trade associations
- Literature review / internet searches
- Visits to shops
- Searches in various materials databases

5.1 Contact with the industry

The Danish Plastics Federation, a Danish plastics industry association, was contacted to request their input for the project. The Danish Plastics Federation referred us to the association's PU division, including the PU division's chairman at Dan-Foam ApS. For that reason, Dan-Foam ApS contacted us to express their interest in the project, and subsequently to contribute general information about PU materials and PU manufacturing in Denmark, as well as about the various certification programmes. We additionally participated in the annual meeting of the PU division on 15 May 2019, titled "The circular economy: a threat or an opportunity for the polyurethane industry". Over the course of the project, we maintained a general dialogue with a wide array of PU raw material vendors and manufacturers.

5.2 Literature review / internet searches

A literature review was performed to find studies describing substances identified as released or emitted from PU foam products. This literature review was performed exclusively by searching the internet for earlier studies of chemicals in or emitted from PU foam products. The results of this search are described in section 6.1 "Literature review".

Additionally, an internet search was performed for different types of products containing PU foam. This was done partially to investigate the market for PU foam products, and partially to identify examples of consumer PU foam products to be selected, purchased, and analysed in this project. As described in the introduction, one of the purposes of this project is precisely to determine whether there are differences in the chemical substances present in products purchased in Denmark, purchased in the EU, and purchased outside the EU. For this reason, the internet search also included searches of foreign websites that ship products to Denmark (such as Amazon, eBay, AliExpress, GearBest, and Wish).

The examples of PU foam products identified in the search were recorded with the following information in an Excel spreadsheet:

- Product name
- Product description, including an image of the product
- Type of product (e.g., mattress, pillow, changing pad, cot bumper, cushion, play furniture, etc.)
- Where was the product manufactured? In what country?
- Geographical purchase category; that is, in which country was the product bought? (Denmark, within the EU but outside of Denmark, outside of the EU)
- The target group for the product (divided into "children aged 0-3 years" and "adults or youths")
- Information about the materials; that is, whether the product is expected to consist of PU foam

- Name, address, and email address of the product's vendor
- Price
- Link to website

It should be noted that it was rather quickly decided to focus on products for small children (i.e., under 3 years) in the product search, or products with long exposure times for adults and youths; that is, emphasising mattresses and pillows.

The materials of which each product consisted were recorded. In some cases, it was explicitly stated that a product consisted of PU. In other cases, it was indicated that product was made of e.g. memory foam, polyether foam, or cold foam. According to chapter 2 "Polyurethane (PU)", this most likely means that PU foam is involved. In some cases, however, only the word "foam" was listed, creating the need to more closely examine the type of material used if such a product was chosen for analysis in the project.

5.3 Shop visits

As a supplement to the internet search for examples of consumer PU foam products, visits to selected shops were conducted, such as shops that sell products for babies and shops that sell beds, mattresses, pillows, etc. The following shops were visited, and examples of PU foam products in these shops were recorded in the cumulative list.

- BabySam
- Ønskebørn
- Drømmeland
- Auping
- Jysk
- Magasin

5.4 Searches in various materials databases

Searches in various materials databases were conducted to acquire information about product ingredients and, by extension, which substances may be emitted from PU foam. The materials database containing information relevant to this project is the ECHA's Plastic Additives Initiative, reviewed in greater detail below.

5.4.1 The ECHA's Plastic Additives Initiative

In 2016, the ECHA began working to survey the use of plastic additives together with 21 trade organisations. This work was published in December 2018 under the title "Plastic Additives Initiative". The work resulted in a list of more than 400 additives used in large quantities in plastics; that is, additives used in quantities of more than 100 tonnes per year in Europe.

This list was searched for additives used in plastics, focusing on additives used in PU. The result of the search is described in section 6.2 “ECHA's plastics database".

6. Substances emitted from PU foam

A search was performed for literature concerning the emission of chemical substances from PU foam. The results of this search are reviewed below. Additionally, the chemical substances used in PU according to the ECHA's Plastic Additives Initiative, and which the ECHA expects may be emitted from PU material, were also reviewed.

6.1 Literature review

A limited amount of literature concerning the emission of chemical substances from PU foam was identified. Among others, (Lattuati-Derieux et al., 2011) write that only a small number of studies have been performed on VOCs emitted from PU. Of those relatively few studies, a limited number of them examined consumer PU foam products like mattresses and pillows, which are a focus of this study. A few studies of PU foam used for insulation were identified, but this type of PU foam is not necessarily identical to that used in furniture or mattresses. Some studies investigated the emission of VOCs from furniture in general, but these studies typically measured emission from wooden furniture with furniture foam; that is, which VOCs are emitted from the wood and which are emitted from the PU foam cannot be identified. For this reason, these studies are not described in this report.

Some studies were performed by CertiPUR; that is, the organisation responsible for the CertiPUR certification programme. These studies are outdated but are nonetheless described below as they seem to be some of the first articles/studies focusing on emission of VOCs from PU foam.

Those studies which identified chemical substances emitted from PU identified a considerable number of different substances. This literature review focuses on those substances emitted at the highest concentrations, and on the most problematic substances; that is, substances whose properties are problematic from a health perspective. The literature often also chooses to focus on the most important VOCs (and reports only on those VOCs which the authors consider to be most important); that is, the most dangerous substances, and the substances emitted at the highest concentrations.

Aside from these few studies of VOC emission from consumer PU foam products, a few general articles were also identified, which will be described for introductory purposes.

6.1.1 General factors associated with PU foam emissions

The literature review on the release of VOCs from PU foam uncovered a number of related general factors, such as VOC impurities in raw materials used to manufacture PU, the natural breakdown of PU, and the fact that besides being a source of VOCs, PU foam can also absorb VOCs from its environment in the home. These factors are briefly described below.

6.1.1.1 VOC impurities in raw materials for PU manufacturing

The Danish PU industry indicates that one source of VOC emission from PU may be the unintentional presence of impurities in raw materials used to manufacture PU. That is, impurities in the raw materials may lead to VOC emissions from PU or be the cause of odours from PU. However, no literature confirming this situation was identified.

6.1.1.2 Natural breakdown of PU foam

In the literature review, some articles discussing the problem of thermal breakdown of PU foam were identified. This problem has been studied because PU foam is also widely used in connection with items of cultural value in museums, either as a part of the items themselves or as a material used to preserve them. Many of these objects are in poor condition because PU foam breaks down over time, and so this topic has been investigated more closely (Lattuati-Derieux et al., 2011).

Studies show that PU foam breaks down both thermally and photochemically (Lattuati-Derieux et al., 2011). In thermal breakdown, urethane linkages break and decompose into isocyanates and polyols, the "building blocks" (monomers) of polyurethane. However, this thermal breakdown does not occur until reaching 200°C (Jiao et al., 2013), so it is not considered to be of interest for PU foam in consumer products, used at temperatures from room temperature to body temperature.

Lattuati-Derieux et al. (2011) describe that the photochemical breakdown process depends on the type of PU foam. Hydrolysis is the dominant breakdown process for polyester-based polyurethane, while oxidation is the dominant process for polyether-based polyurethanes. In their experiments, the authors found that the production of alcohol and glycol derivatives can be considered indicators of PU foam breakdown; that is, these compounds are found when PU foam breaks down photochemically. However, there are differences in the VOCs formed in the breakdown process, depending on the material. Toluenediamine (TDA) isomers and adipic acid are found at higher concentrations when polyester-based polyurethane breaks down via hydrolysis, whereas glycol derivatives are found at higher concentrations when polyether-based polyurethanes undergo a photolytic breakdown process (Curran & Strlic, 2015; Lattuati-Deieux et al., 2011). Since many PU foam products are covered by e.g. a layer of material (in the case of mattresses and pillows), photochemical breakdown in these consumer products will be significantly less severe than that in e.g. PU foam products exposed to direct sunlight (BASF, 2019).

6.1.1.3 PU foam may absorb VOCs from the indoor climate

Zhao et al. (2003) conclude in their study, now more than 15 years old, that PU foam, besides itself being capable of emitting VOCs and thus being a source of VOCs, can also function as a kind of VOC absorber in an indoor climate. Absorption and desorption of VOCs occur in equilibrium with the environment, and thus depend on the concentration of VOCs in the indoor climate. Zhao et al. (2003) describe that at high concentrations of VOCs in an indoor climate, PU foam will absorb VOCs that may be released later, once the concentration of VOCs in the indoor climate drops. The authors thus conclude that PU foam in the home may contribute to changes in the concentration of VOCs in the indoor climate. In the article, they emphasise that PU foam is itself also a source of VOCs, since PU foam typically contains residual amounts of VOCs after manufacturing.

In their experiment, they used a polyether-type PU foam, normally used as a foam filling for pillows, mattresses, sofas, and cushions in homes and offices. The PU foam was cut out in a cylindrical shape and placed in a glass cylinder with openings at either end. VOC-laden air and clean air were alternately passed through the PU foam, and the amounts of known VOCs (including benzene, styrene, and xylene) absorbed and released by the PU foam were measured. In this manner, the authors were able to produce mathematical models for the desorption and absorption of VOCs from PU foam.

The tests they performed showed that the uptake and release of VOCs from PU foam are nearly completely reversible and symmetrical in both scope and rate. The authors also concluded that water vapour in the air reduces the ability of PU foam to absorb VOCs slightly, and reduces the rate at which PU foam absorbs VOCs (Zhao et al., 2003).

This article thus shows that complicated processes are involved in the emission (and uptake) of VOCs in PU foam. If new PU foam products are placed in a "clean" emission chamber, and VOCs in the air of the chamber are measured after a few hours or days, as we did with the emission chambers in this project, then the VOCs measured may originate from the PU foam — but in theory, they may also originate from the packaging, the manufacturing process, etc. We therefore do not know where the emitted VOCs originated, but we analysed the products as they would be received by consumers.

6.1.2 Literature concerning emissions from consumer PU foam products

This section describes the identified studies which directly measured VOC emissions from consumer PU foam products. These studies are:

- The Danish EPA's survey of chemical substances in squishies (2018)
- An American study of VOC emission from cot mattresses (2014)
- A European study of VOCs from PU foam mattresses conducted by EUROPUR (2003)

6.1.2.1 Squishy survey (2018)

One of the most recent studies is the Danish EPA's survey of squishy toys, conducted in 2018 (Klinke et al., 2018). All the squishes examined consisted of PU foam. Emission chamber analyses were performed on a total of 8 squishies. A squishy was compressed ("squished") 10 times in the emission chamber. Then, the chamber was sealed, and an emission analysis was conducted 1 hour later. A number of volatile organic compounds were analysed (carbonyls, short-chain hydrocarbons C_1-C_4 which are VOCs).

In total, about 125 substances were identified, and some unidentified substances were also found. The total of all emitted VOCs was measured at between 2300 and 10,000 µg/m^3 in toluene equivalents.

The identified emitted substances were prioritised partially relative to their classifications, but also relative to the volumes in which they were emitted. This resulted in a list of 16 substances either emitted at a high concentration (e.g., cyclohexanone, N,N-dimethylaminoethanol (DMAE), N,N-dimethylformamide (DMF), and triethylenediamine) or selected for their health-related classifications (e.g., methylene chloride, toluene, styrene, and phenol). These substances and the volumes in which they were emitted are listed below in TABLE 9. However, it should be noted that three of the selected substances are fragrances that are not necessarily relevant for mattresses and pillows. For this reason, they were not included in the table.

Emission chamber analyses were performed on four additional squishes, this time measuring emission after 1 hour and again after 3 days. The result was that the majority of substances were not identified in emission after 3 days. Three amines, N,N-dimethylaminoethanol (DMAE), triethylenediamine, and bis(2-(dimethylamino)ethyl)ether, were found either at higher concentrations or roughly the same concentration in the 3-day measurement as in the 1-hour measurement. The report thus concludes that amines are released from the material more slowly over time than the other measured VOCs.

It further concludes that "the concentrations of the individual substances vary with the type of squishy, suggesting that the weight and surface area of the squishy are correlated with the concentrations of VOCs released in the emission chamber test. This also suggests that the types of substances emitted vary from manufacturer to manufacturer. Even among products from the same manufacturer, significant differences were observed in the chemical content of two squishes in terms of both substances and emission concentrations."

The risk assessment concluded that exposure to a squishy in the breathing zone for 10 hours (i.e., while sleeping) resulted in RCR values greater than 1; that is, the substances constituted

a risk. The critical effect in this case was irritation of the mucous membranes of the eyes and airways; thus, emission of several of these substances will contribute to a heightened, most likely additive effect. The critical substances were:

- N,N-dimethylformamide (DMF),
- N,N-dimethylaminoethanol (DMAE)
- Triethylenediamine
- Bis(2-(Dimethylamino)ethyl)ether
- 1,1,4,7,7-pentamethyldiethylenetriamine
- Cyclohexanone

6.1.2.2 VOCs from cot mattresses (2014)

Boor et al. (2014) studied the emission of VOCs from a total of 20 cot mattresses. The 20 mattresses were described as follows: 13 mattresses were made of PU foam, including two mattresses with soy-based PU foam; the remaining 7 mattresses were polyester-based foam, a variant of PU foam. Of the 13 mattresses, 6 were new mattresses, and 7 had been used for periods ranging from less than one year to as many as 10 years. So-called small-scale emission chamber tests were performed to study the area-specific emission rates (SERs) for VOCs. It is indicated that even the new mattresses were aired out for at least one month at 23°C and 50% relative humidity before testing. The mattresses were cut into blocks measuring 14.3 x 7.5 cm and their sides were sealed off with aluminium foil.

The results showed that all the mattresses, whether new or old, emitted VOCs. The mean emitted volume of TVOCs (total VOCs) from the mattresses was 56 µg/m^{2}h at 23°C and 139 µg/m^{2}h at 36°C. However, emission from the new mattresses was higher than that from the used mattresses, and emission also depended on the material and the presence of a mattress covering. Overall, emission from PU foam was higher than that from the polyester foam PU variant; a greater number of VOCs was emitted from PU foam compared to polyester foam, though emission of individual VOCs was not necessarily greater for PU foam.
Some of the emitted VOCs are listed below in TABLE 9; only those VOCs that were clearly identified and emitted in the greatest volumes in the article are listed.

To conclude, they performed a more realistic study in a larger emission chamber with entire mattresses, and a baby doll whose warmth corresponded to that of an actual baby. TVOCs were collected in the breathing zone, and the results showed that the TVOC concentrations in the simulated breathing zone were 1.8 to 2.4 times greater than the TVOC concentrations of the indoor air climate of the room. Samples of air in the spaces of the mattress were also taken, revealing TVOC concentrations 7.5 to 21 times greater than that of the indoor climate of the room.

6.1.2.3 VOC emissions from PU foam mattresses (EUROPUR, 2003)

This study was conducted by EUROPUR (the European Association of Flexible Polyurethane Foam Block Manufacturers) together with a number of PU foam manufacturers. The article by Hillier et al. (2003) describes the results of this project, which ran for a total of more than 5 years. The purpose of the project was to gain knowledge of VOC emissions from PU foam and make adjustments to manufacturing processes to reduce the volume of emitted VOCs, as well as to reduce the emission of some specific VOCs.

They performed emission tests in large emission chambers of 2 or 3.2 m^3 to measure VOC emissions from mattresses measuring 200 x 100 x 12 cm placed in the chambers in their entirety. The emission chambers were set to 23°C, 50% relative humidity, and an air exchange rate of 0.5 per hour. VOC measurements were taken at 5, 24, 48, 72, 120, and 160 hours.

Analyses were performed on different types of PU foam:

- Traditional standard polyether (density of 38 kg/m^3 and a hardness of 180 N)

- HR ("high resilience") (density of 36 kg/m^3 and a hardness of 135 N)
- HR/FR ("high resilience, flame retardant") (density of 36 kg/m^3 and a hardness of 145 N, containing flame retardant (tris monochloropropyl phosphate (TMCP))
- CMHR ("combustion-modified high resilience) (density of 35 kg/m^3 and a hardness of 115 N)
- CME ("combustion-modified polyether") (density of 33 kg/m^3 and a hardness of 130 N)

The results of the emission tests showed that there were relatively large differences in which and how many VOCs were emitted from PU foam, depending on the particular type of PU foam being tested.

The results of the emission chamber tests showed that the concentrations of most VOCs identified fell drastically over time. Often, the concentration was below the limit of detection within 24 hours. However, the results also illustrated that the least volatile components diffuse slowly out of the PU foam, resulting in a maximum concentration at the end of the 160 hours, not at the beginning (i.e., within the first 24 hours).

In Hillier et al. (2003), there is a long series of tables showing the results of VOC emission from the various types of PU foam at different points in time. The substances identified as emitted in the highest concentrations are presented below in TABLE 9 with intervals representing different types of PU foam and measurements at different times.

Over the long 5-year period for which the project ran, the authors found that the emission of certain VOCs (such as BHT) dropped significantly. The authors conclude that this is due to the industry decreasing its use of volatile antioxidants in manufacturing PU foam. This was confirmed when after 5 years, trace amounts of less volatile antioxidants began to be identified instead of high concentrations of BHT.

In the project, the greatest identified concentrations in the emission chamber are converted to maximum concentrations in a standard room of a home, and risk calculations are performed based on the NOAEL (No Observed Adverse Effect Level) values of the substances. The calculations show that VOC emission does not constitute a risk to health because the highest measured concentrations are below the NOAEL values for the substances in question by a factor of 64 to 16,500. However, safety factors were not used in the calculations, so these values indicate the so-called MoS (margin of safety).

6.1.3 Collection of emitted substances from PU

This section contains a comprehensive table (TABLE 9) of the VOCs identified as emitted from consumer PU foam products in various literature. Not all VOCs are listed in the table; instead, an overview of the "worst" VOCs (i.e., with the "worst" classifications, including toxic to reproduction (Repr.), carcinogenic (Carc.), mutagenic (Mut.), or acute toxic (Acute Tox.)) and the VOCs found to be emitted in the highest volumes. The table is sorted in the way that substances with the "worst" classification and which were measured at the highest emission concentrations are listed first. It should be noted that the studies described show that it is not necessarily the same VOCs being emitted in all instances. Whether this is due to differences in PU foam types or in the analysis methods used is unknown.

TABLE 9. Overview of substances emitted from PU identified in the literature. The list does not contain all the identified emitted substances, but those chemical substances with the most problematic health-related characteristics, or those substances emitted in the highest concentrations. Note that different units of measurement were used in different sources.

Substance	CAS no.	Classification	Concentration ($\mu g/m^3$)	Source
2-butanone	78-93-3	Eye Irrit. 2, H319 STOT SE 2, H336	< 5-3800	Klinke et al., 2018
Chlorooctane	111-85-3	Asp. Tox. 1, H304	DL-67	2003
Chloropropanol	627-30-5	Unknown	DL-34	Hillier et al., 2003
Cyclohexanone	108-94-1	Acute Tox. 4, H332	630-15,000	Klinke et al., 2018
Cyclotetrasiloxane, octamethyl-	556-67-2	Repr. 2, H361f	1-7	Klinke et al., 2018
Decanal	112-31-2	Eye Irrit. 2, H319 Skin Irrit. 2, H315	< 1-5 $\mu g/m^2$ h (23°C) 2-10 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Dichlorobenzene	95-50-1	Acute Tox. 4, H302, H332 Eye Irrit. 2, H319 Skin Irrit. 2, H315 STOT SE 2, H335	DL-2	2003
Dichloropropane	78-87-5	Not in ECHA's C&L database	DL-11	Hillier et al., 2003
N,N-Dimethylaminoethanol	108-01-0	Acute Tox. 4, H302, H312, H332 Skin Corr. 1B, H314	34-6800	Klinke et al., 2018
Dimethyldioxanes	25136-55-4 1331-15-3 15176-21-3	Not in ECHA's C&L database	DL-7.2	Hillier et al., 2003
2,6-bis(1,1-dimethylethyl)-4-(1-oxopropyl) phenol	14035-34-8	Not in ECHA's C&L database	4-14 $\mu g/m^2$ h (23°C) 12-61 $\mu g/m^2$ h (36°C)	Boor et al., 2014
N,N-dimethylformamide*	68-12-2	Acute Tox. 4, H312, H332 Eye Irrit. 2, H319 Repr. 1B, H360D	210-14,000	Klinke et al., 2018
2,6-di-tert-butyl-p-cresol (BHT)	128-37-0	Acute Tox. 4, H302, H312 Eye Irrit. 2, H319 Skin Irrit. 2, H315	5.7-8.3	2003
Ethylbenzene	100-41-4	Acute Tox. 4, H332 Asp. Tox. 1, H304 STOT RE 2, H373 (hearing organs)	< 5-350	Klinke et al., 2018

Substance	CAS no.	Classification	Concentration ($\mu g/m^3$)	Source
2-ethylhexanoic acid	149-57-5	Repr. 2, H361d	< 1-55 $\mu g/m^2$ h (23°C) 5-213 $\mu g/m^2$ h (36°C)	Boor et al., 2014
			DL-99	Hillier et al., 2003
2-ethylhexanol	104-76-7	Eye Irrit. 2, H319 Skin Irrit. 2, H315 STOT SE 3, H335 Acute Tox. 4, H332, H312	3-6 $\mu g/m^2$ h (23°C) 7-8 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Hexenal (trans-hex-2-enal)	6728-26-3	Acute Tox. 4, H302 Acute Tox. 3, H311 Skin Sens. 1B, H317 Skin Irrt. 2, H315	DL-76	Hillier et al., 2003
Isooctanol	26952-21-6	Acute Tox. 4, H302 Skin Irrit. 2, H315 Eye Irrit. 2, H319	< 1-6 $\mu g/m^2$ h (23°C) 4-7 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Isopropyl myristate	110-27-0	Skin Irrit. 2, H315	< 1-3 $\mu g/m^2$ h (23°C) 3-11 $\mu g/m^2$ h (36°C)	Boor et al., 2014
D-limonene (fragrance)	5989-27-5	Skin Irrit. 2, H315 Skin Sens. 1, H317	4-11 $\mu g/m^2$ h (23°C) 9-18 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Linalool (fragrance)	78-70-6	Skin Sens. 1B, H317	3-41 $\mu g/m^2$ h (23°C) 3-9 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Methylene chloride	75-09-2	Carc. 2, H351	< 5-560	Klinke et al., 2018
			< DL-270	Hillier et al., 2003
3-methyl-1-heptanol	1070-32-2	Not in ECHA's C&L database	7-21 $\mu g/m^2$ h (23°C) 7-22 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Neodecanoic acid	26896-20-8	Eye Dam. 1, H318 Acute Tox. 4, H302	3-22 $\mu g/m^2$ h (23°C) 9-40 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Nonanal	124-19-6	Skin Irrit. 2, H315 Eye Irrit. 2, H319	< 1-5 $\mu g/m^2$ h (23°C) 2-10 $\mu g/m^2$ h (36°C)	Boor et al., 2014
Palmitic acid	57-10-3	Eye Irrit. 2, H319 Skin Irrit. 2, H315 STOT SE 3, H335	2-10 $\mu g/m^2$ h (23°C) 12-43 $\mu g/m^2$ h (36°C)	Boor et al., 2014

Substance	CAS no.	Classification	Concentration (µg/m³)	Source
1,1,4,7,7-pentamethyldiethy-lenetriamine	3030-47-5	Acute Tox. 4, H302 Acute Tox. 3, H311 Skin Corr. 1B, H314	< 5-870	Klinke et al., 2018
Phenol	108-95-2	Acute Tox. 3, H301, H311, H331 Skin Corr. 1B, H314 Muta. 2, H341 STOT RE 2, H373	1-10	Klinke et al., 2018
			< 1-62 µg/m² h (23°C) 3-257 µg/m² h (36°C)	Boor et al., 2014
Propanal (propionaldehyde)	123-38-6	Eye Irrit. 2, H319 Skin Irrit. 2, H315 STOT SE 2, H335	DL-42	Hillier et al., 2003
Propylene glycol acetal hex-anal	1599-49-1	Not in ECHA's C&L database	DL-20	Hillier et al., 2003
Propenyloxy propanol	1331-17-5	Not in ECHA's C&L database	DL-9	Hillier et al., 2003
Styrene	100-42-5	Skin Irrit. 2, H315 Eye Irrit. 2, H319 Acute Tox. 4, H332 STOT RE 1, H372 (hearing organs) Repr. 2, H361d	1-51	Klinke et al., 2018
			DL-43	Hillier et al., 2003
Toluene	108-88-3	Skin Irrit. 2, H315 Asp. Tox. 1, H304 STOT SE 3, H336 STOT RE 2, H373 Repr. 2, H361d	3-330	Klinke et al., 2018
			4-270	Hillier et al., 2003
Triethylenediamine	280-57-9	Acute Tox. 4, H302 Skin Irrit. 2, H315 Eye Dam. 1, H318	450-3500	Klinke et al., 2018
			DL-360	Hillier et al., 2003
Tris monocloropropyl phos-phate (TMCP or TCPP)	13674-84-5	Acute Tox. 4, H302	DL-25	Hillier et al., 2003
m-Xylene p-Xylene	108-38-3 106-42-3 179601-23-1	Acute Tox. 4, H312 Skin Irrit. 2, H315 Acute Tox. 4, H332	< 5-920	Klinke et al., 2018
o-Xylene	95-47-6	Acute Tox. 4, H312 Skin Irrit. 2, H315 Acute Tox. 4, H332	14-560	Klinke et al., 2018
Xylenes	All listed above	Acute Tox. 4, H312 Skin Irrit. 2, H315 Acute Tox. 4, H332	DL-17	Hillier et al., 2003

* Present on the REACH Candidate List.
DL = detection limit (the article does not specify a value for the detection limit)

6.2 ECHA's plastics database

ECHA's Plastic Additive Initiative database contains a total of more than 400 different additives used in plastics. ECHA has made it clear that their plastics database should not be taken to be exhaustive, since a number of prerequisites apply (ECHA, 2019a):

- The database contains only the most widely used additives; that is, only those chemical substances which are registered in the REACH system and have a tonnage of more than 100 tonnes per year.
- Additional searches for other substances are not performed; the sole basis is the list of registered chemical substances

The plastics database can be accessed from ECHA's website, and it is possible to see which additives are used for which polymer types. That is, it is possible to see the additives used in PU. However, no distinction is made between e.g. PU and PU foam. The combined list of additives used in PU is shown in 0 and contains a total of 145 chemical substances. 0 is divided by additive type as the ECHA divides them; that is, by:

- Light stabilisers
- Heat stabilisers
- Other stabilisers
- Antioxidants
- Nucleating/clarifying additives
- Pigments
- Anti-static agents
- Flame retardants
- Softeners
- Other functions

For these substances in its plastics database, ECHA has evaluated the potential for these substances to be released from plastics during use. These evaluations were made based on the molecular weights of the additives, their concentrations in plastics, the permeability of the polymer matrices, and usage conditions, such as temperature. For some substances, ECHA has developed "relative release potential" values, which are relative values developed with screening purposes in mind. These release potential evaluations are not made public but are available to member states.

However, release potentials have only been evaluated for a small number of the additives used in PU. These additives are listed in TABLE 10 on the next page.

The release potential evaluation was performed for both dermal uptake and for release into the air (indoor climate). The release potential is given as a relative value; the lower the absolute value of the negative number, the greater the tendency for either dermal release or release into the air. For example, a release potential of -2 indicates that the substance is more readily released than a substance with a release potential of -10. The highest possible value for the release potential is 0.

For the five additives used in PU for which ECHA has evaluated the release potential, a flame retardant and a heat stabiliser have the greatest potential to be released into the indoor climate from PU material, with release potential values of -2 and -3, respectively.

TABLE 10. Excerpt from the ECHA's plastics database: additives used in PU for which release potentials have been evaluated (Source: Danish EPA)

CAS no.	EC no.	Chemical name	Substance type	Role in PU	Molecular weight	Vapour pressure (Pa)	Solubility in water (mg/litre)	log K_{ow}	Release rating, dermal	Release rating, indoor air
37640-57-6	253-575-7	1,3,5-triazine-2,4,6(1H,3H,5H)-trione, compound with 1,3,5-triazine-2,4,6-triamine (1:1)	organic mono-constituent	Flame retardant	255.0	5.93E-16	2.7	-2.28	0	-8
38051-10-4	253-760-2	2,2-bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)	organic mono-constituent	Flame retardant	583.0	2.75E-06	0.312	3.31	-3	-2
40601-76-1	254-996-9	1,3,5-Tis(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)-1,3,5-triazine-2,4,6-(1H, 3H, 5H)- trione	organic mono-constituent	Antioxidant	700.0	8.52E-25	1.19E-11	15.3	-7	-10
	915-687-0	Reaction mass of Bis(1,2,2,6,6-pentamethyl-4-piperidyl) sebacate and Methyl 1,2,2,6,6-pentamethyl-4-piperidyl sebacate	organic UVCB	Heat stabiliser	370.0	3.77E-04	1.97	5.14	-4	-3
37640-57-6	915-687-0	Reaction mass of Bis(1,2,2,6,6-pentamethyl-4-piperidyl) sebacate and Methyl 1,2,2,6,6-pentamethyl-4-piperidyl sebacate	organic UVCB	Heat stabiliser	590.0	1.05E-07	0.0078	6.92	-5	-6

Of those additives whose release potential has been evaluated, a flame retardant and a heat stabiliser have the greatest potential to be released into the indoor climate from PU material, as these two substances have release potentials of -2 and -3, respectively. The groups of softeners and anti-static agents have generally not been evaluated with regard to their release potential from PU, despite the fact that both groups have generally high potential to be released from plastics and should thus also be presumed to be capable of significant release from PU. However, anti-static agents do not seem to be commonly used in PU. According to Annex 1.6, "Anti-static agents", only zinc oxide is used as an anti-static agent in PU, at concentrations of up to 5%. Many different softening compounds (see Annex 1.8, "Softeners"), on the other hand, are used (34 softeners are listed by ECHA), including a number of phthalates on the Candidate List today. These softeners are used at high concentrations ranging from 10% to 35% in PU. It is unknown how widespread the use of softeners is in PU foam, but it is mentioned by several sources. For example, a previous survey for the Danish EPA (Schmidt et al., 2008) identified phthalates in PU foam used in headphones.

It is therefore expected that the following substance groups will have the greatest release potentials from PU:

- Flame retardants
- Heat stabilisers
- Softeners
- Anti-static agents

7.1 Discussion and conclusion

Only a few studies were identified that focused on emission of VOCs from consumer products containing PU foam. These are described here, and they show that typically, a wide array of VOCs is emitted from PU foam. The studies described show that it is not necessarily the same VOCs being emitted in all instances. This may be due to the existence of different types of PU foam manufactured in different ways, even though the starting materials are typically the same. Another explanation may be differences in the analysis methods used.

One interesting aspect discussed in a 2003 article is that, in addition to PU foam itself being a source of emitted VOCs in indoor climates, PU foam can also act as a sort of VOC absorber in indoor climates. According to the authors (Zhao et al., 2003), it can thus accumulate VOCs if the concentration of VOCs in the indoor climate is greater than that in e.g. a mattress or sofa cushion. According to the authors, VOCs absorbed from the indoor climate can later be released back into the indoor climate when the concentration of VOCs in the surrounding air has decreased. This shows that complicated processes are involved in the emission (and uptake) of VOCs in PU foam. How relevant and significant this is in a residential context is unknown, but it will most likely be of significance primarily in especially polluted indoor climates, such as the homes of smokers, where PU foam can apparently maintain the presence of VOCs in the indoor climate over time. However, we expect that when placing new PU foam products in a "clean" emission chamber and measuring the VOCs in the chamber air after several hours or days, as we did for the emission chamber analyses in this project, the measured VOCs should originate from the PU foam.

Additionally, literature was identified describing how PU breaks down photochemically over time. However, these processes are not expected to play a role in this project because the products purchased and analysed are new consumer products, and because the analysed PU foam products in this project are covered by an outer layer that excludes some amount of light.

In their plastics database, ECHA has surveyed the use of the most widely used (by volume) additives in plastics, including in PU. ECHA evaluated the potential of the additives to be released from plastics. The involvement of PU in this evaluation was limited, but based on the

limited information available, it is expected that the following groups of additives will have the greatest release potentials from PU:

- Flame retardants — in particular, the flame retardant 2,2-bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate) (see TABLE 10) is expected to have a high release potential
- Heat stabilisers — a particular heat stabiliser (see TABLE 10) is expected to have a high release potential
- Softeners — there is a broad assortment of phthalates that have high release potentials
- Anti-static agents — anti-static agents collectively are estimated to have a high release potential, but typically only zinc oxide is used in PU, according to ECHA's plastics database

7. Selection of products for analysis

This chapter contains a description of the consumer PU foam products that were selected for analysis in this project.

7.1 Description of approach

The PU foam products selected for purchase and analysis were chosen to cover:

- Purchases from non-EU countries, EU countries other than Denmark, and Denmark
- Different types of PU foam products (e.g., mattresses, pillows, changing pads, cot bumpers, etc.). However, it was decided to focus on products either for very small children (0-3 years) or products used for sleeping (e.g., mattresses and pillows) by adults and youths
- Products at various price levels
- Products from various manufacturers (to the extent that such information was available when purchasing)
- Products either described as containing PU foam or other kinds of foam expected to consist of PU foam

Using the established criteria, a total of 23 products were selected in co-operation with the Danish EPA to be purchased for this project. The 23 products were divided as follows:

- 8 products from non-EU countries. Seven out of these eight products arrived before analyses began, and 5 of the 7 were selected for analysis.
- 5 products from EU countries other than Denmark.
- 10 products from physical shops in Denmark.

7.2 Overview of products selected for analysis

TABLE 11 below gives an overview of the 20 products selected for analysis. The products are named ("Lab no.") based on where they were purchased. Specifically:

- The "N-EU" products were purchased from non-EU countries, typically on Wish.com or Amazon.com
- The "EU products were purchased within the EU (but outside of Denmark), typically on Amazon.de or eBay.co.uk
- The "DK" products were collected for testing by the Chemical Inspection Service within Denmark, from Danish shops

TABLE 11. Names and descriptions of the 20 products selected for analysis

Lab no.	Product type	Intended for	Manufactured in	Material*	Certification
N-EU 2	Pillow	Children aged 0-3 years	Unknown	Memory foam	
N-EU 3	Mattress	Children aged 0-3 years	Unknown	PU	CertiPUR
N-EU 4	Folding mattress	Older children / adults	Unknown	PU	CertiPUR
N-EU 5	Support mattress	Babies 0 years	China	Foam	

Lab no.	Product type	Intended for	Manufactured in	Material*	Certification
N-EU 6	Pillow	Children aged 0-3 years	China	Memory foam	
EU 1	Pillow	Children aged 0-3 years	Unknown	PU	
EU 2	Mattress	Older children / adults	Italy	PU	Oeko-Tex
EU 3	Mattress	Children aged 0-3 years	Unknown	PU	Oeko-Tex
EU 4	Pillow	Older children	Unknown	PU and rayon	
EU 5	Folding mattress	Older children / adults	UK	PU	
DK 1	Mattress	Older children / adults	Denmark	Memory foam	TÜV Rheinland LGA
DK 2	Cot bumper	Children aged 0-3 years	Denmark	PU	Oeko-Tex (textile)
DK 3	Cot bumper	Children aged 0-3 years	Denmark	Unknown	Oeko-Tex
DK 4	Mattress	Children aged 0-3 years	Unknown	PU	CertiPUR, Oeko-Tex
DK 5	Mattress	Children aged 0-3 years	Slovenia	PU	
DK 6	Tumbling mat	Older children	Sweden	Polyether foam	
DK 7	Mattress	Older children	Sweden	PU	
DK 8	Pillow	Older children	Unknown	Memory foam	Oeko-Tex
DK 9	Mattress	Older children / adults	Unknown	PU	CertiPUR, Oeko-Tex
DK 10	Mattress	Children aged 0-3 years	Denmark?	Memory foam	

* Material specified on product or in online product description

The 20 products selected for analysis are distributed as follows:

- By age of intended user:
  - 10 products for babies or small children (i.e., aged 0-3 years).
  - 10 products for older children or adults. Of these, 5 products are intended more for older children than for adults. These include e.g. pillows or mattresses marketed to children ages 4-7 or 8-10 or tumbling/play mats for children over 3 years. These products are indicated with the text "older children" in the "intended for" column.

- By product type:
  - 10 mattresses, 6 of which are mattresses for babies or small children of which one is a support mattress with the purpose to ensure that babies will stay sleeping on their side
  - 2 folding mattresses
  - 1 tumbling mat
  - 5 pillows, 2 of which are pillows for small babies (to help with torticollis)
  - 2 cot bumpers; i.e., foam covered with another material for placing around the edges of a cot

8. Emission analyses

This section describes how samples for the emission analyses were prepared, how the emission analyses were performed, and what the results of the emission analyses were.

8.1 Sample preparation procedure

The procedure below was used to prepare the product samples for emission analyses (emission chamber analyses). The procedure is based on the sampling requirements imposed by CertiPUR (both American and European) as part of its certification programme.

1. The products were stored in the packaging used for the shipment until all the products had been received. Thereafter, they were cut into smaller samples ("blocks") for the analyses.
2. Phthalate-free gloves were used when cutting the products.
3. The 20 products purchased were to be cut into "blocks" measuring 10 x 10 x 10 cm. Attached substances or plastics forming a part of the product on one or more sides were generally left on the blocks. The size of the block was calculated in terms of the sample surface area and the size of the environmental test chambers used, so as to correspond to the value of 0.4 m^2/m^3 (the so-called "loading factor") specified by CertiPUR-US (2019a).[23]
4. Since the height of the purchased products varied, they were cut into block measuring 10 x 10 cm x the product height, if the product height was less than 10 cm. For short products (approx. 5 cm or shorter), however, samples of 15 x 15 cm x the product height were cut in order to achieve the same approximate ratio between the surface area of the product and the volume of the emission chamber in use. The height is defined as the natural height of the product; that is, the apparent natural height of an object like a mattress lying on the floor.
5. The products were cut with an insulation knife and (if needed) a scalpel, if the product was encased in plastic or another material. The insulation knife was cleaned in alcohol (ethanol) between each cutting and allowed to dry for a few minutes before the next cutting. Alcohol is so volatile that it ought not to have any influence on the results of the analyses.
6. The product samples were generally cut into the sizes listed above. Since the products being cut were large, it was not possible to cut them very precisely, but the precise measurements of the products cut were recorded.
7. A total of 5 samples was cut from each product.
8. The samples were cut from the middle of the products whenever possible. However, for smaller products like pillows, this was not always possible. This means that all the product samples have four free sides (without plastic or another substance the product is normally encased in), while the top and bottom of the product have the accompanying plastic or other material attached (as best as it can remain attached naturally to the foam).

