Risk assessment of VOCs in handheld toys for children

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1 Preface

This report presents a risk assessment of VOCs in handheld toys, carried out for the Norwegian Environment Agency in 2021.

Toys (n = 45) were selected and purchased by the Norwegian Environment Agency in autumn 2019.

The risk assessment is conducted using chemical analyses of VOCs emitted from the toys, provided by the Norwegian Institute for Air Research (NILU 2020).

The chemical analyses were performed in two phases: a phase with analyses of VOCs emitted from each toy and a phase with analyses of multiple toys in three locations in a furnished apartment (bedside, room, and adjoining room) without residents.

The chemical analyses and real-life exposure scenarios regarding children's exposure to substances when using the toys have been the foundation for conducting the risk assessment. In cooperation with the Norwegian Environment Agency, relevant toys and substances were selected to be included in the risk assessment.

The aim of this report is to identify the VOCs of most concern regarding exposure of children and based on this knowledge to conduct a risk assessment of the VOCs.

2 Summary and conclusion

Aim of the project

In 2020 the Norwegian Institute for Air Research (NILU) has on behalf of the Norwegian Environment Agency,

conducted a screening study to identify volatile organic chemicals (VOCs) emitted from a total of 45 different handheld toys for children. Based on the analytical results presented by NILU (2020), the aim of the present report is to assess whether the VOC emissions from the toys can give rise to any health concerns for children.

Analytical data

The initial analytical screening study was divided into two parts:

Part 1: Identification of VOCs emitted from each of the 45 individual toys into plastic bags at room temperature.

The chemical analyses from part 1 were used to select 12 toys for part 2.

Part 2: Consisted of measurements of the concentration of VOCs in indoor air in a test flat for four groups of toys placed in a child bed. Measurements were conducted at bedside, in the bedroom and in the living room.

The 12 toys were divided into four groups based on the highest emitted VOCs in part 1:

A) TXIB – toy no. 1 and 39

B) Aromatic VOCs – toy no. 18, 20 and 32

C) Cyclohexanone – toy no. 2, 12, 14 and 42

D) Cyclic siloxanes – toy no. 15, 17 and 19

Screening and hazard assessment of most relevant VOCs for risk assessment

Exposure levels for children using the toys were calculated for the identified VOCs using the measurements of emission from each individual toy. VOCs with estimated exposure levels above 1 µg/m^3 were screened in relation to health hazard classification and tolerable exposure limits. Based on the magnitude of exposure and the health hazard profile (classification and magnitude of tolerable exposure of the substance), the most critical VOCs in relation to human health concern were identified.

For these substances further data were gathered and DNEL values for systemic effects as well as for local effects were derived, using the methodology as recommended by the Scientific Committee on Health, Environmental on Emerging Risks (SCHEER 2021) in their opinion regarding toxicological reference values for certain organic chemicals emitted from squishy toys.

The following critical VOCs and the derived DNEL values are given in the table below:

Table 2.1. Overview of derived DNEL values for systemic and local effects

Substance	DNELsystemic µg/m³ (critical effect)	DNELlocal µg/m³ (critical effect)
Aliphatic and alicyclic hydrocarbons (C8-C13)	4100 (chronic neurotoxicity)	10000 (mucous membrane irritation)
Ethyl benzene	1700 (ototoxicity)	3700 (mucous membrane irritation)
Xylenes	130 (neurotoxicity)	3000 (mucous membrane irritation)
Hexamethyl cyclotrisiloxane, (D3)	320 (liver effects)	3360 (histopathological effects, respiratory tract)
Octamethyl cyclotetrasiloxane, (D4)	13000 (uterus tumours, effects on liver and kidney)	1000 (lung inflammation)
Decamethyl cyclopentasiloxane, (D5)	4300 (liver effects)	5300 (effects on lungs and mucous membranes)
Cyclohexanone	716 (effects on liver and kidney)	10000 (mucous membrane irritation)

It should be noted that for further risk assessment only 10% of the systemic DNEL value was allocated to the toy exposure, as this approach was used by SCHEER (2021) in order to take account of other exposure sources than toys for the same substance. However, for the local DNEL values 100% of the value is allocated to the toy exposure as it is the actual concentration in air and not the systemic dose (i.e. inhaled amount) that is critical for the effect.

Risk assessment

In the risk assessment the estimated exposure is compared with the DNEL value for a substance and a Risk Characterisation Ratio (RCR) is obtained:

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

RCR values exceeding 1 mean that the exposure exceeds the tolerable DNEL value, which again means that the protection level is too low and there may be a risk. If exposure is below the DNEL value the RCR value will be below 1, which then indicates no safety concern.

If the exposure covers several substances of which some of the substances have the same critical effects (e.g., are toxic to the same target organ) an additive approach is assumed and will be used and the RCR values for the substances will be cumulated:

$$RCR_{total} = RCR\ (subst.1) + RCR\ (subst.2) + RCR\ (subst.3)$$

Result

Part 1: In the part 1 experiment RCR values above 1 were found for only one piece of toy (toy no. 17) indicating concern for human health, whereas generally low levels of exposure occurred from the other toys. For toy no. 17 the exposure to xylenes resulted in an RCR value of 4.6 indicating concern for neurotoxic effects from this substance. Further, the combined exposure to the liver toxic substances cyclohexanone + D3 + D4 + D5 resulted in a cumulated RCR value of 1.0 indicating concern also for liver toxicity.

I.e. the RCR for the emission from the other toys were all below 1, and therefore, did not represent a risk.

Part 2: The presence of toy no. 17 also affected the risk assessment of the room measurement. Here the bedside measurement of the group with high emissions of cyclic siloxanes, group D, resulted in the highest measurements of Total Volatile Organic Compounds (TVOCs). Further, it was only the emissions from group D that resulted in an RCR value above 1, with an RCR value of 1.2 for the emission level of xylenes and a cumulated RCR value of 1.2 for the liver toxic substances cyclohexanone + D3 + D4 + D5.

Conclusion

As indicated by the measurement performed by NILU (2020), hundreds of different volatile organic compounds were found to be emitted from a broad range of 45 different handheld toys.

Looking at the emitted levels of these compounds with a risk-based approach, the emitted levels represented in general rather low exposure levels without concern for the user.

However, one toy, toy no. 17, stands out and is considered to represent an unacceptable risk to the user. Unacceptable emissions of xylenes, cyclic siloxanes and cyclohexanone occurred from this toy resulting in an increased risk of neurotoxicity (effects on behaviour and central nervous system functioning) and liver toxicity (increased liver weight and signs of liver toxicity). Also, from the bedside measurements it can be concluded that primarily the emission from this toy constituted a risk.

It should be noted that the unaccepted risk levels obtained for xylene and cyclohexanone from toy no. 17 were obtained in relation to effects related to several months of exposure. Thus, the risk is in relation to repeated exposure during an extended period. If the exposure is mitigated by removing the toy, exposure during a shorter period (days to few weeks) is not considered to constitute a risk.

3 Introduction

During the last couple of years there has been a focus on VOCs emitted from soft/plastic toys, initiated in 2018 by the survey of VOCs in squishy toys by the Danish Environmental Protection Agency (Danish EPA, 2018).

In 2020 the Norwegian Environment Agency initiated a project on the evaporation of volatile organic compounds (VOCs) from toys. On behalf of the Norwegian Environment Agency the Norwegian Institute for Air Research (NILU) performed a screening study to identify VOCs emitted from a total of 45 different handheld toys for children.

The 45 different handheld toys were selected and purchased using the following criteria:

- Handheld (skin contact and in breathing zone)
- Price (low price = easy accessibility)
- Smell
- Material (foam, plastic, and slime)

This report is the health risk assessment of the analytical results performed by NILU, reported in the reference NILU 2020.

3.1 Aim

This report contains a summary of the relevant chemical analytical results (NILU 2020) and exposure scenarios regarding children's' exposure to substances while using the toys, which are used to perform a risk assessment of the chemical substances from the toys.

The aim of the present report is to assess which of the identified substances that give rise to most concern for children and to identify if the exposure can be considered to cause a risk to the children.

4 Analysis of toys

4.1 Aim

The Norwegian Institute for Air Research (NILU) conducted a screening study to identify volatile organic chemicals (VOCs) emitted from a total of 45 different handheld toys for children. The screening study was divided in two parts:

- Part 1: Identification of VOCs emitted from the individual toys at room temperature
- Part 2: Measurement of the composition and concentration of VOCs in indoor air

4.2 Method

4.2.1 Part 1 – Measurements of VOCs emitted from toys

In the first part of the study, the emission of the VOCs from the toys was measured by placing the toys, individually, in inert and airtight plastic ziplock bags together with a passive air sampler. The toys were taken out of their packages and placed directly in the ziplock bag.

The chemical measurements were conducted using passive air samplers (based on Tenax TA adsorption tubes) during 24 hours at room temperature, followed directly by chemical analysis with GC-MS. Results were obtained in toluene-equivalents.

4.2.2 Part 2 – Measurements of VOCs emitted from highly emitting toys to indoor air

The chemical analysis from part 1 were used to select 12 toys for measurements of VOC emissions to indoor air in a test apartment. The 12 toys were divided into four groups based on the highest emitted VOCs:

A) TXIB – toy nr. 1 and 39

B) Aromatic VOCs – toy nr. 18, 20 and 32

C) Cyclohexanone – toy nr. 2, 12, 14 and 42

D) Cyclic siloxanes – toy nr. 15, 17 and 19

The samplings of emissions from each group of toys were conducted in a furnished apartment (40 m^2) without any current residents. There were no personal care products, cleaning products or clothes in the apartment. The toys within one group were placed on a bed in a small bedroom (6 m^2). Sampling of VOCs was done at three locations in the apartment using passive air samplers based on Tenax TA air adsorption tubes. The samplers were placed next to the toys in the bed (in order to resemble the breathing zone of a child), in the other end of the bedroom and in the living room at the other side of the apartment. The adsorption tubes were analyzed using thermal desorption (TD) and gas chromatography coupled to mass spectrometer (GC-MS) in combination with

commercial and in-house databases for identification and quantification of the VOC content.

Setup:

- Small bedroom (6 m^2)
- Three locations in the apartment (40 m^2): bed, bedroom and living room
- 10 hours of sampling duration of the emissions
- Apartment aired for 24 hours before the next measurement

4.3 Results

The results of the measurement of the individual toys and the measurements in the apartment are given in tables in Appendix A (chemical analyses, part 1: measurements of VOCs emitted from toys) and B (chemicals analyses, part 2: measurements of VOCs emitted from highly emitting toys to indoor air). The data are further discussed in Chapter 5.

5 Presentation of exposure scenarios

The handheld toys purchased by the Norwegian Environment Agency were toys intended for children above the age of 3 years. Therefore, the exposure and risk assessment of the toys will be based on the youngest age group for the toys, i.e., a 3-year-old child, as children at this age group will have the highest exposure based on the generally higher inhalation rate per kg bodyweight compared to older children.

As the chemical analysis by NILU (2020) was focusing on emission of volatile organic chemicals (VOCs) and measurements in air, only exposure and risk assessment in relation to inhalation can be conducted.

This can be considered a limitation in relation to a full risk assessment where also oral exposure (sucking and biting of the toy) and dermal exposure are relevant exposure routes for consideration, as recommended by the Scientific Committee on Health, Environmental on Emerging Risks (SCHEER 2021).

Inclusion of these exposure routes would require further analytical chemical data regarding migration of the substances into sweat and saliva in order to quantify the exposure. Thus, it is not considered possible to estimate dermal and oral exposure levels based on the air measurements of the emitted VOCs alone.

5.1 Assessment of scenarios with individual toys

5.1.1 Target group and use scenario

As in the Danish EPA (2018) assessment of squishy toys, the scenario with the highest possible direct exposure from handheld toys is assessed to be a 3-year-old child, who sleeps while hugging the toy, and where the toy is very close to the child's nose and mouth.

Such a scenario has the highest possible exposure potential, partly for skin contact (migration to child's palms) and partly for inhalation of evaporated substances emitted from the toy.

A realistic worst-case scenario for a young child's exposure can be described using the relevant parameters agreed upon by SCHEER in their opinion on risk assessment of squishy toys (SCHEER 2021):

Body weight, child, 3-year-old, 14 kg: A weight of 14 kg was used for a 3-year-old child. In their guidance on consumer exposure, ECHA (2016) refers to RIVM (2014) that indicates a body weight of 12.4 kg for a 2-3-year-old child and 15.7 kg for a 3-6-year-old child based on the 25th percentile in the two age groups, which is why an average of these two age groups of 14 kg is applied for a 3-year-old child.

Inhalation volume during rest/sleep: An inhalation volume of 0.18 m^3 /hour was used. ECHA (2016) refers to RIVM (2014) that indicates an inhalation volume during rest of 0.12 m^3 air/hour for 1-3-year-old children and 0.24 m^3 air/hour for 4-6-year-old children, which is why an average of these two age groups of 0.18 m^3 air/hour is applied for a 3-year-old child.

5.1.2 Duration of exposure

An exposure of 10 hours/day was used. This is considered a pragmatic worst-case estimate for a sleeping child hugging the toy close to her/his body during sleep. Exposure is determined from single toy measurement.

In their opinion on risk assessment of squishy toys (2021), SCHEER considered the emission rate from toys located in the breathing zone as a determining factor for the risk assessment. Thus, as a worst-case scenario it was assumed that 100% of the emission at any specific emission rate would be inhaled by the child. Based on the DNEL of the substance, the corresponding tolerable emission rate per toy unit (E_u) could be calculated from the following equation:

$$E_u \left[\frac{\text{mg}}{\text{hr}}\right] \leq \frac{IEF \times DNEL \left[\frac{\text{mg}}{\text{m}^3}\right] \times \dot{V}_{\text{sleep}} \left[\frac{\text{m}^3}{\text{hr}}\right]}{N_u}$$

Where:

DNEL is the Derived no Effect Level for the specific substance (derived as a 24 h value)

IEF: Intermittent exposure factor. Used for DNEL (24h) values based on systemic effects to adjust for shorter duration of exposure (10h/ 24h= 2.4)

V_{sleep} is the inhalation rate of the child, and

N_u is the number of toys from which emission occurs.

Thus, for the NILU (2020) measurements of the individual toys, it is therefore relevant to examine whether the emission rates from the individual substances can be calculated.

In the NILU (2020) report, the emission of chemicals from the individual toys are given in µg/m^3. The measured concentrations were obtained after 24 hours of emission in a closed plastic-bag having an air volume of approximately 7.5 L. Thus, the emission rate for a specific chemical can be calculated by multiplying the air concentration (µg/m^3) and the air volume (m^3) divided by the emission duration:

E_u (µg/hr) = measured conc. (µg/m^3) x air volume (m^3) / 24hr

E_u (µg/hr) = measured conc. (µg/m^3) x 0.0075 m^3 / 24hr

E_u (µg/hr) = measured conc. (µg/m^3) x 0.00031 m^3/hr

Based on the calculated emission rate and with the assumption that 100% of the substance is emitted into the air inhaled by the child, the exposure concentration in the breathing air can be calculated according to equation given by SCHEER:

E_u (µg/hr) = Exposure conc. (mg/m^3) x V sleep (m^3/hr)/ N_u

Exposure conc. (mg/m^3) = E_u (µg/hr) / V sleep (m^3/hr) x N_u

Exposure conc.(mg/m^3) = (measured conc. (µg/m^3) x 0.00031 m^3/hr) / (0.18 m^3/hr) x 1

Exposure conc. (mg/m^3) = measured conc. (µg/m^3) x 0.0017

Thus, a “conversion factor” of 0.0017 can be used for converting the actual measurement results into *estimated maximum breathing air concentrations* of the child.

As the toys were taken directly out of the packaging material and placed in the emission bags, the estimated exposure thus represents the exposure during the first 24 hours after the toy was unpacked.

Exposure consideration regarding specific toys

Based on the overall measurements of the 45 different toys and analysis of these data, NILU considered the migration from 12 toys as the most significant.

In Table 5.1 below, an extract is given of the measurement results from these 12 toys where the measured values are transformed to inhalation concentrations (in toluene equivalents) using the above conversion factor of 0.0017.

Only findings resulting in an exposure level above 1 µg/m^3 (i.e. a measured level of 588 µg/m^3) are included in the table in order to screen out the substances with very low exposure. All findings are available in Appendix A.

A series of specific individual isomers of aliphatic and alicyclic hydrocarbons were measured and reported separately. As very few toxicological data are available on these specific substances, these measurements are summed up in an overall group of *“aliphatic and alicyclic hydrocarbons”* covering all isomers. In order to get a better overview of the exposure, the aromatic hydrocarbons other than toluene, ethylbenzene and xylenes are summarized as well.

Table 5.1. VOCs identified from the 12 selected toys, > 1 µg/m³ *(in toluene equivalents).
Substances in bold were used by NILU to group the toys into four different groups (A,B,C and D, see table 5.2) for further chemical analysis.

Substance	Measured level µg/m³	Maximum inhalation level µg/m³	Comment
Toy no. 1			
TXIB	1725	2.9	Highest measured level
Cyclohexanone	1022	1.7	
Aliphatic and alicyclic hydrocarbons (C9-C16)	9853	17	
Total identified VOCs	12600	21	
Toy no. 2			
Cyclohexanone	11857	20	
1-butanol	4719	8.0	
xylenes	2274	3.9	
Cyclohexanol, 3,5 dimethyl	2713	4.6	
Aliphatic and alicyclic Hydrocarbons (C8-C13)	70803	120	Highest measured level
Total identified VOCs	90092	148	
Toy no. 12			
Cyclohexanone	2263	3.8	
Ethanol, 2-butoxy	1330	2.3	
xylenes	1176	2.0	
Other C7-C14 aliphatic and aromatic hydrocarbons	830	1.4	
Total identified VOCs	6826	12	
Toy no. 14			
Cyclohexanone	4591	7.8	
Cyclohexanol	606	1.0	
D3 + D4	1054	1.8	
Toluene	1218	2.1	
Other C7-C10 aromatic hydrocarbons	2930	5.0	
Total identified VOCs	11493	20	
Toy no. 15			
Cyclohexanone	1271	2.2	
D4	2670	4.5	
D5	949	1.6	
Toluene	2666	4.5	Highest measured level
Xylenes	6329	11	
Ethylbenzene	1350	2.3	
Aliphatic and alicyclic hydrocarbons (C5-C13)	6148	10	
Total identified VOCs	26668	45	

Substance	Measured level µg/m³	Maximum inhalation level µg/m³	Comment
Toy no. 17			
Cyclohexanone	18589	32	Highest measured level
D3	36372	62	Highest measured level
D4	43901	75	Highest measured level
D5	10944	19	Highest measured level
Toluene	1937	3.3	
Xylenes	84000	143	Highest measured level
Ethylbenzene	22263	38	Highest measured
Aliphatic and alicyclic hydrocarbons (C8-C10)	43114	73	Highest measured level
Acetic acid, butyl ester	18156	31	Highest measured level
Sec-butyl acetate	1426	2.4	
Total identified VOCs	264758	450	
Toy no. 18			
Xylenes	11511	20	
Ethylbenzene	3233	5.5	
Aliphatic and alicyclic hydrocarbons (C9-C12)	1477	2.5	
Total identified VOCs	16779	29	
Toy no. 19			
Cyclohexanone	1446	2.5	
D3	854	1.5	
D4	4822	8.2	
D5	2590	4.4	
Ethyl acetate	958	1.6	
Total identified VOCs	11851	20	
Toy no. 20			
Cyclohexanone	1489	2.5	
Toluene	2143	3.6	
Xylenes	4134	7.0	
Ethylbenzene	607	1.0	
Aliphatic and alicyclic hydrocarbons (C5-C13)	1982	3.7	
Total identified VOCs	10806	18	
Toy no. 32			
Xylenes	4493	7.6	
Ethylbenzene	2648	4.5	
C9-C10 aromatic hydrocarbons	2890	4.9	
Total identified VOCs	11874	20	

Substance	Measured level µg/m³	Maximum inhalation level µg/m³	Comment
Toy no. 39			
TXIB	1026	1.7	
Total identified VOCs	1164	2.0	
Toy no. 42			
Cyclohexanone	1885	3.2	
Total identified VOCs	3309	5.6	

*Used as a low, pragmatic cut-off point for further prioritisation of the substances.

Based on data from the specific toys the following substances were measured at the highest levels:

D3, D4, D5 (highest maximum inhalation level of 62, 75 and 19 µg/m³, respectively) from toy no. 17)
cyclohexanone (highest maximum inhalation level of 32 µg/m³ from toy no. 17)
xylenes (highest maximum inhalation level of 143 µg/m³ from toy no. 17),
ethylbenzene (highest maximum inhalation level of 38 µg/m³ from toy no. 17),
butyl acetate (highest maximum inhalation level of 31 µg/m³ from toy no. 17), and
C8-C10 aliphatic and alicyclic hydrocarbons (highest maximum inhalation level of 120 µg/m³ from toy no. 2).

Even though the emission of *TXIB* was used by NILU (2020) to characterize the group of toys, the highest emitted level corresponding to a maximum inhalation of 2.9 µg/m³ from toy no. 1 can be considered as a very low level.

Also, it should be noted that levels of aldehydes and monoterpenes, known as skin sensitizing constituents in fragrances, were not emitted from any of these 12 toy products at inhalation levels ≥ 1 µg/m³.

5.2 Assessment of exposure scenarios of multiple toys

The assessment of exposure from multiple toys is much more simplistic, as the actual exposure concentrations were measured and reported for a combination of 2-4 toys (divided into four groups according to the chemicals emitted from the single toys measurements):

A) TXIB measurement for toy nr. 1 and 39

B) Aromatic VOCs measurements for toy nr. 18, 20 and 32

C) Cyclohexanone – toy nr. 2, 12, 14 and 42

D) Cyclic siloxanes – toy nr. 15, 17 and 19

Measurements were made at three sites in a furnished test apartment at NILU:

1. Bedside: Besides the toys in the bed, placed to represent toys in the breathing zone of a sleeping child
2. Bedroom: In the other end of the bedroom, to represent stay in the child´s room when awake
3. Living room: In the living room of the apartment, to represent exposure outside the bedroom.

Thus, the measurement can be used directly as exposure levels for the child.

It must be noted that the measurements in part 2 of the chemical analyses were conducted with the same toy items as used for the plastic-bag measurements. The toys were stored in in closed plastic bags in a period of three months between part 1 and part 2 of the chemical analyses, so the exposure levels in the apartment represent levels after the initial peak emission from the toys have levelled off.

When assessing these exposure levels for further risk assessment a stepwise approach will be used, so only if the bedside measurements with the highest exposure levels cause concern, further risk assessment will be made for the bedroom exposure and for the exposure in the living room.

Below in an overview of the data from the bedside measurements are given. The table includes a grading system of the exposure levels, which is used to assess the relevance of further evaluation. The exposure levels have been divided into the following three different intervals: "++": > 100 µg/m3; "+": 10-100 µg/m3; "-" : < 10 µg/m3.

Table 5.2. VOCs identified at the bedside from the 12 selected toys (findings at 1 µg/m^3 and above*

Substance	Conc. µg/m^3	Relevant for further evaluation**
Combination A: Toy no. 1 + 39 (TXIB)		
TXIB (2,2,4-Trimethyl-1,3-pentanediol diisobutyrate)	2.0	-
Monoterpenes: alpha pinene + beta pinene + 3-carene	5.9	- ***
Aldehydes: nonanal + decanal	4.2	- ***
Aromatic hydrocarbons: benzene+ toluene + ethylbenzene + xylenes	3.9	-
Total VOCs	16.7	-
Combination B: Toy no. 18 + 20 + 32 (aromatic group)		
Acetic acid	5.6	- ***
Monoterpenes: alfa-pinene + 3-carene	2.1	- ***
Aldehydes: hexanal, nonanal, benzaldehyde	2.9	- ***
Aromatic hydrocarbons: Benzene + toluene	0.8	-
Total VOC	12.3	-
Combination C: Toy no. 2 + 12 + 14 + 42 (cyclohexane group)		
Cyclohexanone	97.8	+
Aliphatic and alicyclic hydrocarbons (C10-C13)	230	++
Butanol	13.7	+
Butanoic acid butyl ester	5.1	- ***
2-tert-Butyl-3,4,5,6-tetrahydropyridine	9.6	- ***

Substance	Conc. µg/m^3	Relevant for further evaluation**
(4aS,7S,7aR)-4,7-Dimethyl-5,6,7,7a-tetrahydrocyclopenta[c]pyran-1(4aH)-one	6.9	- ***
Total VOCs	369.2	
Combination D: Toy no. 15 + 17 + 19 (siloxane group)		
Cyclotrisiloxane, hexamethyl- (D3)	67.5	+
Cyclotetrasiloxane, octamethyl- (D4)	271.7	++
Cyclopentasiloxane, decamethyl- (D5)	71.0	+
Cyclohexasiloxane, dodecamethyl-	7.3	- ***
Cyclohexanone	24.7	+
Pentasiloxane dodecamethyl	4.8	- ***
Xylenes	37.9	+
Aliphatic and alicyclic hydrocarbons (C8-C20)	137	++
Pentane	7.5	- ***
Isopulegol	6.3	- ***
Total VOCs	677.1	

*used as a low, pragmatic cut-off point for further prioritisation of the substances.

** Quantitative grading of exposure level within three groups:
++: > 100 µg/m3; +: 10-100 µg/m3 - : < 10 µg/m3

*** not identified in part 1

As can be seen from the table, the measured concentrations in relation to the emissions from toy combination A and B resulted in rather low TVOC concentrations of (16.7 µg/m$^{3)}$ and (12 µg/m$^{3)}$, respectively, compared to the TVOC levels in relation to combination C (369 µg/m^3) and D (677 µg/m^3). In general, levels identified to be relevant for further assessment were found for the following substances in group C and D:

Group C: The most significant exposure levels were found for **cyclohexanone** (97.8 µg/m^3) and **C10-C13 aliphatic and alicyclic hydrocarbons** (230 µg/m^3) - found in a relevant level (137 µg/m^3) in group D.