[23] According to CertiPUR-US, a 500-litre chamber is used for samples measuring 20 x 25 x 15 cm (= 0.235 m^2 block surface area, or 0.205 m^2 after excluding one of the small surfaces (measuring 15 x 20) on which the block rests at the bottom of the chamber). This corresponds to approx. 0.4 m2/m3 of the emission chamber. The emission chambers used in this project have a volume of 119 litres, corresponding to a block with a surface area of 0.4 m^2 x 0.119 m^3 / 1 m^3 = 0.0476 m^2. For a block with square surfaces, this corresponds to 9.7 cm x 9.7 cm x 9.7 cm (counting only 5 out of 6 surfaces; i.e., not counting the surface on which the block rests). This has been rounded up to 10 x 10 x 10 cm.

9. The 5 samples of each product were cut as quickly as possible. Thereafter, each sample (i.e., each "block") was packed into aluminium foil. Two people handled the product cutting process: one person cut the samples while the other packed them into aluminium foil immediately after cutting.
10. After each sample was packed into aluminium foil, it was placed into its own sample bag (with a zip closure). The sample bags were marked with the name and number of each sample.
11. Three sample bags were packed into a cardboard box and immediately sent to Eurofins Product Testing A/S for analysis. One sample was retained by FORCE Technology, and the remaining sample was sent to the Danish EPA.
12. At Eurofins Product Testing A/S, one of the received samples was unpacked from its aluminium foil directly in the emission chamber.
13. The sample was placed at the bottom of the emission chamber, resting on its smallest side (by surface area) to ensure the greatest possible surface area for emission. However, if the sample had plastic or another substance on one of its sides, it was always placed resting on that side.
14. The sample was compressed by hand (with a phthalate-free glove) 10 times before the emission chamber was closed. This was done to simulate movements on the product (e.g., on a mattress or pillow in use).
15. Measurements of emitted VOCs from the product were taken after 1 hour, and again after 3 days (72 hours).

8.1.1 Discussion of sample preparation procedure

In the product preparation procedure above, we followed the guidelines specified for CertiPUR (both American and European) as closely as possible. However, it was not possible to ensure that the samples were cut no later than 7 days after manufacturing – as a buyer no information regarding date of production is available. The products were thus preserved in their original packaging until the samples were cut. On arrival, the packages in which the items were shipped were opened briefly to identify the products, then resealed. All the products were additionally packed using plastic and/or cardboard packing materials within the packages.

The products were stored for 7 to 34 days before being cut up and sent away for analysis. The procedure of cutting the products took a total of three days, and the arrival of the samples at the analysis facility (Eurofins Product Testing A/S) was logged four days later. Subsequently, the samples were analysed in the emission chamber within 4 days (DK 1 – DK 7) to 14 days (the remaining products, except EU 3). For a single product (EU 3), 18 days passed between the receipt of the samples and the analysis in the emission chamber. This is due to the fact that the analysis for this product had to be repeated for various reasons. For comparison, the CertiPUR-US requirement is that the sample must be taken no later than 7 days after the foam was manufactured, it must reach the testing laboratory within 14 days, and it must be tested for VOC emissions in the emission chamber within 35 days of receipt of the sample.

The longer a product was allowed to rest before its chemical analysis, the greater the opportunity it had to emit VOCs before the actual chemical analysis performed in this project. For practical (and economic) reasons, however, it was not possible to cut, ship, and analyse each individual product as we received it. Because we do not have any information regarding when the products were manufactured, the time between manufacturing and receipt of each product may well be the longest time period. Similarly, we do not know if the products have been able to emit substances freely for a period of time following manufacturing, or if they were packaged immediately after manufacturing. There are thus significant uncertainties concerning emission; however, these conditions are not any different than those faced by consumers purchasing the products for their own use.

8.2 Analysis method employed

Generally, the emission analyses were performed according to the procedures/standards described in FIGURE 4 below, as well as the particular sampling methods and laboratory analyses specified in FIGURE 5 below. The relative standard deviation (RSD) for the analysis was 22% overall. The expanded uncertainty for TVOCs, UM, is equivalent to 2 x RSD; that is, 44%.

Regulation, protocol or standard	Version	Reporting limit VOC [µg/m³]	Calculation of TVOC	Combined uncertainty[a] [RSD(%)]
EN 16516	October 2017	5	Toluene equivalents	22%
ISO 16000 -3 -6 -9 -11	2006-2011 depending on part	2	Toluene equivalents	22%
ASTM D5116-10	2010	-	-	-

FIGURE 4. The general testing references used by Eurofins Product Testing A/S for the emission chamber analyses. This image was extracted from the original test reports.

Procedure	External Method	Internal SOP	Quantification limit / sampling volume	Analytical principle	Uncertainty[a] [RSD(%)]
Sample preparation	ISO 16000-11:2006, EN16402:2013, CDPH, AgBB, EMICODE	71M549810	-	-	-
Emission chamber testing	ISO 16000-9:2006, EN 16516:2017	71M549811	-	Chamber and air control	-
Sampling of VOC	ISO 16000-6:2011, EN 16516:2017	71M549812	5 L	Tenax TA	-
Analysis of VOC	ISO 16000-6:2011, EN 16516:2017	71M542808B	1 µg/m³	ATD-GC/MS	10%
Sampling of aldehydes	ISO 16000-3:2011, EN 16516:2017	71M549812	35 L	DNPH	-
Analysis of aldehydes	ISO 16000-3:2011, EN 717-1, EN 16516:2017	71M548400	3-6 µg/m³	HPLC-UV	10%
Sampling of dichloromethane	ISO 16200-1	71M549812	60 L	Charcoal	-
Analysis of dichloromethane	ISO 16200-1	71M542404	1 µg	GC-FID	10%

FIGURE 5. The general specific sampling methods and laboratory analyses used by Eurofins Product Testing A/S for the emission chamber analyses. This image was extracted from the original test reports.

8.2.1 Testing parameters used for emission chamber analyses

The testing parameters in effect for all 20 emission chamber analyses were:

- The use of a 119-litre emission chamber
- An air exchange rate of 0.5 per hour
- Relative humidity (RH) of 50 ± 3% for the replacement air
- Temperature of 23 ± 1°C for the replacement air

8.2.2 Preparation of test materials

The material for each test was compressed in the emission chamber 10 times before beginning the analysis. The sample was placed in the emission chamber with its outer face downward; that is, with the exterior material on the top and bottom, so four PU foam surfaces were

exposed, as shown in the example images below (FIGURE 6). Thus, the height of the product determines how much PU foam is exposed in the emission chamber.

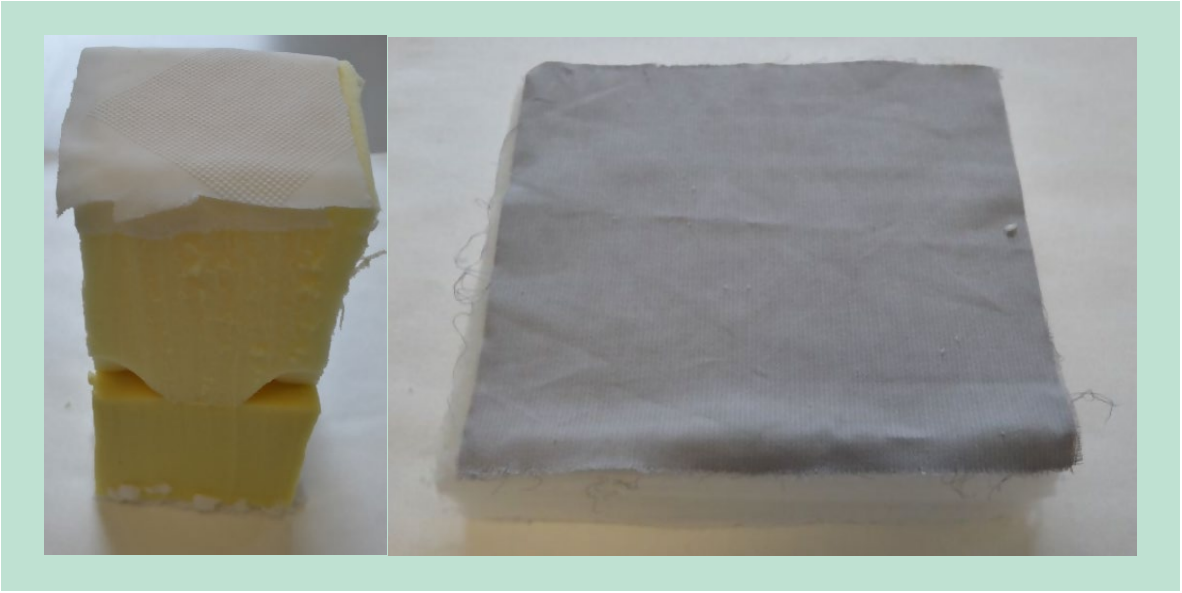

FIGURE 6. Examples of samples before being placed in the emission chamber. The sample to the left is approx. 20 cm tall (a thick mattress), while the sample to the right is only approx. 4 cm thick (cot bumper). The image also shows that the sample to the left consists of a total of six layers: two thin layers on top, two layers of foam, and two layers on the bottom.

8.2.3 Description of VOC emission tests

Emission of volatile compounds was conducted in 119-litre, stainless steel emission chambers, following established testing methods (ISO 16000-9 and EN 16516) for material emission at 23°C, 50% relative humidity, and an air exchange rate of 0.5 per hour. VOC sampling and analysis were performed according to ISO 16000-6, while aldehyde sampling and analysis were performed according to ISO 16000-3. Dichloromethane sampling and analysis were performed using charcoal sorbent tubes according to ISO 16200-1.

Before the sample was placed in the emission chamber, blank samples were taken using the relevant collection media to ensure that the chamber was completely clean.

Samples were extracted from the emission chamber after one hour and after 3 days, using the relevant collection media. For the VOC analyses, 2.5 L and 5 L of air were collected with Tenax at flow rates of 87 and 45 mL/min, respectively; for the carbonyl analyses, 35 L of air were collected with 2,4-dinitrophenylhydrazine coated silica tubes (DNPH tubes) at a flow rate of 330 mL/min. Charcoal sorbent tubes were used to collect 60 L of air at a flow rate of 400 mL/min. All sampling is accredited.

All test results are calculated as specific emission rates (SERs) and as extrapolated air concentrations according to the European Reference Room (EN 16516, AgBB, EMICODE, M1, and Indoor Air Comfort).

8.2.3.1 ISO 16000-6 Screening analyses for emitted substances from emission chamber tests under ATD-GC/MS

The VOCs collected wit Tenax were thermally desorbed (TD) and analysed by gas chromatography paired with mass-selective detection (GC/MS) using a Markes-Agilent system with a 30 m HP-5 GC column.

The identities of the VOCs were identified by NIST library searches with greater than 80% MS spectrum correspondence. The standard prescribes that if the identity of a substance (VOC) cannot be established at a probability greater than 80%, the substance should be listed as "unidentified".

The identified VOCs, VVOCs, and SVOCs at concentrations above 5 µg/m^3 are quantified and reported as both toluene equivalents and specific concentrations; cf. EN 16516. The limit of detection (LOD) varies across substances, but is typically 1-10 ng for Tenax media, corresponding to 1.0-2.5 µg/m^3 in air after collecting 5 litres of air. When collecting 2.5 L of air, the limit of detection is 2.0-5.0 µg/m^3. The analytical uncertainty for VOCs varies across substances but is within about 20% RSD (relative standard deviations). Determinations for components with uncertainties < 10% are accredited; others are not.

In general, all individual substances whose LCI/NIK[24] (lowest concentration of interest) values are specified in the latest relevant publications were identified if present.

VOC, VVOC, and SVOC are defined as follows in this context:

- VOC: volatile organic compound. Defined as all emitted substances from n-hexane (n-C6) to n-hexadecane (n-C16), inclusive.
- VVOC: very volatile organic compound. Defined as all substances emitted before n-hexane (n-C6).
- SVOC: semi-volatile organic compound. Defined as all substances emitted after n-hexadecane (n-C16) up to and including n-docosane (n-C22).
- TVOC: total volatile organic compounds. Defined in this context as the sum of all individual VOCs with a concentration of 5 µg/m^3 or greater.

8.2.3.2 ISO 16000-3: Determination of volatile carbonyls (aldehydes and ketones) collected in 2,4-dinitrophenylhydrazine coated silica tubes (DNPH tubes)

The derivatised carbonyls were eluted with acetonitrile and analysed under HPLC with UV detection. They were identified by retention time and UV spectrum, and quantified using calibrated reference substances. The limits of detection are 0.04 µg for formaldehyde and acetaldehyde, 0.1 µg for butanal, 0.08 µg for acrolein and propanal, and 0.5 µg for crotonaldehyde in DNPH media. The analytical uncertainty for carbonyls is 10% RSD (relative standard deviations); that is, the total uncertainty is 20%. This method is accredited.

8.2.3.3 ISO 16200-1: Determination of dichloromethane collected in charcoal sorbent tubes

The charcoal sorbent tubes were eluted with DMF and analysed under gas chromatography paired with a flame ionisation detector (GC/FID) in an Agilent system. Two 4 m columns were used: 10% Carbowax 1500 on Chromosorb HP, and 10% Carbowax on Chromosorb + 10% DIDP on Chromosorb HP, mixed at a 1:1 ratio. The analytical uncertainty is 10% RSD (relative standard deviations); that is, the total uncertainty is 20%. This method is accredited.

8.3 Results — emission analyses

For each of the 20 PU foam products chosen, emission analyses were performed after 1 hour, and again after 3 days. This resulted in a very large volume of data, because between approx.

[24] LCI, which stands for lowest concentration of interest, is a value used in indoor climate contexts. The lower the LCI, the more concerning the substance is from a health perspective. NIK is the German equivalent of the European LCI value.

10 and 30 unique substances were emitted from each product after 1 hour, and between approx. 1 and 18 unique substances were emitted from each product after 3 days. For this reason, not all data are presented in this report; rather, individual parameters were selected and reported on below. These are as follows:

1. Overview of all substances identified as emitted from one or more samples
2. Graphical overview of the total VOC (TVOC), SVOC (TSVOC), and aldehyde concentrations emitted from 20 samples
3. Graphical overview of the total concentration of emitted substances distributed across DK, EU, and N-EU products
4. Odour observed from samples relative to the total emission of substances from samples
5. Comparison of emitted concentrations with certification programme limit values

These overviews are presented in sections 8.3.1 through 8.3.5, below.

It should be noted that in this report, the specific concentrations of the emitted substances (corresponding to the "Specific Conc." column in the analysis reports; see Appendix 2 for further details) are reported. For comparison, the CertiPUR programmes use the total concentration of emitted VOCs (TVOC) given in toluene equivalents; that is, calculating the concentration of emitted substances as if they were exclusively toluene. Toluene-equivalent emission is not reported in this report, but both values are presented in the comparison of limit values in the certification programmes.

It should additionally be noted that the emission chamber emission analysis standard prescribes that the results be specified for a specific loading factor of 0.4 m^2/m^3, a ratio of surface area (for five sides of the sample, excluding the bottom) to chamber volume. All the results reported are thus adjusted to this particular loading factor, making it immediately possible to compare the results for individual samples in spite of their differences in size (differences in sample cutting and differences in sample height).

8.3.1 All substances identified as emitted from one or more samples

The substances presented in the table below (TABLE 12) are all the substances identified as emitted from one or more of the PU foam samples after 1 hour. A total of 75 unique substances were identified as emitted from PU foam (from one or more samples). Seven rows in the table indicate sums for different groups of substances, or for unidentified substances. Thus, a total of 68 unique chemical substances were identified as substances emitted from PU foam after 1 hour. It should be noted that 38 of the 68 substances were not identified again after 3 days. Meanwhile, five other substances were identified after 3 days which were not identified after 1 hour. However, these five substances typically were emitted from only one product, in low concentrations. The single exception was 2-ethylhexanoic acid, identified as emitted from 3 out of 20 products. These substances are listed below, in TABLE 13, immediately following TABLE 12.

The substances in TABLE 12 are listed in descending order by emitted concentration. In the column furthest to the right, it is also noted whether the substance was identified in PU foam in the Danish EPA's survey of squishies (Klinke et al., 2018).

TABLE 12. Substances identified as emitted after 1 hour from one or more PU foam samples

CAS no.	Substance name	Highest conc. (µg/m³)	Lowest conc. (µg/m³)	Number of product sub-stances emitted from after 1 hour	Sub-stance also ob-served emitted after 3 days	Substance also emit-ted from squishies after 1 hour[25]
-	TVOC (sum of all VOCs)	1900	10	20	Yes	Yes
68-12-2	Dimethylformamide	1500	3.5	6	Yes	Yes
-	Saturated aliphatic hydro-carbons greater than C9	340	46	10	Yes	-
13475-82-6	2,2,4,6,6-Pentame-thylheptane	240	2.6	12	Yes	No
64-19-7	Acetic acid	200	17	4	Yes	No
541-02-6	Decamethylcyclopenta-siloxane	190	3.3	16	Yes	Yes
556-67-2	Octamethylcyclotetra-siloxane	150	11	6	No	Yes
78-40-0	Triethylphosphate	120	120	1	Yes	Yes
104-76-7	2-ethyl-1-hexanol	94	3	8	Yes	No
540-97-6	Dodecamethylcyclohex-asiloxane	87	2.1	11	Yes	Yes
280-57-9	Triethylenediamine	84	84	1	Yes	Yes
34590-94-8	Dipropylene glycol methyl ether	70	23	2	Yes	No
123-38-6	Propionaldehyde	63	0	1	Yes	Yes
-	Sum of unidentified VOCs > C9	57	10	3	Yes	-
13466-78-9	3-Carene	49	2.6	15	Yes	Yes
108-88-3	Toluene	44	2.2	16	Yes	Yes
15176-21-3	1,4-Dioxane, 2,5-dime-thyl- *	42	3.5	3	No	No
-	Unidentified	41.1	2.2	13	Yes	-
80-56-8	α-Pinene	40	3.1	20	Yes	Yes
-	TSVOC	32	0	5	Yes	Yes
593-45-3	n-Octadecane	32	32	1	No	No
3333-52-6	Tetramethylbutanedinitrile	29	24	2	Yes	Yes
141-63-9	Dodecamethylpentasilox-ane	28	3.3	5	Yes	No
-	Other alkylbenzenes	27	2.1	3	No	-
21460-36-6	2-Propanol, 1-(2-pro-penyloxy)-	27	2.2	3	Yes	Yes
629-59-4	n-Tetradecane	21	2.1	3	Yes	Yes
71-36-3	1-Butanol	19	2.3	15	No	Yes
50-00-0	Formaldehyde	18	0	14	Yes	Yes

[25]These data originate from the screening performed in the project "Investigation and risk assessment of perfume and other organic substances in squishy toys" (Klinke et al., 2018)

CAS no.	Substance name	Highest conc. (µg/m^3)	Lowest conc. (µg/m^3)	Number of product sub-stances emitted from after 1 hour	Sub-stance also ob-served emitted after 3 days	Substance also emit-ted from squishies after 1 hour[25]
-	Sum of unidentified SVOCs > C16	17	17	1	No	-
616-38-6	Carbonic acid, dimethyl ester	17	17	1	No	Yes
179601-23-1	m/p-Xylene	15	2.2	10	No	Yes
541-05-9	Hexamethylcyclotrisilox-ane *	15	8.3	2	No	Yes
107-52-8	Hexatetradecame-thylsiloxane *	15	15	1	Yes	No
66-25-1	Hexanal	14	2	18	Yes	No
108-95-2	Phenol *	12	2.4	6	Yes	Yes
78-93-3	Methylethylketone (MEK)**	12	2.1	3	No	Yes
123-86-4	Butyl acetate	11	2.6	4	No	Yes
470-82-6	Eucalyptol	10	10	1	No	No
75-07-0	Acetaldehyde	9.5	0	2	No	Yes
112-40-3	n-Dodecane	9.1	2.2	9	Yes	Yes
141-32-2	Butylacrylate	8.2	2.6	2	No	No
629-50-5	n-Tridecane	8	2.1	4	Yes	Yes
2460-77-7	2,5-di-tert-Butyl-1,4-ben-zoquinone	7.9	7.9	1	Yes	No
95-47-6	o-Xylene	7.6	2.4	2	No	Yes
89-78-1	Menthol	7.4	7.4	1	No	No
475-20-7	Longifolene	7.3	2.4	3	Yes	No
141-62-8	Decamethyltetrasiloxane	7.2	3	3	No	No
127-18-4	Tetrachloroethylene	7.2	2.2	2	No	No
98-83-9	α-Methylstyrene	6.6	2.4	2	Yes	No
128-37-0	Butylhydroxytoluene BHT	6.5	2.2	2	Yes	Yes
1000215-29-0	cis-3-Methyl-endo-tricy-clo[5,2,1,0(2,6)]decane	6.1	6.1	1	No	No
103-11-7	2-Ethylhexyl acrylate	6	6	1	Yes	No
57-55-6	1,2-Propandiol (Propylene glycol)	5.8	5.8	2	No	Yes
1120-21-4	n-Undecane	5.7	2	5	No	Yes
1137-12-8	Longicyclene	5.6	3.1	2	Yes	No
100-42-5	Styrene	5.4	2.2	4	No	Yes
95-50-1	1,2,-Dichlorobenzene	5.4	5.4	1	No	No
106-46-7	1,4-Dichlorobenzene	5	5	1	No	No
100-41-4	Ethylbenzene	4.5	4.5	1	No	Yes
108-94-1	Cyclohexanone	4.4	2.5	5	Yes	Yes
95-63-6	1,2,4-Trimethylbenzene	4.4	2.7	2	No	Yes

CAS no.	Substance name	Highest conc. (µg/m³)	Lowest conc. (µg/m³)	Number of product substances emitted from after 1 hour	Substance also observed emitted after 3 days	Substance also emitted from squishies after 1 hour[25]
-	Total of carcinogenic substances	4.3	0	1	No	-
107-06-2	1,2-Dichloroethane	4.3	4.3	1	No	Yes
629-62-9	n-Pentadecane	3.6	2.7	3	Yes	Yes
617-94-7	2-Phenyl-2-propanol	3.3	3.3	1	No	No
138-86-3	Limonene	3	2.3	4	No	No
124-18-5	n-Decane	2.9	2.9	1	No	Yes
142-82-5	n-Heptane	2.7	2.2	2	No	Yes
100-52-7	Benzaldehyde	2.7	2.7	1	No	Yes
25265-77-4	Texanol	2.7	2.7	1	Yes	No
5131-66-8	1-Butoxy-2-propanol	2.6	2.6	1	No	No
127-91-3	β-Pinene	2.5	2.5	1	No	Yes
103-65-1	n-Propylbenzene	2.5	2.5	1	No	Yes
107-41-5	Hexylene glycol (2-methyl-2,4-pentanediol)	2.4	2.4	1	No	No
1135-66-6	Isolongifolene	2.3	2.3	1	No	Yes

* indicates that values may be overestimated due to contributions from system
** actual values may be higher; method is not optimal for highly volatile substances

TABLE 13. Substances identified as emitted from PU foam samples after 3 days, but not after 1 hour

CAS no.	Substance name	Greatest conc. (µg/m³)	Least conc. (µg/m³)	Number of product substances emitted from after 3 days	Substances also emitted from squishies after 1 hour
108-32-7	Propylene carbonate	110	110	1	Yes
	Saturated aliphatic hydrocarbons > C16	18	18	1	-
29911-82-2	Dipropylene glycol mono-n-butylether	16	16	1	No
62183-79-3	2,2,4,4-Tetramethyloctane	8.9	8.9	1	No
149-57-5	2-ethylhexanoic acid	7.9	5.8	3	No
544-76-3	n-Hexadecane	2.3	2.3	1	No

It can be seen from TABLE 12 and TABLE 13 that many of the same substances (41 out of 68) are identical to the substances identified as emitted from PU foam in squishes (Klinke et al., 2018).

8.3.2 Substance groups identified from the 20 samples

FIGURE 7 below presents an overview of the total concentrations of substances emitted from the 20 PU foam products after 1 hour, and again after 3 days. It can be seen that there are large differences in the total concentrations of emitted substances. The highest emission was

from N-EU 3, with a total concentration of 1905 µg/m^3 after 1 hours, and 410 µg/m^3 after 3 days. The lowest emission was from DK 3, with a total concentration of 36 µg/m^3 after 1 hour; and from DK 7, with a total concentration of emitted substances of 3 µg/m^3 after 3 days.

Overall, it is quite clear that the concentration of emitted substances decreases from the initial 1-hour measurement to the later 3-day measurement. On average, the concentration of emitted substances decreases by 58% from 1 hour to 3 days. However, this figure encompasses major variations, with the drop in concentration from 1 hour to 3 days ranging from -53% to +99%. In two products (DK 10 and N-EU 6), a *higher* concentration of emitted substances was found after 3 days compared to the 1-hour measurement. There was a 2% increase for DK 10, which may be explained by analytical uncertainties, while there was a 53% increase for N-EU 6.

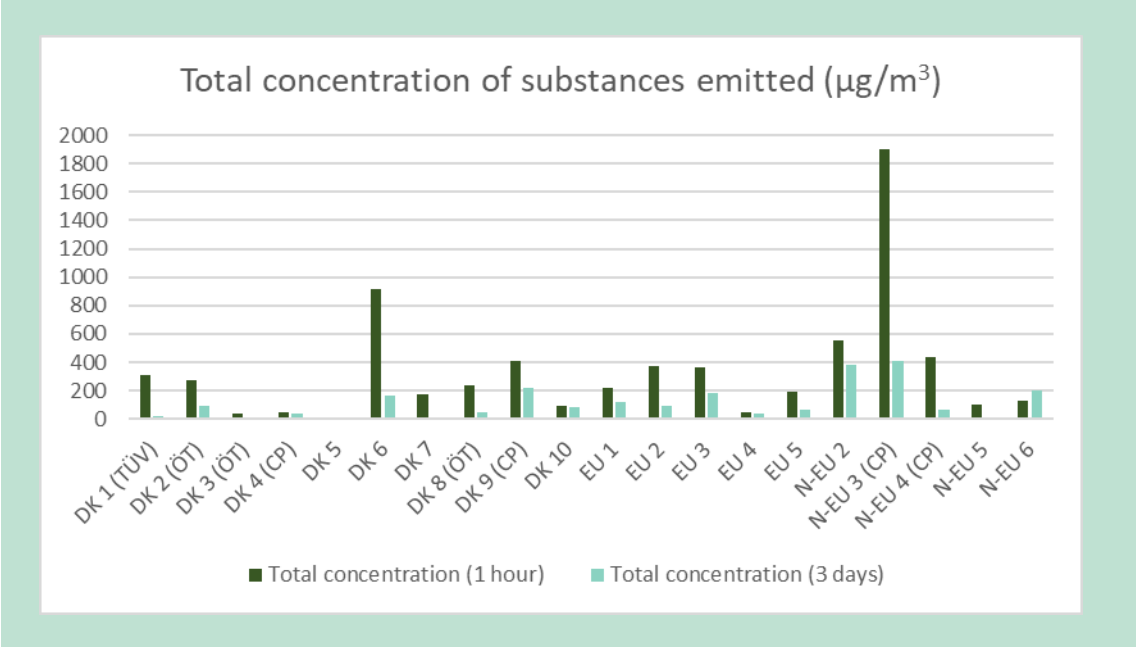

FIGURE 7. The total concentration of substances (in µg/m^3) emitted from the 20 PU foam products after 1 hour (dark green) and 3 days (light green). Product certifications are indicated in parentheses: TÜV = TÜV Rheinland, CP = CertiPUR, ÖT = Oeko-Tex certified.

The total concentration of substances emitted from PU foam products covers the following substance categories:

- VOC
- SVOC
- Aldehydes (primarily formaldehyde, but also acetaldehyde and propionaldehyde in some cases)

Thus, in the following figures (FIGURE 8, FIGURE 9, and FIGURE 10), the distribution between the individual substance types is illustrated. VOCs are given in a separate figure because they clearly represent the highest emitted concentrations from the products. The diagram in FIGURE 8 closely resembles the diagram in FIGURE 7 for this reason.

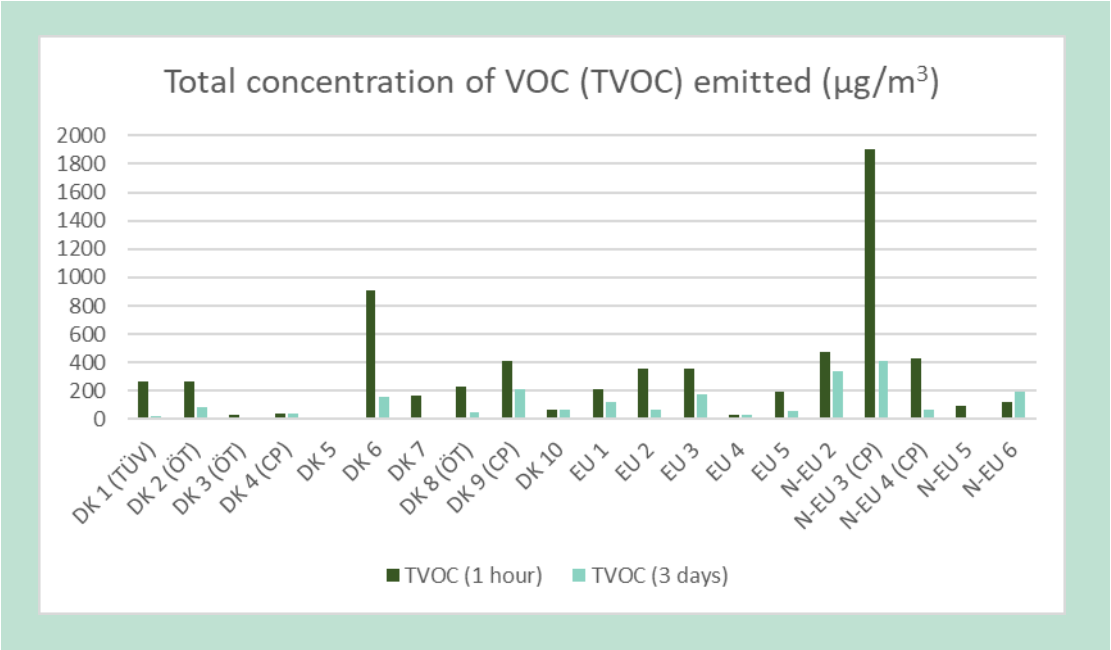

FIGURE 8. The total concentration of VOCs (in µg/m^3) emitted from the 20 PU foam products after 1 hour (dark green) and 3 days (light green). Product certifications are indicated in parentheses: TÜV = TÜV Rheinland, CP = CertiPUR, ÖT = Oeko-Tex certified.

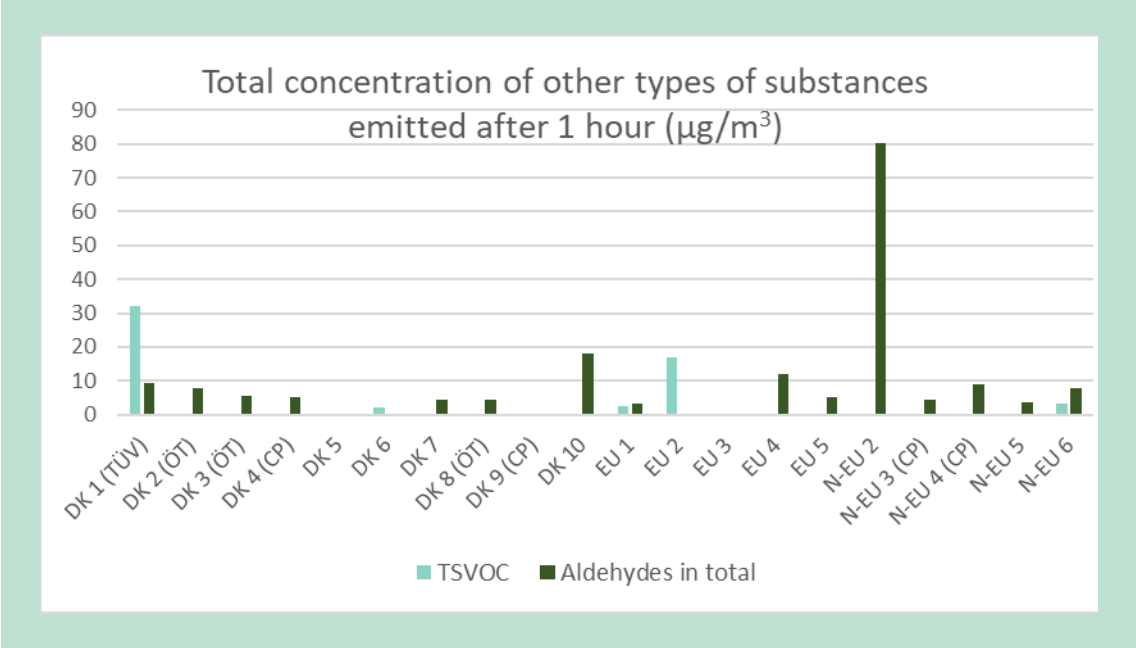

FIGURE 9. The total concentrations of aldehydes and SVOCs (in µg/m^3) emitted from the 20 PU foam products after 1 hour. Product certifications are indicated in parentheses: TÜV = TÜV Rheinland, CP = CertiPUR, ÖT = Oeko-Tex certified.

Due to considerations of space, the total concentrations of aldehydes and SVOCs at 1 hour and at 3 days are shown in separate figures.

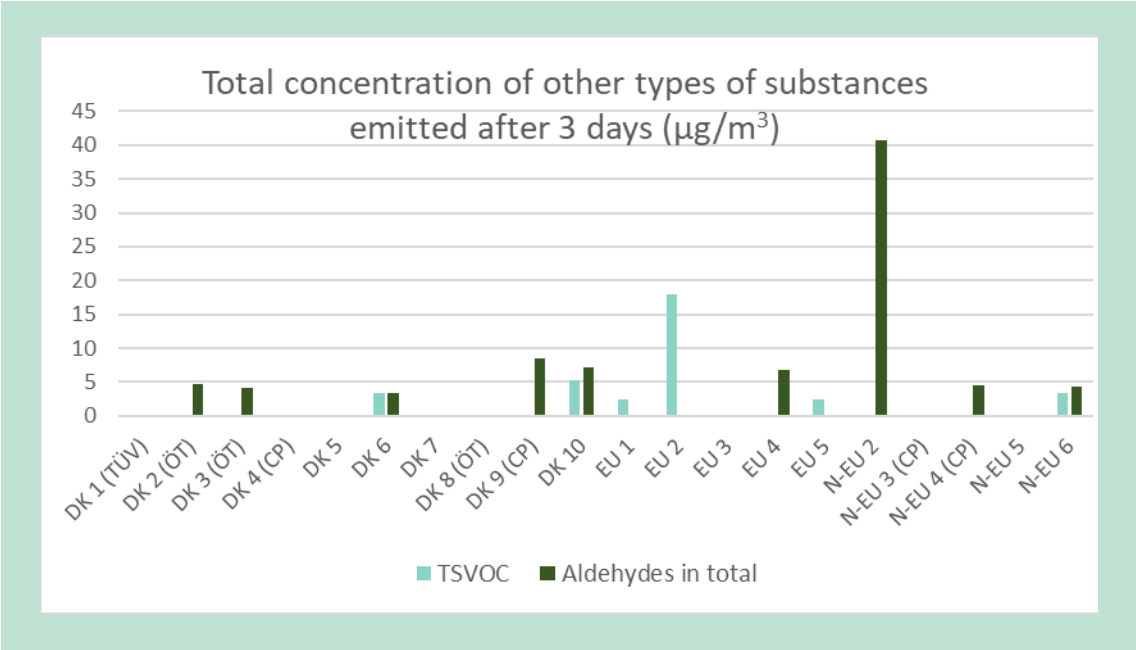

FIGURE 10. The total concentrations of aldehydes and SVOCs (im µg/m^3) emitted from the 20 PU foam products after 3 days. Product certifications are indicated in parentheses: TÜV = TÜV Rheinland, CP = CertiPUR, ÖT = Oeko-Tex certified.

Both the CertiPUR certification programmes and the TÜV Rheinland certification programme include a maximum emission requirement for the sum of CMR 1A- and 1B-classified substances. Based on the classifications of these substances (both the harmonised and the notified classifications (see chapter 9 "Initial hazard assessment")), it was investigated which of the emitted substances that are classified in the CMR categories 1A and 1B. These substances are:

- Formaldehyde (categorised under aldehydes in the figures above)
- Acetaldehyde (categorised under aldehydes in the figures above)
- 1,2-dichloroethane – is not a part of the figure above (small amount and only for one single product)
- Dimethylformamide (categorised under VOCs in the figures above)

Of these four CMR 1A and 1B substances, only formaldehyde and dimethylformamide continue to be emitted after 3 days. The total emission of substances in CMR categories 1A and 1B is given in FIGURE 11 below. It should be noted here that product N-EU 3 emitted a significantly higher amount of CMR 1 substances than all other products. This is due to major emission of dimethylformamide after both 1 hour (1500 µg/m^3) and 3 days (390 µg/m^3).