Group D: The most significant exposure levels were found for the **cyclic siloxanes D3, D4, D5** (67.5 µg/m^3; 271.7 µg/m^3 and 71.0 µg/m^3, respectively) and further for **cyclohexanone** (24.7 µg/m^3)**, xylenes** (37.9 µg/m^3) **and C8-C20 aliphatic and alicyclic hydrocarbons** (137 µg/m^3)**.**

Although aldehydes and monoterpenes, known as skin sensitizing constituents in fragrances, were not emitted from any of the 12 toy products at inhalation levels ≥ 1 µg/m^3 (see section 5.1) these substances (and closely related substances) were found in the group measurements, however, at rather low levels:

Group A: monoterpenes (5.9 µg/m^3); aldehydes (4.2 µg/m^3)

Group B: monoterpenes (2.1 µg/m^3); aldehydes (2.9 µg/m^3)

Group C: no findings

Group D: Isopulegol (6.3 µg/m^3)

Further, when comparing the bedside levels of these substances to the bedroom levels and living room levels no decline in the levels were seen with increasing distance from the toys. This may indicate that the emission of these substances may come from other sources in the apartment than the toys.

6 Hazard assessment

6.1 Screening: Hazard assessment of prioritized substances.

A hazard screening of the measured substances was performed based on the reported substances from the individual toy measurements and the measurements from combined room exposure as reported by NILU (2020).

Data on these substances in relation to classification, the measured levels and tolerable exposure levels were searched and are given in the overview table in Appendix C for a total of 26 specific substances.

In the table in Appendix C, the most relevant among the 26 substances for further risk assessment were identified. This was done by combining the information of the hazard (classification and tolerable exposure levels) with the information of the measured exposure levels:

- Substances only identified in part 2 (apartment measurements) of the chemical analysis were not prioritized, since the source of their origin is questionable and might not be linked to the toys: pentane; cis,trans-1,6-Dimethyl-spiro[4.5]decane; α-pinene; 3-carene; octanal; decanal and benzaldehyde,
- Substances identified in a concentration measured to be below a factor 100 compared to the lowest identified DNEL and not included in a group, were not prioritized: toluene, 1-butanol, sec-butyl acetate, TXIB, hexanal, nonanal and acetic acid.

In Appendix C, the substances selected for further risk assessment are marked with a green colour and are further compiled in Table 6.1 below.

It should be noted that in the table below, all the specific aliphatic and alicyclic hydrocarbons from Appendix C are included in one group of aliphatic and alicyclic hydrocarbons as toxicological data on the individual substances are lacking. A group-based assessment is therefore considered more suitable for these substances. Also, the different isomers of xylene indicated in Appendix C are grouped into one group covering all three isomers.

Table 6.1. Screening DNEL values and critical effects for prioritized substances.

Substance (CAS no.)	Harmonised health hazard classification	DNEL, critical effect	DNEL, inhalation Screening level (source)	Estimated inh. conc. µg/m³ (product no.)	Highest conc. in apartment, µg/m³
Aliphatic and alicyclic hydrocarbons					
Aliphatic and alicyclic hydrocarbons (C7-C13)	White spirit: Asp. Tox. 1 (H304) STOT RE1 (H372 - central nervous system)	Not indicated	6000 µg/m³ (EU-LCI 2020) Saturated cyclic and aliphatic hydrocarbons (C9-C16)	116 (2)	Breathing zone 221
		Chronic neurotoxicity	1425 mg/m³ (Danish EPA 2016)		

Substance (CAS no.)	Harmonised health hazard classification	DNEL, critical effect	DNEL, inhalation Screening level (source)	Estimated inh. conc. µg/m³ (product no.)	Highest conc. in apartment, µg/m³
			C7-C12 hydrocarbons		
Aromatic hydrocarbons					
Ethylbenzene (100-41-4)	Acute Tox. 4 (H332) Asp. Tox. 1 (H304) STOT RE 2 (H373 – hearing organs)	Ototoxicity	850 µg/m³ (EU-LCI 2020)	0.01 – 37.85 (39, 17)	Breathing zone 1.4
		Neurotoxicity and liver effects (Danish EPA 2018)			
		Neurotoxicity	200 µg/m³ - children (Danish EPA 2016)		
Xylenes sum of all isomers (95-47-6) (106-42-3)	Acute Tox. 4 (H312, H332) Skin Irrit. 2 (H315)	Neurotoxicity, respiratory toxicity, eye irritation and developmental toxicity	500 µg/m³ (EU-LCI 2020)	0.09-143 (12**, 17)**	Breathing zone 18.1 Bedroom 4.2
		Neurotoxicity	130 µg/m³ (SCHEER 2021)		
Cyclic siloxanes					
Cyclotrisiloxane, hexamethyl- (D3) (541-05-9)	Not harmonised	Liver effects	0.32 mg/m³ (Danish EPA, 2021)	0.03 – 61.83 (42, 17)	Breathing zone 68 Bedroom 14 Living room 5
Cyclotetra-siloxane, octamethyl- (D4) (556-67-2)	Repr. 2 (H361f)	Unspecified/ Ascribed EU-LCI	1 200 µg/m³ (EU-LCI 2020)	0.01 – 74.6 (39, 17)	Breathing zone 272 Bedroom 73 Living room 37
		Lung effects	1000 µg/m³ (Danish EPA, 2021)		
Cyclopen-tasiloxane, decamethyl (D5) (541-02-6)	Not harmonised	Uterus tumors	4300 µg/m³ (Danish EPA, 2021)	0.01 – 18.61 (39, 17)	Breathing zone 71 Bedroom 15
		Lung effects, liver effects	5400 µg/m³		

Substance (CAS no.)	Harmonised health hazard classification	DNEL, critical effect	DNEL, inhalation Screening level (source)	Estimated inh. conc. µg/m³ (product no.)	Highest conc. in apartment, µg/m³
			(Danish EPA, 2021)		Living room 8.8
Ketones					
Cyclo-hexanone (108-94-1)	Acute Tox. 4 (H332)	Unspecified/ Ascribed EU-LCI (most likely eye and respiratory tract irritation)	410 µg/m³ (EU-LCI 2020)	0.08 – 31.60 (39, 17)	Breathing zone 25-98 Bedroom 6.3-35 Living room 4.3-35
		Liver/kidney degeneration	DNEL: 716 µg/m3 (SCHEER, 2021)		

The argumentation in Appendix C for the prioritization of the substances are:

Aliphatic and alicyclic hydrocarbons C7-C13

Rather low exposure values were detected for the individual substances in this group. The highest level of 26 µg/m³ at bedside was found for 1,1-dimethyl-xyclohexane and decahydro-2,3-dimethyl naphthalene. However, when adding the contribution of additional 22 aliphatic and alicyclic hydrocarbons the exposure level reached 221 µg/ m³ on the bedside. This is considered sufficiently close to the lowest DNEL-screening level of 1425 µg/m³ and therefore to be prioritised for further evaluation.

Ethylbenzene

The highest level of 38 µg/m³ was measured for ethyl benzene in relation to toy no. 17. This exposure level is considered sufficiently close to the lowest DNEL-screening level of 200 µg/m³ to be prioritised for further evaluation.

Xylenes

When adding the contribution from the three isomers of xylene, the highest level of 143 µg/m³ was measured in relation to toy no. 17. Thus, toy 17 is prioritised for further evaluation as this exposure level exceeds the lowest DNEL-screening level of 125 µg/m³.

Cyclic siloxanes, D3, D4 and D5

For the cyclic siloxanes D3, D4 and D5, concentration levels up to 68 µg/m³, 272 µg/m³, and 71 µg/m³ respectively were measured in the breathing zone at bedside. As a similar mode of action may be expected from these substances, the total level of these substances is considered sufficiently close to the DNEL-screening levels of these substances to be prioritised for further evaluation

Cyclohexanone

The highest level of 98 µg/m^3 was measured for cyclohexanone in the breathing zone at bedside. This exposure level is considered sufficiently close to the screening DNEL-levels of 410 µg/m^3 and 2500 µg/m^3 to be prioritised for further evaluation.

Substances that were not prioritised for further assessment

Among the aromatic hydrocarbons detected, very low levels of toluene (up to 4.5 µg/m^3) and of other C9-C10 aromatics (up to 4.7 µg/m^3) were found not to be sufficient for prioritisation.

Although **TXIB** was used by NILU (2020) to characterise the emission from the toys, this substance is not prioritized further, as the highest estimated exposure level of 2.9 µg/m^3 is far below the screening DNEL value of 1300 µg/m^3.

Also, **terpenes** and **aldehydes**, which may occur as fragrances in consumer products, are not prioritised because of the very low exposure levels (in the range of 1-10 µg/m^3 measured in the flat) compared to DNEL screening levels of 900-2500 µg/m^3. Similar conclusions are drawn for **organic acids** and **esters**.

For the substances identified in Table 6.1 a detailed hazard characterisation will be presented in section 6.2 below and use of the most relevant DNEL value for the risk assessment will be discussed, based on further literature search.

6.2 Hazard characterisation and DNEL derivation for the prioritized substances

For the substances prioritized for further hazard and risk assessment (Table 6.1), toxicological data were collected and DNEL values for systemic as well as for local effects were derived, see table 6.2. The derivation of the DNEL levels was made in accordance to the methodology used by SCHEER (2021) that derived DNEL levels for 8 specific substances (including cyclohexanone and xylene). The specific assessments and the derivation of DNEL values are presented in Appendix D.

Table 6.2. Overview of derived DNEL values for systemic and local effects (see Appendix D)

Substance	DNELsystemic µg/m^3 (critical effect)	DNELlocal µg/m^3 (critical effect)	Odour threshold µg/m^3
Aliphatic and alicyclic hydrocarbons (C8-C13)	**4100** (chronic neurotoxicity)	**10 000** (mucous membrane irritation)	500-5000
Ethyl benzene	**1700 (ototoxicity)**	**3700** (mucous membrane irritation)	670
Xylenes	**130** (neurotoxicity)	**3000** (mucous membrane irritation)	160 – 1500
Hexamethyl cyclotrisiloxane (D3)	**320** (liver effects)	**3360**	ND

Substance	DNELsystemic µg/m^3 (critical effect)	DNELlocal µg/m^3 (critical effect)	Odour threshold µg/m^3
		(histopathological effects, respiratory tract)	
Octamethyl cyclotetrasiloxane (D4)	**13 000** (uterus tumours, effects on liver and kidney)	**1000** (lung inflammation)	ND
Decamethyl cyclopentasiloxane (D5)	**4300** (liver effects)	**5300** (effects on lungs and mucous membranes)	ND
Cyclohexanone	**716** (effects on liver and kidney)	**10 000** (mucous membrane irritation)	3500
ND: no data found			

Risk assessment will be conducted for all prioritized substances. Further, substances with effects on same target organ will be grouped and a risk assessment will be performed. The grouping approach is made only from the critical effects on the same target organ and not on a specific mode of action.

The grouping approach will sum up the calculated RCR values for the individual substance in each of the following groups :

- Substances resulting in neurotoxicity: Aliphatic and alicyclic hydrocarbons (C8-C13), Xylenes
- Substances resulting in liver effects: Hexamethyl cyclotrisiloxane, (D3), Octamethyl cyclotetrasiloxane, (D4), Decamethyl cyclopentasiloxane, (D5), Cyclohexanone
- Substances resulting in kidney effects: Octamethyl cyclotetrasiloxane, (D4), Cyclohexanone
- Substances resulting in mucous membrane irritation of the eyes and/or the upper respiratory tract: Aliphatic and alicyclic hydrocarbons (C8-C13), Ethyl benzene, Xylenes, Hexamethyl cyclotrisiloxane, (D3) Decamethyl cyclopentasiloxane, (D5), Cyclohexanone

7 Risk assessment

7.1 Principles of the risk assessment

When performing risk assessment of the handheld toys, the principles given by SCHEER (2021) have been followed.

This means that an emission from the toys equalling an exposure up to 10% of the DNEL value for systemic effects is tolerated as acceptable, as other types of exposure may contribute to the daily exposure of the child. Also, the systemic DNEL value determined as a 24-hour-value should be recalculated to the actual exposure period of the child by multiplication with the IEF (Intermittent exposure factor). For 10 hours of exposure the IEF = 10h/24h= 2.4.

Thus, in the case of a 10-hour exposure period the systemic DNEL levels derived in Chapter 6 should be adjusted by a factor of 0.1 x 2.4 = 0.24

DNEL values of local effects are not adjusted, as it is not the daily inhaled amount of the substance that is considered related to the adverse effect but the actual concentration in the air.

In table 7.1 below, the DNEL values used for the risk assessment of 10 hours of exposure is indicated, as the DNEL levels for systemic effects in table 6.2 have been adjusted by a factor of 0.24.

Table 7.1 DNEL levels (10h values) to be used in the risk assessment

Substance	DNELsystemic µg/m^3 (critical effect)	DNELlocal µg/m^3 (critical effect)	Odour threshold µg/m^3
Aliphatic and alicyclic hydrocarbons (C8-C13)	**984** (chronic neurotoxicity)	**10 000** (mucous membrane irritation)	500-5000
Ethyl benzene	**408 (ototoxicity)**	**3700** (mucous membrane irritation)	670
Xylenes	**31** (neurotoxicity)	**3000** (mucous membrane irritation)	160 - 1500
Hexamethyl cyclotrisiloxane, (D3)	**77** (liver effects)	**3360** (histopathological effects, respiratory tract)	ND
Octamethyl cyclotetrasiloxane, (D4)	**3120** (uterus tumors, effects on liver and kidneys)	**1000** (lung inflammation)	ND
Decamethyl cyclopentasiloxane, (D5)	**1032** (liver effects)	**5300** (effects on lungs and mucous membranes)	ND
Cyclohexanone	**172** (effects on liver and kidneys)	**10 000** (mucous membrane irritation)	3500

In the further risk assessment, the estimated exposure will be compared with the DNEL value for a substance and a Risk Characterisation Ratio (RCR) will be derived:

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

RCR values exceeding 1 mean that the exposure exceeds the tolerable DNEL value, which again means that the protection level is too low and that there may be a risk. If exposure is below the DNEL value the RCR value will be below 1, which then indicates no safety concern.

If the exposure comes from several substance of which some of the substances have the same critical effects (e.g., are toxic to the same target organ), an additive approach will be used and the RCR_{total} values for the substances will be cumulated:

$$RCR_{total} = RCR\ (subst.1) + RCR\ (subst.2) + RCR\ (subst.3)$$

Thus, for the substances in table 7.1 the RCR_{total} values will be calculated in the following way:

Substances with effect on the liver:

$RCR_{total\ (liver)}$ = RCR(D3) + RCR(D4) + RCR (D5) + RCR (cyclohexanone)

Substances with effect on the kidneys:

$RCR_{total\ (kidneys)}$ = RCR(D4) + RCR (cyclohexanone)

Substances with effect on the nervous system:

$RCR_{total(\ neurotox.)}$ = RCR (C8-C13 alif. hydrocarbons) + RCR (xylenes)

Substances causing mucous membrane irritation:

$RCR_{total\ (mucous\ mem.\ irr.)}$ = RCR (C8-C13 alif. hydrocarbons) + RCR (xylenes) + RCR (ethylbenzene) + RCR (D3) + RCR (D5) + RCR (cyclohexanone)

7.2 Risk assessment of exposure from individual toys – plastic bag measurements

Toys no. 2 and 17 were identified as the products emitting the highest levels of the prioritized substances in table 7.1 and are therefore considered to be the products with the highest risk potential.

7.2.1 Toy no. 2

Below in table 7.2 the RCR values are calculated for systemic and local effects for exposure to the individual substances. Furthermore, RCR_{total} values are calculated for the combined exposure to substances with similar effects.

Table 7.2. Risk assessment and RCR calculation for toy no. 1

	Substance	Maximum inhalation level µg/m³	DNEL systemic	DNEL local	RCR systemic	RCR local
1	Cyclohexanone	20	172	10000	**0.12**	**0.002**
2	xylenes	3.9	31	3000	**0.03**	**0.001**
3	Aliphatic and alicyclic Hydrocarbons (C8-C13)	120	984	10000	**0.12**	**0.012**
	Total identified VOC	148	-	-	**-**	**-**
RCR_{total} *= (cumulated RCRs for various critical effects)*						
$RCR_{total(neurotox)}$ = RCR(2)+RCR(3)					**0.15**	
$RCR_{total(mucous\ membr.\ irritation)}$ = RCR(1)+RCR(2)+RCR(3)						**0.015**

As can be seen from the RCR values the product is of no toxicological concern for neither systemic nor local effect as all RCR values are far below 1.

7.2.2 Toy no. 17

Below in table 7.3 the RCR values are calculated for systemic and local effects for exposure to the individual substances. Furthermore, total RCR values are calculated for the combined exposure to substances with similar effects

Table 7.3. Risk assessment and RCR calculation for toy no. 17

	Substance	Maximum inhalation level µg/m³	DNEL systemic	DNEL local	RCR systemic	RCR local
1	Cyclohexanone	32	172	10000	**0.19**	**0.003**
2	D3	62	77	3360	**0.81**	**0.02**
3	D4	75	3120	1000	**0.02**	**0.08**
4	D5	19	1032	5300	**0.02**	**0.004**
5	Xylenes	143	31	3000	**4.6**	**0.05**
6	Ethylbenzene	38	408	3700	**0.09**	**0.01**
7	Aliphatic and alicyclic hydrocarbons (C8-C10)	73	984	10000	**0.07**	**0.007**
	Total identified VOC	450	-	-	**-**	**-**
RCR_{total} *= (cumulated RCRs for various critical effects)*						
$RCR_{total(neurotox)}$ = RCR(5)+RCR(7)					**4.7**	
$RCR_{total(liver)}$ = RCR(1)+RCR(2)+RCR(3)+RCR(4)					**1.0**	
$RCR_{total(kidney)}$ = RCR(1)+RCR(3)					**0.21**	
$RCR_{total(mucous\ mem.\ irr.)}$ = RCR(1)+RCR(2)+RCR(4)+RCR(5)+RCR(6) +RCR(7)						**0.09**

Based on the low RCR values for local effects no concern for local effects from the emission is found.

However, the RCR value of 4.6 for xylene indicates concern for neurotoxic effects. For D3 an RCR value of 0.81 was calculated indicating a narrow gap before concern in relation to liver toxicity arise.

When calculating RCR_{total} values for neurotoxicity a value of 4.7 is obtained (a further contribution from C7-C17 aliphatic hydrocarbons). A total RCR value of 1.0 is obtained for liver toxicity, indicating an overall concern for liver toxicity by inhalation of the combined exposure.

7.3 Risk assessment of exposure from multiple toys – bedside measurements

Emissions from the toy combinations C and D were found to reach the highest exposure levels at bedside, while the exposure levels from toy combinations A and B were so low they can be considered as negligible.

7.3.1 Risk assessment of bedside exposure, combination C

Below in table 7.4 the RCR values are calculated for systemic and local effects for exposure to the individual substances. Furthermore, RCR_{total} values are calculated for the combined exposure to substances with similar effects.

Table 7.4. Risk assessment and RCR calculation for bedside measurement for toy combination C, cyclohexane group (toy 2 + 12 + 14 + 42)

	Substance	Measured bedside level µg/m³	DNEL systemic	DNEL local	RCR systemic	RCR local
1	Cyclohexanone	97.8	172	10 000	**0.57**	**0.01**
2	Aliphatic and alicyclic hydrocarbons (C10-C13)	230	984	10000	**0.23**	**0.02**
	Total identified VOC	369	-	-	**-**	**-**
RCR$_{total}$ *= (cumulated RCRs for various critical effects)*						
$RCR_{total(mucous\ mem.\ irr.)}$= RCR(1)+RCR(2)						**0.03**

As can be seen a relatively high RCR value was calculated for cyclohexanone, although, below the value of 1.

Overall, no risk can be identified for neither systemic nor local effects.

7.3.2 Risk assessment of bedside exposure, combination D

Below in table 7.5 the RCR values are calculated for systemic and local effects for exposure to the individual substances. Furthermore, total RCR values are calculated for the combined exposure to substances with similar effects.

Table 7.5. Risk assessment and RCR calculation for bedside measurement for toy combination D, siloxane group (toy 15 + 17 + 19)

	Substance	Measured bedside level µg/m³	DNEL systemic	DNEL local	RCR systemic	RCR local
1	D3	67.5	77	3360	**0.88**	**0.02**
2	D4	271.7	3120	1000	**0.09**	**0.27**
3	D5	71.0	1032	1000	**0.07**	**0.07**
4	Cyclohexanone	24.7	172	10000	**0.14**	**0.002**
5	Xylenes	37.9	31	3000	**1.2**	**0.01**
6	Aliphatic and alicyclic hydrocarbons (C8-C20)	137	984	10000	**0.14**	**0.01**
	Total identified VOC	677	-	-	**-**	**-**
RCR$_{total}$ *= (cumulated RCRs for various critical effects)*						
$RCR_{total(neurotox)}$ =RCR(5)+RCR(6)					**1.3**	
$RCR_{total(liver)}$ = RCR(1)+RCR(2)+RCR(3)+RCR(4)					**1.2**	
$RCR_{total(kidneys)}$ = RCR(2)+RCR(4)					**0.25**	
$RCR_{total(mucous\ mem.\ irr.)}$ = RCR(1)+RCR(3)+RCR(4)+RCR(5)+RCR(6)						**0.11**

Based on the low RCR values for local effects, there is concern for local effects from the emission.

However, the RCR value of 1.2 for xylene indicates concern for neurotoxic effects. For D3 an RCR value of 0.88 was calculated indicating a narrow gap before concern in relation to liver toxicity arise.

When calculating total RCR values for neurotoxicity a value of 1.3 is obtained (a further contribution comes from C7-C17 aliphatic hydrocarbons). A total RCR value of 1.2 is obtained for liver toxicity which indicates an overall concern for liver toxicity by inhalation of the combined exposure.

It is evident from the single toy measurements in table 5.2. that toy no. 17 can be considered the driver of the risk in the combined scenario where toy 15 and toy 19 were included together with toy 17. Both toy 15 and toy 19 resulted in far lower emissions of xylenes, D3, D4, D5 and cyclohexanone than toy 17.

7.3.3 Risk assessment of measurements from bedroom and living room measurements

The main drivers of concern from the bedside measurements are the levels of xylene and D3.

Whereas the exposure level of xylenes at the bedside measurement was 37.9 µg/m^3, the exposure level of xylenes did not reach a level of concern for the bedroom measurement* and the living room measurement*, as xylene levels here were measured to 8.6 µg/m^3 and 2.9 µg/m^3, respectively. This would lead to RCR values of 0.28 and 0.09, respectively, indicating no concern.

Also, D3 was measured to 67.5 µg/m^3 at the bedside but did not reach a level of concern in relation to the bedroom measurement* and the living room measurement* as D3 levels here were measured to 14.1 µg/m^3 and 5.0 µg/m^3, respectively. This would lead to RCR values of 0.18 and 0.06, respectively, indicating no concern.

If it is assumed that the exposure occurs during 24 hours in the bedroom, the RCR values for systemic effects that were calculated based on 10 hours exposure should be multiplied with a factor of 24 h/10h = 2.4. This would then lead to an RCR value of 0.67 for the level of xylenes and an RCR value of 0.43 for the level of D3.

Also, the levels of the other substances in table 7.5 decreased when bedside levels were compared to bedroom levels* and living room levels*.

Overall, no concern regarding bedroom measurements and living room measurement could be identified.

(*the specific data from bedroom and living room measurements are not included here but obtained from the raw data).

7.4 Limitations and uncertainties

Below limitations and uncertainties will be discussed for the following elements in the risk assessment:

- Methodology for the risk assessment
- DNEL derivation of the substances
- Measurements reflecting the exposure levels

Methodology for the risk assessment

The same methodology for the risk assessment of inhalational exposure has been used as the methodology for handheld toys described by SCHEER (2021) in their risk assessment of squishy toys. Further, SCHEER (2021) also considers dermal exposure as well as oral exposure as relevant for the risk assessment. However, it was not possible to include additional exposure from these exposure routes in our risk assessment, as no measurement data were available for migration of the substances from the toys into sweat and/or saliva. As these exposure routes have not been included, the overall risk from the toys have been underestimated to some unknown extent.

As SCHEER (2021) indicates, the inhalational risk assessment should both include assessment of systemic effects as well as local effects. In the risk assessment of systemic effects SCHEER (2021) allocates 10% of the DNEL value to the exposure from the toys as SCHEER (2021) by this approach also accounts for other exposure sources of the chemicals.

This allocation is considered crucial for the risks identified in this project as risks were only identified for systemic effects and not for local effects (for which 100% of the DNEL value was used for risk assessment). If a 100% allocation had been used for systemic effects also (as was done in the Danish EPA project on squishies (Danish EPA 2018)), no risk would have been identified for any of the toys or for the bed side measurement. However, it is considered relevant in the risk assessment to account for additional exposure to the substance from other sources and exposure to similar acting substances and from mixed exposure during a day by using the approach with e.g., a 10% allocation of the systemic DNEL value.

DNEL derivation

Specifically for xylenes and cyclohexanone we used the DNEL values as derived by SCHEER (2021). It should be noted that xylenes are subject to substance evaluation under REACH and that updated DNEL values for xylenes is proposed. For the other substances DNEL values were derived according to the methodology described in the ECHA (2012) guideline, describing DNEL derivation in the context of REACH in combination with the method used by SCHEER (2021) (that considered systemic DNEL values based on 90-day studies without use of a subchronic to chronic duration factor as sufficiently conservative for the limited exposure duration from the toys).