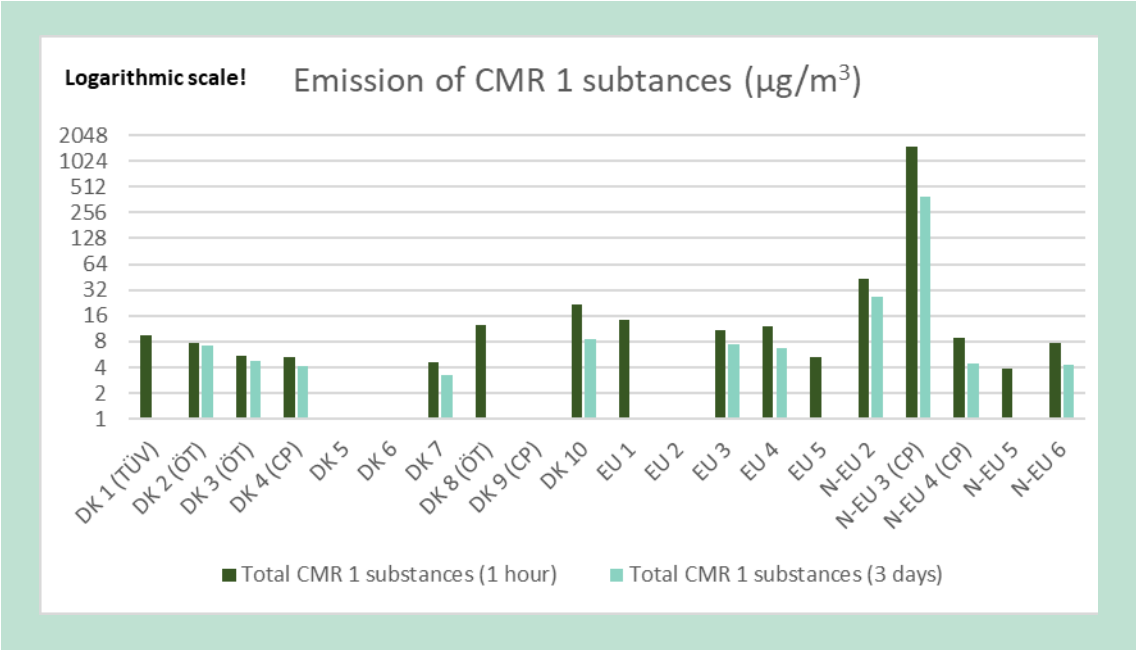

FIGURE 11. Overview of total emission of substances in CMR categories 1A and 1B after 1 hour and after 3 days.

8.3.3 Comparison of emitted substances from DK, EU, and N-EU products

FIGURE 12 and FIGURE 13 below illustrate the difference in the average amount of emitted substances from products purchased in Denmark (DK), in the EU but outside of Denmark (EU), and outside of the EU (N-EU) after 1 hour. In FIGURE 12, the emission of VOCs and the total emission (i.e., TVOCs, TSVOCs, aldehydes, and carcinogens) are compared. In FIGURE 13, the average emission of TSVOCs and aldehydes after 1 hour is shown.

The comparison should be regarded with a certain reservation, since the average of the Danish products is based on 10 products, while the EU and N-EU figures are based on only five products. This means that a single outlier for the EU and N-EU products has a greater influence on the value of the average.

In the figures, a black double arrow indicates the variation in the actual total concentration values within the DK, EU, and N-EU product categories after 1 hour. As shown in the figure, there is a significant variation in the total emitted concentrations from both DK and N-EU products, while the values of the total emitted concentrations for EU products lie relatively close to one another.

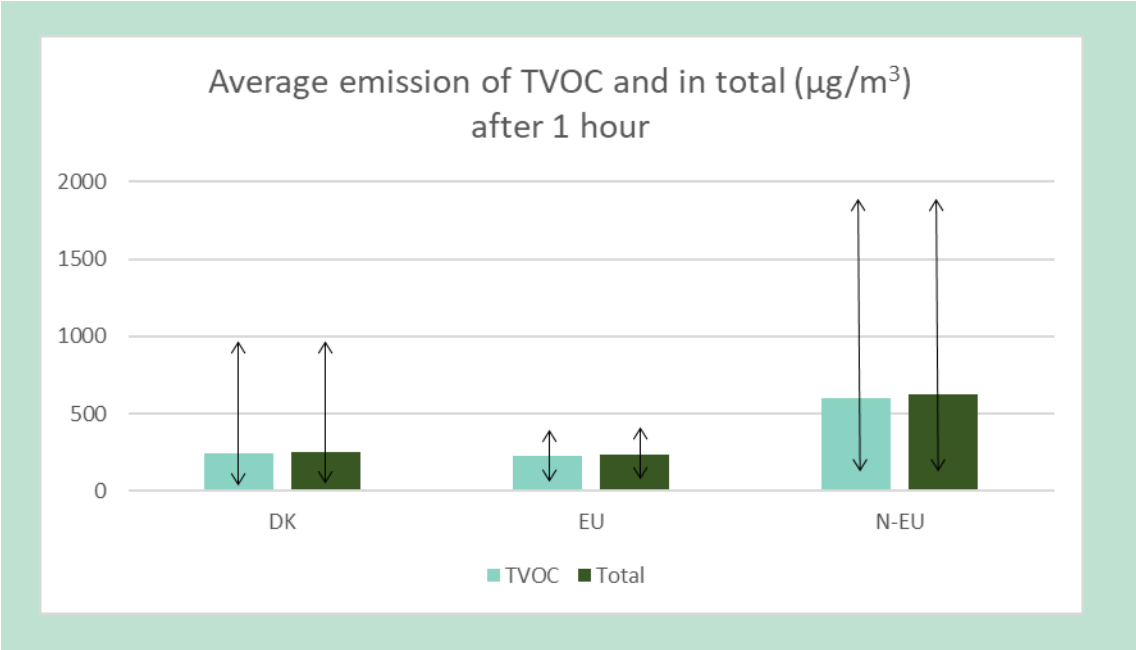

FIGURE 12. Average emission of TVOCs, and total emission from products purchased in Denmark, in the EU, or outside the EU (N-EU).

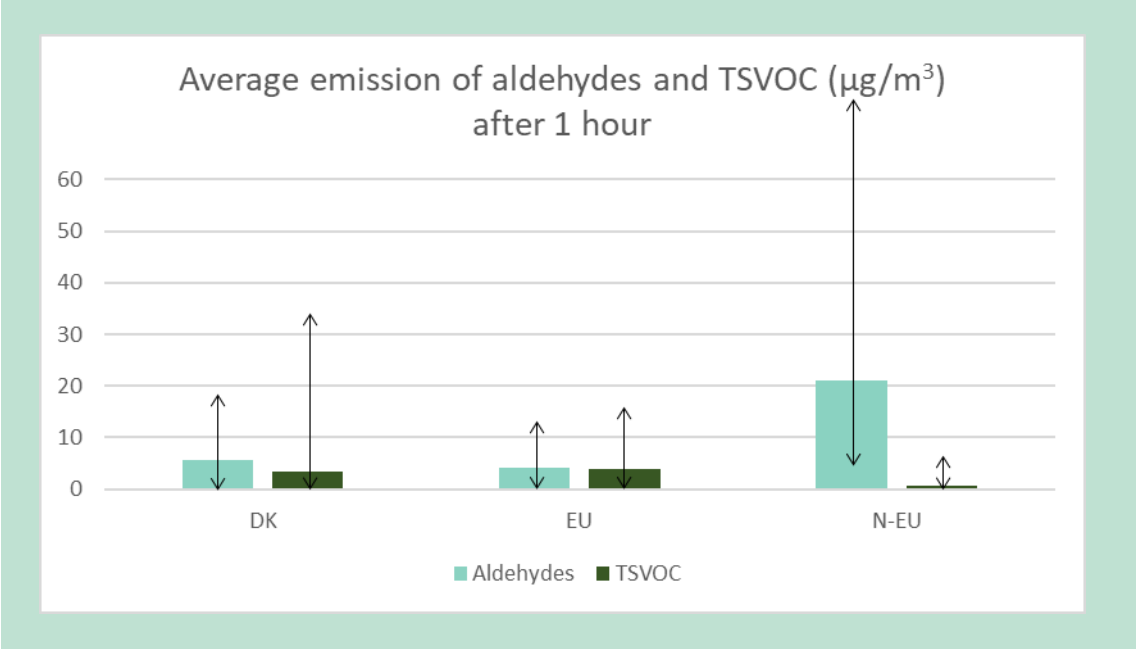

FIGURE 13. Average emission of aldehydes and TVOCs from products purchased in Denmark, in the EU, or outside the EU (N-EU).

It can be seen in these figures that overall, emission of substances from N-EU products is higher than that from EU and DK products (approximately twice as much). Emission levels from EU and DK products are largely the same. The graphs show only the total emission; there is no indication of which substances are involved, or whether the substances are harmful to health. It can also be seen that even though the total emission is higher on average for N-EU products, there is significant variation, including products with low values. One single N-EU product (N-EU 3) has a total emission of TVOC that is almost four times as high as the second

highest emitting N-EU product. Is N-EU 3 not included in the average, the average of the N-EU products is still about 16% higher in total emission compared to the DK and EU products. Moreover, the N-EU product with the lowest total emission still has a significant higher emission compared to the DK and EU products with the lowest emission.

8.3.4 Odour from samples in relation to total emission

As the products were being cut for chemical analyses, the odours from the PU foam itself were also recorded. It should be noted that odours were only recorded as the products were being cut, and not after 3 days. Odours were recorded by the two people responsible for cutting the products, not e.g. people from a trained odour detection panel.

Overall, there were major differences in how much of an odour was emitted from the PU foam. Odour descriptions are given in TABLE 14 below. There may be major differences between which organic substances that smell and how much they smell. For example, some substances have very low odour thresholds, while others have essentially no odour even at high concentrations. No further investigation was performed into which substances gave off a particular odour. In spite of these conditions, the odour descriptions and total concentrations of organic substances emitted from PU foam samples are generally well correlated.

TABLE 14. Sample odours compared with total emitted substance concentrations from PU foam samples after 1 hour

Product	Emitted aldehydes (µg/m³)	Emitted TSVOCs (µg/m³)	Emitted TVOCs (µg/m³)	Total emitted conc. (µg/m³)	Description of sample odour
DK 1 (TÜV)	9.5	32	270	312	Faint, sweet chemical odour
DK 2 (ÖT)	7.7	0	270	278	Faint acidic odour
DK 3 (ÖT)	5.5	0	30	36	Very faint neutral odour
DK 4 (CP)	5.3	0	41	46	Faint acidic odour
DK 5	0	0	10	10	Chemical odour; mild, but more than faint Slightly sweet odour
DK 6	0	2.1	910	912	Has some odour, but perhaps mostly from the plastic on top of the mattress
DK 7	4.6	0	170	175	Faint, slightly sweet odour
DK 8 (ÖT)	4.6	0	230	235	Smells faintly of chemicals
DK 9 (CP)	0	0	410	410	Faint chemical odour
DK 10	18	0	71	89	Very faint chemical odour
EU 1	3.4	2.4	210	216	Very faint chemical odour
EU 2	0	17	360	377	Chemical odour
EU 3	0	0	360	360	Faint odour; slightly chemical
EU 4	12	0	34	46	Faint chemical odour
EU 5	5.3	0	190	195	Smells terribly unpleasant; very strong chemical odour
N-EU 2	80.2	0	470	555*	Very chemical
N-EU 3 (CP)	4.3	0	1900	1904	Chemical odour
N-EU 4 (CP)	8.9	0	430	439	Faint, slightly sweet chemical odour
N-EU 5	3.8	0	94	98	Slight acidic, chemical odour

Product	Emitted aldehydes (µg/m³)	Emitted TSVOCs (µg/m³)	Emitted TVOCs (µg/m³)	Total emitted conc. (µg/m³)	Description of sample odour
N-EU 6	7.7	3.3	120	131	Neutral odour; has essentially no smell

TÜV = TÜV Rheinland, CP = CertiPUR, ÖT = Oeko-Tex certified

* Here, the total emitted concentration is not completely in line with the sum of emitted aldehydes, TSVOCs and TVOCs. This is due to the fact that a low amount of a substance from a fourth category, which has not been described in this report, as it only was identified emitting from this single product.

8.3.5 Comparison of certification programme limit values

To evaluate whether emitted substances were present in high or low concentrations, a selection of emitted substances from TABLE 15 was compared with the limit values from the various certification programmes (CertiPUR-US, CertiPUR, and TÜV Rheinland) as described in chapter 4, "PU foam certification programmes".

It should be noted that the limit values of the certification programmes apply to emission after 3 days, for which reason the corresponding values were used in the comparison. However, certain limit values for the TÜV Rheinland certification programme apply only after 7 days; these were nonetheless compared against the 3-day values from this project. Another difference between the methods is that the analysed samples in this project were compressed several times in the emission chambers before being closed. This is not the procedure used in the certification programmes.

Additionally, the certification programmes specify the total concentration of emitted VOCs (TVOCs) in toluene equivalents, not as the specific concentration of individual substances, as otherwise presented in this report. For this reason, the emitted TVOC values are also given in toluene equivalents below, in TABLE 15.

TABLE 15. Comparison of highest measured emitted values from PU foam products in this project, compared with certification programme limit values. Values are emitted values after 3 days. Values in boldface are toluene equivalents.

Substance name	CAS no.	Measured values (in number of prod.) (µg/m³)	CertiPUR-US limit value (µg/m³)	CertiPUR limit value (µg/m³)	TÜV Rheinland limit value (µg/m³)
Formaldehyde	50-00-0	3.3 - 8.4 (9)	100	10	10
Toluene	108-88-3	11 (1)	500	100	3.5*
Styrene	100-42-5	0 (0)	300	5	6.5**
Tetramethyl-butanedinitrile	3333-52-6	8.4 - 15 (3)	-	-	2.5**
TVOC	-	2 – 410 (19) **Toluene equiv. < 2 - 270**	500	500	15**

Substance name	CAS no.	Measured values (in number of prod.) (µg/m³)	CertiPUR-US limit value (µg/m³)	CertiPUR limit value (µg/m³)	TÜV Rheinland limit value (µg/m³)
Sum of CMR 1A and 1B	-	7.5 – 27 – 390*** **Toluene equiv. 7.5 – 13 - 100** (11)	Prohibited	40	Carc. 1B: 1.5 Repr. 1B: 2.5

* Applies only as a sum of all category 2 CMR substances
** Requirement applies after 7 days, not after 3 days
*** The specification 7.5 – 27 – 390 here means that for the 10 products, the total concentration of CMR 1A/1B substances lies between 7.5 and 27 µg/m³, but a single product (N-EU 3) had a value of 390 µg/m³.

It can be seen in TABLE 15 that all 20 products met the requirements for the two CertiPUR programmes concerning the total concentration of emitted VOCs (TVOC). The requirement here is 500 µg/m³ (or 0.5 mg/m³), and all 20 products fell below this value after 3 days (between 2 and 410 µg/m³). TÜV Rheinland's TVOC requirement is much lower, at 15 µg/m³, but this requirement applies only after 7 days. Because 7-day measurements were not carried out in this project, no conclusions can be drawn as to whether or not this requirement was met. Similarly, TÜV Rheinland has a tetramethylbutanedinitrile requirement for which compliance cannot be assessed because it, too, applies only after 7 days. There were three N-EU products that emitted tetramethylbutanedinitrile (N-EU 3, N-EU 4, and N-EU 5).

Specific limit values are given for styrene and toluene in all certification programmes. It can be seen that the requirements of the CertiPUR programmes were met by all 20 products; however, one product (DK 9) did not meet the more stringent toluene and styrene requirements of TÜV Rheinland. Toluene was emitted after 3 days at a concentration of three times the limit value.

All 20 products were within the established limit values for formaldehyde emission after 3 days.

The certification programmes impose different requirements for the sum of CMR substances in classifications 1A and 1B. In all, for the 20 products analysed, emission of three unique Carc. 1B substances (including formaldehyde) and one Repr. 1B substance was identified after 1 hour. No Mut. 1A/1B substances were found. Overall, we can see that CMR 1A/1B substances were emitted from nearly all products (16 out of 20), but this is due to the fact that formaldehyde (Carc. 1B) was emitted in small amounts from 14 of the 20 products after 1 hour. For a single product (N-EU 3), emission of dimethylformamide (Repr. 1B) was especially high (1500 µg/m³). Concentrations otherwise tended to remain under 20 µg/m³ for the other CMR 1A/1B substances. Common to all products, however, was the fact that the concentration of these CMR 1A/1B substances dropped significantly after 3 days, the point in time at which the certification programmes impose limit values on CMR 1A/1B substances. Only formaldehyde (Carc. 1B) and dimethylformamide (Repr. 1B) were also emitted after 3 days. Formaldehyde from nine products was present at concentrations up to 8 µg/m³, and dimethylformamide from three products was present at concentrations up to 390 µg/m³. Again, N-EU 3 had significantly higher emission levels than the other products (< 20 µg/m³). This means that 19 out of 20 products meet the CertiPUR requirement for CMR 1A/1B substances after 3 days. N-EU 3 had a total emission level far above the limit value, even when measuring emission in toluene equivalents (100 µg/m³). Whether this non-compliance only is related to the differences in the method of analysis used for the certification programmes and the method of analysis used in this project or is an actual higher emission is not known. The CertiPUR-US programme does

not specify a limit value for CMR 1A/1B substances but indicates instead that they are prohibited. TÜV Rheinland uses far lower limit values for CMR 1A/1B substances, of which only nine of 20 products are able to meet its requirements.

Overall, all of the 20 products analysed are able to meet the requirements of both CertiPUR programmes in terms of TVOC and specific substances. One product is not able to meet the CMR 1A/1B substance requirement of the CertiPUR programme. 11 out of 20 products are unable to meet the TÜV Rheinland requirements, but it is unknown whether some products would later fall within the TÜV Rheinland requirements because 7-day measurements were not taken for this project.

11.1 Summary of analysis results

20 emission tests were performed on 20 PU foam products, 10 of which were purchased in Denmark (DK), five of which were purchased in the EU but outside Denmark (EU), and five of which were purchased outside the EU (N-EU). The results revealed major differences in the emission of substances from the products. The highest total emission of substances measured 1 hour after sample unpacking was 1905 µg/m^3, while the lowest emission after 1 hour was 36 µg/m^3.

In general, we can see that the concentration of emitted substances drops from the 1-hour measurement to the 3-day measurement following the unpacking of a sample. On average, the total concentration of the emitted substances decreases by 58% from 1 hour to 3 days. However, this figure encompasses major variations; for a single product, a higher total concentration of emitted substances was observed after 3 days, while another product showed a drop in emission of substances of 99% after 3 days, compared to the 1-hour level. The total emission of chemical substances after 3 days decreases between 3 and 410 µg/m^3.

Relatively few products (10 DK, 5 EU, and 5 N-EU products) were considered in the survey, but on average, emission from N-EU products is higher than that from DK and EU products, which are essentially at the same level in terms of total substance emission. However, one N-EU product has a very high emission, which is resulting in a higher average for the five N-EU products.

Emission levels from the products studied were compared with the requirements in the CertiPUR certification programmes, showing that none of the 20 products studied would have problems complying with the requirements for TVOC and specific substances of the CertiPUR programmes. This is because the limit values for emission of both specific substances and the total concentration of VOCs (TVOC) are far below their limit values in the CertiPUR programmes. The comparison with the CMR 1A/1B substance requirements showed that 19 out of 20 products were able to meet the requirements in the CertiPUR programme (not including the CertiPUR-US programme, which does not set precise requirements here).

The total concentrations of emitted substances after 1 hour were compared with the odours recorded for the products during product cutting. Overall, there is a very strong correlation between the odour descriptions and the total emitted concentrations.

9. Initial hazard assessment

To focus on the most concerning substances in the exposure and risk assessment of the project, an initial hazard assessment was conducted for the substances identified as released in emission from PU foam.

9.1 Hazard assessment approach

This screening-level hazard assessment was based exclusively on the following:

- The classifications of the substances: In general, the harmonised classification is listed. If one does not exist, the most important classifications based on the notified classifications from the ECHA's C&L Inventory[26] are listed. By "the most important classifications" is meant the following classifications:
    - CMR
    - STOT RE
    - STOT SE
    - Acute Tox
    - Skin Sens.
    - Resp. Sens.
- DNEL[27] values for inhalation by consumers as specified in the ECHA's database of registered substances: The value is supplied only if it exists and the substance is registered.
- Measured concentrations emitted from the products: The highest emitted concentration is given, as well as how many of the 20 products the substance was emitted from.

It should be noted that classification indications for substances without a harmonised classification comprise exclusively the classification types listed above. That is, classifications for skin and eye irritation or corrosion, as well as environmental and physical hazard classifications, are not listed.

The result of the initial, screening-level hazard assessment is given in the tables in Appendix 3.

9.2 Selection of substances for risk assessment

The "Priority" column in Appendix 3 primarily indicates whether substances were selected for focus in the subsequent exposure and risk assessment. The following factors were considered when selecting substances:

- Substances have concerning health-related properties, particularly when inhaled; specifically, the following classifications were emphasised:
    - CMR effects
    - Acute Tox 1, 2, and 3 with H330, H331, and H332 respectively, corresponding to "Fatal/toxic/harmful if inhaled"
    - STOT SE 1 and 2 with H370 and H371 respectively, "Causes / may cause damage to organs"
    - STOT SE 3 H335, "May cause respiratory irritation"
    - STOT SE 3 H336, "May cause drowsiness or dizziness"

[26] https://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

[27] DNEL = derived no effect level; that is, the exposure level considered to have no health-related effects.

    - STOT RE 1 and 2 with H372 and H373 respectively, "Causes / may cause damage to organs through prolonged or repeated exposure"
- Substances are emitted at high concentrations, or are emitted from several of the 20 products analysed
- Substances are registered such that data on health-related effects that may be used in the exposure and risk calculations exists

The following eight substances were selected as the focus substances in the subsequent exposure and risk assessment. The eight substances are listed below in TABLE 16. The "classification" column gives the harmonised classification, if one exists. If it exists, it is given in boldface. If a harmonised classification does not exist, the notified classifications are listed instead, and the number of businesses that have notified each classification is given in parentheses. For notified classifications, the focus was on the aforementioned list of classifications.

TABLE 16. Emitted substances selected for subsequent exposure and risk assessment. For more details, see Appendix 3.

Substance name	**CAS no.**	**Highest concentration after 1 hour / 3 days ($\mu g/m^3$)**	**Emitted from, after 1 hour / 3 days (number of prod.)**	**Classification** (Harmonised (boldface) or notified classification with number of notifications in parentheses)	**Reason for priority**
Dimethylformamide *	68-12-2	1500 / 390	6 / 3	**Acute Tox. 4 H312** **Eye Irrit. 2 H319** **Acute Tox. 4 H332** **Repr. 1B H360D**	High concentration and acute toxicity when inhaled. Continued emission after 3 days. On REACH Candidate List due to Repr. 1B.
Decamethylcyclopentasiloxane * (D5)	541-02-6	190 / 4.1	16 / 3	Not classified (2828) Acute Tox. 3 H331 (18) STOT SE 3 H335 (2)	High concentration and emitted from many products. Also emitted after 3 days. However, classification is uncertain.
Octamethylcyclotetrasiloxane (D4)	556-67-2	150 / -	6 / -	**Aquatic Chronic 4 H413** **Repr. 2 H361f**	High concentration and reprotoxic. However, not emitted after 3 days.
2-ethyl-1-hexanol	104-76-7	94 / 60	8 / 8	Acute Tox. 4 H332 (1839) STOT SE 3 H335 (1795) Acute Tox. 4 H312 (66) Skin Sens. 1 H317 (10)	High concentration and present in many products. Continued emission after 3 days.
Dodecamethylcyclohexasiloxane * (D6)	540-97-6	87 / 11	48 / 10	Not classified (242)	In many products. Also emitted after 3 days.
Toluene	108-88-3	44 / 11	16 / 1	**Flam. Liq. 2 H225** **Skin Irrit. 2 H315** **Asp. Tox. 1 H304** **STOT SE 3 H336** **STOT RE 2 H373** **Repr. 2 H361d**	High concentration in many products. Reprotoxic. Also emitted after 3 days, though in few products.

Substance name	**CAS no.**	**Highest concentration after 1 hour / 3 days (µg/m³)**	**Emitted from, after 1 hour / 3 days (number of prod.)**	**Classification** (Harmonised (boldface) or notified classification with number of notifications in parentheses)	**Reason for priority**
α-Pinene *	80-56-8	40 / 5.6	20 / 1	Acute Tox. 4 H302 (86) Asp. Tox. 1 H304 (1064) Skin Sens. 1 H317 (899)	Emitted from many products. However, declines after 3 days. Low DNEL.
Formaldehyde	50-00-0	18 / 8.4	14 / 9	**Acute Tox. 3 H301** **Acute Tox. 3 H311** **Skin Corr. 1B H314** **Skin Sens. 1 H317** **Acute Tox. 3 H331** **Muta. 2 H341** **Carc. 1B H350**	Emitted from many products. Toxic when inhaled; carcinogenic. Also emitted after 3 days.
Phenol *	108-95-2	12 / 13	6 / 7	**Acute Tox. 3 H301** **Acute Tox. 3 H311** **Skin Corr. 1B H314** **Acute Tox. 3 H331** **Muta. 2 H341** **STOT RE 2 H373**	Toxic when inhaled; still emitted from some products after 3 days.

* indicates that values may be overestimated due to contributions from system

10. Control analyses / content analyses

Apart from investigating emission from various types of PU foam products, this project also had the purpose to investigate the extent to which legally established limit values for chemical substances are exceeded. For this reason, it was decided together with the Danish EPA that the following content analyses would be performed on PU foam products, the first content analyses of which were performed as control analyses; that is, to ascertain whether products comply with applicable legislation in the area:

- Quantitative content analyses to verify phthalate content
- Quantitative content analyses to verify brominated flame retardant content
- Quantitative content analyses to investigate chlorinated phosphorus-based flame retardant content

The 20 PU foam products studied in this project contain a minimum of three layers: a central foam layer surrounded by an exterior layer (usually textile). The exterior layer may be the same on all sides of the product, or there may be distinct front and back exterior layers. Additionally, some products contain many more layers, such as two to three distinct exterior layers and two distinct foam layers (for example, see FIGURE 6). To ensure compliance with legislation, the control analyses are generally to be performed on each individual, homogeneous part; that is, on each individual layer. For targeting of the analyses, both control analyses and content analyses made to the products in this project have exclusively been made on specific layers of the products. Based on among other things the literature and previous studies, we have assessed in which layer/material where the greatest probability to identify the substances in question would be. This assessment was also conducted in co-operation with experts in the field from the Danish EPA. The result was that the following control analyses and content analyses were performed on the following parts of the PU foam products:

- All control analyses for phthalate content, and content analyses for chlorinated phosphorus-based flame retardants were performed exclusively on the foam itself (the PU foam). For products comprising more than one foam layer, the content analysis was performed only on the softest layer (i.e., the layer expected to contain memory foam) or, alternatively, on the thickest layer of foam.
- All control analyses for brominated flame retardant content were performed on the outermost textile layer, even if there were several exterior textile layers around the PU foam.

10.1 Control analyses / content analyses for phthalate content in childcare articles

Control analyses were performed on the 10 Danish products to assess their compliance with legislative requirements on phthalate content. As described above, all content analyses for phthalates were performed exclusively on the foam. Additionally, corresponding analyses for phthalate content in the foam were performed on the 10 foreign products to see if there were any differences between products purchased within Denmark and outside of Denmark.

10.1.1 Analysis method

Phthalate analysis was performed according to CPSC-CH-C1001-09.3 and DS/EN 14372. The sample was extracted with dichloromethane, and the extract was injected into a combined gas

chromatograph and mass spectrometer (GC/MS). The quantitative analysis of the components was performed using an internal standard, based on external calibration standards. The limit of detection for most phthalates is 5 mg/kg, but may be as high as 50 mg/kg, depending on the phthalate in question. The method is accredited with a relative standard deviation (RSD) of 15%; that is, the total analytical uncertainty (expanded uncertainty) is 15% for most phthalates when performed using the accredited method. The analytical uncertainty is higher for certain other phthalates and may be as high as 60%.

The content analysis for the phthalates DEP, DIBP, DBP, BBP, DEHP, DnOP, and DINP was performed in an accredited manner, while determinations for the phthalates DIDP, DMEP, PiPP, DnPP, DCP, DHNUP, DnHP, DIHpP, DIPP, and other phthalates were not accredited.

Limits of detection and uncertainties for individual phthalates are specified in TABLE 17 below. The content analyses for phthalates were performed with true duplicate determination.

TABLE 17. Limits of detection and analytical uncertainties for phthalate content analyses

Phthalate	CAS no., if any	Limit of detection	Analytical uncer-tainty
Benzylbutyl phthalate (BBP)	85-68-7	< 5 mg/kg	30%
Di(2-methoxyethyl) phthalate (DMEP) *	117-82-8	< 10 mg/kg	30%
Di(ethylhexyl) phthalate (DEHP)	117-81-7	< 5 mg/kg	30%
Dibutyl phthalate (DBP)	84-74-2	< 5 mg/kg	30%
Dicyclohexyl phthalate (DCP) *	84-61-7	< 5 mg/kg	30%
Diethyl phthalate (DEP)	84-66-2	< 5 mg/kg	30%
Diheptylnonylundecyl phthalate (DHNUP) *	68515-42-4	< 50 mg/kg	60%
Diisobutyl phthalate (DIBP)	84-69-5	< 5 mg/kg	30%
Diisodecyl phthalate (DIDP) *	68515-49-1	< 30 mg/kg	60%
Diisoheptyl phthalate (DIHpP) *	41451-28-9	< 25 mg/kg	30%
Diisononyl phthalate (DINP)	68515-48-0	< 30 mg/kg	60%
Diisopentyl phthalate (DIPP) *	605-50-5	< 5 mg/kg	30%
Di-n-hexyl phthalate (DnHP) *	84-75-3	< 5 mg/kg	30%
Di-n-octyl phthalate (DNOP)	117-84-0	< 5 mg/kg	60%
Di-n-pentyl phthalate (DNPP) *	131-18-0	< 5 mg/kg	30%
n-Pentylisopentyl phthalate (PiPP) *	776297-69-9	< 5 mg/kg	30%
Extractable content, other phthalates *	-	< 50 mg/kg	60%

* Phthalates not analysed using an accredited method

10.1.2 Analysis results

The analysis results for the 20 products for which content analyses for phthalates in the foam were performed show that only small quantities of a few phthalates were identified in 6 out of 20 products. For the remaining 14 products, phthalates were not identified in quantities above the limits of detection specified above. The results show that the phthalates DEHP, DIDIP, DBP and/or DIBP were not identified in the six products. However, the amounts found in all products were small and likely arise from impurities in other components added.

TABLE 18. Analysis results for quantitative content analyses of phthalates performed with true duplicate determination. Results are listed for only those products where content above the limit of detection was identified.

Phthalate	DK 4 (mg/kg)	DK 5 (mg/kg)	N-EU 2 (mg/kg)	N-EU 3 (mg/kg)	N-EU 4 (mg/kg)	N-EU 5 (mg/kg)
Di(ethylhexyl) phthalate (DEHP)	6.2**	5.5**	5.9**	-	-	5.4**
Diisodecyl phthalate (DIDP) *	-	-	29***	-	-	-
Dibutyl phthalate (DBP)	-	-	-	59	65	-
Diisobutyl phthalate (DIBP)	-	-	-	4.7***	-	-

- indicates that the substance was not identified in the product above the limit of detection
* Phthalates not analysed using an accredited method
** The results in the first determination were 7.3 mg/kg (DK 4), 5.9 (DK 5), 6.7 (N-EU 2), and 5.7 (N-EU 5); the results in the second determination were < 5 mg/kg. The result is indicated as the average of 5 mg/kg and the value for the first determination.
*** It was possible to indicate a value for the first determination that falls below the official limit of detection. In both cases, the result of the second determination was less than the limit of detection. The value for the first determination is indicated.

Considering that the limit values in legislation are set at 500 or 1000 mg/kg (as a sum of all or certain phthalates) depending on the particular law in question, all 20 products investigated are in compliance with phthalate content legislation. However, it should be noted that only the foam was analysed for phthalate content, not every individual product layer. Even so, the foam layer was analysed because it is the layer considered most likely to contain phthalates if present in larger quantities.

10.2 Control analyses for brominated flame retardant content

Control analyses were performed on the 10 Danish products to assess their compliance with legislative requirements on brominated flame retardant content. As described above, all content analyses for brominated flame retardants were performed exclusively on the outermost layer of the product. This layer consists of a textile in most cases, but consists of plastic for DK 6 (a tumbling mat).

10.2.1 Analysis method

A 5 mm x 5 mm x 5 mm sample was cut and extracted for flame retardant analysis according to SOP QMA504-333. The extract was injected into a combined gas chromatograph and mass spectrometer (GC-MS). The quantitative analysis of the components was performed based on external calibration standards.

Limits of detection and uncertainties for the individual brominated flame retardants vary from approx. 50 to 2400 µg/kg. The analytical uncertainty is estimated at approx. 30-40%.

Limits of detection and uncertainties for individual brominated flame retardants are specified in TABLE 19 below. The limit of detection varies from product to product and depends on such factors as the sample volume used to analyse the various products. The highest limit of detection for the 10 analysed products, and for the two analyses performed (true duplicate determination), is given in TABLE 19.

TABLE 19. Limits of detection and analytical uncertainties for brominated flame retardant content analyses

Flame retardant	CAS no., if any	Limit of detection	Analytical uncertainty
HBCDD (alpha, beta, gamma)	-	< 150 µg/kg	30-40 % (35%, 40%, 30%)
PBDEs			
Sum of TriBDEs	-	< 50 µg/kg	30%
Sum of TetraBDEs	-	< 240 µg/kg	30%
Sum of PentaBDEs	-	< 470 µg/kg	30%
Sum of HexaBDEs	-	< 560 µg/kg	30 – 40%
Sum of HeptaBDEs	-	< 700 µg/kg	40%
Sum of OctaBDEs	-	< 930 µg/kg	40%
Sum of NonaBDEs	-	< 1900 µg/kg	60%
DecaBDE (BDE 209)	1163-19-5	< 2400 µg/kg	60%
Sum of all BDEs analysed	**-**	**< 7100 µg/kg**	**40%**

The individual PBDEs analysed, which are included in the individual BDE sums, are listed in Appendix 4.

10.2.2 Analysis results

The analysis results for the 10 Danish products (DK 1 through DK 10), for which content analyses were performed on the outermost textile layers of the products, show that none of the products analysed contains the brominated flame retardants listed above in excess of the maximum limits of detection in TABLE 19. However, decaBDE content of 850 µg/kg was found in a single product (DK 1) in one determination, but none (< 310 µg/kg) was found in the second determination. The limit of detection for decaBDE varies from 310 to 2400 µg/kg, depending on the product.

Considering that the legislative limit values are set at 10, 100, or 1000 mg/kg, depending on the type of flame retardant in question, this means that all 10 Danish products studied comply with the legal requirements on brominated flame retardant content (the highest limit of detection is 2.4 mg/kg). However, it should be noted that only the outermost layer of each product was analysed for brominated flame retardants, not every individual product layer. Even so, the outermost layer was analysed because brominated flame retardants are most often found in the outermost textile layer.

10.3 Content analyses for chlorinated phosphorus-based flame retardant content

As described above, all 20 content analyses for chlorinated phosphorus-based and simple phosphorus-based flame retardants were performed exclusively on the PU foam itself.

10.3.1 Analysis method

The foam sample was cut up finely and extracted using Soxhlet or liquid-liquid extraction. Thereafter, a GC/MS was used to perform the flame retardant analysis. The limit of detection varies by component, from approx. 8 to 35 mg/kg. The analytical uncertainty is estimated at approx. 40% on average for the listed chlorinated phosphorus-based flame retardants.

Limits of detection and uncertainties for individual chlorinated phosphorus-based flame retardants are specified in TABLE 20 below. The limit of detection varies from product to product

and depends on such factors as the sample volume used to analyse the various products. The highest limit of detection for the 20 products is given in TABLE 20 and represents the average of the true duplicate determination.

TABLE 20. Limits of detection and analytical uncertainties for chlorinated phosphorus-based flame retardant content analyses

Flame retardant	CAS no.	Limit of detection	Analytical uncer-tainty
Tri-o-cresyl phosphate (TOCP)	78-30-8	< 8.8 mg/kg	30%
Tricresyl phosphate (TCP)	1330-78-5	< 35.5 mg/kg	40%
Tri(2-chloroisopropyl)phosphate (TCPP)	13674-84-5	< 17.7 mg/kg	30%
Tris(1,3-dichloroisopropyl)phosphate (TDCP)	13674-87-8	< 3.5 mg/kg	30%
Tributyl phosphate (TBP)	126-73-8	< 17.7 mg/kg	30%
Triisobutyl phosphate (TiBP)	126-71-6	< 35.5 mg/kg	70%
2-ethylhexyl diphenyl phosphate (EHDP)	1241-94-7	< 17.7 mg/kg	30%
Tris(2-chloroethyl)phosphate (TCEP)	115-96-8	< 8.9 mg/kg	30%
Triphenyl phosphate (TPhP)	115-86-6	< 8.9 mg/kg	30%

It should be noted that there were problems identifying two substances in the analysis, namely tris(2-butoxyethyl)phosphate (TBEP) and tris(2-ethylhexyl)phosphate (TEHP), which produced invalid results. For this reason, these substances are not listed in the tables.

10.3.2 Analysis results

The analysis results for the quantitative determination of chlorinated phosphorus-based flame retardants in PU foam are listed in TABLE 21 below. Results are listed for only those products where levels above the limit of detection were identified for individual substances. The results are the average of the results from the true duplicate determination.

TABLE 21. Analysis results for quantitative content analyses of chlorinated phosphorus-based flame retardants performed with true duplicate determination. Results are listed for only those products where content above the limit of detection was identified.

Flame retardant	CAS no.	DK 4 (mg/kg)	EU 1 (mg/kg)	EU 2 (mg/kg)	N-EU 5 (mg/kg)
Tri(2-chloroisopropyl)phosphate (TCPP)	13674-84-5	21.2	-	29.2	-
Tris(1,3-dichloroisopropyl)phosphate (TDCP)	13674-87-8	-	13.4	-	-
Triphenyl phosphate (TPhP)	115-86-6	-	-	-	17.8

- indicates that the flame retardant was not identified in the product above the limit of detection

TABLE 21 thus shows that of the nine chlorinated phosphorus-based flame retardants under analysis, only three were identified, and those only in four out of the 20 products studied. No more than one flame retardant was identified in any product, and the levels identified are generally so low (< 0.003%) that these must be impurities; they could hardly be added at these levels to give the PU foam a flame retardant effect.

10.4 Summary and discussion of analysis results

The control analyses for phthalate content in childcare articles and other PU foam products (20 products in all) performed in this project show that all the products are in compliance with applicable legislation on phthalates. However, it should be noted that phthalate analyses were performed only on the foam itself. In a total of six out of 20 products, small quantities of one or two phthalates were identified, but the quantities were so small (0.007%) as to suggest levels arising from impurities, rather than the deliberate addition of phthalates to the PU foam.
All certification programmes for PU foam impose phthalate content requirements on PU foam. These requirements are a total content of 0.01% (as a sum of certain phthalates, for CertiPUR) or 0.1% (as a sum of certain phthalates, for TÜV Rheinland). All 20 products thus meet the phthalate content requirements of these certification programmes.

Correspondingly, the control analyses for brominated flame retardant content in outer textile layers of the 10 Danish products show that all products comply with applicable legislation. Neither HBCDD nor PBDE content was found at levels above the limits of detection.

To improve knowledge of chlorinated phosphorus-based flame retardants in PU foam, content analyses were performed on all 20 purchased products. The result was that a total of three unique chlorinated phosphorus-based flame retardants (TCPP, TDCP, and TPhP) were identified in four products, though only one flame retardant was found in each. Generally, the amounts found are so small (< 0.003%) as to most likely be the result of impurities; they can hardly be added at these levels to give the PU foam a flame retardant effect.
All PU foam certification programmes set requirements on certain chlorinated phosphorus-based flame retardants (TCEP, TCCP, and TCPP). Of these, only TDCP was identified in a single product (EU 1), but at a level below the limit value set in the TÜV Rheinland programme (< 0.005%). The CertiPUR programmes specify only that TDCP may not be used. No specific limit value for the flame retardant is given.

11. Exposure scenarios

This project has chosen to focus on substances emitted from PU foam products, and exposure scenarios have only been created for exposure via inhalation. Thus, potential dermal exposure to emitted substances with properties that enable diffusion through the skin are not considered. Furthermore, consumers do not come into direct skin contact with the PU foam itself when using these products (there is always a textile or other layer surrounding it). For these reasons, only inhalation is considered as an exposure vector.

11.1 Relevant age groups and exposure scenarios

The age groups upon which the exposure scenarios in this project are based were chosen based on the products purchased for the project. They are:

- Babies (0 years) — values for newborns are chosen as worst-case scenarios, since some of the products purchased are intended for babies
- Young children, ages 4-6
- Older children and youth; i.e., teenagers (13-14 years)
- Adults

TABLE 22 below contains an overview of the types of products purchased and analysed for emission in this project, as well as which of the above age groups they are intended for. A coloured cell indicates that the product is used by or intended for the age group in question. A white cell indicates that the product is not used by or intended for the age group in question. Common to almost all the products chosen for analysis is that they are used in connection with sleep. The only product not used in connection with sleep is the tumbling mat that was selected.

TABLE 22. Overview of products intended for different age groups (coloured cells indicate products intended for / used by this age group)

Product / age group	Babies (0 years)	Young children (4-6 years)	Teenagers (13-14 years)	Adults
Baby pillow				
Baby mattress				
Cot bumper				
Support mattress for babies				
Folding mattress				
Tumbling mat				
Pillow for children				
Pillow for adults				
Adult mattress				

The relevant exposure pathway, and the exposure pathway focused on in this project, is inhalation. It is thus possible for several of the products studied to emit in one room simultaneously. The exposure scenarios in TABLE 23 below are therefore chosen as realistic worst-case scenarios. The scenarios created represent activities throughout the day; that is, inhalation of emitted substances from PU foam products in connection with sleep, and inhalation of

emitted substances from PU foam products in connection with play or with time spent in a teenager's room. The rationales for the selection of the scenarios below are:

- that a newborn baby sleeps in a bedroom with its parents all night, and lies on a tumbling mat in the living room during some of its time awake
- that a child aged 4 to 6 years sleeps in a bedroom with its parents all night and plays on a tumbling mat throughout the day
- that teenagers spend time in their bedrooms, where they also sleep, for a significant portion of the day (particularly on weekends), and that they may be exposed to additional products if a friend spends the night
- that adults sleep with their newborn babies in their bedrooms all night, and spend time in a room with a tumbling mat in it throughout the day

TABLE 23. Description of realistic worst-case scenarios

Parameter	Babies (0 years)	Young children (4-6 years)	Older children and youth (13-14 years)	Adults
Relevant room for sleep	Small bedroom (with parents)	Small bedroom (with parents)	Teenager's small bedroom	Small bedroom
Products in use during sleep	2 adult mattresses 1 baby mattress 2 adult pillows 1 baby pillow or support mattress 1 cot bumper	2 adult mattresses 1 children's pillow 2 adult pillows	1 adult mattress 1 folding mattress 1 tumbling mat 2 adult pillows	2 adult mattresses 1 baby mattress 2 adult pillows 1 baby pillow or support mattress 1 cot bumper
Relevant room for waking hours	Living room	Child's small bedroom Potentially increased respiratory volume during play	Teenager's small bedroom Extended time spent in room while awake	Living room
Products in use during waking hours	1 tumbling mat	1 adult mattress 1 children's pillow 1 tumbling mat	1 adult mattress 1 folding mattress 1 tumbling mat 2 adult pillows	1 tumbling mat

The above realistic worst-case scenarios cover scenarios in which emission from each individual PU foam product spreads throughout a room where people sleep and spend time. In this situation, the emission from these products is distributed throughout a large space. However, for a person lying directly on a mattress or pillow, the worst case would involve higher concentrations, since emission from these products occurs directly in the inhalation zone. The exposure for babies will be higher, as they sleep longer compared to adults and therefore is exposed to the emitted substances for a longer time. It is therefore also relevant to consider a scenario in which emission takes place in the inhalation zone.

11.2 Data chosen for exposure scenarios

The values used which are relevant to the exposure scenarios in this project are given below in TABLE 24. The selection of values is justified in greater detail in the text below (after the table). TABLE 24 lists the relevant values for both sleep and waking hours (time spent in a teenager's room, children playing, etc.).

Generally, values used are those used in RIVM (2014), as this Dutch report provides the latest data relative to other sources. In some cases, values recommended by REACH (ECHA, 2016) for exposure scenarios are used.

Because all DNEL values (i.e., the exposure considered to have no health-related effects) for the substances being assessed (see chapter 13, "Hazard assessment") are expressed as concentrations in µg/m^3, it is not necessary to consider parameters such as body weight or respiratory volume. Therefore, only the parameters relevant to the exposure calculations are described.

TABLE 24. Values used for exposure scenarios in this project

Parameter	Values used in this project	Source
Exposure time (during sleep)	18 hours (babies) 12 hours (4-6 years) 10 hours (13-14 years) 9 hours (adults)	Danish Health Authority (2011) Danish Health Authority (2011) Danish Health Authority (2011) VFF (2015)
Exposure time (during waking hours)	3 hours (babies) 2 hours (4-6 years) 8 hours (13-14 years) 2 hours (adults)	Realistic worst-case guess
Volume of space	21 m^3 (bedroom and child's room) 58 m^3 (living room)	RIVM (2014) RIVM (2014)
Air exchange rate	0.5 times per hour	RIVM (2014)

11.2.1 Exposure time (sleep)

The exposure time for essentially all the purchased and analysed products will be the same, since the products are primarily used in connection with sleep. However, exposure times do depend on for how long a period people in each age group sleep each night.

For a source on sleep, the Danish Health Authority's guide on preventive health services for children and youth was used (Danish Health Authority, 2011). According to this guide, newborns ages 1 to 4 weeks sleep from 15 to 18 hours a day. As a worst case, we presume that a newborn sleeps for an entire day in its parents' bedroom with the PU foam products listed in TABLE 23. For **babies** (0 years), an exposure time of **18 hours** was selected.
For **young children** (4-6 years), the Danish Health Authority (2011) recommends 10-12 hours of sleep per night; therefore, **12 hours** is used as a worst-case sleep duration. Similarly, a sleep duration of **10 hours** is used for **teenagers** based on a recommendation of 8-10 hours of sleep.
For **adults,** a worst-case sleep exposure value of **9 hours** is used as specified in a report about sleep and health from the Vidensråd for Forebyggelse ["Scientific Preventative Board"] (VFF, 2015). In this report, it is indicated that adults generally require between 6 and 9 hours of sleep per day, with most adults sleeping between 7 and 9 hours. The average sleep duration is given as approx. 7.5 hours per day.

11.2.2 Exposure time (waking hours)

Apart from exposure during sleep, as indicated in TABLE 23, exposure from PU foam products occurs during waking hours as well. Sources addressing this topic were not identified, so only exposure times considered to be realistic worst-case exposure times were used:

- Babies (0 years) — 3 waking hours on a tumbling mat (the remaining 3 waking hours are expected to be used for nursing or in other locations)
- Young children (4-6 years) — 2 hours of play in a child's room
- Teenagers (13-14 years) — 8 hours spent in a teenager's bedroom
- Adults — 2 hours spent in the same room as a tumbling mat

11.2.3 Volume of space

In the project on "squishy toys" (Klinke et al., 2018), a worst-case child's room measuring 7 m^2 was used. However, a somewhat larger room (21 m^3) was chosen as worst case of the current project, corresponding to a room with a floor area of 8.5 m^2 (RIVM (2014)). This is justified by the fact that the room must be large enough to contain two or more mattresses and must be spacious enough for a teenager to spend many waking hours in it.
Thus, **21 m^3** is used as a worst-case room volume for both a bedroom and a child's room. In RIVM (2014), a volume of **58 m^3** is given for a living room, corresponding to an area of 22 m^2. This volume is used for the exposure scenario in which a baby (and adult) are spending time in a room with a tumbling mat.

11.2.4 Air exchange rate

As a standard, an air exchange rate of **0.5 times per hour** is used, which is also used as an average air exchange rate for ordinary rooms according to RIVM (2014), and which is also used as the standard for CertiPUR measurements, among other applications. This is also the air exchange rate used in the emission analyses in this project.

11.3 Selected exposure scenarios

Due to the large amount of data in this project, it was decided to focus the exposure scenarios on two consumer groups exposed to the highest amounts of PU foam for the longest periods of time; namely,

- Babies, which are exposed to a total of seven PU foam products for 18 hours (sleep) and one product for 3 hours (waking hours)
- Teenagers, which are exposed to a total of five PU foam products for 18 hours (10 hours of sleep and 8 waking hours in the same room)

Both young children (who spend less waking hours around PU foam products) and adults, who sleep less, are thus also covered by these worst-case scenarios.

Lastly, it was decided to focus on a scenario with multiple products in the inhalation zone. Here, the group selected was babies, as they sleep for the longest period and are exposed to the highest number of products directly in the inhalation zone (a baby mattress, baby pillow, and cot bumper).

12. Exposure levels from indirect sources

In the risk assessment section (see chapter 14 “Exposure and risk assessment method"), a risk assessment is performed for the nine selected substances; specifically, it was assessed whether an expected worse-case exposure to the PU foam products studied in this project would constitute a health risk when the products are used alone or together with the other PU foam products studied.

At the same time, consumers are also exposed to the nine selected substances from other sources. For this reason, this chapter describes the other significant sources (indirect sources) that exist for consumers' exposure to these nine substances. Primarily, earlier survey projects from the Danish EPA were used as references for identifying exposure levels from indirect sources.

The nine selected substances are:
- Dimethylformamide (DMF) (CAS no. 68-12-2)
- Decamethylcyclopentasiloxane (D5) (CAS no. 541-02-6)
- Octamethylcyclotetrasiloxane (D4) (CAS no. 556-67-2)
- 2-ethyl-1-hexanol (CAS no. 104-76-7)
- Dodecamethylcyclohexasiloxane (D6) (CAS no. 540-97-6)
- Toluene (CAS no. 108-88-3)
- α-Pinene (CAS no. 80-56-8)
- Formaldehyde (CAS no. 50-00-0)
- Phenol (CAS no. 108-95-2)

12.1 Incidence and use of the selected substances

The incidence and use of the nine selected substances are briefly described below in TABLE 25. The sources used are indicated in parentheses below the name of each substance in the table. Primarily, ECHA documents summarising information about substances and LOUS[28] reports from the Danish EPA were used, when they exist. The purpose of the table is to describe which other significant sources exist for consumer exposure to these substances, such that the total exposure to the substances can then be calculated in chapter 14 “Exposure and risk assessment method".

For the nine selected substances, the other primary, indirect sources of exposure are generally other consumer products. The substances are mainly emitted into the indoor climate, and exposure is by inhalation.

Both toluene and phenol are present in low concentrations in the air, but these levels are below the levels measured in the emission chambers in this project. For this reason, exposure scenarios calculated with all 24 hours of the day spent in the home are worst-case situations. Unique among these substances, phenol may occur in certain food products (particularly smoked foods), but this is not considered to be a significant source of exposure (Danish EPA, 2014). For this reason, exposure from food products is not included.

[28] LOUS = List Of Undesirable Substances [Danish: *Listen Over Uønskede Stoffer]*

Exposure to siloxanes D4, D5, and D6 is primarily via e.g. cosmetic products, though D4 and D5 were prohibited in cosmetic products designed to be washed off on 31 January 2020 by REACH Annex XII,[29] due to their bioaccumulative and persistent properties in the environment (vPvB[30]). Additionally, there is a proposal to restrict the content of the three siloxanes under REACH Annex XVII to a concentration of no more than 0.1% in chemical mixtures[31].

TABLE 25. General incidence and use of the selected substances

Substance name (sources used)	CAS no.	Uses	Incidence and exposure
Dimethylformamide (Larsen et al., 2014) (Klinke et al., 2018)	68-12-2	Solvent Industrial cleaner	Primarily via working environment. Substance observed to be emitted by a few consumer products, but not expected to result in significant exposure. However, the 2018 study on squishies made of PU foam showed that exposure to this substance from squishies in nurseries is significant.
Decamethylcyclopentasiloxane (D5) (ECHA, 2018a)	541-02-6	Production of silicone polymers for uses including: Cosmetic products Polishes and waxes Washing and cleaning products Fabric treatment products Colourants Car care products	Exposure occurs primarily when using products containing the substance. Exposure may occur in indoor climate when released by e.g. textiles. Restricted by REACH Annex XVII in cosmetic products (wash-off products) as of 31 January 2020. Proposed restriction in Annex XVII of REACH for substance content, maximum concentration 0.1% in chemical substances.
Octamethylcyclotetrasiloxane (D4) (ECHA, 2018b)	556-67-2	Production of silicone polymers for uses including: Leather care products Lubricants Cosmetic products Colourants Washing and cleaning products Polishes and waxes	Exposure occurs primarily when using products containing the substance. Exposure may occur in indoor climate when released by e.g. furniture, curtains, construction materials. Restricted by REACH Annex XVII in cosmetic products (wash-off products) as of 31 January 2020. Proposed restriction in Annex XVII of REACH for substance content, maximum concentration 0.1% in chemical substances.
2-ethyl-1-hexanol (ECHA, 2015)	104-76-7	Paints Cleaning products	Primarily used in professional contexts. Exposure may occur after emission from products containing the substance.
Dodecamethylcyclohexasiloxane (D6)	540-97-6	Production of silicone polymers for uses including: Cosmetic products Washing and cleaning products	Exposure occurs primarily when using products containing the substance. Proposed restriction in Annex XVII of REACH for substance content, maximum concentration 0.1% in chemical substances.

[29] REACH Annex XVII no. 70. This is a restriction that has been adopted, but which has yet to enter into force. https://echa.europa.eu/documents/10162/50e79685-efaf-ac9a-4acb-d8be3f0e9ddc

[30] vPvB = very Persistent, very Bioaccumulative

[31] REACH Annex XVII no. 70. This is a proposed restriction that has yet to be adopted. https://echa.europa.eu/documents/10162/11f77453-8a0d-411b-38c3-7f992a136cca

Substance name (sources used)	CAS no.	Uses	Incidence and exposure
		Polishes and waxes	
Toluene (Kjølholt et al., 2014)	108-88-3	Solvent in chemical products. Thinning agent Cleanser	Low levels in outdoor air (1.3 – 3.7 µg/m^3) in urban areas with heavy traffic. Exposure occurs when using products containing the substance.
α-Pinene (Andersen et al., 2015) (Joint Research Centre, 2013)	80-56-8	Fragrance mixtures Ingredient in turpentine Wood Construction materials	α-pinene is an important ingredient in turpentine and is naturally emitted by evergreen trees, such as pines and spruces. Exposure thus occurs primarily in indoor climate, as many construction materials emit α-pinene.
Formaldehyde (ECHA, 2019b) (Andersen et al., 2014)	50-00-0	Glue and paints Particleboard Ink and toner Fuel Waxes and polishes Cosmetic products Air fresheners Washing and cleaning products Textiles etc.	Formaldehyde content in consumer mixtures is typically the result of the use of formaldehyde as a biocide, or the use of substances that emit formaldehyde. Exposure typically occurs via the indoor climate, where many products emit formaldehyde (construction materials, insulation, rugs, etc.). The indoor climate concentration is typically between 20 and 40 µg/m^3.
Phenol (Møller et al., 2014) (Danish EPA, 2014)	108-95-2	Solvent in chemical products Preservative Plywood panels	Phenol is a natural component of plant materials and is naturally secreted by plants and humans during metabolic processes. It is present at very low concentrations in outdoor air, since it breaks down quickly in the atmosphere. Concentrations not specified. Exposure occurs when using products containing the substance. Exposure from food products does occur, but at lower levels than those found in consumer products. Occurs primarily in smoked food products. Not considered a significant exposure.

12.2 Sources for substance exposure levels

A search of the Danish EPA's database[32] of chemical substances in consumer products was performed for the nine selected substances listed previously. The information found in the search is shown below in TABLE 26. TABLE 26 shows which consumer products either contain or emit the nine selected substances, according to the Danish EPA's database. While measurements relevant to this project were not necessarily available for all products, the table gives an overview of the consumer products that may contribute to indirect exposure to the same substances.

[32] https://vidensbank.mst.dk/v2/. The database is not fully updated; for this reason, the most recent reports (following survey report no. 164, which is in the database) published on the Danish EPA website were also searched. https://mst.dk/kemi/kemikalier/forskning-og-kortlaegning/kortlaegning-af-forbrugerprodukter/

TABLE 26. Other sources of exposure to the selected substances in consumer products

Substance name	CAS no.	Consumer products containing the substance	Consumer products which emit the substance
Dimethylformamide	68-12-2	Squishy toys Balloons Waders	Play houses (tents) and igloos Fold-out tents Squishy toys
Decamethylcyclopentasiloxane (D5)	541-02-6	Pet care products	Various sex toys Squishy toys Energy-saving light bulbs DIY products
Octamethylcyclotetrasiloxane (D4)	556-67-2	Shoe care products Cosmetic products (crèmes)	Rubberised toy figures Energy-saving light bulbs DIY products
2-ethyl-1-hexanol	104-76-7	Wires 3D printing materials Sex toys Car care products for interiors Lamination materials Breastfeeding pillows, baby mattresses Bags for toys, school bags, pencil cases Exotic woods	Electronic products (TVs, etc.) Toys Slime toys Various sex toys Parquet flooring made from exotic woods Floor rugs Igloo tents Fold-out tents
Dodecamethylcyclohexasiloxane (D6)	540-97-6	*No products specified*	Squishy toys Energy-saving light bulbs DIY products
Toluene	108-88-3	Sports injury products (salves, etc.) Waders Knee bandages/wraps Car care products for interiors Diving gear Pencil cases, erasers Wooden toys Jackets Ceramic paints Sealants Christmas decorations	Pipe beads and bead art Various sex toys Play houses (tents) and igloos Modelling clay Rubberised toy figures Tape Incense Liquid latex for costumes 3D printing materials Textile spray adhesives Electronic products (TVs, lamps, etc.) Paints and other DIY products Scented candles Energy-saving light bulbs Squishy toys
α-Pinene	80-56-8	Massage oils and intimate creams Car care products for interiors Skin adhesives for costumes	Incense Electronic products (TVs, etc.) Rugs Squishy toys
Formaldehyde	50-00-0	Modelling clay Jackets, gloves Bedding, fabrics Breastfeeding and changing pads Soap bubble solutions Slime toys Rugs Car seats Baby carriers and baby mattresses Pet toys Hobby products (glue, paint) Toys	Igloo and fold-out tents 3D printing materials Incense Electronic products (TVs, etc.) Floor rugs Squishy toys DIY products
Phenol	108-95-2	Waders Sports injury products (lotion, etc.) Diving gear Jackets Balloons Lamination materials	Various sex toys Fold-out tents 3D printing materials Squishy toys Floor rugs DIY products

Substance name	CAS no.	Consumer products containing the substance	Consumer products which emit the substance
		Christmas decorations Toy and school bags Changing pads Hobby products (glitter glue, etc.)	

Subsequently, the Danish EPA's database of chemical substances in consumer products was searched for information related to safety assessments including the nine selected substances; that is, information including measured exposure levels that were used in a later exposure and risk assessment. Projects in which only screening analyses were performed were not included. For this project, it was decided to focus exclusively on values for projects in which emissions of the nine selected substances were measured, primarily in projects where emissions were measured in an emission chamber, yielding comparable levels. For example, many of the nine selected substances were measured in emissions from both rugs and energy-saving light bulbs, but these levels are not comparable to the exposure levels calculated in this project because they have not been converted to emitted concentrations in a room of a house.

The concentrations measured and indicated exposure situations are given below in TABLE 27. If the substance was not identified in some of the products studied, this is indicated as a range from zero to the maximum concentration measured. If a risk assessment in which an RCR value was calculated for the substance and exposure (for the highest value) in the project, it is given in the table with the DNEL value used in parentheses. However, these RCR values were not calculated in the oldest reports.

The concentrations listed below thus offer an idea of the extent of indirect exposure via the indoor climate from sources other than PU foam products. Theoretically, the concentrations listed can be compared with the concentrations from the PU foam products, thereby representing the total concentration in the indoor climate from other sources as well. The reason that this is only theoretically possible is that emission concentrations were not measured at the same points in time in all projects. Similarly, the emission chamber analyses performed in previous projects may not have used the same emission chamber size or conditions (e.g., air exchange rates). Furthermore, there are large differences in whether concentrations were measured after e.g. 1 hour, 5 hours, or 7 hours; and after 1 day, 3 days, 9 days, or 28 days. Whether it is realistic for emissions from these types of products to occur in the scenarios (rooms) presented in this project (bedrooms, living rooms, teenagers'/children's rooms) should also be considered. Regardless, the table shows that there are multiple sources of emissions of the selected substances in the home.

It should be noted that in previous reports, RCR values higher than 1 were calculated for some substances, indicating that for some product types, the product itself can cause health effects. This is the case for:

- Squishy toys for DMF
- Application of DIY products (acid-curing floor finishes) for formaldehyde

Some of these products have since been taken off the market because they posed a risk.

For the reasons given above, the emissions of the nine substances from other sources were not included in the exposure calculations for this project, but it is important to be aware of the fact that emissions of these substances may also occur in other products.

TABLE 27. Exposure levels for emissions of the selected substances from other indirect sources in the home

Substance name (CAS no.)	Measured levels (µg/m^3)	Calculated RCR values	Exposure situation	Reference
Dimethylformamide (DMF) (68-12-2)	Play tents: 4-345 (1½ hours), <1-100 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004
	Squishy toys: 520-14,000 (1 hour), 1200-3600 (3 days)	RCR calculated for small children, 10 hours' sleep with a squishy toy, measurement after 1 hour, RCR = 73; measurement after 3 days, RCR = 19 (DNEL = 80).	Emission chamber (measured 1 hour and after 3 days)	Klinke et al., 2018
Decamethylcyclopentasiloxane (D5) (541-02-6)	Electronics: Clothing iron: 12 (7 hours), 3 (9 days), as sum of D4 and D5 Toaster oven: 130 (7 hours), 33 (9 days), as sum of D4 and D5 Printer: 2.5 (7 hours), below detection limit (DL) after 9 days (sum of siloxanes) Mobile phone with charger: 0.2 (7 hours), below DL after 9 days (sum of siloxanes) Personal computer: 3 (7 hours), 5 (9 days) (sum of siloxanes) Space heater: 1 (7 hours), below DL after 9 days (sum of siloxanes)	Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005
	DIY products: Floor paints: 14-200 (5 hours) Floor finishes: 13 (5 hours)	Not calculated for substance	Emission chamber (measured after 5 hours, 3 days, and 28 days). Values after 3 days and after 28 days not specified (possibly equal to zero).	Lassen et al., 2018

Substance name (CAS no.)	Measured levels (µg/m^3)	Calculated RCR values	Exposure situation	Reference
Octamethylcyclotetra-siloxane (D4) (556-67-2)	Electronics: Clothing iron: 12 (7 hours), 3 (9 days), as sum of D4 and D5 Toaster oven: 130 (7 hours), 33 (9 days), as sum of D4 and D5 Printer: 2.5 (7 hours), below detection limit (DL) after 9 days (sum of siloxanes) Mobile phone with charger: 0.2 (7 hours), below DL after 9 days (sum of siloxanes) Personal computer: 3 (7 hours), 5 (9 days) (sum of siloxanes) Space heater: 1 (7 hours), below DL after 9 days (sum of siloxanes)	Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005
	Squishy toys: 0-7 (1 hour), 0-2 (3 days)	Not calculated for substance	Emission chamber (measured 1 hour and after 3 days)	Klinke et al., 2018
	DIY products: Floor paints: 10-190 (5 hours), 1-3 (3 days) PU foam: 4 (5 hours) Floor finishes: 27 (5 hours)	Not calculated for substance	Emission chamber (measured after 4-5 hours, 3 days, and 28 days). Values after 28 days not specified (possibly equal to zero).	Lassen et al., 2018
2-ethyl-1-hexanol (104-76-7)	Play tents: 0-140 (1½ hours), 0-12 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004
	Electronics: Toaster oven: 2 (7 hours), <1 (9 days) Hair dryer: 0.5 (7 hours), <0.4 (9 days) Lamp: 0 (7 hours), 0.7 (9 days) Electrical panel: 0.6 (7 hours), 0.3 (9 days) TV: 0.6-0.69 (7 hours), <0.3-0.46 (9 days) Monitor: 19.8 (7 hours), 9.7 (9 days) Game console: 1.26 (7 hours), 0.00 (9 days) Transformer: 6.0 (7 hours), 3.9 (9 days)	Not calculated. Method was not used; older report. Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005 Malmgren-Hansen et al., 2003

Substance name (CAS no.)	Measured levels (µg/m³)	Calculated RCR values	Exposure situation	Reference
Dodecamethylcyclo-hexasiloxane (D6) (540-97-6)	DIY products: Floor paints: 10-62 (5 hours) Moisture-resistant paint: 12 (5 hours) Floor finishes: 10 (5 hours)	Not calculated for substance	Emission chamber (measured after 5 hours, 3 days, and 28 days). Values after 3 days and after 28 days not specified (possibly equal to zero).	Lassen et al., 2018
Toluene (108-88-3)	Play tents: 10-19 (1½ hours), 13-21 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004
	Electronics: Clothing iron: 2.9 (7 hours), 0.1 (9 days) Lamp: 6.7 (7 hours), 1.0 (9 days) Rechargeable batteries: 8.9 (7 hours), 1.1 (9 days) TV: 1.95 (7 hours), 2.18 (9 days) Monitor: 38.3 (7 hours), 16.0 (9 days) Game console: 0.23 (7 hours), 0.23 (9 days) Transformers: 35.3 (7 hours), 14.8 (9 days)	Not calculated. Method was not used; older report. Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005 Malmgren-Hansen et al., 2003
	Indoor climate: Nursery: 49.2 (3 days?) — due solely to electronics	Not calculated. Method was not used; older report.	Calculations for model room with air exchange based on values identified in the literature. Calculations for 3 days? (unclear)	Jensen & Knudsen, 2006
	Nursery: Cumulative emissions: 52.4 (24 hours) for markers, tape, modelling clay, paint/lacquer. Electronics turned on, but allowed to enter sleep mode. Electronics, in all: 49.2 Indoor environment, generally: 28.4 (95th percentile) Actual measurements in nursery: 1.6-54 (230 due to shed containing chemicals)	Nursery (as sum of markers, tape, modelling clay, paint/lacquer from older reports and actual measurements from furniture, computers, new flooring, and electronics): RCR = 0.072 after 24 hours (DNEL = 725) Indoor climate in three nurseries: RCR = 0.07, 0.32, and 0.03 for measurements over 2 hours (DNEL = 725)	Exposures are combined from various other sources, including electronics. Field measurements from actual nurseries were taken for 2 hours. One nursery had unusually high values because it was adjacent to a shed in which chemicals were stored. Values from here are given in parentheses.	Larsen et al., 2016
	Squishy toys: 3-330 (1 hour), 0-25 (3 days)	RCR calculated for small children, 10 hours' sleep with a squishy toy, measurement after 1 hour, RCR = 0.19; measurement after 3 days, RCR = 0.01 (DNEL = 725). RCR calculated for older children with 40 squishies in the room. Measurement after 1 hour, RCR = 0.05;	Emission chamber (measured 1 hour and after 3 days)	Klinke et al., 2018., 2018

Substance name (CAS no.)	Measured levels (µg/m^3)	Calculated RCR values	Exposure situation	Reference
		measurement after 3 days, RCR = 0.01 (DNEL = 725)		
	DIY products: Epoxy floor paint (water-based): 12 (5 hours) PU foam: 12 (5 hours) Floor finishes: 5 (5 hours) Epoxy finish (water-based): 140 (5 hours)	RCR values calculated for the following: Floor paints: RCR = 0.1 for application in the zone of respiration (DNEL = 2900) Epoxy floor paint: RCR = 0.0 for application in the zone of respiration (DNEL = 2900) PU foam: RCR = 0.0 after 5 hours (DNEL = 2900) Floor finishes: RCR = 0.0 for application in the zone of respiration (DNEL = 2900) Floor wax: RCR = 0.7 for application in the zone of respiration (DNEL = 2900)	Emission chamber (measured after 5 hours, 3 days, and 28 days). Values after 3 days and after 28 days not specified (possibly equal to zero).	Lassen et al., 2018
α-Pinene (80-56-8)	Play tents: 3-23 (1½ hours), <1-5 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004., 2004
	Electronics: Toaster oven: 1 (7 hours), 1 (9 days) TV: 0.11 (7 hours), <0.11 (9 days) Monitor: 25.6 (7 hours), 4.9 (9 days) Game console: 0.57 (7 hours), 0.00 (9 days) Transformer: 0.4 (7 hours), 0.1 (9 days)	Not calculated. Method was not used; older report. Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005 Malmgren-Hansen et al., 2003., 2003
	Squishy toys: 7-16 (1 hour), 0-<5 (3 days)	RCR calculated for small children, 10 hours' sleep with a squishy, measurement after 1 hour, RCR = approx. 0; measurement after 3 days, RCR = approx. 0 (DNEL = 2500). RCR calculated for older children with 40 squishies in the room. Measurement after 1 hour, RCR = approx. 0; measurement after 3 days, RCR = approx. 0 (DNEL = 2500)	Emission chamber (measured after 1 hour and after 3 days) Note that the L-isomer is the one measured in this project, not the listed CAS no.	Klinke et al., 2018

Substance name (CAS no.)	Measured levels (µg/m^3)	Calculated RCR values	Exposure situation	Reference
Formaldehyde (50-00-0)	Play tents: 15-163 (3 hours), 5-80 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004., 2004
	Electronics: Printer: 0.4 (7 hours), 0.9 (9 days) Toaster oven: 18 (7 hours), 24 (9 days) Hair dryer: 0.5 (7 hours), 0.7 (9 days) Clothing iron: 3.3 (7 hours), 0.0 (9 days) Lamp: 19.5 (7 hours), 4.9 (9 days) Personal computer: 3.3 (7 hours), 0.7 (9 days) TV: 0.34-1.5 (7 hours), <0.23-0.3 (9 days) Electrical panel: <0.1 (7 hours), 0.1 (9 days) Space heater: 0.4 (7 hours), 0.4 (9 days) Monitor: 3.0 (7 hours), 2.8 (9 days) Game console: 0.8 (7 hours), 0.46 (9 days) Transformer: 11.1 (7 hours), 4.3 (9 days)	Not calculated. Method was not used; older report. Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005 Malmgren-Hansen et al., 2003
	Indoor climate: Nursery: 40.0 (3 days?) — due solely to electronics	Not calculated. Method was not used; older report.	Calculations for model room with air exchange based on values identified in the literature. Calculations for 3 days? (unclear)	Jensen & Knudsen, 2006
	Squishy toys: 3.1-23 (1 hour)	Not calculated for substance	Emission chamber (measured after 1 hour)	Klinke et al., 2018
	DIY products: Acid-cured floor finish: 10,627 (5 hours), 1,772 (3 days), 85 (28 days) Floor wax: 4.3 (5 hours), 2.3 (3 days), 1.2 (28 days) Floor paint (solvent-based): 1.5-6.7 (5 hours), 8-13 (3 days), 3.2-4.4 (28 days) Epoxy floor paint (water-based): 1.7 (3 days), 1.9 (28 days) Floor stain: 9.8 (5 hours), 13 (3 days), 3.4 (28 days)	RCR values calculated for the following: Acid-cured floor finish: RCR = 113 for application in the zone of respiration, RCR = 106 after 5 hours, RCR = 18 after 3 days, RCR = 0.9 after 28 days (DNEL = 100) Floor wax: RCR = 0.0 after 5 hours, after 3 days, and after 28 days (DNEL = 100) Floor paint (solv.): RCR = 0.0 after 5 hours, RCR = 0.1 after 3 days, RCR = 0.0 after 28 days (DNEL = 100) Epoxy floor paint: RCR = 0.0 after 3 days and after 28 days (DNEL = 100)	Emission chamber (measured after 5 hours, 3 days, and 28 days).	Lassen et al., 2018

Substance name (CAS no.)	Measured levels (µg/m³)	Calculated RCR values	Exposure situation	Reference
	Floor oil: 2.7 (5 hours), 15 (3 days), 1.7 (28 days) Moisture-resistant paint: 9.7 (5 hours), 2.0 (3 days), 2.1 (28 days)	Moisture-resistant paint: RCR = 0.2 after 5 hours, RCR = 0.1 after 3 days and after 28 days (DNEL = 100)		
Phenol (108-95-2)	Play tents: 0-16 (1 hour), 0-15 (3 days)	Not calculated. Method was not used; older report.	Emission chamber (measured after, e.g., 1½ hours and 3 days)	Hansen et al., 2004
	Electronics: Toaster oven: 1 (7 hours), <1 (9 days) Clothing iron: 1.4 (7 hours), 0.2 (9 days) Personal computer: 16.1 (7 hours), 16.1 (9 days) TV: 2.53-3.4 (7 hours), <0.3-2.99 (9 days) Game console: 1.49 (7 hours), 0.46 (9 days) Transformer: 0.0 (7 hours), 4.2 (9 days)	Not calculated. Method was not used; older report. Not calculated. Method was not used; older report.	Emission chamber (measured after 7 hours and after 9 days, with simulated relevant usage pattern). Calculated room concentrations after 7 hours and after 9 days are specified.	Mortensen, 2005 Malmgren-Hansen et al., 2003
	Indoor climate: Nursery: 43.6 (3 days?) — due solely to electronics	Not calculated. Method was not used; older report.	Calculations for model room with air exchange based on values identified in the literature. Calculations for 3 days? (unclear)	Jensen & Knudsen, 2006
	Squishy toys: 1-10 (1 hour)	Not calculated for substance	Emission chamber (measured after 1 hour). Screening only — measured as toluene equivalents.	Klinke et al., 2018
	DIY products: Pre-paint cleaner: 41 (5 hours), 9 (3 days) Wall paint (water-based): 32 (5 hours), 26 (3 days) Floor stain: 19 (5 hours), 6 (3 days) Chemically treated wood: 50 (5 hours) Moisture-resistant paint: 30 (3 days) Acid-cured floor finish: 79 (5 hours) Clear lacquer (epoxy): 25 (5 hours), 5 (3 days) PU sealing foam: 30 (3 days)	RCR values calculated for the following: Water-based floor paint: RCR = 0.3 after 5 hours and RCR = 0.3 after 3 days (DNEL = 100) Chemically treated wood: RCR = 0.5 after 5 hours (DNEL = 100) Moisture-resistant paint: RCR = 0.9 after 3 days (DNEL = 100) Acid-cured floor finish: RCR = 0.8 after 5 hours (DNEL = 100) PU sealing foam: RCR = 0.3 after 3 days (DNEL = 100)	Emission chamber (measured after 5 hours, 3 days, and 28 days). Values after 28 days not specified (possibly equal to zero).	Lassen et al., 2018

13. Hazard assessment

This chapter describes a hazard assessment performed for the nine selected substances. The hazard assessment is based on existing assessments and primarily establishes the DNEL values to be used in the risk assessment. The hazard assessment was performed for the nine selected substances (listed in TABLE 16 and in chapter 12 “Exposure levels from indirect sources").

13.1 Establishment of DNEL values

Existing assessments were used as a starting point for establishing DNEL values. These are primarily EU-LCI values ("Lowest Concentration of Interest"), but risk assessments performed in the Danish EPA's previous and ongoing consumer projects to survey chemical substances in consumer products were also used, as well as other relevant reports. The primary approach chosen is such that if the substances were recently evaluated, and inhalation DNEL values were set in one of the Danish EPA's previous survey projects within the last few years, these DNEL values were used directly in the project, and their source is given.

In several cases, the DNEL values were determined based on LCI values. LCI values are tolerable exposure levels for a number of individual substances, set by the EU to limit the emission of chemical substances from construction materials. The LCI values are set using the same method used to set DNEL values in REACH. On its EU-LCI website, the European Commission emphasises that LCI values are not an expression of indoor air quality guidelines, but have instead been developed to evaluate emissions from individual construction products/elements, where the purpose is to avoid health effects from long-term exposure (EC, 2013; EU-LCI, 2019). According to the report that serves as a backdrop for the EU-LCI values, LCI values are derived in such a manner as to be safe for both children and adults, even in the case of lifelong exposure to substances from a product (EC, 2013). For this reason, the same DNEL values are used in all scenarios, regardless of whether children or adults are involved. Correspondingly, Germany's AgBB has established LCI values for a number of substances (here referred to as NIK values). Generally, the EU-LCI value is used in Germany when one has been set for a substance, but AgBB has set LCI values for numerous substances, including D4, D5, D6, and DMF (AgBB, 2018). These values are thus also listed in TABLE 28 below. For DMF, it should be noted that AgBB has set the lowest observed limit value of 15 µg/cm^3, but because background documentation was not available, the critical effect supporting this limit value is unknown. The EU has proposed the same LCI value, but it has yet to be adopted. For these reasons, it has been decided to use a slightly higher DNEL value set by the EU's Expert Group on Toy Safety, also used by Klinke et al., 2018, which is 80 µg/cm^3.

For D4, D5, and D6, it was decided to use the DNEL values set in an ongoing project for the Danish EPA regarding siloxanes in cosmetics (Larsen et al., 2020). These values were chosen because the data for these substances has been reviewed recently, and because the DNEL values used are below the EU-LCI values, for which background documentation is additionally unavailable, making it impossible to know the basis upon which the EU-LCI values were set.