Thus, limited uncertainty applies to the DNEL values used in this report.

Measurement reflecting exposure levels

In this report the results from NILU measurements were used as exposure levels. This is considered a valid approach, especially for the bedside and the bedroom and living room measurement as these values can be considered as real exposure levels for the inhaled air.

For the plastic bag measurements of the individual toys, we converted the measured concentration levels after 24 hours in the plastic bag into a total emission rate from the toy over 24 hours. It was then assumed - according to the methodology by SCHEER (2021), that the emitted substances to an extent of 100% was inhaled by the child, i.e., no dilution into the air in the near surroundings was anticipated. This is to be considered as a very conservative approach that can overestimate the risk.

As used by the Danish EPA (2018) and SCHEER (2021) a daily exposure duration of 10 hours was used in the risk assessment for the child, corresponding to 10 hours stay in bed with the toy. A more extreme scenario of 24 hours could be used as well for a child having a new toy – and in such a case the calculated RCR values would be a factor 2.4 higher than calculated in this report. However, based on the current measurements this would not have resulted in identification of additional toys being at risk, but the risk for toy no. 17 would then have been further substantiated.

Also, the plastic bag measurements only reflected the emission over the first 24 hours after unpacking the toys. Therefore, the risk assessment does not consider the declining emission rate over time, which again will overestimate the risk.

7.5 Conclusion of the risk assessment

As indicated by the measurement performed by NILU (2020) hundreds of different volatile organic compounds were found to be emitted from a broad range of 45 different handheld toys.

Looking at the emitted compound levels with a risk-based approach the emitted levels represented rather low exposure levels without concern for the user.

However, one toy, toy no. 17, stands out and is considered to represent an unacceptable risk to the user. Unacceptable emissions of xylenes, cyclic siloxanes and cyclohexanone occurred from this toy resulting in an increased risk of neurotoxicity (effects on behaviour and central nervous system functioning) and liver toxicity (increased liver weight and signs of liver toxicity). Also, from the bedside measurements it can be concluded that primarily the emission from this toy constituted a risk.

It should be noted that the unaccepted risk levels obtained for xylene and cyclohexanone from toy no. 17 were obtained in relation to effects related to several months of exposure. Thus, the risk is in relation to repeated exposure during an extended period. If the exposure is mitigated by removing the toy, exposure during a shorter period (days to few weeks) is not considered to constitute a risk.

8 Recommendation for future projects

The following recommendations may be considered for future projects

- It is important to define the most relevant exposure scenarios for the toy and design the analytical chemical measurements to reflect this, to gain analytical results that can be used directly in the risk assessment. This may be achieved by cooperation between the toxicologist and the chemical analyst of the analytical test design.
- For a more detailed risk assessment it would be necessary to follow the emission and exposure level over time (e.g., up to several weeks) to obtain a better knowledge of exposure and variation over time
- For a more complete risk assessment it would be necessary to include migration testing of substances from the toy into artificial sweat/saliva to include contributions from dermal and oral exposure in the risk assessment as well.

9 List of abbreviations

E_u	corresponding tolerable emission rate per toy unit
D3	Hexamethyl cyclotrisiloxane
D4	Octamethyl cyclotetrasiloxane
D5	Decamethyl cyclopentasiloxane
DNEL	the Derived no Effect Level
GC-MS	Gas Chromatography coupled to Mass Spectrometer
IEF	Intermittent Exposure Factor
LCI	Lowest Concentration of Interest
NILU	the Norwegian Institute for Air Research
N_u	the number of toys from which emission occurs
OEL	Occupational Exposure Level
RCR	Risk Characterisation Ratio
SCHEER	Scientific Committee on Health, Environmental on Emerging Risks
TD	Thermal Desorption
TVOCs	Total Volatile Organic Compounds
TXIB	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate
VOCs	Volatile Organic Chemicals
V_{sleep}	the inhalation rate of the child

10 References

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Appendix A

Summary of chemical analyses, Part 1. Including results from the 12 selected products.

In the tables below many non-aromatic hydrocarbons (i.e. aliphatic and alicyclic hydrocarbons) are specifically identified (marked with * in the tables). As few toxicological data are available on these specific substances they are treated as one group, and the concentrations of the substances are added together and presented below the tables. A factor of 0.0017 was used to convert the measured levels to an estimated maximum breathing air concentrations of the child, see chapter 5.2 for further explanation.

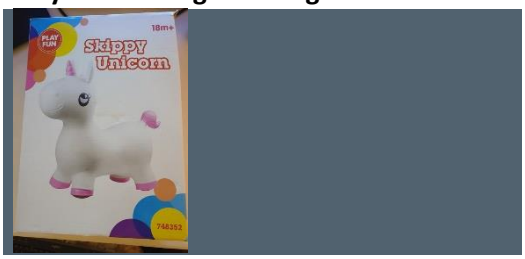
Also, the sum of aromatic hydrocarbons other than toluene, ethylbenzene, xylenes are grouped (marked with **).

Toy no. 1. Weight 98 g

Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (TXIB)	6846-50-0	1725	2,93
*2,6-dimethylnonane	17302-28-2	177	1,74
*2-methyldecane	6975-98-0	288	1,54
*2-methylnonane	871-83-0	188	1,15
*3,3,4-trimethyldecane	49622-18-6	226	1,11
*3-methyldecane	13151-34-3	318	0,91
*3-methylnonane	5911-04-6	298	0,86
*4-methyldecane	2847-72-5	271	0,78
*4-methylnonane	17301-94-9	209	0,68
*5-methyldecane	13151-35-4	352	0,67
*cis, cis-3-Ethylbicyclo[4.4.0]decane	66660-42-2	289	0,60
*Cyclohexane, (2-methylpropyl)-	1678-98-4	202	0,60
*Cyclohexane, 1-methyl-3-propyl-	4291-80-9	315	0,54
cyclohexanone	108-94-1	1022	0,54
*decane	124-18-5	392	0,54
*Decane, 3,7-dimethyl-	17312-54-8	260	0,51
*Decane, 3,8-dimethyl-	17312-55-9	212	0,51
*Dodecane	112-40-3	460	0,49
*Naphthalene, decahydro-	91-17-8	654	0,49
*Naphthalene, decahydro-2,3-dimethyl-	1008-80-6	298	0,46
*Naphthalene, decahydro-2,6-dimethyl-	1618-22-0	507	0,44
*Naphthalene, decahydro-2-methyl-	2958-76-1	355	0,44
*trans, cis-3-Ethylbicyclo[4.4.0]decane	66660-43-3	253	0,43
*trans-Decalin, 2-methyl-	1000152-47-3	679	0,40
*Tridecane	629-50-5	237	0,38
*undecane	1120-21-4	905	0,36
*Undecane, 2-methyl-	7045-71-8	399	0,36
*Undecane, 3-methyl-	1002-43-3	317	0,34
*Undecane, 4-methyl-	2980-69-0	257	0,32
*Undecane, 5-methyl-	1632-70-8	535	0,30
Total concentration of identified components		12600	21
Number of identified components		30	
Total concentraion of volatile organic compounds		17213	29
Number of components included in TVOC (conc.>1µg/m3)		134	

* Sum of aliphatic and alicyclic hydrocarbons (C10-C13): 9853 µg/m³ 17 µg/m³

Toy no. 2. Weight 1278 g



Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
1-butanol	71-36-3	4719	20,16
*1-Methyl-2-methylenecyclohexane	2808-75-5	5906	10,04
*1-Methyldecahydronaphthalene	2958-75-0	3591	9,39
*2,6-Dimethyldecane	13150-81-7	5525	8,60
*2,6-dimethylnonane	17302-28-2	2344	8,02
*cis, cis-3-Ethylbicyclo[4.4.0]decane	66660-42-2	2700	6,90
*Cyclohexane, (1-ethylpropyl)-	26321-98-2	2156	6,52
*Cyclohexane, 1-methyl-4-(1-methylethylidene)-	1124-27-2	3138	6,10
Cyclohexanol, 3,5-dimethyl-	5441-52-1	2713	6,05
cyclohexanone	108-94-1	11857	5,34
*Cyclopentane, 1-methyl-1-(2-methyl-2-propenyl)-	74764-47-9	1901	5,34
*Decane	124-18-5	3558	4,61
*Decane, 3-methyl-	13151-34-3	2571	4,59
*Decane, 4-methyl-	2847-72-5	2651	4,51
*Dodecane	112-40-3	1879	4,45
*Naphthalene, decahydro-1,2-dimethyl-	3604-14-7	1611	4,37
*Naphthalene, decahydro-2,3-dimethyl-	1008-80-6	2201	3,99
*Naphthalene, decahydro-2,6-dimethyl-	1618-22-0	1805	3,98
*nonane	111-84-2	1811	3,87
*Nonane, 3-methyl-	005911-04-6	3141	3,74
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	2274	3,66
*trans-Decalin, 2-methyl-	1000152-47-3	5061	3,62
*Tridecane	629-50-5	2347	3,23
*Undecane	1120-21-4	4057	3,19
*Undecane, 2-methyl-	7045-71-8	2130	3,08
*Undecane, 3-methyl-	1002-43-3	3832	3,07
*Undecane, 5-methyl-	1002-43-3	2615	2,74
Total concentration of identified components		90092	153
Number of identified components		27	
Total concentraion of volatile organic compounds		141542	241
Number of components included in TVOC (conc.>1µg/m3)		134	

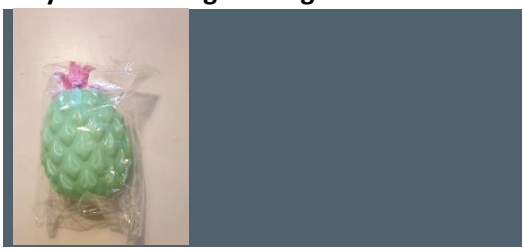
* Sum of aliphatic and alicyclic hydrocarbons (C8-C13): 68529 µg/m³ 116 µg/m³

Toy no. 12. Weight 140 g

Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
1-Hexanol, 2-ethyl-	104-76-7	209	3,85
2-Butanone	78-93-3	457	2,26
2-Ethylhexyl acrylate	103-11-7	56	1,46
Acetic acid, butyl ester	123-86-4	148	0,78
Acetone	67-64-1	86	0,54
**Benzene, 1,2,3,4-tetramethyl-	488-23-3	68	0,44
**Benzene, 1,2,4,5-tetramethyl-	95-93-2	20	0,35
**Benzene, 1-ethyl-2,4-dimethyl-	874-41-9	55	0,25
**Benzene, 2-ethyl-1,4-dimethyl-	1758-88-9	20	0,19
Butanoic acid, 3-methyl-, 3-methylbutyl ester	659-70-1	20	0,19
Cyclohexanone	108-94-1	2263	0,15
*Decane	124-18-5	43	0,13
*Dodecane	112-40-3	111	0,13
Ethanol, 2-butoxy-	111-76-2	1330	0,12
Ethyl Acetate	141-78-6	110	0,11
Ethylbenzene	100-41-4	256	0,10
Hexanoic acid, ethyl ester	123-68-2	33	0,09
Methylene chloride	75-09-2	31	0,09
**Naphthalene	91-20-3	19	0,07
**o-Cymene	527-84-4	19	0,06
o-xylene (1,2-dimethylbenzene)	95-47-6	317	0,05
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	859	0,04
Styrene	100-42-5	55	0,03
*Tetradecane	629-59-4	21	0,03
Toluene	108-88-3	65	0,03
*Tridecane	629-50-5	78	0,03
*Undecane	1120-21-4	78	0,03
Total concentration of identified components		6826	12
Number of identified components		27	
Total concentraion of volatile organic compounds		7463	13
Number of components included in TVOC (conc.>1µg/m3)		142	

* Sum of aliphatic and alicyclic hydrocarbons (C10-C14):	331 µg/m³	0.6 µg/m³
* *Sum of aromatic hydrocarboncs (C9-C10):	201 µg/m³	0.3 µg/m³