For comparison, the column with the LCI values also indicates the threshold limit values in working environments (marked TLV) set for DMF, toluene, formaldehyde, and phenol. The occupational threshold workplace environment limit values are generally significantly higher than the DNEL values used.

TABLE 28. Classification, DNEL values, and critical effect for selected substances. Harmonised classifications are given in boldface; otherwise, the notified classification is given with the number of notifications for the listed classification in parentheses. The chosen DNEL value is presented in boldface.

Substance name	**CAS no.**	**Classification[33] (health)**	**EU-LCI value (AgBB LCI value) TLV in working environment ($\mu g/m^3$)**	**DNEL for inhalation ($\mu g/m^3$) (critical effect)**	**Comments**	**Reference**
Dimethylformamide (DMF)	68-12-2	**Acute Tox. 4, H312** **Eye Irrit. 2, H319** **Acute Tox. 4, H332** **Repr. 1B, H360D** *On REACH Candidate List due to reproductive toxicity*	*None* Proposed: 15[34] (15) TLV: 15,000 (EU) Proposed LV: 3200 (ECHA)	Acute: **80** (mucous membrane irritation) Chronic: 100 (hepatotoxicity) 15 *(effect unknown)*	The value set by the Expert Group on Toy Safety was chosen because the EU-LCI value has yet to be adopted, and because the documentation supporting the LCI value cannot be found.	Expert Group on Toy Safety (per Danish EPA[35]) Klinke et al., 2018 AgBB, 2018 ECHA, 2019d
Decamethylcyclopentasiloxane (D5)	541-02-6	Not classified (4248) Acute Tox. 3 H331 (20) STOT SE 3 H335 (9) *On REACH Candidate List due to PBT, vPvB properties*	*None* *Value under development[36]* (1500)	Acute: 2.643 (lung irritation) Chronic: **4,314** (uterine tumours) 1500 *(reprotoxic effects, read-across from D4)* **5,300** (lung effects)	The documentation supporting the LCI value cannot be found. For this reason, DNEL values set by the Danish EPA's 2020 project on siloxanes are used, as this is a more recent assessment.	Calculated based on SCCS/1549/15, 2016 AgBB, 2018. Joint Research Centre, 2013. Larsen et al., 2020

[33] Harmonised classifications are given in boldface. Otherwise, the notified classification is given with the number of notifications for the listed classification in parentheses. The number is that indicated as of 20 October 2019 in a search of the ECHA's CL Inventory.

[34] According to Klinke et al. (2018), an EU-LCI value of 15 $\mu g/m^3$ has been proposed, but not yet adopted. The background for this value is likely the German system corresponding to EU-LCI values, called AgBB, which has set a limit value of 15 $\mu g/m^3$ for the substance (Joint Research Centre, 2013).

[35] Documentation received by the Danish EPA in connection with this project.

[36] Per EU LCI master list, July 2018 (https://ec.europa.eu/growth/sectors/construction/eu-lci/values_en)

Substance name	CAS no.	Classification[33] (health)	EU-LCI value (AgBB LCI value) TLV in working environment (µg/m³)	DNEL for inhalation (µg/m³) (critical effect)	Comments	Reference
Octamethylcyclotetrasiloxane (D4)	556-67-2	**Aquatic Chronic 4, H413** **Repr. 2, H361f** *On REACH Candidate List due to PBT, vPvB properties* *Considered an endocrine disruptor*	1200	Acute: *None* Chronic: 13,000 (hepatotoxicity) 1200 (reprotoxic effects) **1000** (lung effects)	The documentation supporting the LCI value cannot be found. For this reason, DNEL values set by the Danish EPA's 2020 project on siloxanes are used, as this is a more recent assessment.	Calculated based on SCCS/1241/10, 2010 EU-LCI, 2018. Joint Research Centre, 2013. CeHoS, 2018 Larsen et al., 2020., 2018 Larsen et al., 2020., 2020
2-ethyl-1-hexanol	104-76-7	Acute Tox. 4, H332 (1839) STOT SE 3, H335 (1795) Acute Tox. 4, H312 (66) Skin Sens. 1, H317 (10)	300	Acute: 26,000 (irritation) **300** (eye irritation) Chronic: 2300 *(none — highest dose tested)*	A CoRAP assessment agrees with the DNEL values set in registration documents. The EU-LCI value was selected because it is the lowest value.	ECHA, 2015 ECHA registration documents EU-LCI, 2014 EU-LCI, 2018 ECHA registration documents
Dodecamethylcyclohexasiloxane (D6)	540-97-6	Not classified (245) Eye Irrit. 3, H319 (19) Asp. Tox. 1, H304 (1) *On REACH Candidate List due to PBT,* vPvB properties	*None* *Value under development* (1200)	Acute: 1500 (lung irritation) Chronic: 2700 (hepatotoxicity) 1200 (reprotoxic effects, read-across from D4) **130** (lung/liver effects)	The documentation supporting the LCI value cannot be found. For this reason, DNEL values set by the Danish EPA's 2020 project on siloxanes are used, as this is a more recent assessment.	ECHA registration documents Greve et al., 2014 ECHA registration documents AgBB, 2018 Joint Research Centre, 2013 Larsen et al., 2020
Toluene	108-88-3	**Flam. Liq. 2, H225** **Skin Irrit. 2, H315** **Asp. Tox. 1, H304** **STOT SE 3, H336** **STOT RE 2, H373** **Repr. 2, H361d**	2900 TLV: 94,000 (DK)	Acute: 226.000 (lung irritation) Chronic: **2900** (neurotoxicity, colour vision)	The EU-LCI value was selected because it is the lowest value.	ECHA registration documents EU-LCI, 2018 EU-LCI, 2012b Larsen et al., 2016

Substance name	CAS no.	Classification[33] (health)	EU-LCI value (AgBB LCI value) TLV in working environment (µg/m³)	DNEL for inhalation (µg/m³) (critical effect)	Comments	Reference
α-Pinene	80-56-8	Acute Tox. 4, H302 (108) Asp. Tox. 1, H304 (1435) Skin Sens. 1, H317 (1241) Skin Irrit. 2, H315 (1607) Acute Tox. 2, H300 (22) Acute Tox. 2, H310 (22)	2500	Acute: *None* Chronic: 2500 (affects bladder) **674** (affects fertility)	While an EU-LCI value exists, the lower DNEL value from the registration documents was selected.	EU-LCI, 2012a ECHA registration documents
Formaldehyde	50-00-0	**Acute Tox. 3, H301** **Acute Tox. 3, H311** **Skin Corr. 1B, H314** **Skin Sens. 1, H317** **Acute Tox. 3, H331** **Muta. 2, H341** **Carc. 1B, H350**	100 LV: 400 (DK)	Acute: 100 (eye and airway irritation) Chronic: **50** (carcinogenic)	The slightly lower DNEL value was chosen, set by the RAC in a draft received from the Danish EPA. Based on extra uncertainty factors relative to the setting of the EU-LCI value.	EU-LCI, 2018 EU-LCI, 2016 RAC[37] per Danish EPA
Phenol	108-95-2	**Acute Tox. 3, H301** **Acute Tox. 3, H311** **Skin Corr. 1B, H314** **Acute Tox. 3, H331** **Muta. 2, H341** **STOT RE 2, H373**	70 TLV: 4,000 (DK)	Acute: *None* Chronic: 1320 (airway irritation) 100 (airway effects) **70** (effect unknown)	The EU-LCI value was selected because it is the lowest value. The documentation supporting the LCI value cannot be found. In the Danish EPA report (Lassen et al., 2018), a DNEL of 100 was calculated based on the same values as were used in the registration documents.	ECHA registration documents ECHA registration documents Lassen et al., 2018 (SCOEL, 2003) EU-LCI, 2018

[37] A draft of an ongoing assessment of formaldehyde and formaldehyde release by the RAC and SEAC was received from the Danish EPA. The RAC's suggested DNEL value is presented here. The RAC proposes the addition of extra safety factors.

13.2 Comparable mechanisms of action for the selected substances

The exposure and risk assessment takes into account the degree to which some substances may have comparable mechanisms of action. This assessment is based on the critical effects listed in TABLE 28.

Regarding D4 and D6, the critical effect for the lowest DNEL value selected (given in boldface) is lung effects, which were identified for both substances (Larsen et al., 2020). Meanwhile, for D5, the DNEL value for lung effects is not the lowest value. The critical effect for the lowest DNEL value for D5 is uterine tumours. D4, D5, and D6 strongly resemble each other structurally, and they have comparable effects (lung damage with long-term exposure) according to the Danish EPA's project on establishing quality criteria for siloxanes (Greve et al., 2014) and the Danish EPA's ongoing project on siloxanes in cosmetics (Larsen et al., 2020). Exposure to these siloxanes is thus grouped together in the exposure and risk assessment when using DNEL values for this effect (i.e., effects on the lungs). Thus, in the case of D5, where a lowest DNEL value exists for another effect (uterine tumours), both DNEL values listed in boldface in TABLE 28 are used.

In the case of dimethylformamide (DMF), the critical effect for the DNEL value used is mucous membrane irritation as described in Klinke et al. (2018).

Phenol and 2-ethyl-1-hexanol both have irritation listed as the critical effect; however, while the critical effect is unknown for the DNEL value chosen for phenol. It is likely to be airway irritation, as specified for the other DNEL values described, since this value is also based on a LCI value. According to the background document for 2-ethyl-1-hexanol, the critical effect for the selected DNEL value for this substance is eye irritation. These substances are therefore considered individually in the exposure and risk assessment.

For the remaining substances (toluene, alpha-pinene, and formaldehyde), there are different critical effects. These substances are therefore considered individually in the exposure and risk assessment.

14. Exposure and risk assessment method

This section describes the methods used to calculate exposures for the various exposure scenarios, as well as for risk calculations.

14.1 Exposure calculation method

As described in chapter 11, "Exposure scenarios" (Table 23), exposure scenarios were created for different groups of consumers, as well as for the products to which they are exposed in the worst case. These exposure scenarios are based on two different exposure calculations methods:

- Exposure in the zone of respiration during sleep
- Exposure from substances emitted by products, which become distributed throughout the entire room which a consumer occupies or sleeps in

14.1.1 Exposure calculation method for the zone of respiration

In the emission analyses for the PU foam products, samples of the PU foam products measuring approx. 10 x 10 cm were cut, or 15 x 15 cm for products with a thickness equal to or less than 5 cm (see chapter 8, "Emission analysis"). These cut products were put in a 119-litre emission chamber, which suitably simulates the zone of respiration for a baby (0 years of age).

The emission chambers used for the analyses in this project had an air exchange rate of 0.5 changes per hour. This air exchange rate is indicated as a standard air exchange rate by both EuroPUR and CertiPUR-US. The air exchange rate of 0.5 per hour used here is roughly equivalent to the standard air exchange rate of 0.6 changes per hour specified in the REACH guidance document for consumer exposure (ECHA, 2016) and an air exchange rate of 0.6 changes per hour for bedrooms with closed windows (varies from 0.3 to 0.9 per hour) according to RIVM (2014).

The concentrations measured in the environmental chamber analyses can therefore be used directly as a measure of exposure in the zone of respiration, where the air exchange rate corresponds to the standard air exchange rate for a room with closed windows.

The measured concentration is for the size of product cut for analysis (a block measuring approx. 10 x 10 cm x the height of the product), not for the entire product. For this reason, in consultation with the Danish EPA, it was decided that as the worst case for exposure in the zone of respiration, a block of 40 x 40 cm x the height of the product should be used, considered to be the size of the surface area of the product in the immediate vicinity of a baby's zone of respiration.

Emissions were measured for the cut block of approx. 10 x 10 cm x height, but the analysis results presented are converted and presented for a standard "loading factor" of 0.4 m^2/m^3 for all products, so that the analysis results are comparable across products. The so-called "loading factor" is described in chapter 8.1, "Procedure for sample preparation", defined as the ratio of the sample surface area to the size of the emission chambers used. It is therefore necessary to calculate the surface area (for five sides; i.e., excluding the side on which the product stands) for each product, and to divide it by the volume of the emission chamber to obtain the loading factor of the product. The loading factor of the product is then corrected to the stand-

ard loading factor of 0.4 m^2/m^3 used here, and with which all analysis data has been converted. However, for the baby pillows in particular, the entire pillows were placed in the emission chamber, and the loading factors used are those indicated.

The calculation can thus be presented as follows:

$$C_{around\ head} = C_{measured} \times \frac{LF_{Product}}{LF_{Standard}}$$

where

$C_{around\ head}$	is the calculated concentration immediately around the head	measured in $\mu g/m^3$
$C_{measured}$	is the concentration measured in the emission chamber	measured in $\mu g/m^3$
$LF_{product}$	is the calculated loading factor for the product when using an upper surface of 40 cm x 40 cm x the height of the product, and an emission chamber of 0.119 m^3	measured in m^2/m^3
$LF_{standard}$	is the standard loading factor for which analysis data is presented (0.4 m^2/m^3)	measured in m^2/m^3

The emitted concentrations of the selected substances can be calculated for each of the 20 purchased products. For the exposure scenarios described, the simultaneously emitted concentrations of substances from numerous products (baby pillows, baby mattresses, and cot bumpers) are taken together, yielding the total concentration in the zone of respiration. The emitted concentration is given in µg of substance per m^3 and can thus be directly compared to the DNEL value, also given in $\mu g/m^3$.

14.1.2 Exposure calculation method for occupied rooms

A more realistic scenario is to calculate the exposure for product emissions that have become distributed throughout an entire occupied room. Here, the exposure is calculated based on the measured concentrations in the emission chamber. It is important to emphasise that the concentrations measured in the emission chamber are based on emissions of substances from samples measuring approx. 10 x 10 cm x product height, in a 119-litre chamber.

To then calculate the actual emissions from an entire product, it is necessary to scale up the actual emitted quantity for the size of the entire product. This scaling is accomplished by applying the ratio of the total surface area of the cut block for which emissions were measured to the total surface area (on five sides) of the entire product. This supposes that emissions occur from the surfaces, and only from five surfaces, since the product rests on the sixth and final surface.

In scaling, the fact that the analysis results are presented for a standard loading factor of 0.4 m^2/m^3 for all products is also used. In practice, the analyses were performed on the cut block, but the emission results have been converted to this standard loading factor, making the analysis results comparable across products. With an emission chamber volume of 119 litres (0.119 m^3), this means that the emissions for all products are calculated for a surface area of 0.4 m^2/m^3 x 0.119 m^3, corresponding to 0.048 m^2. To scale up to the total surface area of a particular product, the surface area for five surfaces (excluding the surface on which the product rests) is calculated.

Because the largest product is an adult mattress measuring 90 x 200 x 20 cm, and the smallest product is a baby pillow measuring 26 x 20.5 x 2.5 cm in the shape of a ring (an oval with a hole in the centre), the highest and lowest scaling values are thus factors of 62.1 and 2.1.

Additionally, the emitted quantity will not distribute itself throughout only 119 litres, but throughout an entire room; that is, either a bedroom, nursery, or living room, as specified in the exposure scenarios. A dilution of the emitted quantity will thus take place, corresponding to the ratio of the volume of the emission chamber to that of the room. In practice, this is a dilution by a factor of 0.119 m^3 / 21 m^3 (bedroom) or 0.119 m^3 / 58 m^3 (living room); that is, a factor of 0.0057 or 0.0021, corresponding to dilution by either 176.5 or 487.4 times.

The calculation can thus be presented as follows:

$$C_{room} = C_{measured} \times \frac{TSA_{Product}}{TSA_{measured\ block}} \times \frac{V_{emission\ chamber}}{V_{Room}}$$

where

C_{room}	is the calculated concentration in the room	measured in µg/m^3
$C_{measured}$	is the concentration measured in the emission chamber	measured in µg/m^3
$TSA_{product}$	is the total surface area of the intact product (for five sides, excluding the side on which the product rests)	measured in cm^2
$TSA_{measured\ block}$	is the total surface area of the block measured in the emission chamber (i.e., 0.048 m^2 as a standard)	measured in cm^2
$V_{emission\ chamber}$	is the volume of the emission chamber (i.e., 0.119 m^3)	measured in m^3
V_{room}	is the volume of the room in the exposure scenario	measured in m^3

In practice, there is thus a maximum scaling of the concentration by a factor of 62.1, and a simultaneous dilution by a factor of at least 176.5 on account of the size of the room. Thus, in this exposure scenario, the measured concentration in the emission chamber will be diluted by a factor of at least 2.8. This means that the exposure scenario with direct application of the measured concentration in the emission chamber as a measure of the zone of respiration will result in a higher exposure than this exposure calculation, where the concentration becomes distributed throughout an entire room.

The scaling of the emitted quantity (via the area of the entire product relative to the measured block) and the dilution of the emitted quantity (into the whole room) will naturally depend on the size of the product and the size of the room in the various exposure scenarios.

Many of the exposure scenarios involve multiple products in the same room. In this case, the concentrations of the same substance (or substances with the same mechanism of action) are added together, giving the total concentration of the substance (or substances with the same mechanism of action) in the room.

14.2 Risk calculation method

In calculating the risk (specifically, the Risk Characterisation Ratio, also called the RCR value), the calculated exposure is divided by the DNEL value established; that is, the value considered not to result in health effects.

$$RCR = \frac{Exposure\ (\mu g/m^3)}{DNEL\ (\mu g/m^3)}$$

RCR values greater than 1 indicate that the exposure exceeds the DNEL value, meaning that the protection level for the consumer is too low. A health risk may therefore be present.

In calculating the total risk, the calculated RCR values can be added together. Specifically, RCR values calculated for the same substance for two different products can be directly added to yield an expression of the combined exposure risk from both (or all) products. Correspondingly, RCR values for the same mechanism of action can be added. In this case, only RCR values calculated for D4, D5, and D6 can be added.

The DNEL values represent the concentrations which consumers (both adults and children) can inhale daily over a long period of time without incurring health effects. Most DNEL values used are based on LCI values, which are developed to be safe for both children and adults, even in the case of lifelong exposure to substances from a product (EC, 2013). For this reason, the same DNEL values are used in all scenarios, regardless of whether children or adults are involved.

When calculating the exposure scenarios in this project, the same exposure does not occur for all 24 hours in a day. For example, it is supposed that babies (and adults) occupy their bedrooms when they sleep, and spend the majority of their remaining waking hours in the living room (the worst-case situation here is a weekend, or a day spent at home with a baby while on maternity leave). For this reason, the DNEL value for a 24-hour exposure must be converted for the number of hours during which exposure occurs. For example, for a baby that sleeps 18 hours, the DNEL value will be a factor of 24 hours / 18 hours higher.

The RCR value is calculated for both waking hours and sleeping hours as illustrated by the formula below, where the sum of waking hours (w) and sleeping hours (z) is 24 hours (w + z = 24 hours).

$$RCR = RCR_V + RCR_Z = \frac{Exposure\ for\ V\ hours\ (\mu g/m^3)}{DNEL\ (\mu g/m^3) \times \frac{24\ hours}{V\ hours}} + \frac{Exposure\ for\ Z\ hours\ (\mu g/m^3)}{DNEL\ (\mu g/m^3) \times \frac{24\ hours}{Z\ hours}}$$

14.3 Stepwise approach to risk calculation

Preliminarily, the risk for each individual product was calculated in this project for a person (a baby, child, or adult) exposed to that product alone in the zone of respiration for 18 hours out of the 24 hours in a day. 18 hours was selected as the worst case, since babies are presumed to sleep for 18 hours per day. This applies regardless of whether products for babies are involved. Subsequently, the described exposure scenarios from chapter 11 (exposure to multiple products at once) were calculated.

A large amount of data is involved in this project, and exposure calculations were planned for:

- Multiple groups of consumers,
- exposed to multiple distinct products,
- in differently sized rooms of a house or in the zone of respiration,
- at two different times (measured after 1 hour and after 3 days),
- and exposed to nine different substances,
- several of which have the same mechanism of action (exposures must be combined).

This implies a large amount of data, including calculable RCR values, and the resulting amount of data could be unmanageably large. For this reason, an approach was selected in which absolute worst-case situations are calculated first for all substances with the same mechanism of action, and only in the event that the RCR values exceed 1 — that is, only if a

potential health risk exists – the calculations are refined using new, more realistic exposure calculations and risk assessments.

In general, for the nine substances selected, the concentrations measured after 1 hour were higher than the concentrations measured after 3 days, though there are some exceptions, particularly for values at lower levels. For this reason, the following steps were taken in the exposure and risk assessments for each of the nine substances (and for D4, D5, and D6 together). In each case, the next step is taken only if the RCR is higher than 1:

6. Exposure to the most products in the zone of respiration; that is, a baby exposed to a baby mattress, baby pillow, and cot bumper in the zone of respiration.
    - The highest concentration measured for the substance after 1 hour (or 3 days, if this value is higher) is used for calculations, regardless of whether it was measured in these types of products or not. Thus, in practice, the highest concentration measured is multiplied by three for the three products.
    - It is assumed that this exposure applies for all 24 hours of the day.
7. Exposure to the most products in the zone of respiration; that is, a baby exposed to a baby mattress, baby pillow, and cot bumper in the zone of respiration while sleeping (18 hours) and to a tumbling mat in the zone of respiration in the living room during waking hours (3 hours).
    - The concentrations measured after 1 hours (and after 3 days) for the products named are used for calculations.
    - The highest measured concentrations for the selected products are used. That is, the highest measured concentration of the substances for each of a baby mattress, a baby pillow, and a cot bumper.
8. Exposure of a baby to multiple products simultaneously, distributed throughout the room in a bedroom (18 sleeping hours) and living room (3 waking hours).
    - The measured concentrations after 1 hour (and after 3 days) are used for the named types of products.
9. Exposure of a teenager to multiple products simultaneously, distributed throughout a teenager's bedroom (sleeping and waking hours; total of 18 hours).
    - The measured concentrations after 1 hour (and after 3 days) are used for the named types of products.

The first scenario is assumed to be an extreme worst case, and is not considered particularly realistic, but it is calculated to be able to exclude substances from further calculations if they are not considered to constitute a health risk. If there is no risk in the extreme worst-case scenario, the substance is assumed not to be capable of posing a health risk in the other scenarios.

As described earlier, exposure to the selected substances from other sources is not added, as these are not immediately comparable (measured) under similar conditions, but exposure to the substances from other sources must be accounted for in the subsequent discussion of the results.

15. Exposure and risk assessment

In this chapter, both exposure calculations and a risk assessment are performed. Exposure calculations calculate the exposure (dose) that consumers are exposed to when using the PU foam products studied. In the risk assessment, an assessment is made as to whether the calculated exposures may constitute a health risk by comparing them to the established DNEL values from chapter 13; namely, levels that do not cause health effects. The calculations are made based on the method described in chapter 14.

As described in chapter 14, a stepwise approach is used to calculate risk. Initially, a calculation is performed for exposure in the zone of respiration for each of the 20 purchased products individually. For the described exposure scenarios with exposure to multiple PU foam products at once, an extreme worst-case scenario with exposure to multiple products in the zone of respiration is calculated first, before considering other more realistic scenarios. If substances are found not to constitute a risk in the extreme worst-case situation, the substances are considered incapable of posing a health risk in more realistic worst-case scenarios, and so they are excluded from further assessment.

15.1 Exposure in the zone of respiration for individual products

Initially, RCR values for the nine selected substances were calculated for each of the 20 purchased PU foam products individually, to provide an overview of the risk from each of the purchased products. The calculations are based on the following assumptions:

- Exposure in the zone of respiration, since this should theoretically post the highest risk (the measured concentration is used directly, without dilution in a larger space).
- An exposure time of 18 hours is assumed, equivalent to worst-case sleeping hours for a baby. This exposure time is used for all 20 products, whether they are for babies or older children and adults, who either sleep less or use the products for a shorter time compared to a baby.
- Calculations are made based on a piece of 40 x 40 cm x the height of the product, which is the portion of the products assumed to emit substances directly in zone of respiration.

The data supporting these calculations is given in Appendix 5 “Calculation of exposure and risk". In TABLE 29 below, only the calculated RCR values for 1 hour and for 3 days (in parentheses) are given. A dash ("-") for the RCR value indicates that the substance was not emitted from the product in question above the level of detection. A single dash for a product indicates that no emission of the substance was measured after 1 hour or after 3 days. The bottom row of the table indicates the total number of products out of 20 which emitted the substance in question. As shown, only α-pinene was emitted by all 20 products after 1 hour, but at low concentrations. D5, D6, toluene and formaldehyde were emitted by the majority of products (between 11 and 16 products) after 1 hour, while DMF, D4, 2-ethyl-1-hexanol, and phenol were only emitted by between 6 and 8 of the 20 products purchased. However, the overall impression is that substances are emitted from fewer products after 3 days. Among other examples, no emission of D4 was seen after 3 days above the detection limit; and D5, toluene, and α-pinene were emitted from far fewer products after 3 days.

TABLE 29. Calculated RCR values for the 20 purchased PU foam products and for the nine selected substances after 1 hour. The numbers in parentheses are RCR values for emissions after 3 days. The calculations are based on 18 hours of exposure.

Product	DMF	D4	D5*	D6	Sum D4+D5+D6*	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formalde-hyde	Phenol
N-EU 2**	0.28 (0.26)	-	0.004 (0.001)	0.22 (0.15)	0.23 (0.15)	- (0.01)	0.02 (-)	0.01 (-)	0.26 (0.17)	- (0.04)
N-EU 3	**106.4** (**27.7**)	0.85 (-)	0.14 (-)	**1.75** (0.27)	**2.71** (0.27)	-	0.03 (-)	0.06 (-)	0.49 (-)	-
N-EU 4	-	0.32 (-)	0.19 (-)	**2.05** (**1.07**)	**2.52** (**1.07**)	-	0.004 (-)	0.06 (-)	0.78 (0.38)	-
N-EU 5	-	-	0.004 (-)	0.41 (0.12)	0.41 (0.12)	-	0.04 (-)	0.02 (-)	0.31 (-)	-
N-EU 6	-	-	0.004 (-)	0.08 (-)	0.08 (-)	- (0.15)	0.004 (-)	0.02 (-)	0.76 (0.42)	0.22 (0.15)
EU 1	0.12 (-)	-	-	-	-	0.04 (0.03)	0.001 (-)	0.01 (-)	0.06 (-)	0.15 (0.15)
EU 2	-	0.13 (-)	0.04 (0.004)	0.57 (0.26)	0.73 (0.26)	-	0.01 (-)	0.03 (-)	-	- (0.81)
EU 3	0.42 (0.28)	-	0.004 (-)	0.11 (0.07)	0.12 (0.07)	0.95 (0.61)	-	0.02 (-)	-	0.25 (0.24)
EU 4	-	-	-	-	-	0.04 (0.03)	0.003 (-)	0.02 (-)	0.98 (0.56)	-
EU 5	-	0.05 (-)	0.02 (-)	-	0.07 (-)	-	0.01 (-)	0.07 (-)	0.51 (-)	0.46 (0.28)
DK 1	-	0.08 (-)	0.06 (-)	0.56 (0.12)	0.69 (0.12)	0.08 (-)	0.01 (-)	0.28 (-)	-	-
DK 2	-	-	0.01 (-)	-	0.01 (-)	0.05 (-)	-	0.02 (-)	0.50 (0.47)	0.11 (-)
DK 3	-	-	0.003 (-)	-	0.002 (-)	0.04 (0.02)	0.003 (-)	0.02 (-)	0.39 (0.33)	-
DK 4	-	-	0.04 (-)	**1.47** (0.45)	**1.50** (0.45)	-	0.01 (-)	0.04 (-)	0.48 (0.38)	-
DK 5	-	-	0.01 (-)	-	0.01 (-)	0.04 (-)	0.01 (-)	0.07 (-)	-	-
DK 6	-	-	-	-	-	-	0.003 (-)	0.19 (0.03)	-	-
DK 7	-	-	0.003 (-)	-	0.003 (-)	-	0.01 (-)	0.04 (-)	0.41 (0.29)	-
DK 8	0.37 (-)	-	0.01 (-)	0.75 (0.43)	0.76 (0.43)	-	0.04 (-)	0.07 (-)	0.34 (-)	-
DK 9	-	0.33 (-)	0.18 (0.004)	**3.29** (**1.82**)	**3.77** (**1.82**)	- (0.04)	- (0.02)	0.06 (-)	-	0.84 (0.91)
DK 10	0.17 (-)	-	-	-	-	0.06 (0.04)	-	0.03 (-)	**1.39** (0.65)	-

Product	DMF	D4	D5*	D6	Sum D4+D5+D6*	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formalde-hyde	Phenol
# of prod. with emis-sions	6 (3)	6 (0)	16 (3)	11 (10)	16 (10)	8 (8)	16 (1)	20 (1)	14 (9)	6 (7)

* The D5 column uses the lowest DNEL value of 4.3 µg/m^3, whereas the siloxane sum calculations (in the "D4+D5+D6" column) use the higher DNEL value of 5.3 µg/m^3, where the effect is the same for all siloxanes.
** It should be noted that the numbering of the N-EU products starts at N-EU 2 because a FT-IR analysis of product N-EU 1 found that the product did not consist of PU foam. For this reason, the product was not analysed.

It can be seen in TABLE 29 that RCR values are generally low: less than 1 for the nine substances and for many of the 20 products analysed. However, there are certain products and substances for which the RCR values calculated are higher than 1 at the 1-hour measurement (and in one case, also after 3 days). These products may thus constitute a health risk under the conditions used for these calculations. These products are:

- Baby mattress N-EU 3 for DMF and D6, and thus also the sum of D4, D5, and D6 (a health risk still exists for DMF after 3 days, but not for D6).
- Folding mattress N-EU 4 for D6, and thus also the sum of D4, D5 and D6 (for both 1 hour and 3 days)
- Baby mattress DK 4 for D6, and thus also the sum of D4, D5 and D6 (no risk after 3 days)
- Adult mattress DK 9 for D6, and thus also the sum of D4, D5 and D6 (for both 1 hour and 3 days)
- Baby mattress DK 10 for formaldehyde (no risk after 3 days)

Since the above five products have RCR values above 1, RCR values are also calculated for more realistic scenarios; specifically, for the adult mattress, a sleeping time of 9 hours is used, and for the baby products, a sleep time of 12 hours is used. In other words, it is assumed that sleeping time during the day takes place somewhere else, such as in a pram or on a rug in the living room.

TABLE 30. Calculated RCR values for the 20 purchased PU foam products and for the nine selected substances after 1 hour. The numbers in parentheses are RCR values for emissions after 3 days. The calculations are based on a 12-hour exposure for baby products and a 9-hour exposure for adult products.

Product	DMF	D4	D5*	D6	Sum D4+D5+D6*	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formalde-hyde	Phenol
N-EU 3	**70.9** (**18.4**)	0.57 (-)	0.10 (-)	**1.16** (0.18)	**1.81** (0.18)	-	0.02 (-)	0.04 (-)	0.33 (-)	-
N-EU 4	-	0.16 (-)	0.10 (-)	**1.02** (0.54)	**1.26** (0.54)	-	0.002 (-)	0.03 (-)	0.39 (0.19)	-
DK 4	-	-	0.03 (-)	0.98 (0.30)	**1.00** (0.30)	-	0.004 (-)	0.02 (-)	0.32 (0.25)	-
DK 9	-	0.16 (-)	0.09 (0.002)	**1.64** (0.91)	**1.88** (0.91)	- (0.02)	- (0.01)	0.03 (-)	-	0.42 (0.46)

Product	DMF	D4	D5*	D6	Sum D4+D5+D6*	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formalde-hyde	Phenol
DK 10	0.11 (-)	-	-	-	-	0.04 (0.03)	-	0.02 (-)	0.93 (0.43)	-

* The D5 column uses the lowest DNEL value of 4.3 µg/m^3, whereas the siloxane sum calculations (in the "D4+D5+D6" column) use the higher DNEL value of 5.3 µg/m^3, where the effect is the same for all siloxanes.

It can be seen in TABLE 30 that there are still some products with a calculated RCR value higher than 1. However, for the sum of siloxanes, the RCR value is only slightly above 1 in most cases. This means that the following products may thus constitute a health risk under the conditions used for the calculations:

- Baby mattress N-EU 3 for DMF and D6, and thus also the sum of D4, D5, and D6 (a health risk still exists for DMF after 3 days, but not for D6).
- Folding mattress N-EU 4 for D6, and thus also the sum of D4, D5 and D6 (but no risk after 3 days)
- Baby mattress DK 4 for D6, and thus also the sum of D4, D5 and D6 (but no risk after 3 days)
- Adult mattress DK 9 for D5 and D6, and thus also the sum of D4, D5 and D6 (but no risk after 3 days)

For baby mattress N-EU 3, the calculated RCR values of 106 and 28 for DMF in the zone of respiration are for after 1 hour and 3 days, respectively. This means that a baby that sleeps 18 hours a day on this baby mattress immediately after the mattress is removed from its packaging is at risk of health effects in the form of mucous membrane irritation, as this is the critical effect for DMF. It can be seen that the RCR value drops significantly after the 3 days but is still far above 1. Even with a more realistic 12-hour usage period for the mattress, presuming that it is only used at night, and that the baby sleeps elsewhere during the day, the RCR values are still far above 1 (at 71 and 18 after 1 hour and 3 days, respectively). Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long DMF emissions remain high enough to produce mucous membrane irritation. However, this product has an extremely high emission of DMF compared to the other products that emitted DMF, so this does not immediately indicate a general issue with PU foam products. 14 of 20 products did not emit DMF at all, and for the other five products that emitted DMF, the emissions were so low that they do not cause any health effects in a baby (or other person) that sleeps for 18 hours on the product.

For folding mattress N-EU 4 and adult mattress DK 9, the calculated RCR value for D6, and thus also the sum of D4, D5, and D6 (siloxanes) is above 1 (between 2.1 and 3.3, with a sum between 2.5 and 3.8) after 1 hour. The RCR values for D6, and thus also the RCR values for the sum of D4, D5, and D6 also are above 1 (at 1.1 and 1.8, respectively, after 3 days). This means that a baby that sleeps for 18 hours of the day on these mattresses immediately after they are removed from their packaging is at risk of health effects in the form of effects on the lungs, as this is the critical effect for the siloxanes. Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long siloxane emissions remain high enough to produce effects on the lungs. However, emissions for both products decreased over time. With more realistic mattress usage times of 9 hours for adults, the RCR values remain above 1 after 1 hour for the two products (at 1.3 and 1.9, respectively), but they fall below 1 after 3 days. For adults, who sleep half the time a baby sleeps, there will thus be no health effects after the 3 days.

For baby mattresses N-EU 3 and DK 4, the calculated RCR value for D6, and thus for the sum of the siloxanes, is above 1 (sum of siloxanes between 1.5 and 2.7) after 1 hour. The emission of siloxanes for these products, however, fell significantly after just 3 days, placing the calculated RCR value for the sum of siloxanes no higher than 0.5 after 3 days. Since the calculations assume that the measured concentration at 1 hour is constant for 18 hours, these substances are not considered to cause health issues, as the concentration is expected to decrease significantly over the 18 hours — though to what extent is unknown, since analyses were only performed after 1 hour and after 3 days. For the adult mattresses, primarily assumed to be used by older children and adults, the sleeping time of 18 hours used in the calculations will be an overestimate. The assessment is therefore that D4, D5 and D6 will not constitute a health problem when considering these products individually, despite the calculated RCR value above 1. The levels of the siloxanes can be expected to have dropped to a level that does not constitute a risk during the first day (however, this has not been investigated).

For all products that emit siloxanes, even though the RCR values are above 1, thereby posing a risk of effects on the lungs, which is the critical effect for the siloxanes, the decreasing values over time suggest that there is hardly a long-term exposure lasting numerous months/years, which is what the DNEL values for siloxanes are based on (long-term effects). The calculations with the more realistic use times (sleep times) show that for all products, the RCR values are less than 1 for the sum of the siloxanes after 3 days. There is thus a short-term health risk. Moreover, it should be noted that the concentration measured after 1 hour (where it is the highest) has been assumed to be constant throughout the sleep period — knowing fully that the concentration decreases over time. The calculations are thus overestimates.

For baby mattress DK 10, the calculated RCR value for formaldehyde emissions exceeds 1 (1.4) after 1 hour. However, the emissions decrease significantly after 3 days, at which point the RCR value is below 1 (0.65). The calculations assume, as previously stated, that the measured value after 1 hour is constant over the 18 hours, which is naturally not the case. The critical effect of formaldehyde is carcinogenicity, and this is an effect that can occur after long-term exposure above the DNEL value for a long period. The analyses show that exposure will only briefly (for no more than 1-2 days) be above the DNEL value. This product is therefore not expected to constitute a health risk alone.

Thus, of the 20 products examined, only baby mattress N-EU 3, with its high levels of DMF emissions, can be expected to cause deleterious health effects if the product is used immediately after it is removed from its packaging. For folding mattress N-EU 4 and adult mattress DK 9, more calculations based on more realistic usage times show that there will be no health risk after 3 days. For the remaining products, they are not expected to be able to cause health effects alone. It should be noted that the calculated RCR values for emissions after 1 hour may be affected by the fact that the products were compressed 10 times in the emission chamber before it was closed and measurement began, in order to simulate movement when a person lies on the products. Conversely, there was no compression of the PU foam sample from time zero to 3 days, where in reality there will be movement from a person moving in their sleep. Therefore, the actual emitted concentrations after 3 days may be higher than those measured.

For the products whose calculations are close to the DNEL value, it is necessary to account for other products in the home that may emit formaldehyde (textiles, rugs, electronics, etc.) and DMF (squishy toys, play tents) (see chapter 12 “Exposure levels from indirect sources"). However, these calculations were not performed in this project, as the values from the previous studies are not immediately comparable to the measurements taken in this project.

15.2 Extreme worst case: Several products in the zone of respiration

In this scenario, which can be considered an extreme worst case, the exposure and risk are calculated based on the following:

- Exposure in the zone of respiration, since this should theoretically post the highest risk (the measured concentration is used directly, without dilution in a larger space).
- It is assumed that exposure is to the same concentration for all 24 hours of the day, despite the fact that measurements from 1 hour and 3 days show that emissions decrease somewhat over time.
- It is assumed that exposure in the zone of respiration occurs for 24 hours, not only while asleep.
- It is assumed that exposure is to three products (a baby mattress, a baby pillow, and a cot bumper) at the same time.
- The highest measured emissions for the substances are used for all of the products listed, regardless of whether the substance was found to be emitted by that type of product; that is, the highest measured concentration is multiplied by three in practice.

An example of more detailed exposure and risk (RCR value) calculations is presented in Appendix 5.2. All calculated concentrations in the zone of respiration, as well as RCR values, are listed in TABLE 47 to TABLE 53 in this appendix.

In TABLE 31 below, the most important data is presented for all nine substances; specifically, the highest concentration measured, as well as the calculated RCR values for exposure to the three products in the zone of respiration (baby mattress, baby pillow, and cot bumper). Note that in this worst-case calculation, only calculations based on the 1-hour measurements are made. In the vast majority of cases, these were the highest. If no risk exists in this extreme worst-case situation, there is no need to perform calculations for more realistic scenarios.

TABLE 31. Calculated RCR values for the extreme worst-case scenario, with multiple products in the zone of respiration, based on the 1-hour measurements

Substance name	Greatest concentration measured after 1 hour (µg/m^3)	DNEL value (µg/m^3)	RCR Total for three products at 1 hour
DMF	1500	80	**253.5**
D4 (lung effects)	150	1000	**2.0**
D5 (uterine tumours)	190	4314	0.6
D5 (lung effects)	190	5300	0.5
D6 (lung effects)	87	130	**7.4**
Sum: D4, D5, D6 (lung effects)	-	-	**9.9**
2-ethyl-1-hexanol	94	300	**3.1**
Toluene	44	2900	0.21
α-pinene	40	674	0.80
Formaldehyde	18	50	**4.0**
Phenol	13	70	**2.5**

It can be seen in TABLE 31 that toluene and α-pinene both have calculated RCR values for the PU foam products under 1; that is, there is no risk of health effects from these substances

taken individually. Since the siloxanes have comparable mechanisms of action, their RCR values can be added, and the overall RCR value clearly exceeds 1 (9.9). It is therefore necessary to look at more realistic exposure scenarios for the following substances:

- DMF
- D4, D5 and D6
- 2-ethyl-1-hexanol
- Formaldehyde
- Phenol

At the levels of toluene and α-pinene emitted from the investigated PU foam products, these are not considered to constitute a health risk. In the case of toluene and α-pinene, previous studies (described in chapter 12) have calculated low RCR values for emissions of these substances from other sources, such as electronics and squishies. While this calculation was not performed, there is likely no health risk present, even when adding in exposure from other products that can emit these substances.

Thus, it is not considered necessary to calculate more realistic scenarios for either toluene or α-pinene, and therefore, these substances are not further addressed in this report.

15.3 Realistic worst case: Zone of respiration in bedroom and living room

For DMF, D4, D5 and D6, 2-ethyl-1-hexanol, formaldehyde and phenol, where it was not possible to rule out a risk in the extreme worst-case scenario, the exposure (and risk) is therefore calculated for a more realistic worst-case scenario. This scenario is based on the following:

- Exposure in the zone of respiration, since this should theoretically post the highest risk (the measured concentration is used directly, without dilution in a larger space)
- It is assumed that exposure is to the same concentration for all 24 hours of the day, despite the fact that measurements from 1 hour and 3 days show that emissions decrease somewhat over time
- Exposure to three products simultaneously (baby mattress, baby pillow, and cot bumper) for 18 hours is assumed, with a baby sleeping in the parents' bedroom, as well as exposure to a tumbling mat for 3 hours during the baby's waking hours. For the remaining 3 hours of the day, the baby is presumed not to be exposed to PU foam products in the zone of respiration.
- The actual measured concentrations are used for the types of products mentioned.
- Calculations are made based on both measurements, i.e. after 1 hour and after 3 days.

An example of more detailed exposure and risk (RCR value) calculations is presented in Appendix 5.3. All calculated concentrations in the zone of respiration, as well as RCR values, are listed in TABLE 54 to TABLE 58 in this appendix.

As for the extreme worst-case scenario, the total RCR value is given for exposure to the three products in the zone of respiration during sleep (baby mattress, baby pillow, and cot bumper) and for the tumbling mat during waking hours.

TABLE 32. Calculated RCR values for the more realistic worst-case scenario, with multiple products in the zone of respiration, based on the 1-hour measurements. Calculated RCR values after 3 days are indicated in parentheses below.

Substance name	Highest concentration measured after 1 hour (3 days) (µg/m³)	DNEL value (µg/m³)	RCR Total for PU foam products
DMF (highest value*)	1500 (390)	80	**106.6 (27.9)**
DMF (second highest value*)	11 (7.5)	80	0.66 (0.50)
D4 (lung effects)	150 (0)	1000	0.85 (0)
D5 (lung effects)	110 (4.1)	5300	0.13 (0.001)
D5 (uterine tumours)	110 (4.1)	4314	0.16 (0.001)
D6 (lung effects)	42 (18)	130	**1.7** (0.58)
Sum: D4, D5, D6 (lung effects)	-	-	**2.6** (0.58)
2-ethyl-1-hexanol	94 (60)	300	**1.04** (0.66)
Formaldehyde	18 (8.4)	50	**2.1 (1.3)**
Phenol	12 (13)	70	0.74 (0.61)

* Calculations have been made for two different baby mattresses, as one baby mattress (N-EU 3) stood out with a very high emission of DMF compared to the other products

It can be seen in TABLE 32 that for phenol, D4 and D5, the RCR values calculated for the PU foam products, are below 1 for exposure after 1 hour; that is, there is no risk of health effects for these substances in this scenario. The calculated RCR values for the sum of D4, D5, and D6, as well as for 2-ethyl-1-hexanol, are above 1 (at 2.6 and 1.04, respectively) after one hour, but the exposure decreases significantly after the 3-day measurement, leaving the RCR values below 1 and thereby not posing a health risk after 3 days. Since it is assumed in these calculations that the measured concentration after 1 hour is constant over 18 hours (which the 3-day measurements demonstrate not to be the case), there are considered to be no deleterious health effects from 2-ethyl-1-hexanol in this scenario, as the RCR value for the substance was only slightly above 1 after 1 hour. For the sum of the siloxanes (D4, D5 and D6) there may be a risk, as the RCR value is exceeded during the first few days (but the RCR is less than 1 at 3 days). However, it should be emphasised that the critical effects for the siloxanes, which are effects on the lungs, are first seen after long-term exposure. In addition, products for which the highest emissions of D4, D5 and D6 were used in calculating the RCR values for D4, D5, and D6. In other words, these are not the same products that are significant for the combined RCR value for the three siloxanes. These are the same products significant for D4 and D5 (N-EU 3 and N-EU 2), but other products are significant for the combined RCR value for D6 (DK 4 and N-EU 2). Therefore, the actual combined RCR value for the same three products is not 2.6, but 1.7. However, the RCR value is still above 1 at the 1-hour measurement, though it falls below 1 after 3 days. Because the RCR value is below 1 for the sum of the siloxanes after 3

days, this is not a case of long-term exposure to excessive levels. The siloxanes are therefore not considered to constitute a health risk from this relatively brief exposure.

For formaldehyde, the exposure from PU products gives an RCR value above 1 after both 1 hour and 3 days (2.1 and 1.3, respectively). DMF gives an RCR value above 1, but only for the product with the highest concentration emitted. DMF and formaldehyde are therefore discussed in more detail below. However, the result of the more realistic worst-case scenario means that it is necessary to examine other exposure scenarios for DMF, formaldehyde, and the siloxanes in the following section.

For DMF, there is a special situation wherein a single product (baby mattress N-EU 3) was identified with very high DMF emissions of 1500 µg/m^3, whereas the emissions of other products fell between 3.5 and 21 µg/m^3 (for the 6 products out of 20 in which emissions of the substance were identified). Therefore, exposure calculations for DMF were performed using both the highest value for a baby mattress of 1500 µg/m^3 and for the second highest value for a baby mattress (EU 3) of 11 µg/m^3. The exposure calculations show that RCR values well above 1 occur when using the highest emitted concentration of DMF, while RCR values above 1 occur neither after one 1 hour nor after 3 days when using the second highest emitted concentration for a baby mattress. This means that a baby that sleeps 18 hours a day on this baby mattress (N-EU 3) immediately after the mattress is removed from its packaging is at risk of health effects in the form of mucous membrane irritation. It can be seen that the RCR value drops significantly after the 3 days, but is still far above 1. Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long DMF emissions remain high enough to produce mucous membrane irritation. However, this product has an extremely high emission of DMF compared to the other products that emitted DMF, so this does not immediately indicate a general issue with PU foam products. 14 of 20 products did not emit DMF at all, and for the other five products that emitted DMF, the emissions were so low as to cause no health effects in a baby (or other person) that sleeps for 18 hours on the product.

In the case of formaldehyde, PU foam products may constitute a health risk in the zone of respiration for this scenario, even after 3 days, at which point the RCR value is just above 1 (1.3). Therefore, there is a risk of health effects from formaldehyde emissions in this scenario if a baby sleeps for 18 hours in close contact with three products (a baby mattress, a baby pillow, and a cot bumper) that have been recently removed from their packaging. The critical effect of formaldehyde is carcinogenicity, and this is an effect that can occur after long-term exposure above the DNEL value for a long period. Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long formaldehyde emissions remain high enough to produce health effects. Contributions to exposure from other sources, such as textiles, rugs, electronics, etc. must also be added to this (see chapter 12 “Exposure levels from indirect sources").

15.4 Realistic worst case calculated for room concentration

For DMF, formaldehyde, and the siloxanes D4, D5, and D6, where a risk could not be ruled out using the more realistic worst-case scenario in the zone of respiration after 1 hour, the exposure (and risk) are thus calculated for the realistic worst-case scenario in which persons occupy a room containing the PU foam products in question. Specifically, we here take into account that the emitted quantities of DMF, formaldehyde, and siloxanes become distributed throughout the room, diluting them. In turn, emissions from the entire product are considered, rather than only a block of about 40 x 40 cm near the zone of respiration. The two scenarios used in calculations here are:

10. A baby occupying the parents' bedroom while sleeping (18 hours) and the living room for some waking hours (3 hours). Here, only babies are considered as the

worst case, since they occupy (i.e., sleep in) bedrooms for the longest time, with the most PU foam products.

11. Older children and teenagers that occupy their own rooms for a large portion of the day (the worst case here is a weekend day or holiday). Teenagers are considered here as the worst case, because they spend more time in their own rooms (10 hours of sleep and 8 waking hours) with more PU foam products.

15.4.1 Scenario with room concentration for baby

For DMF, formaldehyde, and the siloxanes, the exposure (and risk) is calculated for a scenario involving occupying a room containing PU foam products where the emitted quantities are distributed throughout the room. This scenario is based on the following:

- Exposure is based on the emitted quantity from all relevant products being distributed throughout the occupied space.
- It is assumed that exposure is to the same concentration for all 24 hours of the day, despite the fact that measurements from 1 hour and 3 days show that emissions decrease somewhat over time. Exposure is calculated for both 1 hour and 3 days.
- Exposure to seven products simultaneously (baby mattress, baby pillow, cot bumper, two adult mattresses, two pillows) in a bedroom for 18 hours is assumed, with a baby sleeping in the parents' bedroom, as well as exposure to a tumbling mat for 3 hours during the baby's waking hours. For the remaining 3 hours of the day, the baby assumed not to be exposed to products made of PU foam, but the baby may be exposed to the substances from other sources.
- The actual measured concentrations are used for the types of products mentioned.

An example of more detailed exposure and risk (RCR value) calculations is presented in Appendix 5.4. All calculated concentrations in the zone of respiration, as well as RCR values, are listed in TABLE 59 to TABLE 61 in this appendix.

As in the above scenarios, the total RCR value is given for exposure to the seven products in the zone of respiration during sleep (baby mattress, baby pillow, cot bumper, two adult mattresses, and two head pillows) and for the tumbling mat during waking hours.

TABLE 33. Calculated RCR values for products where emissions from several products have spread throughout the room (based on the 1-hour measurements). Calculated RCR values after 3 days are indicated in parentheses below.

Substance name	Highest concentration measured after 1 hour (3 days) (µg/m^3)	DNEL value (µg/m^3)	RCR Total for PU foam products
DMF (highest value*)	1500 (390)	80	**2.5** (0.7)
DMF (second highest value*)	11 (7.5)	80	0.01 (0.004)
D4 (lung effects)	150 (0)	1000	0.05 (0)
D5 (lung effects)	160 (4.1)	5300	0.02(0.0001)
D5 (uterine tumours)	160 (4.1)	4314	0.02 (0.0002)
D6 (lung effects)	87 (48)	130	0.34 (0.09)

Substance name	Highest concentration measured after 1 hour (3 days) (µg/m³)	DNEL value (µg/m³)	RCR Total for PU foam products
Sum of D4, D5 and D6 (lung effects)	-	-	0.41 (0.09)
Formaldehyde	18 (8.4)	50	0.09 (0.05)

* Calculations have been made for two different baby mattresses, as one baby mattress (N-EU 3) stood out with a very high emission of DMF compared to the other products

It can be seen in TABLE 33 that for formaldehyde; the siloxanes; the sum of D4, D5, and D6; and the lower values of DMF, the calculated RCR values for PU foam products are well below 1 for exposure after 1 hour; that is, there is no risk of health effects from these substances in this scenario.

For DMF, the product with the greatest emissions (baby mattress N-EU 3) still results in an RCR value greater than 1, but not after 3 days. It is assumed in these calculations that the concentration measured after 1 hour is constant throughout the entire sleeping period of 18 hours, which is not the case. Furthermore, this scenario assumes that a person goes to sleep in a room with the baby mattress immediately after the product is removed from its packaging. Whether there would be health effects in the form of mucous membrane irritation at the beginning of sleep cannot be decisively determined from the measurements performed in this project.

15.4.2 Scenario with room concentration for older children / teenagers

For DMF, formaldehyde, and the siloxanes, the exposure (and risk) is calculated for a scenario involving occupying a room containing PU foam products where the emitted quantities are distributed throughout the room. This scenario is based on the following:

- Exposure is based on the emitted quantity from all relevant products being distributed throughout the occupied space.
- It is assumed that exposure is to the same concentration for all 24 hours of the day, despite the fact that measurements from 1 hour and 3 days show that emissions decrease somewhat over time. Exposure is calculated for both 1 hour and 3 days.
- It is assumed that exposure is to five products in the room (mattress, folding mattress (for visiting guests), two pillows, and a tumbling mat) simultaneously for the 10 hours a teenager spends sleeping in their room, and for the 8 waking hours a teenager spends in their room. For the remainder of the day, the teenager is assumed not to be exposed to PU foam products.
- The actual measured concentrations are used for the types of products mentioned.

An example of more detailed exposure and risk (RCR value) calculations is presented in Appendix 5.5. All calculated concentrations in the zone of respiration, as well as RCR values, are listed in TABLE 62 to TABLE 64 in this appendix.

As for the above scenarios, the total RCR value is given for exposure to the five products in the zone of respiration during sleep (mattress, folding mattress for guests, two pillows, and tumbling mat).

TABLE 34. Calculated RCR values for products where emissions from several products have spread throughout a teenager's room (based on the 1-hour measurements). Calculated RCR values after 3 days are indicated in parentheses below.

Substance name	Highest concentration measured after 1 hour (3 days) (µg/m³)	DNEL value (µg/m³)	RCR Total for PU foam products
DMF	11 (0)	80	0.03 (0)
D4 (lung effects)	73 (0)	1000	0.02 (0)
D5 (lung effects)	190 (3.5)	5300	0.02(0.0001)
D5 (uterine tumours)	190 (3.5)	4314	0.02 (0.0002)
D6 (lung effects)	87 (48)	130	0.35 (0.11)
Sum of D4, D5 and D6 (lung effects)	-	-	0.39 (0.11)
Formaldehyde	12 (8.4)	50	0.04 (0.03)

It can be seen in TABLE 34 that for all substances (DMF, formaldehyde, D4, D5, and D6, as well as the sum of the siloxanes), the calculated RCR values for PU foam products are well below 1; that is, there is no risk of health effects from these substances in this scenario.

15.5 Comparison with restriction proposals

For formaldehyde, the siloxanes, and DMF, which are the substances emitted at the highest concentrations relative to their DNEL values, a comparison has been made with the restriction proposals, currently under consideration for these substances.

15.5.1 Restriction proposals for formaldehyde

In March 2019, a restriction proposal was suggested, providing that articles may not emit formaldehyde at a concentration higher than 0.124 mg/m^3 under the test conditions described in EN 717-1 (ECHA, 2019b). For this proposal, the objective is to be added to Annex XVII of the REACH regulation, should it be adopted.

According to Annex D to the restriction proposal (ECHA, 2019c), EN 717-1 contains the following conditions for emission chamber analyses; the conditions used in this project are given in parentheses afterwards:

- Temperature: 23 °C ± 0,5 °C (23 ± 1 °C)
- Relative humidity: 45 ± 3 % (50 ± 3 %)
- Air exchange rate: 1.0 ± 0.05 per hour (0.5 per hour)
- Loading factor: 1.0 ± 0.02 m^2/m^3 (approx. 0.4 m^2/m^3)
- Chamber volume: 12 m^3, 1 m^3 or 0.225 m^3 (0.119 m^3)
- Measurement time: Equilibrium must be reached (corresponding to a concentration that changes by no more than 5% over 4 days); that is, measurements are taken at many times. Measurements taken for a maximum of 28 days (3 days)

As can be seen, the air exchange rate is twice as high in EN 717-1, compared to the air exchange rate used for the emission chamber analyses in this project. Additionally, the loading factor (the ratio of the sample material to the size of the chamber) is somewhat higher in EN 717-1, compared to the loading factor used in this project. Thus, 2.5 times more material should be placed in the emission chamber according to EN 717-1, but conversely, with twice the air exchange rate used for the emission chamber analyses in this project. Furthermore, the measurement times for the two methods differ. In EN 717-1, measurements are taken until equilibrium is reached (which requires a minimum of 4 days), whereas emissions were measured after 3 days in this project. Therefore, the values are not directly comparable.

The maximum emission of formaldehyde for the samples in this project was 8.4 µg/m^3 after 3 days, far below the proposed limit value of 124 µg/m^3. For comparison, the Danish Working Environment Authority accepts a maximum concentration of 150 µg/m^3 in the working environment, and building regulations recommend following the WHO's limit value of 100 µg/m^3 (Portal for indoor climate, 2018).

15.5.2 Restriction proposals for the siloxanes (D4, D5 and D6)

For the siloxanes D4, D5 and D6, a restriction proposal was suggested in March 2019 (ECHA, 2019d), and in December 2019, an opinion from the RAC and SEAC was adopted in which the restriction proposal is listed and has now been submitted for consultation (ECHA, 2019e).

However, the restriction proposal contains only a restriction on D4, D5 and D6 in chemical mixtures (limit value 0.1%), but not in articles. The restriction proposal is therefore not relevant for PU foam products.

15.5.3 Restriction proposals for DMF

For DMF, a restriction proposal was suggested in 2018 proposing that the use of DMF be limited in chemical mixtures to a maximum concentration of 0.3% (ECHA, 2018d). The restriction proposal also includes one proposed DNEL value for the working environment of 3.2 mg/m^3, which is to cover prolonged exposure to inhalation of DMF in a working environment. The restriction proposal was assessed by RAC and SEAC in September 2019, and is awaiting final adoption (ECHA, 2019f).

If the DNEL value proposed for the working environment is converted to a continuous consumer exposure by accounting for 24 hours of exposure instead of 8 hours, and 7 days of exposure instead of 5 working days, a DNEL value of 0.76 mg/m^3 is obtained for consumers, or 760 µg/m^3, below the highest measured emission concentration of DMF, which was 1500 µg/m^3. However, the highest emitted concentration after 3 days had decreased to 390 µg/m^3, so there is no long-term exposure to DMF from this product (N-EU 3). The remaining five products that emit DMF (no more than 21 µg/m^3) emit it at levels far below the proposed limit value.

15.6 Limitations and uncertainties

There are multiple limitations and uncertainties in the exposure calculations performed in this project. These are as follows:

- Concentrations measured at 1 hour and at 3 days were held constant for periods of 24 hours.
- Analysis data is based on a standard air exchange rate of 0.5 times per hour.
- For some substances, the results in the analysis reports are indicated as “may be overestimated”.
- The product samples were left untouched while in the emission chamber.

It should be highlighted first and foremost that all exposure calculations performed in this report are worst-case calculations. This is primarily because pointwise measurements of emission levels of substances at particular times (1 hour and 3 days) were used as constant levels for a full day, knowing that emissions from the products decrease over time, rather than remaining constant. This condition alone means that the calculated exposure levels and RCR values will be overestimated.

In addition, it should be noted that the emitted concentrations measured in the emission chamber analyses are for a standard air exchange rate of 0.5 per hour, corresponding to a room with closed windows and natural ventilation. It is clear that if a room is aired out (e.g., when sleeping with open windows), the air exchange rate will be significantly higher, and the concentrations in the zone of respiration or in the room will be significantly lower.

For DMF, D5, D6, α-pinene, and phenol, it is clear from the analysis reports that the specified concentrations may be overestimated due to contributions from the system (see also TABLE 16). This means that, all in all, calculations are based on worst case in many regards: exposure scenarios, concentrations and air exchange.

Lastly, it should be emphasised that essentially all PU foam products are compressed (they "work") during use, as when moving in one's sleep on the products — perhaps with the exception of the cot bumper and support mattress. This does not occur in the emission chamber tests, where the products remain untouched once the emission chamber was closed. However, product samples were compressed by hand 10 times before the emission chamber was closed in order to simulate movement on the product (e.g., on a mattress or pillow in use). This may mean that 1-hour measurements are higher than during normal use, while the 3-day measurements may be lower than during normal use. In other words, there is a possibility that VOC emissions will be greater during actual use, as one continually turns over on a mattress or head pillow.

15.7 Discussion and conclusion

This project has shown that there may be large variations in the quantity of VOCs emitted by different PU foam products. In general, there were large differences in how much of an odour came from the PU foam in the various PU foam products when they were removed from their packaging. The descriptions of the sample odours were compared with the quantities of emitted VOCs. There was generally a good correlation between the description of the odour and the total concentration of organic substances emitted from the PU foam samples. However, it should be noted that some VOCs have a much higher odour threshold (the concentration at which they can be smelled) than others, so there is not necessarily a direct correlation with the total concentration of emitted VOCs.

The combined VOC emission results show a tendency for N-EU products, on average, to emit slightly higher quantities of VOCs, compared to products purchased either in Denmark or the greater EU. However, the average encompasses large variations in emissions across products, so it is not an unambiguous depiction. If baby mattress N-EU 3, which had extremely high emissions of the VOC DMF, is excluded from the calculations, then the average for N-EU products is only about 16% higher than that of the DK and EU products.

This project has also shown that the products studied comply with regulatory requirements on phthalate content in the PU foam itself, and on brominated flame retardant content in the outermost layer of the PU foam products. Low levels of certain phthalates were identified in individual products, but exclusively at allowable levels, and at levels so low as to suggest that they resulted from impurities.

The exposure calculations performed for the different scenarios show that for most substances in most scenarios, there is no risk of health effects based on the worst-case scenarios presented for time spent in a room, even with multiple PU foam products. The exceptions, however, are baby mattress N-EU 3, which had high DMF emissions; and the substances formaldehyde and the siloxanes in the worst-case scenario with multiple products in the zone of respiration, where a baby sleeps with three products (baby mattress, baby pillow, and cot bumper) freshly removed from their packaging. These scenarios are therefore discussed in more detail below.

For a single product (baby mattress N-EU 3), the dimethylformamide (DMF) emissions were so high that even calculations based on the situation where the emitted quantity becomes distributed throughout the entire room, and the room is only occupied for sleep (18 hours for a baby), there may be a risk of health effects, based on the 1-hour measurement. DMF emissions from this baby mattress (N-EU 3) were measured at a concentration 71 times greater than that of the product with the second greatest DMF emissions. It should be noted here that the health effect which the DNEL value is based on is mucous membrane irritation.

The RCR values calculated for DMF in the scenario with a baby sleeping on this baby mattress, and where the emitted quantity becomes distributed throughout the room, are 2.5 and 0.7 for the concentrations measured after 1 hour and 3 days, respectively. As indicated by the RCR value falling from 1 hour to 3 days, the emission of DMF from the product declines over time, and the concentration is thereby not constant during the 18 hours assumed in the calculations. For this reason, the calculated RCR values are overestimates. Despite this, it appears that baby mattress N-EU 3 emits DMF at levels that may result in a health effect (mucous membrane irritation) during the first day of use. This is particularly the case when considering that the RCR values for concentrations in the zone of respiration are 106 and 28 after 1 hour and 3 days, respectively. The amount of time that must pass before the emission level is low enough to bring the RCR value under 1 for this product is unknown. This would have required longer analyses in the emission chamber than were performed in this project.

It should be noted that the highest emitted concentration of DMF, 1500 µg/m^3, measured after 1 hour, is above the proposed DNEL value from RAC/SEAC for working environments of 3.2 mg/m^3, which can be converted to a DNEL value for constant exposure of 760 µg/m^3 (see section 15.5.3 "Restriction proposals for DMF"). However, the highest emitted concentration of DMF after 3 days had decreased to 390 µg/m^3, so there is no long-term, problematic exposure to DMF from this product (N-EU 3). There is thus no doubt that the high DMF emissions from baby mattress N-EU 3 are problematic and may result in health effects in the form of mucous membrane irritation. However, DMF emissions were problematic solely for this one product. 14 of the 20 products studied do not emit DMF above the limit of detection, and emissions for the five other products that emit DMF are not at levels that constitute a health issue.

For the exposure scenario with a baby sleeping with several products in the zone of respiration, emissions of siloxane D6 alone from PU foam products may constitute a health risk in the zone of respiration after 1 hour, at which point the RCR value is above 1 (1.7). For D4 and D5, the RCR value is below 1. Naturally, this means that the RCR value for the sum of the siloxanes is also over 1 (at 2.6) after 1 hour. However, the concentration of the siloxanes decreases substantially after 3 days, such that the RCR values for the sum of the siloxanes are below 1 (at 0.6) after 3 days. It should be emphasised that the concentration of the siloxanes after 1 hour has been used as a constant concentration for the first 24 hours, even though the measurements show that the concentration declines significantly over time. How much time must pass before the total concentration of siloxanes does not constitute a health risk is unknown, since measurements were only taken after 1 hour and after 3 days in this project.
For this scenario, there may be a risk of health effects due to the emission of the siloxanes for the first one to two days. However, this is exclusively in the case of a baby being put to sleep

on or near three products (baby mattress, baby pillow, and cot bumper) recently removed from their packaging. Even so, there are numerous aspects that suggest that in reality, there would hardly be a health risk present:

- First, the health effects associated with the siloxanes are effects on the lungs, and these appear only after long-term exposure. The critical effect is based on studies involving longer exposure periods. An exposure just above the DNEL value for a day or two will hardly bring about the effects seen after prolonged exposure.
- Second, the products with the highest measured emissions of D4, D5, and D6 were used for calculating the RCR values for D4, D5, and D6, but these are not the same products that give the highest RCR value for D4, D5, and D6. This means that the actual combined RCR value is slightly lower, though still above 1.
- A baby does not necessarily sleep all 18 hours in the same place. It is probably more realistic that sleep during the day occurs in a pram outside or on a rug in the living room.
- Realistically, hardly anybody goes to sleep near so many new products immediately after removing them from their packaging. If this were to occur just a few hours or half a day after the items were removed from their packaging, the emissions would already be lower.

Conversely, there are other aspects that suggest that the actual concentrations may be higher than those measured:

- The DNEL values used are not specifically calculated for babies.
- Whether other consumer products emit the same siloxanes into the same room has not been accounted for.
- The products are only compressed immediately before the emission chamber analyses (to simulate use), but it was not possible to do so during the tests in the emission chamber. Therefore, the values measured after 3 days, in particular, may be underestimated.

All in all, the above means that the siloxanes are not considered to constitute a health risk from this relatively brief exposure

Regarding formaldehyde, in the exposure scenario with a baby sleeping with multiple products in the zone of respiration, the PU foam products may constitute a health risk in the zone of respiration, even after 3 days, with an RCR value slightly above 1 (1.3). Therefore, there is a risk of health effects from formaldehyde emissions in this scenario if a baby sleeps for 18 hours in close contact with three products (a baby mattress, a baby pillow, and a cot bumper) that have been recently removed from their packaging. The critical effect of formaldehyde is carcinogenicity, and this is an effect that can occur after long-term exposure above the DNEL value for a long period. Because analyses of emissions at times later than 3 days were not performed in this project, no statement can be made on how long formaldehyde emissions remain high enough to produce health effects. It should, however, be noted that when calculation is based on a scenario where emissions become distributed throughout the entire room, the RCR values for formaldehyde are far below 1, both after 1 hour and after 3 days.
Even so, the results show that there may be a risk of health effect from formaldehyde, but that this applies exclusively to the worst-case scenario in which three new products are simultaneously brought into use, right as a baby is put to sleep. None of the products will cause health effects individually after 3 days.

However, it is important to note that contributions to exposure to formaldehyde and DMF from other sources, such as textiles, rugs, electronics, toys, etc. must be added to the calculated exposures for all substances (see chapter 12 “Exposure levels from indirect sources"). This means that bedroom ventilation has a significant influence on the concentration of substances that are hazardous to health. Similarly, it may be appropriate to allow new products to release these substances for a few days before beginning to use them.

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Appendix 1. ECHAs 'Plastic additives initiative'

In 2016, ECHA initiated a process of mapping the use of additives for plastic together with 21 industrial industry associations. This work was published in December 2018 under the headline ´Plastic additives initiative´. The work has resulted in a list of more than 400 additives used in large amounts in plastics – i.e. additives that are used in amounts exceeding 100 tons per year in Europe.

This plastic database of ECHA is divided into the following groups of additives:

- Light stabilisers
- Heat stabilisers
- Other stabilisers
- Antioxidants
- Nucleating agents
- Pigments agents
- Antistatic agents
- Flame retardants
- Plasticisers
- Other functions

The next pages contain tables of the total of 145 additives that according to the plastic database of ECHA are used in PU. It is not possible to distinguish, which of these additives that are used in PU foam. It should be noticed that no nucleating agents are listed as used in PU.

Appendix 1.1 Light stabilisers

List of the 4 additives that are used as light stabilisers in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 35. Light stabilisers used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
217-421-2	1843-05-6	Octabenzone	Other stabilisers	0.2 - 5.0
223-445-4	3896-11-5	Bumetrizole	-	0.3 - 1.0
274-570-6	70321-86-7	2-(2H-benzotriazol-2-yl)-4,6-bis(1-methyl-1-phenylethyl)phenol	Other stabilisers	0.2 - 5.0
915-687-0		Reaction mass of Bis(1,2,2,6,6-pentamethyl-4-piperidyl) sebacate and Methyl 1,2,2,6,6-pentamethyl-4-piperidyl sebacate	Heat stabilisers	0.2 - 0.5

Appendix 1.2 Heat stabilisers

List of the one additive used as heat stabiliser in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 36. Heat stabilisers used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
401-990-0	106990-43-6	N,N',N'',N'''-tetrakis(4,6-bis(butyl-(N-methyl-2,2,6,6-tetramethylpiperidin-4-yl)amino)triazin-2-yl)-4,7-diazadecane-1,10-diamine	Other stabilisers	1.5

Appendix 1.3 Other stabilisers

List of the two additives used as other stabilisers in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 37. Other stabilisers used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
215-138-9	1305-78-8	Calcium oxide	-	1
234-319-3	11097-59-9	[carbonato(2-)]hexadecahydroxybis(aluminium)hexamagnesium	-	0.5

Appendix 1.4 Antioxidants

List of the six additives used as antioxidants in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 38. Antioxidants used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
229-722-6	6683-19-8	Pentaerythritol tetrakis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate)		0.002 - 0.5
250-709-6	31570-04-4	Tris(2,4-ditert-butylphenyl) phosphite	Other stabilisers	0.004 - 0.5
251-156-3	32687-78-8	2',3-bis[[3-[3,5-di-tert-butyl-4-hydroxyphenyl]propionyl]]propionohydrazide		0.002 - 3.0
253-039-2	36443-68-2	Ethylenebis(oxyethylene) bis[3-(5-tert-butyl-4-hydroxy-m-tolyl)propionate]		0.005 - 3.0

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
254-996-9	40601-76-1	1,3,5-Tis(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)-1,3,5-triazine-2,4,6-(1H, 3H, 5H)- trione		-
406-040-9	125643-61-0	reaction mass of isomers of: C7-9-alkyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate		-

Appendix 1.5 Pigments

List of the 82 additives used as pigments in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 39. Pigments used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
201-344-6	81-33-4	Perylene-3,4:9,10-tetracarboxydiimide		2
201-375-5	81-77-6	6,15-dihydroanthrazine-5,9,14,18-tetrone		2
205-685-1	147-14-8	29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32 copper		0.5 – 2.0
207-439-9	471-34-1	Calcium carbonate		5
209-378-3	574-93-6	29H,31H-Phthalocyanine		2
213-561-3	980-26-7	5,12-dihydro-2,9-dimethylquino[2,3-b]acridine-7,14-dione		2
213-879-2	1047-16-1	5,12-dihydroquino[2,3-b]acridine-7,14-dione		2
215-160-9	1308-38-9	Chromium (III) oxide		1
215-168-2	1309-37-1	Diiron trioxide		1
215-251-3	1314-98-3	Zinc sulphide		2.0 - 10.0
215-277-5	1317-61-9	Triiron tetraoxide		1
215-282-2	1317-80-2	Titanium dioxde (rutil)		5
215-524-7	1328-53-6	Polychloro copper phthalocyanine		1
215-609-9	1333-86-4	Carbon black	Antistatic agent; UV/light stabiliser	2.5 - 40.0
215-693-7	1344-37-2	Lead sulfochromate yellow		1
219-730-8	2512-29-0	2-[(4-methyl-2-nitrophenyl)azo]-3-oxo-N-phenylbutyramide		2
221-264-5	3049-71-6	2,9-bis[4-(phenylazo)phenyl]anthra[2,1,9-def:6,5,10-d'e'f']diisoquinoline-1,3,8,10(2H,9H)-tetrone		2
221-424-4	3089-17-6	2,9-dichloro-5,12-dihydroquino[2,3-b]acridine-7,14-dione		2
222-530-3	3520-72-7	4,4'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[2,4-dihydro-		2

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
		5-methyl-2-phenyl-3H-pyrazol-3-one]		
223-460-6	3905-19-9	N,N'-phenylene-1,4-bis[4-[(2,5-dichlorophenyl)azo]-3-hydroxynaphthalene-2-carboxamide]		2
223-754-4	4051-63-2	4,4'-diamino[1,1'-bianthracene]-9,9',10,10'-tetraone		1.0 - 2.0
225-590-9	4948-15-6	2,9-bis(3,5-dimethylphenyl)anthra[2,1,9-def:6,5,10-d'e'f']diisoquinoline-1,3,8,10(2H,9H)-tetrone		2
225-822-9	5102-83-0	2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[N-(2,4-dimethylphenyl)-3-oxobutyramide]		2
226-103-2	5280-68-2	N-(4-chloro-2,5-dimethoxyphenyl)-3-hydroxy-4-[[2-methoxy-5-[(phenylamino)carbonyl]phenyl]azo]naphthalene-2-carboxamide		2
226-106-9	5280-78-4	N,N'-(2-chloro-1,4-phenylene)bis[4-[(2,5-dichlorophenyl)azo]-3-hydroxynaphthalene-2-carboxamide]		2
226-107-4	5280-80-8	3,3'-[(2,5-dimethyl-p-phenylene)bis[imino(1-acetyl-2-oxoethylene)azo]]bis[4-chloro-N-(5-chloro-o-tolyl)benzamide]		2
226-109-5	09-04-5281	Calcium 3-hydroxy-4-[(4-methyl-2-sulphonatophenyl)azo]-2-naphthoate		2
226-789-3	5468-75-7	2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[N-(2-methylphenyl)-3-oxobutyramide]		2
226-866-1	5521-31-3	2,9-dimethylanthra[2,1,9-def:6,5,10-d'e'f']diisoquinoline-1,3,8,10(2H,9H)-tetrone		2
226-970-7	5580-57-4	3,3'-[(2-chloro-5-methyl-p-phenylene)bis[imino(1-acetyl-2-oxoethylene)azo]]bis[4-chloro-N-(3-chloro-o-tolyl)benzamide]		2
227-930-1	6041-94-7	4-[(2,5-dichlorophenyl)azo]-3-hydroxy-N-phenylnaphthalene-2-carboxamide		2
228-787-8	6358-85-6	2,2'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[3-oxo-N-phenylbutyramide]		2
231-784-4	7727-43-7	Barium sulfate		50
232-353-3	8007-18-9	Antimony nickel titantium oxide yellow		1
232-466-8	05-07-8048	Cadmium zinc sulfide yellow		5
233-257-4	10101-66-3	Ammonium manganese(3+) diphosphate		5

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
235-049-9	12062-81-6	Iron manganese trioxide		0.5
235-330-6	12167-74-7	Pentacalcium hydroxide tris(orthophosphate)		5
235-425-2	12225-06-8	N-(2,3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-hydroxy-4-[[2-methoxy-5-[(phenylamino)carbonyl]phenyl]azo]naphthalene-2-carboxamide		2
235-462-4	12236-62-3	2-[(4-chloro-2-nitrophenyl)azo]-N-(2,3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-oxobutyramide		2
235-476-0	12239-87-1	Copper chlorophthalocyanine		2
235-759-9	12656-85-8	Lead chromate molybdate sulfate red		5
235-790-8	12737-27-8	Chromium iron oxide		5
235-811-0	12769-96-9	Ultramarine Violet		0.5
236-675-5	13463-67-7	Titanium dioxide	UV/light stabiliser	5.0 - 20.0
237-898-0	14059-33-7	Bismuth vanadium tetraoxide		0.5
238-238-4	14302-13-7	[1,3,8,16,18,24-hexabromo-2,4,9,10,11,15,17,22,23,25-decachloro-29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]copper		2
239-898-6	15793-73-4	4,4'-[(3,3'-dichloro[1,1'-biphenyl]-4,4'-diyl)bis(azo)]bis[2,4-dihydro-5-methyl-2-(p-tolyl)-3H-pyrazol-3-one]		2
242-159-0	18282-10-5	Tin dioxide		5
247-304-1	25869-00-5	Ammonium iron(3+) hexakis(cyano-C)ferrate(4-)		0.5
249-125-4	28654-73-1	[N,N,N',N',N'',N''-hexaethyl-29H,31H-phthalocyaninetrimethylaminato(2-)-N29,N30,N31,N32]copper		2
250-063-5	30125-47-4	3,4,5,6-tetrachloro-N-[2-(4,5,6,7-tetrachloro-2,3-dihydro-1,3-dioxo-1H-inden-2-yl)-8-quinolyl]phthalimide		2
253-256-2	36888-99-0	5,5'-(1H-isoindole-1,3(2H)-diylidene)dibarbituric acid		2
255-005-2	40618-31-3	N,N'-(2,5-dichloro-1,4-phenylene)bis[4-[(2,5-dichlorophenyl)azo]-3-hydroxynaphthalene-2-carboxamide]		2
257-098-5	51274-00-1	Iron hydroxide oxide yellow		5
261-218-1	58339-34-7	Cadmium sulfoselenide red		5
263-272-1	61847-48-1	Methyl 4-[[(2,5-dichlorophenyl)amino]carbonyl]-2-[[2-hydroxy-3-[[(2-methoxyphenyl)amino]carbonyl]-1-naphthyl]azo]benzoate		2