Toy no. 14. Weight 174 g

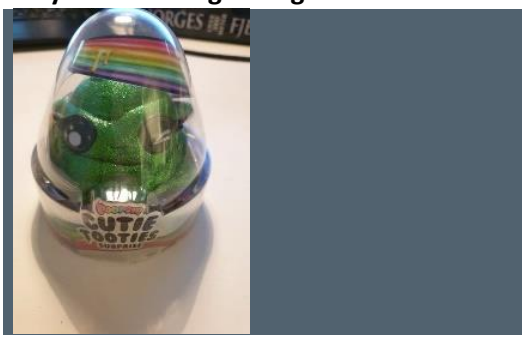


Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
**(E)-1-Phenyl-1-butene	1005-64-7	43	7,80
1,1-Dichloro-1-fluoroethane	1717-00-6	29	2,07
*1-H-Indene, 1,3-dimethyl	2177-48-2	31	2,02
*2-Ethyl-1-H-indene	17059-50-6	64	1,44
3-Buten-2-one, 4-phenyl-, (E)-	1896-62-4	111	1,03
Acetic acid	64-19-7	55	0,84
acetic acid butylester	123-86-4	114	0,61
**Benzene, (2-methyl-1-butenyl)-	56253-64-6	74	0,51
**Benzene, 1,3-diethenyl-	108-57-6	303	0,37
**Benzene, 1,4-diethenyl-	105-06-6	219	0,35
**Benzene, 1-ethenyl-3-ethyl-	100-80-1	493	0,31
**Benzene, 1-ethenyl-4-ethyl-	622-97-9	1189	0,28
Cinnamaldehyde, cis	14371-10-9	116	0,24
Cinnamaldehyde, trans	14371-10-9	81	0,21
Cyclohexanol	108-93-0	606	0,20
Cyclohexanone	108-94-1	4591	0,19
*Dodecane	112-40-3	139	0,19
Ethanone, 1-(4-ethylphenyl)-	937-30-4	34	0,16
ethylbenzene	100-41-4	125	0,14
hexamethyl cyclotrisiloxane (D3)	541-05-9	846	0,13
octamethyl cyclotetrasiloxane (D4)	556-67-2	208	0,11
o-xylene (1,2-dimethylbenzene)	95-47-6	167	0,09
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	360	0,07
toluene	108-88-3	1218	0,06
*Tridecane	629-50-5	183	0,05
*Undecane	1120-21-4	95	0,05
Total concentration of identified components		11493	20
Number of identified components		26	
Total concentraion of volatile organic compounds		12616	21
Number of components included in TVOC (conc.>1µg/m3)		137	

* Sum of aliphatic and alicyclic hydrocarbons (C10-C13): 512 µg/m³ 0.9 µg/m³

** Sum of aromatic hydrocarboncs (C10): 2321 µg/m³ 4.0 µg/m³

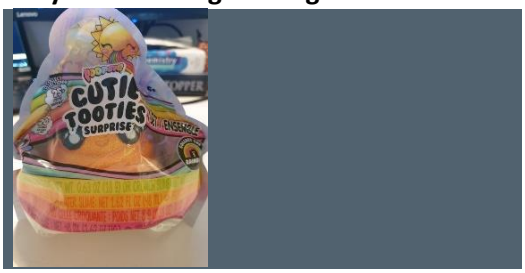
Toy no. 15. Weight 78 g



Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
1-Propanol, 2-methyl-	78-83-1	168	6,64
2,4-Pentadien-1-ol, 3-pentyl-, (2Z)-	1000142-19-7	385	4,54
*4-Octene, 2,6-dimethyl-, [S-(E)]-	62960-76-3	274	4,53
Benzene, 1,3-dimethyl-	108-38-3	2423	4,12
*Butane, 2-methyl-	78-78-4	605	2,30
*Cyclohexane, 1,1-dimethyl-	590-66-9	770	2,16
*Cyclohexane, 1-methyl-4-(1-methylethyl)-, cis-	6069-98-3	207	2,13
*Cyclohexane, propyl-	1678-92-8	205	1,61
Cyclohexanone	108-94-1	1271	1,31
decamethyl cyclopentasiloxane (D5)	541-02-6	949	1,08
*Decane	124-18-5	1255	1,03
*Decane, 2-methyl-	6975-98-0	197	0,87
*Decane, 2-methyl-	6975-98-0	172	0,82
*Decane, 4-methyl-	2847-72-5	351	0,67
*Decane, 5-ethyl-5-methyl-	17312-74-2	271	0,65
*Decane, 5-methyl-	13151-35-4	226	0,62
Ethylbenzene	100-41-4	1350	0,60
hexamethyl cyclotrisiloxane (D3)	541-05-9	510	0,48
*Naphthalene, decahydro-	91-17-8	284	0,47
*Nonane	111-84-2	635	0,46
*Nonane , 4,5-dimethyl	17302-23-7	196	0,38
*Nonane, 3-methyl-	5911-04-6	367	0,37
octamethyl cyclotetrasiloxane (D4)	556-67-2	2670	0,35
Octane, 2,6-dimethyl-	2051-30-1	219	0,35
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	95-47-6	3906	0,33
sec-Butyl acetate	105-46-4	480	0,33
*Toluene	108-88-3	2666	0,29
*Undecane	1120-21-4	395	0,29
Total concentration of identified components		23407	40
Number of identified components		28	
Total concentraion of volatile organic compounds		26668	45
Number of components included in TVOC (conc.>1µg/m3)		140	

* Sum of aliphatic and alicyclic hydrocarbons (C5-C13): 9076 µg/m³ 15 µg/m³

Toy no. 17. Weight 126 g

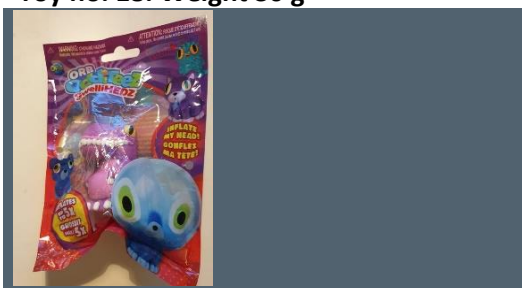


Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	54632	92,87
octamethyl cyclotetrasiloxane (D4)	556-67-2	43901	74,63
hexamethyl cyclotrisiloxane (D3)	541-05-9	36372	61,83
o-xylene (1,2-dimethylbenzene)	95-47-6	29368	49,93
Ethylbenzene	100-41-4	22263	37,85
Cyclohexanone	108-94-1	18589	31,60
Acetic acid, butyl ester	123-86-4	18156	30,87
decamethyl cyclopentasiloxane (D5)	541-02-6	10944	18,60
*Cyclohexane, 1,1-dimethyl-	590-66-9	5479	9,31
*Cyclohexane, 1-ethyl-2,3-dimethyl-	7058-05-1	3770	6,41
*Nonane	111-84-2	3137	5,33
*Cyclohexane, 1-methyl-4-(1-methylethyl)-, trans-	1678-82-6	2577	4,38
*1H-Indene, octahydro-, cis-	4551-51-3	2211	3,76
*Cyclohexane, 1-ethyl-2,3-dimethyl-	7058-05-1	2187	3,72
*Naphthalene, decahydro-, cis-	493-01-6	2151	3,66
Toluene	108-88-3	1937	3,29
*Cyclohexane, butyl-	1678-93-9	1765	3,00
sec-Butyl acetate	105-46-4	1426	2,42
*Cyclohexene, 1-butyl-	3282-53-9	1317	2,24
*Cyclopentane, 1-methyl-1-(2-methyl-2-propenyl)-	74764-47-9	1311	2,23
*Octane, 2,6-dimethyl-	2051-30-1	1264	2,15
Total concentration of identified components		264758	450
Number of identified components		21	
Total concentraion of volatile organic compounds		303691	516
Number of components included in TVOC (conc.>1µg/m3)		96	

* Sum of aliphatic and alicyclic hydrocarbons (C8-C10): 25169 µg/m³ 43 µg/m³

Sum of all aromatic and aliphatic hydrocarbons 227 µg/m³

Toy no. 18. Weight 30 g



Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	6315	10,74
o-Xylene	95-47-6	5196	8,83
Ethylbenzene	100-41-4	3233	5,50
**Benzene, (1-methylethyl)-	98-82-8	367	0,62
*Nonane	111-84-2	236	0,40
*Ethylidenecycloheptane	10494-87-8	183	0,31
*Bicyclo[2.2.1]heptane, 2-ethyl-	2146-41-0	160	0,27
*Octane, 2-methyl-	3221-61-2	132	0,22
*Octane, 3-methyl-	2216-33-3	118	0,20
Cyclohexanone	108-94-1	116	0,20
*Decane	124-18-5	86	0,15
*Cyclohexane, 1-ethyl-4-methyl-, cis-	4926-78-7	73	0,12
*Undecane	1120-21-4	73	0,12
*Cyclohexane, 1,1-dimethyl-	590-66-9	65	0,11
*Dodecane	112-40-3	64	0,11
*Cyclohexane, 1,1,3-trimethyl-	3073-66-3	50	0,08
**Benzene, propyl-	103-65-1	48	0,08
*Tridecane	629-50-5	46	0,08
*Pentalene, octahydro-	694-72-4	45	0,08
*Decane, 5-methyl-	13151-35-4	30	0,05
*Cyclohexane, (2-methylpropyl)-	1678-98-4	28	0,05
*Naphthalene, decahydro-	91-17-8	27	0,05
*Decane, 4-methyl-	2847-72-5	24	0,04
hexamethyl cyclotrisiloxane (D3)	541-05-9	23	0,04
*Nonane, 3-methyl-	5911-04-6	20	0,03
*Cyclohexane, 1-methyl-4-(1-methylethyl)-, trans-	1678-82-6	17	0,03
Total concentration of identified components		16779	29
Number of identified components		26	
Total concentraion of volatile organic compounds		17344	30
Number of components included in TVOC (conc.>1µg/m3)		141	

* Sum of aliphatic and alicyclic hydrocarbons (C8-C13):	1477 µg/m³	2.5 µg/m³
* Sum of aromatic hydrocarbons (C9):	415 µg/m³	0.7 µg/m³

Toy no. 19. Weight 138 g

Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
octamethyl cyclotetrasiloxane (D4)	556-67-2	4822	8,20
decamethyl cyclopentasiloxane (D5)	541-02-6	2575	4,38
cyclohexanone	108-94-1	1446	2,46
acetic acid ethylester (ethylacetate)	141-78-6	958	1,63
hexamethyl cyclotrisiloxane (D3)	541-05-9	854	1,45
acetic acid butylester	123-86-4	205	0,35
2-methyl-1-propanol (isobutanol)	78-83-1	162	0,28
dodecamethyl cyclohexasiloxane (D6)	540-97-6	143	0,24
*dodecane	112-40-3	60	0,10
2-propanone (acetone)	67-64-1	57	0,10
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	56	0,10
hexamethyl disiloxane L2	107-46-0	56	0,09
2-butoxyethanol	111-76-2	49	0,08
*undecane	1120-21-4	47	0,08
octamethyl trisiloxane (L3)	107-51-7	43	0,07
o-xylene (1,2-dimethylbenzene)	95-47-6	42	0,07
TXIB (2,2,4-Trimethyl-1,3-pentanediol diisobutyrate)	6846-50-0	41	0,07
*tridecane	629-50-5	38	0,06
*heptane	142-82-5	38	0,06
1-butanol	71-36-3	30	0,05
toluene	108-88-3	27	0,05
2-ethyl-1-hexanol	104-76-7	16	0,03
*methylcyclohexane	108-87-2	15	0,03
ethylbenzene	100-41-4	15	0,02
decamethyl cyclopentasiloxane (D5)	541-02-6	15	0,02
2-methylpropanal	78-84-2	13	0,02
Total concentration of identified components		11821	20
Number of identified components		26	
Total concentraion of volatile organic compounds		12324	21
Number of components included in TVOC (conc.>1µg/m3)		137	

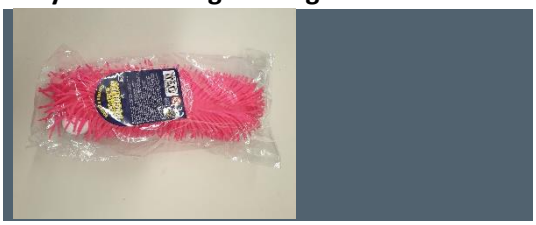
* Sum of aliphatic and alicyclic hydrocarbons (C7-C13): 198 µg/m³ 0.3 µg/m³

Toy no. 20. Weight 72 g

Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	2435	4,14
Toluene	108-88-3	2124	3,61
o-xylene (1,2-dimethylbenzene)	108-38-3	1699	2,89
Cyclohexanone	108-94-1	1489	2,53
*Butane, 2-methyl-	78-78-4	767	1,30
*Pentane, 2,2,4-trimethyl-	540-84-1	635	1,08
Ethylbenzene	100-41-4	607	1,03
*Dodecane	112-40-3	124	0,21
Acetic acid	64-19-7	116	0,20
Styrene	100-42-5	115	0,20
*Nonane	111-84-2	105	0,18
*Tridecane	629-50-5	82	0,14
Ethanol, 2-butoxy-	111-76-2	74	0,13
*Undecane	1120-21-4	69	0,12
Tetramethylbutanedinitrile	3333-52-6	66	0,11
Ethanol, 2-phenoxy-	122-99-6	53	0,09
*Octane, 2-methyl-	3221-61-2	43	0,07
*Octane, 3-methyl-	2216-33-3	39	0,07
*Naphthalene, decahydro-2,3-dimethyl-	1008-80-6	23	0,04
*Cyclopentane, 1-methyl-2-propyl-	3728-57-2	23	0,04
*Cyclohexane, ethyl-	1678-91-7	21	0,04
*Decane	124-18-5	21	0,04
Toluene	108-88-3	19	0,03
*trans-Decalin, 2-methyl-	1000152-47-3	15	0,03
*Octane, 4,5-diethyl-	1636-41-5	15	0,03
Benzene, (1-methylethyl)-	98-82-8	14	0,02
Acetic acid, butyl ester	123-86-4	12	0,02
Total concentration of identified components		10806	18
Number of identified components		27	
Total concentraion of volatile organic compounds		11198	19
Number of components included in TVOC (conc.>1µg/m3)		133	