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
265-634-4	65212-77-3	Calcium 4,5-dichloro-2-[[4,5-dihydro-3-methyl-5-oxo-1-(3-sulphonatophenyl)-1H-pyrazol-4-yl]azo]benzenesulphonate		2
269-049-5	68186-87-8	Cobalt zinc aluminate blue spinel		5
269-050-0	68186-88-9	Zinc iron chromite brown spinel		5
269-052-1	68186-90-3	Chrome antimony titanium buff rutile.		1
269-053-7	68186-91-4	Copper chromite black spinel		0.5
269-054-2	68186-92-5	Chrome tungsten titanium buff rutile.		5
269-056-3	68186-94-7	Manganese ferrite black spinel		5
269-060-5	68186-97-0	Iron cobalt chromite black spinel		5
269-072-0	68187-11-1	Cobalt chromite blue green spinel		5
269-075-7	68187-15-5	Zirconium praseodymium yellow zircon		5
269-103-8	68187-51-9	Zinc ferrite brown spinel		5
270-185-2	68412-38-4	Manganese antimony titanium buff rutile		5
271-176-6	68516-73-4	Tetramethyl 2,2'-[1,4-phenylenebis[imino(1-acetyl-2-oxoethane-1,2-diyl)azo]]bisterephthalate		2
272-713-7	68909-79-5	Hematite, chromium green black		5
274-324-8	70131-50-9	Bentonite, acid-leached		5
275-738-1	71631-15-7	Nickel iron chromite black spinel		5
276-344-2	72102-84-2	5-[(2,3-dihydro-6-methyl-2-oxo-1H-benzimidazol-5-yl)azo]barbituric acid		2
279-356-6	79953-85-8	3,3'-[(2-chloro-5-methyl-p-phenylene)bis[imino(1-acetyl-2-oxoethylene)azo]]bis[4-chloro-N-[2-(4-chlorophenoxy)-5-(trifluoromethyl)phenyl]benzamide]		2
279-767-0	81457-65-0	Copper, [29H,31H-phthalocyaninato(2-)-N29,N30,N31,N32]-, [[3-(1-methylethoxy)propyl]amino]sulfonyl derivs.		2
309-928-3	101357-30-6	Silicic acid, aluminum sodium salt, sulfurized		5
310-077-5	102184-95-2	Silicic acid, zirconium salt, cadmium pigment-encapsulated		5
310-193-6	1345-16-0	Cobalt aluminate blue spinel		5
401-540-3	84632-65-5	3, 6 - bis (4 - chlorophenyl)- 2, 5 - dihydro - 1, 4 - diketo pyrrolo [3, 4 - c] pyrrole; Pyrrolo[3,4-c]pyrrole-1,4-dione, 3,6-bis(4-chlorophenyl)-2,5-dihydro-		2

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
936-897-9	1373399-58-6	Reaction mass of willemite, white and zinc iron chromite brown spinel		5
939-379-0		Reaction mass of melamine and Nickel, 5,5'-azobis-2,4,6(1H,3H,5H)-pyrimidinetrione complexes		2

Appendix 1.6 Antistatic agents

List of the one additive used as an antistatic agent in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 40. Antistatic agents used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
215-222-5	1314-13-2	Zinc oxide	UV/light stabiliser; flame retardant	5

Appendix 1.7 Flame retardants

List of the 13 additives used as flame retardants in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 41. Flame retardants used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
201-114-5	78-40-0	Triethyl phosphate		10
203-615-4	108-78-1	Melamine		25
242-555-3	18755-43-6	Dimethyl propylphosphonate		15
244-492-7	21645-51-2	Aluminium hydroxide	Pigment	0.25 - 50.0
253-575-7	37640-57-6	1,3,5-triazine-2,4,6(1H,3H,5H)-trione, compound with 1,3,5-triazine-2,4,6-triamine (1:1)		5.0 - 30.0
253-760-2	38051-10-4	2,2-bis(chloromethyl)trimethylene bis(bis(2-chloroethyl)phosphate)		12
264-150-0	63449-39-8	Paraffin waxes and Hydrocarbon waxes, chloro	Plasticiser	-
273-066-3	68937-41-7	Phenol, isopropylated, phosphate (3:1)	Plasticiser	15.0 - 35.0
284-366-9	84852-53-9	1,1'-(ethane-1,2-diyl)bis[pentabromobenzene]		15.0 - 35.0
287-477-0	85535-85-9	Alkanes, C14-17, chloro	Plasticiser	15

306-832-3	97416-84-7	1,1'-(isopropylidene)bis[3,5-dibromo-4-(2,3-dibromo-2-methylpropoxy)benzene]		15
911-815-4		Reaction mass of tris(2-chloropropyl) phosphate and tris(2-chloro-1-methylethyl) phosphate and Phosphoric acid, bis(2-chloro-1-methylethyl) 2-chloropropyl ester and Phosphoric acid, 2-chloro-1-methylethyl bis(2-chloropropyl) ester	Plasticiser	15

Appendix 1.8 Plasticisers

List of the 34 additives used as plasticisers in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 42. Plasticisers used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
201-067-0	77-90-7	Tributyl-O-Acetyl citrate		10.0 - 35.0
201-070-7	77-93-0	Triethyl citrate		10.0 - 35.0
201-071-2	77-94-1	Tributyl citrate		10.0 - 35.0
201-557-4	84-74-2	Dibutyl phthalate		10.0 - 35.0
203-090-1	103-23-1	Bis(2-ethylhexyl) adipate		10.0 - 35.0
203-350-4	105-99-7	Dibutyl adipate		10.0 - 35.0
203-431-4	106-79-6	Dimethyl sebacate		10.0 - 35.0
203-672-5	109-43-3	Dibutyl sebacate		10.0 - 35.0
203-757-7	110-33-8	Dihexyl adipate		10.0 - 35.0
204-211-0	117-81-7	Di-2-ethylhexyl phthalate		2.0 - 35.0
204-558-8	122-62-3	Decanedioic acid, 1,10-bis (2-ethylhexyl) ester		10.0 - 35.0
205-016-3	131-17-9	Di-allyl phthalate		10.0 - 35.0
217-803-9	1962-75-0	Di-n-butyl terephthalate		10.0 - 35.0
222-823-6	3622-84-2	N-butylbenzenesulphonamide; N-butylbenzenesulfonamide		10.0 - 15.0
224-081-9	4196-89-8	1,3-Propanediol, 2,2-dimethyl-, 1,3-dibenzoate		10.0 - 35.0
232-401-3	03-11-8016	Linseed oil, epoxidized		10.0 - 35.0
239-937-7	15834-04-5	2,2-bis[[(1-oxopentyl)oxy]methyl]propane-1,3-diyl divalerate		10.0 - 35.0
241-029-0	16958-92-2	Bis(tridecyl) adipate		10.0 - 35.0
247-660-8	26401-35-4	Diisotridecyl adipate		10.0 - 35.0
248-368-3	27253-26-5	Di-isotridecyl phthalate		10.0 - 35.0
249-079-5	28553-12-0;68515-48-0	Diisononylphthalate		10.0 - 35.0
249-828-6	29761-21-5	Isodecyl diphenyl phosphate		10
251-646-7	33703-08-1	Diisononyladipate		10.0 - 35.0

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
258-469-4	53306-54-0	Bis(2-propylheptyl) phthalate		10.0 - 35.0
271-089-3	68515-47-9	1,2-Benzenedicarboxylic acid, di-C11-14-branched alkyl esters, C13-rich		10.0 - 35.0
271-090-9	68515-48-0	Di-C8-10-Branched alkyl esters, C9-rich		10.0 - 35.0
271-091-4	68515-49-1	Di-C9-11-Branched alkyl esters, C10-rich; Di-isodecyl phthalate		10.0 - 35.0
290-580-3	90193-76-3	1,2-Benzenedicarboxylic acid, di-C16-18-alkyl esters		10.0 - 35.0
304-780-6	94279-36-4	1,2,4-Benzenetricarboxylic acid, tri-C9-11-alkyl esters		10.0 - 35.0
431-890-2	166412-78-8	1,2-Cyclohexanedicarboxylic acid, diisononyl ester, reaction products of hydrogenation of di-isononylphthalates (n-butenes based); Di-isononyl cyclohexa-noate		10.0 - 35.0
447-010-5	670241-72-2	Nonylbenzoate, branched and linear		10.0 - 35.0
905-983-8		Reaction mass of benzyl 2-ethylhexyl adipate, bis (2-ethylhexyl) adipate, dibenzyl adipate		10.0 - 35.0
931-251-2		bis(decyl and/or dodecyl) ben-zene-1,2-dicarboxylate		10.0 - 35.0
939-588-7		Dodecanoic acid, ester with 1,2,3-propanetriol, acetylated		10.0 - 35.0

Appendix 1.9 Additives with other functions

List of the three additives with other functions used in PU according to ECHA (2019). The extract is from the plastic database of ECHA, i.e. additives which have been registered and used in amounts above 100 tonnes per year.

TABLE 43. Additives with other functions used in PU according to ECHA (2019)

EC no.	CAS no.	Chemical name	Other function in plastic	Typical concentration in percent (%)
245-442-7	23128-74-7	N,N'-hexane-1,6-diylbis[3-(3,5-di-tert-butyl-4-hydroxy-phenylpropionamide]		0.5
306-084-8	95912-88-2	Fatty acids, C16-18, isotridecyl esters	Lubricant	-
309-913-1	101357-16-8	Benzenamine, reaction products with aniline hydrochloride and nitrobenzene, hydrochlorides		1

Appendix 2. Example of emissions report

This appendix presents an example of how emissions from PU foam products are reported in the analysis reports received. The product with the highest emissions, N-EU 3, is used in the example.

The following columns are given in the report on the emitted substances:

- The name of the substance (the chemical name of the identified substance) — according to the standard used, substances must be identified with 80% or higher certainty. Otherwise, "not identified" must be indicated.
- CAS no. — the CAS number of the identified substance.
- Retention time — the time at which the substance appears as a peak on a chromatogram.
- ID cat. — various categories for the identities of substances. The strongest identification is category 1, where the mass spectrum from the chromatogram is compared with the mass spectrum in a library and supported by other information. The amount is quantified using a specialised calibration for the substance. The other ID categories are described in FIGURE 16 below. In the worst case, the substance is not identified, in which case "not identified" is listed, and the amount is given in toluene equivalents.
- Specific conc. — the specific calculated concentration. For substances in ID category 1, this corresponds to the actual concentration of the substance. For ID categories 2 through 4, the amount of the substance is calculated as if it were toluene; that is, as toluene equivalents.
- Toluene eq. — the concentration of emitted substances, calculated as toluene equivalents. This is the concentration which the total amount of VOCs (TVOC) must be calculated in for comparisons with TVOC emission requirements in CertiPUR certification programmes.
- Specific SER — short for specific emission rate; indicates the rate at which the substance is emitted (calculated as a specific concentration for the substance, for substances in ID category 1).

4.1 VOC Emission Test Results after 1 Hour

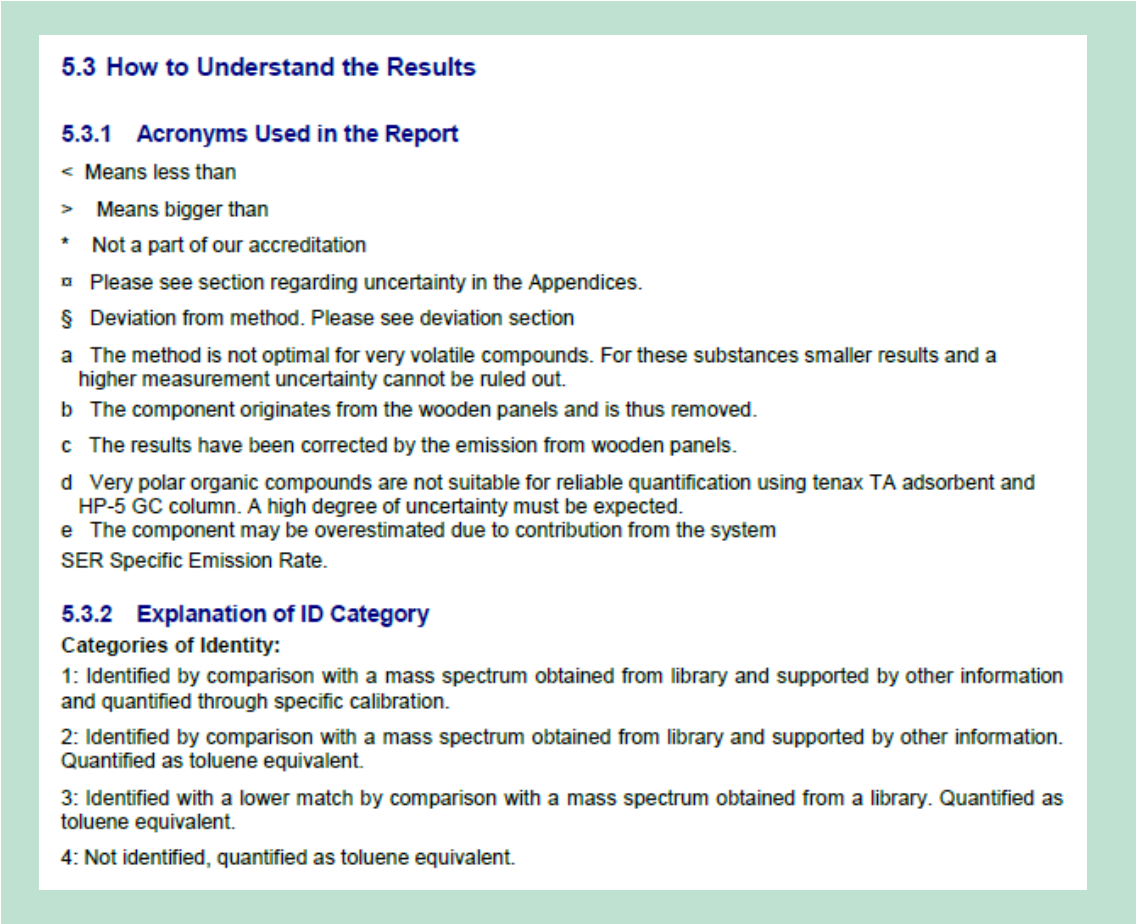
	CAS No.	Retention time [min]	ID-Cat	Specific Conc. [µg/m³]	Toluene eq. [µg/m³]	Specific SER [µg/(m²·h)]
VOC compounds						
Carbonic acid, dimethyl ester *	616-38-6	2.39	2	17	17	22
1-Butanol	71-36-3	2.75	1	19	5.7	24
Toluene	108-88-3	4.44	1	15	15	19
Dimethylformamide *	68-12-2	4.72	1	1500	380	1800
Not identified *		4.92	4	3.0	3.0	3.8
Not identified *		5.01	4	2.3	2.3	2.9
Hexanal	66-25-1	5.13	1	5.5	2.7	6.8
Butyl acetate	123-86-4	5.46	1	4.7	2.4	5.9
1,4-Dioxane, 2,5-dimethyl- *	15176-21-3	5.77	3	3.8	3.8	4.7
m/p-Xylene *	179601-23-1	6.57	1	3.7	4.0	4.6
Styrene	100-42-5	6.97	1	5.4	5.5	6.7
α-Pinene *	80-56-8	7.75	1	7.3	7.2	9.1
1,2,4-Trimethylbenzene	95-63-6	8.21	1	2.7	3.3	3.4
Not identified *		8.59	4	2.0	2.0	2.5
2,2,4,6,6-Pentamethylheptane *	13475-82-6	8.65	1	32	37	40
Octamethylcyclotetrasiloxane [e]	556-67-2	8.73	1	150	300	190
3-Caren *	13466-78-9	8.98	1	4.0	4.1	5.0
Tetramethylbutanedinitrile *	3333-52-6	9.22	3	29	29	36
Decamethyltetrasiloxane *	141-62-8	9.71	2	7.2	7.2	9.0
Not identified *		10.38	4	2.1	2.1	2.7
Decamethylcyclopentasiloxane *	541-02-6	10.77	1	110	180	130
Not identified *		10.91	4	3.9	3.9	4.9
Not identified *		11.01	4	3.5	3.5	4.4
n-Dodecane	112-40-3	11.35	1	2.3	3.9	2.8
Dodecamethylpentasiloxane *	141-63-9	11.86	2	6.0	6.0	7.5
Dodecamethylcyclo-hexasiloxane *	540-97-6	12.68	1	40	39	50
Longifolene *	475-20-7	13.76	1	2.4	2.7	3.0
Not identified *		14.38	4	3.5	3.5	4.4
TVOC				1900	1100	2400
VVOC compounds						
None determined						
TVVOC				< 2	< 2	< 3
SVOC compounds						
None determined						
TSVOC				< 2	< 2	< 3
Carcinogens						
Total carcinogens				< 1	< 1	< 2
Additional compounds						
Dichloromethane	75-09-2		1	< 20		< 30
Aldehydes						
Formaldehyde	50-00-0		1	4.3		5.3
Acetaldehyde	75-07-0		1	< 3		< 4
Propionaldehyde	123-38-6		1	< 3		< 4
Butyraldehyde	123-72-8		1	< 3		< 4
2-butenal	123-73-9		1	< 5		< 7
Glutaraldehyde	111-30-8		1	< 5		< 7

FIGURE 14. Excerpt from a substance emission analysis report for N-EU 3 after 1 hour (Eurofins Product Testing A/S)

4.2 VOC Emission Test Results after 3 Days

	CAS No.	Retention time [min]	ID-Cat	Specific Conc. [µg/m³]	Toluene eq. [µg/m³]	Specific SER [µg/(m²·h)]
VOC compounds						
Dimethylformamide *	68-12-2	4.69	1	390	100	480
Tetramethylbutanedinitrile *	3333-52-6	9.23	3	13	13	16
Not identified *		10.94	4	2.4	2.4	2.9
Dodecamethylcyclohexasiloxane *	540-97-6	12.74	1	6.3	6.2	7.9
TVOC				410	120	510
VVOC compounds						
None determined						
TVVOC				< 2	< 2	< 3
SVOC compounds						
None determined						
TSVOC				< 2	< 2	< 3
Carcinogens						
Total carcinogens				< 1	< 1	< 2
Additional compounds						
Dichloromethane	75-09-2		1	< 20		< 30
Aldehydes						
Formaldehyde	50-00-0		1	< 3		< 4
Acetaldehyde	75-07-0		1	< 3		< 4
Propionaldehyde	123-38-6		1	< 3		< 4
Butyraldehyde	123-72-8		1	< 3		< 4
2-butenal	123-73-9		1	< 5		< 7
Glutaraldehyde	111-30-8		1	< 5		< 7

FIGURE 15. Excerpt from a Eurofins Product Testing A/S substance emission analysis report for N-EU 3 after 3 days



5.3 How to Understand the Results

5.3.1 Acronyms Used in the Report

< Means less than

> Means bigger than

* Not a part of our accreditation

¤ Please see section regarding uncertainty in the Appendices.

§ Deviation from method. Please see deviation section

a The method is not optimal for very volatile compounds. For these substances smaller results and a higher measurement uncertainty cannot be ruled out.

b The component originates from the wooden panels and is thus removed.

c The results have been corrected by the emission from wooden panels.

d Very polar organic compounds are not suitable for reliable quantification using tenax TA adsorbent and HP-5 GC column. A high degree of uncertainty must be expected.

e The component may be overestimated due to contribution from the system

SER Specific Emission Rate.

5.3.2 Explanation of ID Category

Categories of Identity:

1: Identified by comparison with a mass spectrum obtained from library and supported by other information and quantified through specific calibration.

2: Identified by comparison with a mass spectrum obtained from library and supported by other information. Quantified as toluene equivalent.

3: Identified with a lower match by comparison with a mass spectrum obtained from a library. Quantified as toluene equivalent.

4: Not identified, quantified as toluene equivalent.

FIGURE 16. Explanations of abbreviations used in the Eurofins Product Testing A/S analysis report

Appendix 3. Preliminary hazard assessment

This appendix contains information regarding the aspects listed below for the substances that were identified as emitted from the 20 PU foam products. Two tables are listed – one table for substances emitted after 1 hour and one table for substances emitted after 3 days.

The following data are listed in the tables:

- CAS no. of the substance
- Chemical name of the substance
- The highest measured concentration (in µg/m^3), which was emitted from the 20 PU foam products
- Number of products from which the substance is emitted (out of the total of 20 analysed PU foam products)
- Classification of the substance: In general, the harmonised classification is listed. However, if such a classification does not exist, the most important classifications based on the notified classifications from the REACH registration of the substances in the C&L Inventory[38] of ECHA are listed. By the most important classifications are meant the following classifications:
    - CMR
    - STOT RE
    - STOT SE
    - Acute Tox
    - Skin Sens.
    - Resp. Sens.
- DNEL values for inhalation for consumers, as listed in ECHAs database of registered substances. The value is only listed, if it exists and if the substance has been registered.
- The measured emitted concentrations from the products. The highest emitted concentration is listed as well as the number of the 20 products from which the substance is emitted.

[38] https://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

Appendix 3.1 Substances that are emitted from the 20 PU foam products after 1 hour

TABEL 44. Emitted substances after 1 hour – the amount emitted is listed in µg/m^3. The substances have been sorted according to the highest concentration (the highest emitted concentration is listed in top of the table). Substances which have been selected for exposure and risk assessment are marked in bold and green background colour in the table.

CAS No.	Name of substance	Highest measured concentration (µg/m^3)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m^3)	DNEL-inhalation for consumers (short-term, local effects) (mg/m^3)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
Sum of VOC	TVOC	1900	20	-	-	-	-	-	-	-
68-12-2	**Dimethylformamide ***	**1500**	**6**	**Acute Tox. 4 H312 Eye Irrit. 2 H319 Acute Tox. 4 H332 Repr. 1B H360D**	**15**	**30**	**Repeated dose toxicity**	**No**	**Yes (Repr.)**	**Yes, high concentration and acute toxicity for inhalation. Is still emitted after 3 days. Is on the REACH Candidate list due to Repr. 1B.**
Sat. Aliph. HC > C9	Saturated aliphatic hydrocarbons higher than C9 *	340	10	-	-	-	-	-	-	
13475-82-6	2,2,4,6,6-Pentamethylheptane *	240	12	Asp. Tox. 1 H304 (88) STOT SE 3 H336 (20) Not classified (6)	no hazard identified	no hazard identified	-	No	No	No, even though high concentration in many products. Is still emitted after 3 days. But is not regarded as a hazard according to registration data.
64-19-7	Acetic acid * a	200	4	Flam. Liq. 3 H226 Skin Corr. 1A H314	no hazard identified	25	Irritation (respiratory tract)	No	No	
541-02-6	**Decamethylcyclopentasiloxane * (D5)**	**190**	**16**	**Not classified (2828) Acute Tox. 3 H331 (18) STOT SE 3 H335 (2)**	**17.3**	**no hazard identified**	**Repeated dose toxicity**	**No**	**Yes (PBT)**	**Yes, high concentration and emitted from many products, also after 3 days. Classification however uncertain.**

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
556-67-2	**Octamethylcyclotetrasiloxane (D4)**	**150**	**6**	**Aquatic Chronic 4 H413 Repr. 2 H361f**	**13**	**no hazard identified**	**Repeated dose toxicity**	**No**	**Yes (PBT)**	**Yes, high concentration and reprotoxic –However not emitted after 3 days**
78-40-0	Trietylphosphate *	120	1	Acute Tox. 4 H302	1.74	low hazard (no threshold derived)	-	No	No	No, low hazard and only emitted from one product
104-76-7	**2-Ethyl-1-hexanol**	**94**	**8**	**Acute Tox. 4 H332 (1839) STOT SE 3 335 (1795) Acute Tox. 4 H312 (66) Skin Sens. 1 H317 (10)**	**2.3**	**26.6**	**Irritation (respiratory tract)**	**Yes**	**No**	**Yes, high concentration and in many products. Is still emitted after 3 days.**
540-97-6	Dodecamethylcyclohexasiloxane * (D6)	87	11	Not classified (242) Eye Irrit. 2 H319 (19)	2.7	1.5	Repeated dose toxicity	No	Yes (PBT)	-
280-57-9	Triethylenediamine *	84	1	Acute Tox. 4 H302 (563) STOT SE 3 H335 (122) Acute Tox. 4 H332 (50) Acute Tox. 4 H312 (2) Not classified (5)	no hazard identified	no hazard identified	Skin irritation/corrosion	No	No	
34590-94-8	Dipropylene glycolmethylether *	70	2	Not classified (3703) Acute Tox. 4 H302 (5) STOT SE 3 H335 (11)	37.2	no hazard identified	-	No	No	
123-38-6	Propionaldehyde	63	1	Flam. Liq. 2 H225 Skin Irrit. 2 H315 Eye Irrit. 2 H319 STOT SE 3 H335	no data for inhalation	no data for inhalation	-	No	No	
Sum NI-VOC > C9	Sum of not identified VOC >C9 *	57	3	-	-	-	-	-	-	
13466-78-9	3-Carene *	49	15	Asp. Tox. 1 H304 (999) Skin Sens. 1. H317 (999)	no information on tox	no information on tox	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
108-88-3	**Toluene**	**44**	**16**	**Flam. Liq. 2 H225 Skin Irrit. 2 H315 Asp. Tox. 1 H304 STOT SE 3 H336 STOT RE 2 H373 Repr. 2 H361d**	**56.5**	**226**	**Irritation (respiratory tract)**	**Yes**	**No**	**Yes, in high concentration. Emitted from many products. Reprotoxic. Also emitted after 3 days.**
15176-21-3	1,4-Dioxane, 2,5-dimethyl- *	42	3	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	No	No	
Not identified	Not identified *	41.1	13	-	-	-	-	-	-	
80-56-8	**α-Pinene ***	**40**	**20**	**Acute Tox. 4 H302 (86) Asp. Tox. 1 H304 (1064) Skin Sens. 1 H 317 (899)**	**0.674**	**no hazard identified**	**-**	**No**	**No**	**Yes, emitted from many products. However, decreasing after 3 days. Low DNEL.**
Sum SVOC	TSVOC	32	5	-	-	-	-	-	-	No (not relevant hazard)
593-45-3	n-Octadecane *	32	1	Asp. Tox. 1 H304 (849) Not classified (80) STOT SE 3 H335 (4)	no hazard identified	no hazard identified	-	No	No	
3333-52-6	Tetramethylbutanedinitrile *	29	2	Acute Tox. 1 H300 (470) Acute Tox. 1 H310 (445) Acute Tox. 1 H330 (445) STOT SE 1 H370 (68) STOT RE 1 H372 (68) STOT SE 2 H371 (25) STOT RE 2 H373 (25) Not classified (1)	Not registered	Not registered	-	No	No	
141-63-9	Dodecamethylpentasiloxane *	28	5	Not classified (133) STOT SE 3 H335 (24)	25	no hazard identified	-	Yes	No	-
Other alkylbenzenes	Other alkylbenzenes *	27	3	-	-	-	-	-	-	
21460-36-6	2-Propanol, 1-(2-propenyloxy)- *	27	3	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
629-59-4	n-Tetradecane	21	3	Asp. Tox. 1 H304 (1064) STOT SE 3 H336 (41) Not classified (2)	no hazard identified	no hazard identified	-	No	No	
71-36-3	1-Butanol	19	15	Flam. Liq. 3 H226 Acute Tox. 4 H302 Skin Irrit. 2 H315 Eye Dam. 1 H318 STOT SE 3 H335 STOT SE 3 H336	55.357	no hazard identified	Irritation (respiratory tract)	Yes	No	
50-00-0	**Formaldehyde**	**18**	**14**	**Acute Tox. 3 H301 Acute Tox. 3 H311 Skin Corr. 1B H314 Skin Sens. 1 H317 Acute Tox. 3 H331 Muta. 2 H341 Carc. 1B H350**	**3.2**	**no hazard identified**	**Repeated dose toxicity**	**Yes**	**No**	**Yes, emitted from many products, toxic when inhaled, carcinogenic. Also emitted after 3 days.**
Sum NI-SVOC > C16	Sum of not identified SVOC > C16 *	17	1	-	-	-	-	-	-	
616-38-6	Carbonic acid, dimethyl ester *	17	1	Flam. Liq. 2 H225	4.4	42.5	Not listed	No	No	No (not relevant hazard)
179601-23-1	m/p-Xylene *	15	10	Flam. Liq. 3 H226 Acute Tox. 4 H312 Skin Irrit. 2 H315 Acute Tox. 4 H332	65.3	260	Irritation (respiratory tract)	Yes	No	Perhaps, but not emitted after 3 days
541-05-9	Hexamethylcyclotrisiloxane * e	15	2	Not classified (386) STOT SE 3 H335 (41)	64 (but for workers)	no data for inhalation	-	No	No	
107-52-8	Hexatetradecamethylsiloxane * e	15	1	Not classified (26) STOT SE 3 H335 (1)	25.4	no hazard identified	-	No	No	
66-25-1	Hexanal	14	18	Eye Irrit. 2 H319 (1125) Skin Irrit. 2 H315 (7)	2.9	no hazard identified	-	No	No	No (not relevant hazard)

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
108-95-2	**Phenol ***	**12**	**6**	**Acute Tox. 3 H301 Acute Tox. 3 H311 Skin Corr. 1B H314 Acute Tox. 3 H331 Muta. 2 H341 STOT RE 2 H373**	**1.32**	**exposure based waiving**	**-**	**Yes**	**No**	**Yes, toxic when inhaled, emitted from some products also after 3 days**
78-93-3	Methylethylketone (MEK) a	12	3	Flam. Liq. 2 H225 Eye Irrit. 2 H319 STOT SE 3 H336	106	no hazard identified	-	Yes	No	
123-86-4	Butyl acetate	11	4	Flam. Liq. 3 H226 STOT SE 3 H336	35.7	300	Irritation (respiratory tract)	No	No	
470-82-6	Eucalyptol *	10	1	Skin Sens. 1B H317 (1138) Not classified (8) STOT SE 3 H335 (2)	1.74	no hazard identified	-	No	No	
75-07-0	Acetaldehyde	9.5	2	Flam. Liq. 1 H224 Eye Irrit. 2 H319 STOT SE 3 H335 Muta. 2 H341 Carc. 1B H350	no data for inhalation	no data for inhalation	-	No	No	No, even if carcinogenic. No data for inhalation and not emitted after 3 days.
112-40-3	n-Dodecane	9.1	9	Asp. Tox. 1 H304 (422) STOT SE 3 H335 (33) Not classified (4)	no hazard identified	no hazard identified	-	No	No	
141-32-2	Butylacrylate	8.2	2	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Eye Irrit. 2 H319 Skin Sens. 1 H317 STOT SE 3 H335	no hazard identified	no hazard identified	Irritation (respiratory tract)	Yes	No	
629-50-5	n-Tridecane	8	4	Asp. Tox. 1 H304 (330) STOT SE 3 H335 (17) STOT SE 3 H336 (7)	no hazard identified	no hazard identified	-	No	No	
2460-77-7	2,5-di-tert-Butyl-1,4-benzoquinone*	7.9	1	STOT SE 3 H335 (59)	no information on tox	no information on tox	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
95-47-6	o-Xylene	7.6	2	Flam. Liq. 3 H226 Acute Tox. 4 H312 Skin Irrit. 2 H315 Acute Tox. 4 H332	65.3	260	Irritation (respiratory tract)	Yes	No	Perhaps, but is not emitted after 3 days
89-78-1	Menthol *	7.4	1	STOT SE 3 H335 (31) Not classified (6) Acute Tox. 4 H 302 (3)	16.3	0.5	Not listed	No	No	
475-20-7	Longifolene *	7.3	3	Asp. Tox. 1 H304 (880) Skin Sens. 1 H317 (880)	no data for inhalation	no data for inhalation	-	No	No	
141-62-8	Decamethyltetrasiloxane *	7.2	3	Not classified (103)	25	no hazard identified	-	Yes	No	
127-18-4	Tetrachloroethylene *	7.2	2	Carc. 2 H351 Aquatic Chronic 2 H411	0.25	no hazard identified	-	Yes	No	Perhaps (carc.), but not emitted after 3 days
98-83-9	α-Methylstyrene	6.6	2	Flam. Liq. 3 H226 Eye Irrit. 2 H319 STOT SE 3 H335 Aquatic Chronic 2 H411	41	no data for inhalation	-	No	No	
128-37-0	Butylhydroxytoluene BHT *	6.5	2	Not classified (181) Acute Tox. 4 H302 (339) Acute Tox. 4 H312 (131) Acute Tox. 4 H332 (80) STOT SE 3 H335 (113) STOT RE 2 H373 (113) Skin Sens. 1 H317 (56) STOT SE 1 H370 (49)	0.86	no-threshold effect and/or no dose-response information available	-	Yes	No	
1000215-29-0	cis-3-Methyl-endo-tricyclo[5.2.1.0(2.6)]decane *	6.1	1	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	-	-	
103-11-7	2-Ethylhexyl acrylate	6	1	Skin Irrit. 2 H315 Skin Sens. 1 H317 STOT SE 3 H335	no data for inhalation	low hazard (no threshold derived)	Irritation (respiratory tract)	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
57-55-6	1,2-Propandiol (Propylene glycol) *	5.8	2	Not classified (4430) Acute Tox. 4 H302 (16) STOT SE 3 H335 (9) Skin Sens. 1 H317 (2)	50	no hazard identified	Repeated dose toxicity	No	No	
1120-21-4	n-Undecane	5.7	5	Asp. Tox. 1 H304 (304) STOT SE 3 H335 (5)	no hazard identified	no hazard identified	-	No	No	
1137-12-8	Longicyclene *	5.6	2	Kun klassificeret med miljøfare	Not registered	Not registered	-	No	No	No (not relevant hazard)
100-42-5	Styrene	5.4	4	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Eye Irrit. 2 H319 Acute Tox. 4 H332 STOT RE 1 H372 (hearing organs) Repr. 2 H361d	10.2	182.75	acute toxicity	No	No	Perhaps, but not emitted after 3 days
95-50-1	1,2-Dichlorbenzen *	5.4	1	Acute Tox. 4 H302 Skin Irrit. 2 H315 Eye Irrit. 2 H319 STOT SE 3 H335 Aquatic Acute 1 H400 Aquatic Chronic 1 H410	1	medium hazard (no threshold derived)	Irritation (respiratory tract)	Yes	No	
106-46-7	1,4-Dichlorobenzene	5	1	Eye Irrit. 2 H319 Carc. 2 H351 Aquatic Acute 1 H400 Aquatic Chronic 1 H410	8.2	no data for inhalation	-	No	No	
100-41-4	Ethylbenzene	4.5	1	Flam. Liq. 2 H225 Acute Tox. 4 H332 Asp. Tox. 1 H304 STOT RE 2 H373 (hearing organs)	15	no hazard identified	-	No	No	
108-94-1	Cyclohexanone *	4.4	5	Flam. Liq. 3 H226 Acute Tox. 4 H332	10	40	Skin irritation/corrosion	Yes	No	Perhaps. Is toxic when inhaled and is emitted after 3 days

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
95-63-6	1,2,4-Trimethylbenzene	4.4	2	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Eye Irrit. 2 H319 Acute Tox. 4 H332 STOT SE 3 H335 H335 Aquatic Chronic 2 H411	29.4	29.4	Irritation (respiratory tract)	No	No	No, not emitted after 3 days
Sum carcinogens	Total carcinogens	4.3	1	-	-	-	-	-	-	
107-06-2	1,2-Dichloroethane	4.3	1	Flam. Liq. 2 H225 Acute Tox. 4 H302 Skin Irrit. 2 H315 Eye Irrit. 2 H319 STOT SE 3 H335 Carc. 1B H350	2.9	no data for inhalation	-	No	Yes	No, even if carcinogenic. But not emitted after 3 days and only from one product.
629-62-9	n-Pentadecane *	3.6	3	Asp. Tox. 1 H304 (226) STOT SE 3 H336 (7) STOT SE 3 H335 (4) Not classified (4)	no-threshold effect and/or no dose-response information available	no-threshold effect and/or no dose-response information available	-	No	No	
617-94-7	2-Phenyl-2-propanol *	3.3	1	Acute Tox. 4 H302 (1071) STOT SE 3 H335 (25) Acute Tox. 4 H312 (2) Acute Tox. 4 H332 (1)	no information on tox	no information on tox	-	No	No	
138-86-3	Limonene *	3	4	Flam. Liq. 3 H226 Skin Irrit. 2 H315 Skin Sens. 1 H317 Aquatic Acute 1 H400 Aquatic Chronic 1 H410	no data for inhalation	no data for inhalation	-	No	No	
124-18-5	n-Decane	2.9	1	Asp. Tox. 1 H304 (1043) STOT SE 3 H335 (60) Acute Tox. 4 H332 (71) Acute Tox. 4 H302 (24)	no hazard identified	no hazard identified	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term, local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
142-82-5	n-Heptane	2.7	2	Flam. Liq. 2 H225 Skin Irrit. 2 H315 Asp. Tox. 1 H304 STOT SE 3 H336 Aquatic Acute 1 H400 Aquatic Chronic 1 H410	447	no data for inhalation	-	No	No	
100-52-7	Benzaldehyde e	2.7	1	Acute Tox. 4 H302	4.9	no hazard identified	Irritation (respiratory tract)	Yes	No	
25265-77-4	Texanol *	2.7	1	Not classified (499) STOT SE H335 (1)	14.5	no hazard identified	-	No	No	
5131-66-8	1-Butoxy-2-propanol *	2.6	1	Skin Irrit. 2 H315 Eye Irrit. 2 H319	43	no hazard identified	-	No	No	
127-91-3	β-Pinene *	2.5	1	Asp. Tox. 1 H304 (1421) Skin Sens. 1 H317 (1410) STOT SE 3 H335 (23) Acute Tox. 4 H302 (3) Acute Tox. 4 H312 (6) Acute Tox. 4 H332 (6)	Not registered	Not registered	-	No	No	
103-65-1	n-Propylbenzene	2.5	1	Flam. Liq. 3 H226 Asp. Tox. 1 H304 STOT SE 3 H335 Aquatic Chronic 2 H411	Not registered	Not registered	-	No	No	
107-41-5	Hexylene glycol (2-methyl-2,4-pentanediol) *	2.4	1	Skin Irrit. 2 H315 Eye Irrit. 2 H319	7.8	49	Skin irritation/corrosion	No	No	
1135-66-6	Isolongifolene *	2.3	1	Asp. Tox. 1 H304 (916) Skin Sens. 1 H317 (18) Acute Tox. 4 H302 (1)	no information on tox	no information on tox	-	No	No	

Appendix 3.2 Substances that are emitted from the 20 PU foam products after 3 days

TABEL 45. Emitted substances after 3 days – the amount emitted is listed in µg/m^3. The substances have been sorted according to the highest concentration (the highest emitted concentration is listed in top of the table). Substances which have been selected for exposure and risk assessment are marked in bold and green background colour in the table

CAS No.	Name of substance	Highest measured concentration (µg/m^3)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m^3)	DNEL-inhalation for consumers (short-term. local effects) (mg/m^3)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
Sum VOC	TVOC	410	19	-	-	-	-	-	-	
68-12-2	**Dimethylformamide ***	**390**	**3**	**Acute Tox. 4 H312 Eye Irrit. 2 H319 Acute Tox. 4 H332 Repr. 1B H360D**	**15**	**30**	**Repeated dose toxicity**	**No**	**Yes (Repr.)**	**Yes, high concentration and acute tox by inhalation, and still emitted after 3 days. Is on the REACH Candidate list due to Repr. 1B.**
78-40-0	Trietylphosphate *	190	1	Acute Tox. 4 H302	1.74	low hazard (no threshold derived)	-	No	No	No, low hazard and only emitted from one product
280-57-9	Triethylenediamine *	180	1	Acute Tox. 4 H302 (563) STOT SE 3 H335 (122) Acute Tox. 4 H332 (50) Acute Tox. 4 H312 (2) Not classified (5)	no hazard identified	no hazard identified	Skin irritation/corrosion	No	No	
108-32-7	Propylene carbonate *	110	1	Eye Irrit. 2 H319	17.4	no hazard identified	Repeated dose toxicity	No	No	
Sat. Aliph. HC > C9	Saturated aliphatic hydrocarbons higher than C9 *	72	8	-	-	-	-	-	-	
104-76-7	**2-Ethyl-1-hexanol**	**60**	**8**	**Acute Tox. 4 H332 (1839) STOT SE 3 H335 (1795) Acute Tox. 4 H312 (66) Skin Sens. 1 H317 (10)**	**2.3**	**26.6**	**Irritation (respiratory tract)**	**Yes**	**No**	**Yes, high concentration and in many products. Is still emitted after 3 days.**
Not identified	Not identified *	48.3	11	-	-	-	-	-	-	

CAS No.	Name of sub-stance	Highest meas-ured con-centra-tion (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhala-tion for con-sumers (long-term systemic effects) (mg/m³)	DNEL-inhala-tion for con-sumers (short-term. local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
540-97-6	Dodecamethylcyclo-hexasiloxane *	48	10	Not classified (242) Eye Irrit. 2 H319 (19)	2.7	1.5	Repeated dose toxicity	No	Yes (PBT)	-
13475-82-6	2,2,4,6,6-Pentame-thylheptane *	36	2	Asp. Tox. 1 H304 (88) STOT SE 3 H336 (20) Not classified (6)	no hazard iden-tified	no hazard identified	-	No	No	No, even though high concentration from many products and still emitted after 3 days. However, is not regarded as a hazard according to registration data.
123-38-6	Propionaldehyde	33	1	Flam. Liq. 2 H225 Skin Irrit. 2 H315 Eye Irrit. 2 H319 STOT SE 3 H335	no data for in-halation	no data for in-halation	-	No	No	
34590-94-8	Dipropylene glycol-methylether *	33	2	Not classified (3703) Acute Tox. 4 H302 (5) STOT SE 3 H335 (11)	37.2	no hazard identified	-	No	No	
64-19-7	Acetic acid * a	28	4	Flam. Liq. 3 H226 Skin Corr. 1A H314	no hazard iden-tified	25	Irritation (respir-atory tract)	No	No	
Sum SVOC	TSVOC	18	6	-	-	-	-	-	-	
Sat. Aliph. HC > C16	Saturated aliphatic hydrocarbons >C16 *	18	1	-	-	-	-	-	-	
107-52-8	Tetradecame-thylhexasiloxane *	18	1	Not classified (26) STOT SE 3 H335 (1)	25.4	no hazard identified	-	No	No	
Sum NI-VOC > C9	Sum of not identi-fied VOC >C9 *	17	2	-	-	-	-	-	-	
29911-82-2	Dipropylene glycol mono-n-butylether *	16	1	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term. local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
3333-52-6	Tetramethylbutanedinitrile *	15	3	Acute Tox. 1 H300 (470) Acute Tox. 1 H310 (445) Acute Tox. 1 H330 (445) STOT SE 1 H370 (68) STOT RE 1 H372 (68) STOT SE 2 H371 (25) STOT RE 2 H373 (25) Not classified (1)	Not registered	Not registered	-	No	No	
108-95-2	**Phenol ***	**13**	**7**	**Acute Tox. 3 H301 Acute Tox. 3 H311 Skin Corr. 1B H314 Acute Tox. 3 H331 Muta. 2 H341 STOT RE 2 H373**	**1.32**	**exposure based waiving**	**-**	**Yes**	**No**	**Yes, toxic when inhaled, is emitted from some products also after 3 days**
629-59-4	n-Tetradecane	13	1	Asp. Tox. 1 H304 (1064) STOT SE 3 H336 (41) Not classified (2)	no hazard identified	no hazard identified	-	No	No	
141-63-9	Dodecamethylpentasiloxane *	13	1	Not classified (133) STOT SE 3 H335 (24)	25	no hazard identified	-	Yes	No	-
108-88-3	**Toluene**	**11**	**1**	**Flam. Liq. 2 H225 Skin Irrit. 2 H315 Asp. Tox. 1 H304 STOT SE 3 H336 STOT RE 2 H373 Repr. 2 H361d**	**56.5**	**226**	**Irritation (respiratory tract)**	**Yes**	**No**	**Yes in high concentrations. Emitted from many products. Reprotoxic. Also emitted after 3 days.**
128-37-0	Butylhydroxytoluene BHT *	10	2	Not classified (181) Acute Tox. 4 H302 (339) Acute Tox. 4 H312 (131) Acute Tox. 4 H332 (80) STOT SE 3 H335 (113) STOT RE 2 H373 (113) Skin Sens. 1 H317 (56) STOT SE 1 H370 (49)	0.86	no-threshold effect and/or no dose-response information available	-	Yes	No	?

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term. local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
2460-77-7	2,5-di-tert-Butyl-1,4-benzoquinone*	9.7	1	STOT SE 3 H335 (59)	no information on tox	no information on tox	-	No	No	
62183-79-3	2,2,4,4-Tetra-methyloctane *	8.9	1	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	No	No	
108-94-1	Cyclohexanone *	8.5	1	Flam. Liq. 3 H226 Acute Tox. 4 H332	10	40	Skin irritation/corrosion	Yes	No	Perhaps
50-00-0	**Formaldehyde**	**8.4**	**9**	**Acute Tox. 3 H301 Acute Tox. 3 H311 Skin Corr. 1B H314 Skin Sens. 1 H317 Acute Tox. 3 H331 Muta. 2 H341 Carc. 1B H350**	**3.2**	**no hazard identified**	**Repeated dose toxicity**	**Yes**	**No**	**Yes, emitted from many products, toxic when inhaled, carcinogenic. Also emitted after 3 days.**
149-57-5	2-Ethylhexanoic acid *	7.9	3	Repr. 2 H361d	3.5	low hazard (no threshold derived)	-	Yes	No	
475-20-7	Longifolene *	5.7	2	Asp. Tox. 1 H304 (880) Skin Sens. 1 H317 (880)	no data for inhalation	no data for inhalation	-	No	No	
80-56-8	**α-Pinene ***	**5.6**	**1**	**Acute Tox. 4 H302 (86) Asp. Tox. 1 H304 (1064) Skin Sens. 1 H 317 (899)**	**0.674**	**no hazard identified**	**-**	**No**	**No**	**Yes, emitted from many products. However, decreasing after 3 days. Low DNEL.**
21460-36-6	1-(2-Propenyloxy)-2-propanol *	5.4	2	Not in ECHA database	Not in ECHA database	Not in ECHA database	-	No	No	
13466-78-9	3-Carene *	5.2	1	Asp. Tox. 1 H304 (999) Skin Sens. 1. H317 (999)	no information on tox	no information on tox	-	No	No	
629-62-9	n-Pentadecane *	4.9	1	Asp. Tox. 1 H304 (226) STOT SE 3 H336 (7) STOT SE 3 H335 (4) Not classified (4)	no-threshold effect and/or no dose-response information available	no-threshold effect and/or no dose-response information available	-	No	No	

CAS No.	Name of substance	Highest measured concentration (µg/m³)	Emitted from no. of 20 products	Classification (number in brackets list the number of notified classifications)	DNEL-inhalation for consumers (long-term systemic effects) (mg/m³)	DNEL-inhalation for consumers (short-term. local effects) (mg/m³)	Critical effect (local effects)	On the CoRAP list	SVHC	Prioritisation
25265-77-4	Texanol *	4.8	1	Not classified (499) STOT SE H335 (1)	14.5	no hazard identified	-	No	No	
1137-12-8	Longicyclene *	4.2	1	Kun klassificeret med miljøfare	Not registered	Not registered	-	No	No	No (not relevant hazard)
541-02-6	**Decamethylcyclopentasiloxane ***	**4.1**	**3**	**Not classified (2828) Acute Tox. 3 H331 (18) STOT SE 3 H335 (2)**	**17.3**	**no hazard identified**	**Repeated dose toxicity**	**No**	**Yes (PBT)**	**Yes, high concentration and emitted from many products. Also emitted after 3 days. However, classification uncertain.**
112-40-3	n-Dodecane	3.4	1	Asp. Tox. 1 H304 (422) STOT SE 3 H335 (33) Not classified (4)	no hazard identified	no hazard identified	-	No	No	
103-11-7	2-Ethylhexyl acrylate	3	1	Skin Irrit. 2 H315 Skin Sens. 1 H317 STOT SE 3 H335	no data for inhalation	low hazard (no threshold derived)	Irritation (respiratory tract)	No	No	
98-83-9	α-Methylstyrene	3	1	Flam. Liq. 3 H226 Eye Irrit. 2 H319 STOT SE 3 H335 Aquatic Chronic 2 H411	41	no data for inhalation	-	No	No	
66-25-1	Hexanal	2.9	4	Eye Irrit. 2 H319 (1125) Skin Irrit. 2 H315 (7)	2.9	no hazard identified	-	No	No	No (not relevant hazard)
629-50-5	n-Tridecane	2.7	1	Asp. Tox. 1 H304 (330) STOT SE 3 H335 (17) STOT SE 3 H336 (7)	no hazard identified	no hazard identified	-	No	No	
544-76-3	n-Hexadecane	2.3	1	Asp. Tox. 1 H304 (1063) STOT SE 3 H335 (45)	no-threshold effect and/or no dose-response information available	no-threshold effect and/or no dose-response information available	-	No	No	

Appendix 4. Overview of the analysed flame retardants

This appendix contains an overview of the individual brominated flame retardants for which chemical analysis have been carried out. The overview also describes which flame retardants that are included in the sums described in section 10.2 ”Control analyses for brominated flame retardant content”.

Name	CAS
alpha-HBCD¤	134237-50-6
beta-HBCD¤	134237-51-7
gamma-HBCD¤	134237-52-8
HBCD (total alpha, beta, gamma)¤	Sum of the above
2,2',4-TriBDE (BDE-17) ¤	147217-75-2
2,4,4'-TriBDE (BDE-28)¤	41318-75-6
sum of analysed TriBDEs ¤	Sum of the above
2,2',4,4'-TetraBDE (BDE-47)¤	5436-43-1
2,2',4,5'-TetraBDE (BDE-49) ¤	243982-82-3
2,3',4,4'-TetraBDE (BDE-66)¤	189084-61-5
2,3',4',6-TetraBDE (BDE-71)¤	189084-62-6
3,3',4,4'-TetraBDE (BDE-77)¤	93703-48-1
sum of analysed TetraBDEs ¤	Sum of the above
2,2',3,4,4'-PentaBDE (BDE-85)¤	182346-21-0
2,2',4,4',5-PentaBDE (BDE-99)¤	60348-60-9
2,2',4,4',6-PentaBDE (BDE-100)¤	189084-64-8
2,3',4,4',6-PentaBDE (BDE-119)¤	189084-66-0
3,3',4,4',5-PentaBDE (BDE-126) ¤	366791-32-4
sum of analysed PentaBDEs ¤	Sum of the above
2,2',3,4,4',5'-HexaBDE (BDE-138)¤	182677-30-1
2,2',4,4',5,5'-HexaBDE (BDE-153)¤	68631-49-2
2,2',4,4',5,6'-HexaBDE (BDE-154)¤	207122-15-4
2,3,3',4,4',5-HexaBDE (BDE-156)¤	
sum of analysed HexaBDEs ¤	Sum of the above
2,2',3',4,4',5',6-HeptaBDE (BDE-183)¤	207122-16-5
2,2',3,4,4',6,6'-HeptaBDE (BDE-184)¤	117948-63-7
2,3,3',4,4',5',6-HeptaBDE (BDE-191)¤	189084-68-2
sum of analysed HeptaBDEs ¤	Sum of the above
2,2',3,3',4,4',5,6'-OctaBDE (BDE-196)¤	446255-39-6
2,2',3,3',4,4',6,6'-OctaBDE (BDE-197)¤	
sum of analysed OctaBDEs ¤	Sum of the above
2,2',3,3',4,4',5,5',6-NonaBDE (BDE-206)¤	63387-28-0
2,2',3,3'4,4',5,6,6'-NonaBDE (BDE-207)¤	437701-79-6
sum of analysed NonaBDEs ¤	Sum of the above
DecaBDE (BDE-209)¤	1163-19-5
Sum of analysed BDEs¤	Sum of all of the above

FIGUR 17. Overview of the individual brominated flame retardants for which chemical analysis have been carried out

Appendix 5. Calculation of exposure and risk

This appendix presents more detailed exposure calculations, as well as RCR value calculations; that is, the risk of health effects. Tables with the values used for the calculations are presented on the following pages. The method used for the calculations is that described in chapter 14.

The calculations presented in this appendix are:

1. Exposure for each of the 20 products investigated in the zone of respiration (see section 15.1).
2. Extreme worst case: several products in the zone of respiration (see section 15.2)
3. Realistic worst case: multiple products in the zone of respiration, but divided by sleeping and awake time (see section 15.3)
4. Realistic worst-case: multiple products in one room, where emissions from the products spread throughout the room. Here, a scenario was calculated for babies (see section 15.4.1) and for teenagers (see section 15.4.2).

Appendix 5.1 Exposure for each of the 20 products investigated in the zone of respiration

Initially, exposure was calculated for each of the 20 products, assuming a 40 x 40 x product height block emitting substances directly in the zone of respiration. The raw data used for the calculations is given below in TABLE 46. It includes:

- The emitted concentrations for individual products for the given standard loading factor of 0.4 m^2/m^3 at both 1 hour and 3 days (given in parentheses).
- These concentrations can be converted to actual concentrations for a 40 cm x 40 cm x product height block by calculating the actual loading factor (see method description in chapter 14). The actual loading factors are calculated for the 20 products. The calculation of the actual concentrations is not given in the table.
- The RCR values are calculated using the corrected DNEL values, taking into account 18 hours of exposure instead of 24 hours. The corrected DNEL values used for the 9 substances are listed, but the calculated RCR values are not. These can be found in TABLE 29 in chapter 15.1.

TABLE 46. Raw data used for calculations of RCR value: Emitted concentrations (in $\mu g/m^3$) after 1 hour (and 3 days) for the nine selected substances from the 20 PU foam products purchased; calculated actual loading factor for 40 x 40 cm x product height block of the 20 products, and the corrected DNEL values for the nine substances, accounting for 18 hours of exposure. Empty fields indicate that no emission of the substance was measured above the detection limit.

Product	DMF	D4	D5	D6	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formalde-hyde	Phenol	Calculated actual load-ing factor (m^2/m^3)
N-EU 2	21 (19)		18 (4.1)	27 (18)	0 (2.1)	44 (0)	3.8 (0)	12 (7.8)	0 (2.4)	0.58
N-EU 3	1500 (390)	150 (0)	110 (0)	40 (6.3)		15 (0)	7.3 (0)	4.3 (0)		3.03
N-EU 4		73 (0)	190 (0)	61 (32)		2.7 (0)	8.8 (0)	8.9 (4.4)		2.33
N-EU 5			3.7 (0)	13 (3.7)		26 (0)	4.1 (0)	3.8 (0)		2.18
N-EU 6			3.5 (0)	2.1 (0)	0 (9)	2.3 (0)	3.1 (0)	7.7 (4.3)	3.1 (2.1)	2.64
EU 1	11 (0)				15 (11)	2.5 (0)	5.9 (0)	3.4 (0)	12 (12)	0.47
EU 2		17 (0)	21 2.4)	10 (4.5)		4.9 (0)	3.1 (0)		0 (7.6)	3.97
EU 3	11 (7.5)		6.2 (0)	4.8 (2.8)	94 (60)		3.9 (0)		5.7 (5.5)	1.61
EU 4					3 (2.4)	2.2 (0)	3.8 (0)	12 (6.8)		2.18
EU 5		11 (0)	18 (0)			3.1 (0)	9.7 (0)	5.3	6.7 (4.1)	2.54
DK 1		11 (0)	34 (0)	9.6 (2.1)	3.1 (0)	2.4 (0)	25 (0)			4.05
DK 2			10 (0)		5 (0)		4.2 (0)	7.7 (7.1)	2.4 (0)	1.75
DK 3			3.3 (0)		3.7 (2)	2.6 (0)	4.1 (0)	5.5 (4.7)		1.88
DK 4			40 (0)	42 (13)		4 (0)	5.5 (0)	5.3 (4.2)		2.42
DK 5			13 (0)		3 (0)	3.4 (0)	11 (0)			2.29
DK 6						2.3 (0)	40 (5.6)			1.75
DK 7			3.4 (0)			3.4 (0)	5.6 (0)	4.6 (3.3)		2.35
DK 8	8 (0)		15 (0)	26 (15)		33 (0)	12 (0)	4.6 (0)		1.99
DK 9		67 (0)	160 (3.5)	87 (48)	0 (2.5)	0 (11)	8.5 (0)		12 (13)	2.62
DK 10	3.5 (0)				4.8 (3.4)		5 (0)	18 (8.4)		2.06
No of prod. with emis-sions	**6 (3)**	**6 (0)**	**16 (3)**	**11 (10)**	**8 (8)**	**16 (1)**	**20 (1)**	**14 (9)**	**6 (7)**	

Product	DMF	D4	D5	D6	2-ethyl-1-hexanol	Toluene	alpha-pinene	Formaldehyde	Phenol	Calculated actual loading factor (m^2/m^3)
Corrected DNEL	107	1333	5752	173	400	3867	899	67	93	

At the bottom of the table, the number of the 20 products that emitted each of the nine selected substances, after both 1 hour and 3 days (in parentheses) is given.

Appendix 5.2 Extreme worst case: several products in the zone of respiration in the bedroom

TABLE 47. Example of calculation of exposure and risk for DMF for the extreme worst-case scenario with multiple products in the zone of respiration

Product	Product with highest concentration	Product used for calculating surface area	Highest concentration of substance (µg/m^3)	Product height (m)	Product length (m)	Product width (m)	Calculated product surface area (m^2)	Emission chamber volume (m^3)	Actual loading factor for the product (m^2/m^3)	Standard loading factor (m^2/ m^3)	Calculated concentration in zone of respiration (µg/m^3)	Exposure time (hours)	DNEL (µg/m^3)	RCR (-)
Baby mattress	N-EU3	N-EU 3	1500	0.125	0.40	0.40	0.360	0.119	3.03	0.4	11,345	24	80	**141.8**
Baby pillow	N-EU3	EU 1	1500	*Actual loading factor used here* *				0.119	0.5	0.4	1875	24	80	**23.4**
Cot bumper	N-EU3	DK 3	1500	0.04	0.40	0.40	0.224	0.119	1.88	0.4	7059	24	80	**88.2**
Total for all products											**20,278.4**			**253.5**

* The baby pillow was fully inserted into the emission chamber, which is why the actual loading factor from the analysis report is used

The calculations for the eight other substances were performed similarly. However, they are not shown in detail, as the basic data for the calculations are the same, though with natural variations in the highest concentration measured and DNEL value used. The results of the calculations are shown in the following tables, from TABLE 48 to TABLE 53 below.

TABLE 48. Calculation of exposure and risk (RCR value) for D4, D5 and D6 for extreme worst case in zone of respiration

Product Substance name: D4, D5 and D6	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
D4 (lung effects): Based on N-EU 3, having the highest measured concentration of 150 $\mu g/m^3$			
Total for three products	2027.8	1000	**2.0**
D5 (uterine tumours): Based on N-EU 4, having the highest measured concentration of 190 $\mu g/m^3$			
Total for three products	2568.6	4314	0.6
D5 (lung effects): Based on N-EU 4, having the highest measured concentration of 190 µg/m3			
Total for three products	2568.6	5300	0.5
D6 (lung effects): Based on DK 9, having the highest measured concentration of 87 µg/m3			
Total for three products	963.8	130	7.4
Sum of D4 + D5 + D6 — PU foam			**9.9**

TABLE 49. Calculation of exposure and risk (RCR value) for 2-ethyl-1-hexanol for extreme worst case in zone of respiration

Product Substance name: 2-ethyl-1-hexanol	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Based on EU 3, having the highest measured concentration of 94 µg/m3			
Total for three products	935.9	300	**3.1**

TABLE 50. Calculation of exposure and risk (RCR value) for toluene for extreme worst case in zone of respiration

Product Substance name: toluene	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Based on N-EU 2, having the highest measured concentration of 44 µg/m3			
Total for three products	594.8	2900	0.21

TABLE 51. Calculation of exposure and risk (RCR value) for α-pinene for extreme worst case in zone of respiration

Product Substance name: α-pinene	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Based on DK 6, having the highest measured concentration of 40 $\mu g/m^3$			
Total for three products	540.8	674	0.80

TABLE 52. Calculation of exposure and risk (RCR value) for formaldehyde for extreme worst case in zone of respiration

Product Substance name: formaldehyde	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Based on DK 10, having the highest measured concentration of 18 $\mu g/m^3$			
Total for three products	199.8	50	**4.0**

TABLE 53. Calculation of exposure and risk (RCR value) for phenol for extreme worst case in zone of respiration

Product Substance name: phenol	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Based on DK 9, having the highest measured concentration of 13 $\mu g/m^3$			
Total for three products	175.7	70	**2.5**

Appendix 5.3 Realistic worst case: zone of respiration in bedroom and living room

This scenario assumes that a baby is exposed to a baby mattress, baby pillow, and cot bumper in the zone of respiration for the 18 hours it is presumed that a baby sleeps. For three waking hours, it is assumed that a baby is lying on a tumbling mat in the living room. For the remaining of the three hours of the day, there is no exposure to other PU foam products. The example below gives calculations for two baby mattresses, since one of the baby mattresses has extremely high emissions (marked with green background and "HIGH") of DMF, relative to other products.

TABLE 54. Example of calculation of exposure and risk for DMF for the realistic worst-case scenario with multiple products in the zone of respiration. Calculated for 1 hour and 3 days (in parentheses).

Product	Product with highest concentration	Product used for calculating surface area	Highest concentration of substance (µg/m^3)	Product height (m)	Product length (m)	Product width (m)	Calculated product surface area (m^2)	Emission chamber volume (m^3)	Actual loading factor for the product (m^2/m^3)	Standard loading factor (m^2/ m^3)	Calculated concentration in zone of respiration (µg/m^3)	Exposure time (hours)	DNEL – corrected (µg/m^3)	RCR (-)
Baby mattress (HIGH)	N-EU 3	N-EU 3	1500 (390)	0.125	0.40	0.40	0.360	0.119	3.03	0.4	11,345 (2949.6)	18	107	**106.4 (27.7)**
Baby mattress	EU 3	EU 3	11 (7.5)	0.019	0.40	0.40	0.190	0.119	1.60	0.4	44 (30)	18	107	0.41 (0.28)
Baby pillow	N-EU 2	N-EU 2	21 (19)	*Actual loading factor used here* *				0.119	0.5	0.4	26 (23.8)	18	107	0.25 (0.22)
Cot bumper		DK 3	0 (0)	0.04	0.40	0.40	0.224	0.119	1.88	0.4	0 (0)	18	107	0
Tumbling mat		DK 6	0 (0)	0.03	0.40	0.40	0.208	0.119	1.75	0.4	0 (0)	3	640	0 (0)
Total of all products — including second highest value														0.66 (0.50)

* The baby pillow was fully inserted into the emission chamber, which is why the actual loading factor from the analysis report is used

The calculations for the other substances (D4, D5, D6, and the sum of these, as well as 2-ethyl-1-hexanol and formaldehyde) are performed similarly. However, they are not shown in detail, as the basic data for the calculations are the same, though with natural variations in the highest concentration measured, the height of the blocks cut for measurement, and the DNEL value used. Note that the DNEL value is corrected for the time period used in the calculations, since the DNEL values described in chapter 13 are based on 24 hours. The result of the calculations is shown in the following tables, from TABLE 55 to TABLE 57 below. For all tables, the RCR values are based on emissions after 1 hour, with RCR values based on emissions after 3 days listed below in parentheses.

TABLE 55. Calculation of exposure and risk (RCR value) for D4, D5 and D6 for realistic worst case in zone of respiration. Calculated for 1 hour and 3 days (in parentheses).

Product **Substance name: D4, D5 and D6**	**Concentration ($\mu g/m^3$)**	**DNEL value corrected ($\mu g/m^3$)**	**RCR (-)**
D4 (lung effects):			
Total for three products (sleeping hours)	1134.5 (0)	1333	0.85 (0)
Total for products (waking hours)	0 (0)	8000	0 (0)
Total for PU foam products			0.85 (0)
D5 (uterine tumours):			
Total for three products (sleeping hours)	898.1 (5.1)	5752	0.16 (0.001)
Total for products (waking hours)	0 (0)	34,512	0 (0)
Total for PU foam products			0.16 (0.001)
D5 (lung effects):			
Total for three products (sleeping hours)	898.1 (5.1)	7067	0.13 (0.001)
Total for products (waking hours)	0 (0)	42,400	0 (0)
Total for PU foam products			0.13 (0.01)
D6 (lung effects):			
Total for three products (sleeping hours)	287.9 (101.2)	173	1.7 (0.58)
Total for products (waking hours)	0 (0)	1040	0 (0)
Total for PU foam products			1.7 (0.58)
Sum of D4 + D5 + D6 — PU foam			**2.6** (0.58)

TABLE 56. Calculation of exposure and risk (RCR value) for 2-ethyl-1-hexanol for realistic worst case in zone of respiration. Calculated for 1 hour and 3 days (in parentheses).

Product Substance name: 2-ethyl-1-hexanol	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Total for three products (sleeping hours)	416.6 (262.5)	400	**1.04** (0.66)
Total for products (waking hours)	0 (0)	2400	0 (0)
Total for PU foam products			**1.04** (0.66)

TABLE 57. Calculation of exposure and risk (RCR value) for formaldehyde for realistic worst case in zone of respiration. Calculated for 1 hour and 3 days (in parentheses).

Product Substance name: formaldehyde	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Total for three products (sleeping hours)	141.2 (84.0)	67	**2.12** **(1.26)**
Total for products (waking hours)	0 (0)	400	0 (0)
Total for PU foam products			**2.12** **(1.26)**

TABLE 58. Calculation of exposure and risk (RCR value) for phenol for realistic worst case in zone of respiration. Calculated for 1 hour and 3 days (in parentheses).

Product Substance name: phenol	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Total for three products (sleeping hours)	69.4 (56.6)	93	0.74 (0.61)
Total for products (waking hours)	0 (0)	560	0 (0)
Total for PU foam products			0.74 (0.61)

Appendix 5.4 Realistic worst case: room concentration for babies in bedroom and living room

This scenario assumes that a baby is exposed to a baby mattress, baby pillow, cot bumper, two adult mattresses, and two pillows in the zone of respiration for the 18 hours it is presumed that a baby sleeps. For three waking hours, it is assumed that a baby is lying on a tumbling mat in the living room. For the remaining of the three hours of the day, there is no exposure to other PU foam products. Calculations are based on the concentration in the room (i.e., the amount emitted from all products becomes distributed throughout the room), not on the concentration in the zone of respiration. The example below gives calculations for two baby mattresses, since one of the baby mattresses has extremely high emissions (marked with green background and "HIGH") of DMF, relative to other products.

TABLE 59. Example of calculation of exposure and risk for DMF for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room. Calculated for 1 hour and 3 days (in parentheses).

Product	Number of products in room	Product with highest concentration	Product used for calculating surface area	Highest concentration of substance (µg/m^3)	Total concentration of substance (µg/m^3)	Actual measurements of entire product (cm)	Actual surface area for entire product (m^2)	Standard surface area measurements based on (m^2)	Emission chamber volume (m^3)	Volume of room (m^3)	Calculated concentration in the room (µg/m^3)	Exposure time (hours)	DNEL – corrected (µg/m^3)	RCR (-)
Baby mattress (HIGH)	1	N-EU 3	N-EU 3	1500 (390)	1500 (390)	140x70x12.7	1.513	0.4 m^2/m^3 x 0.119 m^3 = 0.0476	0.119	21	270 (70.3)	18	107	**2.5** (0.7)
Baby mattress	1	EU 3	EU 3	11 (7.5)	11 (7.5)	30x30x2	0.284	0.0476	0.119	21	0.37 (0.25)	18	107	0.003 (0.002)
Baby head pillow	1	N-EU 2	N-EU 2	21 (19)	21 (19)	26x20.5x2.5	0.061	0.0476	0.119	21	0.15 (0.14)	18	107	0.001 (0.001)
Cot bumper	1	DK 3	DK 3	0 (0)	0 (0)	340x30x4	2.200	0.0476	0.119	21	0 (0)	18	107	0 (0)
Adult mattress	2		DK 1	0 (0)	0 (0)	200x90x20	2.96	0.0476	0.119	21	0 (0)	18	107	0 (0)
Pillow	2	DK 8	DK 8	8 (0)	16 (0)	40x26x6	0.18	0.0476	0.119	21	0.35 (0)	18	107	0.003 (0)
Tumbling mat	1		DK 6	0 (0)	0 (0)	185x78x3	1.601	0.0476	0.119	58	0 (0)	3	640	0 (0)
Total of all products — including second highest value														0.01 (0.004)

The calculations for D4, D5, D6, and formaldehyde are performed correspondingly. However, this calculation is not shown in detail, as the basic data for the calculations are the corresponding data with variations in the highest measured concentration, entire product sizes, and DNEL values used. Note that the DNEL value is corrected for the time period used in the calculations, since the DNEL values described in chapter 13 are based on 24 hours. The result of the calculations is shown in the following tables (from TABLE 60 to TABLE 61). For all tables, the RCR values are based on emissions after 1 hour, with RCR values based on emissions after 3 days listed below in parentheses.

TABLE 60. Calculation of exposure and risk (RCR value) for D4, D5, and D6 for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room (parents' bedroom). Calculated for 1 hour and 3 days (in parentheses).

Product **Substance name: D4, D5 and D6**	**Concentration ($\mu g/m^3$)**	**DNEL value corrected ($\mu g/m^3$)**	**RCR (-)**
D4 (lung effects):			
Total for seven products (sleeping hours)	65.9 (0)	1333	0.05 (0)
Total for products (waking hours)	0 (0)	8000	0 (0)
Total for PU foam products			0.05 (0)
D5 (uterine tumours):			
Total for seven products (sleeping hours)	116.1 (1.0)	5752	0.02 (0.0002)
Total for products (waking hours)	0 (0)	34,512	0 (0)
Total for PU foam products			0.02 (0.0002)
D5 (uterine effects):			
Total for seven products (sleeping hours)	116.1 (1.0)	7067	0.02 (0.0001)
Total for products (waking hours)	0 (0)	42,400	0 (0)
Total for PU foam products			0.02 (0.0001)
D6 (lung effects):			
Total for seven products (sleeping hours)	59.0 (15.5)	173	0.34 (0.09)
Total for products (waking hours)	0 (0)	1040	0 (0)
Total for PU foam products			0.34 (0.09)
Sum of D4 + D5 + D6 — PU foam			0.41 (0.09)

TABLE 61. Calculation of exposure and risk (RCR value) for formaldehyde for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room (parents' bedroom). Calculated for 1 hour and 3 days (in parentheses).

Product **Substance name: formaldehyde**	**Concentration ($\mu g/m^3$)**	**DNEL value ($\mu g/m^3$)**	**RCR (-)**
Total for seven products (sleeping hours)	5.96 (3.4)	67	0.09 (0.05)
Total for products (waking hours)	0 (0)	400	0 (0)
Total for PU foam products			0.09 (0.05)

Appendix 5.5 Realistic worst-case: room concentration for teenagers in their own room

This scenario supposes that a teenager is exposed to a mattress, a folding mattress (for guests), two pillows and a tumbling mat in the 18 hours they are assumed to occupy their rooms (10 sleeping hours and 8 waking hours). For the remaining of the hours of the day, there is assumed to be no exposure to other PU foam products. Calculations are based on the concentration in the room (i.e., the amount emitted from all products becomes distributed throughout the room), not on the concentration in the zone of respiration.

TABLE 62. Example of calculation of exposure and risk for DMF for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room. Calculated for 1 hour and 3 days (in parentheses).

Product	Number of products in room	Product with highest concentration	Product used for calculating surface area	Highest concentration of substance (µg/m^3)	Total concentration of substance (µg/m^3)	Actual measurements of entire product (cm)	Actual surface area for entire product (m^2)	Standard surface area measurements based on (m^2)	Emission chamber volume (m^3)	Volume of room (m^3)	Calculated concentration in the room (µg/m^3)	Exposure time (hours)	DNEL – corrected (µg/m^3)	RCR (-)
Folding mattress	1	EU 5	EU 5	11 (0)	11 (0)	200x80x9	2.104	0.0476	0.119	21	2.76	18	107	0.03 (0)
Adult mattress	1		DK 1	0 (0)	0 (0)	200x90x20	2.96	0.0476	0.119	21	0.00	18	107	0 (0)
Pillow	2	DK 8	DK 8	8 (0)	16 (0)	40x26x6	0.18	0.0476	0.119	21	0.35	18	107	0.003 (0)
Tumbling mat	1		DK 6	0 (0)	0 (0)	185x78x3	1.60	0.0476	0.119	21	0.00	18	107	0 (0)
Total for all products														0.03 (0)

The calculations for D4, D5, D6, and formaldehyde are performed correspondingly. However, this calculation is not shown in detail, as the basic data for the calculations are the corresponding data with variations in the highest measured concentration, entire product sizes, and DNEL values used. Note that the DNEL value is corrected for the time period used in the calculations, since the DNEL values described in chapter 13 are based on 24 hours. The result of the calculations is shown in the following tables (from TABLE 63 to TABLE 64). For all tables, the RCR values are based on emissions after 1 hour, with RCR values based on emissions after 3 days listed below in parentheses.

TABLE 63. Calculation of exposure and risk (RCR value) for D4, D5, and D6 for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room (teenager's bedroom). Calculated for 1 hour and 3 days (in parentheses).

Product **Substance name: D4, D5 and D6**	**Concentration ($\mu g/m^3$)**	**DNEL value corrected ($\mu g/m^3$)**	**RCR (-)**
D4 (lung effects):			
Total for five products (sleeping hours)	29.9 (0)	1333	0.02 (0)
Total for products (waking hours)	0 (0)	8000	0 (0)
Total for PU foam products			0.02 (0)
D5 (uterine tumours):			
Total for five products (sleeping hours)	120.6 (1.0)	5727	0.02 (0.0002)
Total for products (waking hours)	0 (0)	34,512	0 (0)
Total for PU foam products			0.02 (0.0002)
D5 (lung effects):			
Total for five products (sleeping hours)	120.6 (1.0)	7067	0.17 (0.0001)
Total for products (waking hours)	0 (0)	42,400	0 (0)
Total for PU foam products			0.17 (0.0001)
D6 (lung effects):			
Total for five products (sleeping hours)	60.3 (18.8)	173	0.35 (0.11)
Total for products (waking hours)	0 (0)	1040	0 (0)
Total for PU foam products			0.35 (0.11)
Sum of D4 + D5 + D6 — PU foam			0.39 (0.11)

TABLE 64. Calculation of exposure and risk (RCR value) for formaldehyde for the realistic worst-case scenario, calculated for room concentration with multiple products in the same room (teenager's bedroom). Calculated for 1 hour and 3 days (in parentheses).

Product Substance name: formaldehyde	Concentration ($\mu g/m^3$)	DNEL value ($\mu g/m^3$)	RCR (-)
Total for five products (sleeping and waking hours)	2.96 (2.2)	67	0.04 (0.03)

Survey and risk assessment of VOCs in PU foam products

A previous Danish EPA survey project on PU foam products (squishy toys) showed that emissions of certain volatile organic compounds (VOCs) may constitute a health risk. As a result, this project investigated other products made of PUR foam like mattresses and pillows. Within the project, 20 products were analyzed, of these 10 are products for baby's and 10 are products for grown up .These products were analyzed for their content of flame retardants and phthalates as these are already regulated, additionally the products emission and volatile organic compounds were analyzed. Results showed that no products violated the limit values for flame retardants and phthalates but one baby mattress emitted large concentrations of dimethylformamide which also was found in squishy toys, and is therefore no longer sold to Danish consumers.

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