* Sum of aliphatic and alicyclic hydrocarbons (C5-C13): 1982 µg/m³ 3 µg/m³

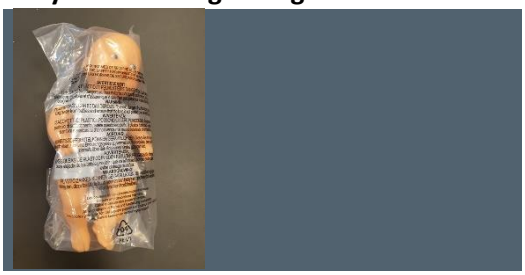
Toy no. 32. Weight 126 g



Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
ethylbenzene	100-41-4	2648	4,50
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	2646	4,50
o-xylene (1,2-dimethylbenzene)	95-47-6	1847	3,14
**Benzene, 1-ethenyl-4-ethyl-	622-97-9	1320	2,24
**Benzene, 1-ethenyl-3-ethyl-	7525-62-4	511	0,87
**Benzene, 1,3-diethenyl-	108-57-6	510	0,87
**Benzene, 1,4-diethenyl-	105-06-6	267	0,45
*Tridecane	629-50-5	212	0,36
3-Buten-2-one, 4-phenyl-, (E)-	1896-62-4	183	0,31
Cinnamaldehyde, trans- (natural form) cas 104-55-2	14371-10-9	147	0,25
Styrene	100-42-5	136	0,23
*Undecane	1120-21-4	124	0,21
*D-Limonene	5989-27-5	121	0,20
*Bicyclo[2.2.1]heptane, 2-ethyl-	2146-41-0	96	0,16
Cinnamaldehyde, cis- (artifical form) cas 104-55-2	14371-10-9	95	0,16
*Pentalene, octahydro-	694-72-4	95	0,16
*Nonane	111-84-2	91	0,15
*2,2-Dimethylindene, 2,3-dihydro-	20836-11-7	87	0,15
**Benzene, 1-ethenyl-3-methyl-	100-80-1	86	0,15
*Decane, 3-methyl-	13151-34-3	86	0,15
Benzoic acid	65-85-0	81	0,14
*Cyclohexane, ethyl-	1678-91-7	80	0,14
Ethanone, 1-(4-ethylphenyl)-	937-30-4	72	0,12
*3-Octanol, 3,7-dimethyl-	78-69-3	71	0,12
*1H-Indene, 1,3-dimethyl-	2177-48-2	70	0,12
*Cyclopentane, (2-methylpropyl)-	3788-32-7	67	0,11
**Benzene, (1-methylethyl)-	98-82-8	65	0,11
**Benzene, (2-methyl-1-propenyl)-	768-49-0	61	0,10
Total concentration of identified components		11874	20
Number of identified components		28	
Total concentraion of volatile organic compounds		13594	23
Number of components included in TVOC (conc.>1µg/m3)		129	

* Sum of aliphatic and alicyclic hydrocarbons (C9-C13):	1200 µg/m³	2 µg/m³
** Sum of aromatic hydrocarboncs (C9-C10):	2755 µg/m³	4.7 µg/m³

Toy no. 39. Weight 86 g



Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	6846-50-0	1026	1,74
Propylene Glycol	57-55-6	130	0,22
*Dodecane	112-40-3	103	0,18
*Tridecane	629-50-5	70	0,12
*Undecane	1120-21-4	69	0,12
Cyclohexanone	108-94-1	44	0,08
Nonanal	124-19-6	32	0,05
o-xylene (1,2-dimethylbenzene)	95-47-6	26	0,04
Butanoic acid, 1-methylpropyl ester	819-97-6	23	0,04
*Decane	124-18-5	19	0,03
1-Hexanol, 2-ethyl-	104-76-7	17	0,03
Propanoic acid, 2-methyl-, 3-hydroxy-2,2,4-trimethylpentyl ester	77-68-9	17	0,03
Ethanol, 2-phenoxy-	122-99-6	12	0,02
1-butanol	71-36-3	10	0,02
*Tetradecane	629-59-4	8	0,01
2-propanol (isopropylalkohol)	67-63-0	8	0,01
Cyclohexanone, 3,3,5-trimethyl-	873-94-9	8	0,01
Toluene	108-88-3	8	0,01
*Cyclohexane, pentyl-	4292-92-6	7	0,01
Ethylbenzene	100-41-4	6	0,01
Octamethyl cyclotetrasiloxane (D4)	556-67-2	6	0,01
1-Octen-3-ol	3391-86-4	6	0,01
Decamethyl cyclopentasiloxane (D5)	541-02-6	5	0,01
Tetrasiloxane, decamethyl-	141-62-8	4	0,01
Total concentration of identified components		1664	2.8
Number of identified components		24	
Total concentraion of volatile organic compounds		1874	3.2
Number of components included in TVOC (conc.>1µg/m3)		124	

* Sum of aliphatic and alicyclic hydrocarbons (C10-C14): 276 µg/m³ 0.5 µg/m³

Toy no. 42. Weight 86 g

Component	CAS No.	Toluene equivalent (µg/m³)	Converted to inhalation conc (µg/m³) (x 0.0017)
Cyclohexanone	108-94-1	1885	3,20
1-Hexanol, 2-ethyl-	104-76-7	270	0,46
o-xylene (1,2-dimethylbenzene)	95-47-6	160	0,27
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	106-42-3	106	0,18
*Dodecane	112-40-3	103	0,17
Toluene	108-88-3	99	0,17
Acetic acid, butyl ester	123-86-4	97	0,17
*Undecane	1120-21-4	91	0,15
*Tridecane	629-50-5	71	0,12
Hexanal, 2-ethyl-	123-05-7	44	0,08
*Decane	124-18-5	38	0,07
Ethanol, 2,2'-oxybis-	111-46-6	38	0,06
1-butanol	71-36-3	31	0,05
Nonanal	124-19-6	29	0,05
ethylbenzene	100-41-4	27	0,05
1-(1-Methoxypropan-2-yloxy)propan-2-yl 3-methylbutanoate	1000367-13-2	27	0,05
Phenol	108-95-2	27	0,05
Mesitylene	108-67-8	25	0,04
*Decane, 3-methyl-	13151-34-3	25	0,04
Hexanal	66-25-1	21	0,04
Propane, 1,2-dichloro-	78-87-5	21	0,03
*Heptane, 2,2,4,6,6-pentamethyl-	13475-82-6	20	0,03
hexamethyl cyclotrisiloxane (D3)	541-05-9	19	0,03
sec-Butyl acetate	105-46-4	17	0,03
*trans-Decalin, 2-methyl-	1000152-47-3	17	0,03
Total concentration of identified components		3309	5.6
Number of identified components		25	
Total concentraion of volatile organic compounds		3893	6.6
Number of components included in TVOC (conc.>1µg/m3)		142	

* Sum of aliphatic and alicyclic hydrocarbons (C10-C13): 348 µg/m³ 0.6 µg/m³

Appendix B

Chemical measurements, Part 2, bedside

Group A **Toys no. 1 and 39 (high emissions of TXIB)**		
Date and time of sampling	**24 - 25.February - 10ml/min in 10 hours**	
Date of Tenax-TA air samplers analyse	**25.February 2020**	
Component	**Concentration**	**CAS NO.**
Alfa pinene	4,2	80-56-8
Nonanal	3,0	124-19-6
TXIB (2,2,4-Trimethyl-1,3-pentanediol diisobutyrate)	2,0	6846-50-0
3-carene	1,5	13466-78-9
Ethylbenzene	1,4	100-41-4
Decanal	1,2	112-31-2
Toluene	0,9	108-88-3
o-xylene (1,2-dimethylbenzene)	0,7	95-47-6
Benzene	0,7	71-43-2
Hexamethyl cyclotrisiloxane (D3)	0,5	541-05-9
Beta pinene	0,2	127-91-3
Cyclohexanone	0,2	108-94-1
p-and m- Xylene (1,4 og 1,3 dimethylbenzene)	0,2	106-42-3

Group B **Toys no. 18, 20 and 32 (high emissions of aromatic VOCs)**		
Date and time of sampling	**25 - 26.February - 10ml/min in 10 hours**	
Date of Tenax-TA air samplers analyse	**26.February 2020**	
Component	**Concentration**	**CAS NO.**
Acetic acid	5,6	64-19-7
Alfa pinene	1,6	80-56-8
Nonanal	1,2	124-19-6
Hexanal	0,9	66-25-1
Benzaldehyde	0,8	100-52-7
3-carene	0,5	13466-78-9
Toluene	0,4	108-88-3
Benzene	0,4	71-43-2
TXIB (2,2,4-Trimethyl-1,3-pentanediol diisobutyrate)	0,3	6846-50-0
Tridecane	0,3	629-50-5
Hexamethyl cyclotrisiloxane (D3)	0,2	541-05-9

Group C **Toys no. 2, 12, 14 and 42 (high emissions of cyclohexanone)**		
Date and time of sampling	**26 - 27.February - 10ml/min in 10 hours**	
Date of Tenax-TA air samplers analyse	**27.February 2020**	
Component	**Concentration**	**CAS NO.**
	)	
Cyclohexanone	97,8	108-94-1
*Naphthalene, decahydro-2,3-dimethyl-	26,2	001008-80-6
*cis,trans-1,6-Dimethylspiro[4.5]decane	18,1	590-66-9
*Trans-Decalin, 2-methyl-	17,6	1000152-47-3
*Tridecane	16,6	000629-50-5
*Undecane, 5-methyl-	15,5	001632-70-8
*Bicyclo[4.1.0]heptane, 3-methyl-7-pentyl-	14,9	041977-48-4
1-butanol	13,7	71-36-3
*Dodecane	12,3	000112-40-3
*Naphthalene, decahydro-2,6-dimethyl-	11,8	001618-22-0
*Naphthalene, decahydro-2-methyl-	11,6	002958-76-1
*trans decahydronaphthalene	10,5	493-02-7
2-tert-Butyl-3,4,5,6-tetrahydropyridine	9,6	090949-17-0
*Naphthalene, decahydro-1,2-dimethyl-	9,5	003604-14-6
*Naphthalene, decahydro-1,2-dimethyl-(isomer)	9,0	003604-14-6
*Undecane	7,7	001120-21-4
*Decalin, 2-syn-methyl- (isomer)	7,5	1000155-85-6
*Cyclohexane, 1-methyl-4-(1-methylethylidene)-	7,1	001124-27-2
(4aS,7S,7aR)-4,7-Dimethyl-5,6,7,7a-tetrahydrocyclopenta[c]pyran-1(4aH)-one	6,9	021651-62-7
*Decalin, 2-syn-methyl- (isomer)	6,6	1000155-85-6
*Undecane, 3-methyl-	6,5	001002-43-3
*cis-Decalin, 2-syn-methyl-	6,5	1000155-85-6
*Naphthalene, decahydro-2,6-dimethyl-	5,6	001618-22-0
*Cyclohexane, 1-methyl-4-(1-methylethylidene)-	5,5	001124-27-2
*Cyclododecane	5,3	000294-62-2
Butanoic acid butylester	5,1	109-21-7
*cis-Decalin, 2-syn-methyl-	4,3	1000155-85-6

* Sum of aliphatic and alicyclic hydrocarbons (C10-C13): 221 µg/m^3

Group D **Toys no. 15, 17 and 19 (high emissions of cyclic siloxanes)**		
Date and time of sampling	**27 - 28.February - 10ml/min in 10 hours**	
Date of Tenax-TA air samplers analyse	**28.February 2020**	
Component	**Concentration**	**CAS NO.**
Cyclotetrasiloxane, octamethyl-	271,7	000556-67-2
Cyclopentasiloxane, decamethyl-	71,0	000541-02-6
Cyclotrisiloxane, hexamethyl-	67,5	000541-05-9
*Cyclohexane, 1,1-dimethyl-	25,7	000590-66-9
Cyclohexanone	24,7	000108-94-1
*Decane	19,9	000124-18-5
p-Xylene	19,8	000106-42-3
o-Xylene	18,1	000095-47-6
*Cyclodecene	13,0	003618-12-0
*Cyclohexane, butyl-	12,7	001678-93-9
*Hexadecane, 2,6,11,15-tetramethyl-	11,7	000504-44-9
*Cyclohexene, 4-methyl-1-(1-methylethyl)-	11,0	000500-00-5
*Cyclohexane, 1-ethyl-2,3-dimethyl-	9,8	007058-05-1
*1H-Indene, octahydro-, cis-	9,7	004551-51-3
*Nonane, 3-methyl-	9,6	005911-04-6
*Cyclohexane, 1-methyl-4-(1-methylethenyl)-, trans-	9,2	001124-25-0
*Pentane	7,5	000109-66-0
Cyclohexasiloxane, dodecamethyl-	7,3	000540-97-6
*Cyclohexane, 1-methyl-4-(1-methylethyl)-, cis-	7,0	006069-98-3
*Cyclohexane, 1-methyl-4-(1-methylethylidene)-	6,8	001124-27-2
Isopulegol	6,3	000089-79-2
*1H-Indene, octahydro-5-methyl-	5,7	019744-64-0
*Trans-1,4-diethylcyclohexane	5,4	013990-93-7
Pentasiloxane, dodecamethyl-	4,8	000141-63-9
*Naphthalene, decahydro-	4,5	000091-17-8
Acetic acid	4,2	000064-19-7
*Trans-1,4-diethylcyclohexane	4,1	013990-93-7

*Cyclohexane, 1-ethyl-2,3-dimethyl-	4,1	007058-05-1
*Bicyclo[4.1.0]heptane, 3,7,7-trimethyl-	4,1	000554-59-6

* Sum of aliphatic and alicyclic hydrocarbons (C5-C10): 178 µg/m^3

Appendix C

Hazard screening of measured substances

Data on tolerable exposure limits have been collected from the following sources:

- Recent consumer projects/limit value projects from the Danish Environmental Protection Agency
- The EU-LCI list “Agreed LCI values”
- WHO’s limit values for indoor and outdoor air
- Opinions from ECHA’s risk assessment committee, RAC
- The US EPA IRIS database (given as reference concentrations, RfC).
- SCHEER’s adopted toxicological refence values for certain organic chemicals emitted from squishy toys.

When several expert assessments have been identified, the newest and most updated ones have been applied.

The EU-LCI list constitutes an important source, since it provides exposure levels for a number of individual substances. Lowest Concentration of Interest (abbrev. LCI) is a concentration determined to limit emission of chemical substances from building materials. In a report from the European Commission from 2013, LCI values have been derived for a total of 21 substances based on the same methodology as in the REACH regulation for establishment of DNEL values. The EU LCI list “Agreed LCI values” is continuously updated and can be downloaded from the EU LCI working group's website (EU-LCI 2020). Thus, use of the LCI values is considered relevant as a screening tool for identifying the most relevant substances.

At the same time the opinion of SCHEER (2021) has to be acknowledged *“SCHEER does not recommend applying the EU-LCI values as toxicological reference values for inhalative exposure to chemicals from toys in general. EU-LCI values are derived for building products on the basis of specific exposure scenarios that may differ from those to be used when assessing health risks for children playing with toys”.*

However, as the LCI values have been derived since 2013 according to the methodology for DNEL derivation for consumers, it is still considered justified to use the LCI value as an adequate screening tool for identifying the most relevant substances.

According to a search in the above-mentioned sources, the table below shows the result from the data search on 26 substances which have been prioritized based on emissions measured by NILU (2020).

After filling out of the table, the substances in green were marked as the most relevant substances to consider in the risk assessment. Criteria and substance prioritized for risk assessment is further elaborated in text after the table.

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m^3	Highest conc. in apartment. µg/m^3. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
Aliphatic and alicyclic hydrocarbons						
Pentane (109-66-0)	Asp. Tox. 1 (H304) STOT SE 3 (H336)	Not relevant/prioritized		Not identified*		Living room (6.8)
Cis,trans-1,6-Dimethyl-spiro[4.5]decane (1000111-72-3)	No notifications	Not relevant/prioritized		Not identified*		Breathing zone (18) Living room (6.7)
Cyclohexane, 1,1-dimethyl- (590-66-9)	No notifications	Not identified in literature	Derived in task 3	65 – 5479 (18, **17**)	0.11 – 9.31 (18, **17**)	Breathing zone (26) Bedroom (4.5)
Trans-Decalin, 2-methyl (1000152-47-3)	No notifications	Not identified in literature	Derived in task 3	15 – 5061 (20, **2**)	0.03 -8.61 (20, **2**)	Breathing zone (18) Living room (6.5)
Tridecane (629-50-5)	Not harmonised	Not identified in literature	Derived in task 3	38 – 2 347 (19, **2**)	0.07 – 3.99 (19, **2**)	Breathing zone (17)
Naphthalene, decahydro-2,3-dimethyl- (1008-80-6)	No notifications	Not identified in literature	Derived in task 3	23 – 2201 (20, **2**)	0.04 – 3.74 (20, **2**)	Breathing zone (26) Living room (9.7)
Naphthalene, decahydro-2,6-dimethyl- (1618-22-0)	No notifications	Not identified in literature	Derived in task 3	507 – 1805 (1, **2**)	0.86 – 3.07 (1, **2**)	Bedroom (6.5) BLiving room (11)

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m³	Highest conc. in apartment. µg/m³. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
Sum of aliphatic and alicyclic hydrocarbonse (C7-C13)	White spirit: Asp. Tox. 1 H304 STOT RE1 H372 (nervous system)	Not indicated	6000 µg/m³ (EU-LCI 2020) Saturated cyclic and aliphatic hydrocarbons (C9-C16)	198- 68529/ (19, 2)	0.3-116 (19, 2)	Breathing zone (221)
		Chronic neurotoxicity	1425 mg/m³ (Danish EPA 2016) C7-C12 hydrocarbons			
Aromatic hydrocarbons						
Toluene 108-88-3	Skin Irrit. 2 (H315) Asp. Tox. 1 (H304) STOT SE 3 (H336) STOT RE 2* (H373**) Repr. 2 (H361d)	Neurological effects	2900 µg/m³ (EU-LCI 2020)	8-2666 (39, 15)	0.01 – 4.5 (39, 15)	Breathing zone (0.9) Bedroom (1.3) Living room (2.9)
			725 µg/m³ - children (Danish EPA 2016)			
Ethylbenzene** (100-41-4)	Acute Tox. 4 (H332) Asp. Tox. 1 (H304) STOT RE 2 (H373 – hearing organs)	Ototoxicity	850 µg/m³ (EU-LCI 2020)	6 – 22 263 (39, **17**)	0.01 – 38 (39, **17**)	Breathing zone (1.4)
		Neurotoxicity and liver effects (Danish EPA 2018)	200 µg/m³ - children (Danish EPA 2016)			
o-xylene*** 95-47-6	Acute Tox. 4* (H312, H332)	Neurotoxicity, respiratory toxicity, eye	500 µg/m³	6 - 29368	0.04 – 50 (39, 17)	Breathing zone (18.1)

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m^3	Highest conc. in apartment. µg/m^3. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
	Skin Irrit. 2 (H315)	irritation and developmental toxicity Neurotoxicity	(EU-LCI 2020) 130 µg/m3 (SCHEER 2021)	(31, 17)		Bedroom (4.2)
p-and m-Xylene*** 106-42-3	Acute Tox. 4* (H312, H332) Skin Irrit. 2 (H315)	Neurotoxicity, respiratory toxicity, eye irritation and developmental toxicity Neurotoxicity Neurotoxicity	500 µg/m^3 (EU-LCI 2020) 130 µg/m^3 (SCHEER 2021) 125 µg/m^3 (Danish EPA 2016)	56 – 54632 (19, 17)	0.04 – 93 (12, 17)	Breathing zone (19.8) Bedroom (4.4) Living room (2.9)

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m^3	Highest conc. in apartment. µg/m^3. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
Aromatic hydrocaarbons (C9-C10)	1,2,4-trimethyl benzen Acute Tox. 4, Skin Irrit. 2, Eye Irrit. 2, STOT RE 3 Cumene: Asp. Tox. 1 (H302), STOT SE 3 (H335)	irritation Respiratory irritation	450 µg/m^3 trimethyl benzenes (C9): - (1700 µg/m^3 cumene (C9) (EU-LCI 2020))	2755 (32)	4.7 (32)	Not found
Monoterpenes						
α-pinene (80-56-8)	Not harmonised	2500 µg/m^3 (EU-LCI 2020)		Not identified*	-	Breathing zone (bed) (1.6-4.2) Bedroom (0.2-4.2) Living room (1.5-5.2)
3-carene (13466-78-9)	Not harmonised	1500 (EU-LCI 2020)		Not identified*	-	Breathing zone (1.5) Bedroom (1.5)
Alcohols						
1-butanol (71-36-3)	Acute tox. 4 (H302) Skin Irrit. 2 (H315) Eye Dam. 1 (H318)	Ascribed EU-LCI	3 000 µg/m^3 (EU-LCI 2020)	10 - 4719 (39, **2**)	0.017 – 8.02 (39, **2**)	Bedroom (6.4) Living room (7.6)

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m^3	Highest conc. in apartment. µg/m^3. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
	STOT SE 3 (H335 and H336)					
Aldehydes						
Hexanal (66-25-1)	Not harmonised	900 µg/m^3 (EU-LCI 2020)		21 (42)	0.04 (42)	Breathing zone (0.9)
Octanal (124-13-0)	Not harmonised	900 µg/m^3 (EU-LCI 2020)		Not identified*	-	Living room (2.0)
Nonanal (124-19-6)	Not harmonised	900 µg/m^3 (EU-LCI 2020)		29 – 32 (42, 39)	0.05 – 0.05 (42, 39)	Breathing zone (1.2-3.0) Bedroom (3.0) Living room (2.7-4.4)
Decanal (112-31-2)	Not harmonised	900 µg/m^3 (EU-LCI 2020)		Not identified*	-	Living room (1-2.7)
Benzaldehyde (100-52-7)	Acute Tox. 4 (H302)			Not identified*	-	Breathing zone (0.8) Bedroom (1.5) Living room (1.3)
Organic acids						
Acetic acid (64-19-7)	Skin Corr. 1A (H314)	1200 µg/m^3 (EU-LCI 2020)		55-116 (14, 20)	0.09 – 0.20 (14, 20)	Breathing zone (5.6) Bedroom (1.6-8.0) Living room

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m³	Highest conc. in apartment. µg/m³. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
						(4.9-6.4)
Ketones						
Cyclohexanone (108-94-1)	Acute Tox. 4 (H332)	Unspecified/ Ascribed EU-LCI (most likely eye and respiratory tract irritation)	410 µg/m³ (EU-LCI 2020)	44 – 18 589 (39, **17**)	0.08 – 31.60 (39, **17**)	Breathing zone (25-98) Bedroom (6.3-35) Living room (4.3-35)
		Liver/kidney degeneration	DNEL: 716 µg/m3 (SCHEER, 2021)			
Esters						
Acetic acid, butyl ester, butyl acetate* 123-86-4	STOT SE 3 (H336)	Unspecified/ascribes EU-LCI	4800 µg/m³ (EU-LCI 2020)	12 - 18156 (20, 17)	0.02 – 30.87 (20, 17)	Not measured
Sec-butyl acetate* 105-46-4	Not harmonised	A DNEL was not identified and the DNEL value of Isobutylacetate** has been used instead.		17 - 1426 (42, 17)	0.03 – 2.42 (42, 17)	Not measured
		Unspecified/ascribes EU-LCI	4800 µg/m³ (EU-LCI 2020)			
Cyclic siloxanes						
Cyclotrisiloxane, hexamethyl- (D3) (541-05-9)	Not harmonised	Liver effects	0.32 mg/m³ (Danish EPA, 2021)	19 – 36 372 (42, **17**)	0.03 – 61.83 (42, **17**)	Breathing zone (68) Bedroom (14) Living room (5)

Substance (CAS no.)	Harmonised health hazard classification*	DNEL, critical effect	DNEL, inhalation (source)	Measured product concentration interval	Inhalation conc. µg/m^3	Highest conc. in apartment. µg/m^3. (Applicable. See section 5.2)
				The measured concentrations (left column) must be converted with the conversion factor of 0.0017, as described in section 5.1.2, before it reflects the actual inhalation concentration (right column)		
Cyclotetrasiloxane, octamethyl- (D4) (556-67-2)	Repr. 2 (H361f***)	Unspecified/ Ascribed EU-LCI	1 200 µg/m^3 (EU-LCI 2020)	6 – 43 901 (39, **17**)	0.01 – 74.6 (39, **17**)	Breathing zone (272) Bedroom (73) Living room (37)
		Lung effects	1000 µg/m^3 (Danish EPA, 2021)			
Cyclopentasiloxane, decamethyl (D5) (541-02-6)	Not harmonised	Uterus tumors Lung effects, liver effects	4300 µg/m^3 5400 µg/m^3 (Danish EPA, 2021)	5 – 10 944 (39, **17**)	0.01 – 18.61 (39, **17**)	Breathing zone (71) Bedroom (15) Living room (8.8)
TXIB						
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (TXIB) (6846-50-0)	Not harmonised	Increased liver weights	1300 µg/m^3 (EU-LCI 2020)	41 – 1725 (19, **1**)	0.07 – 2.93 (19, **1**)	Breathing zone (2) Bedroom (0.2)
*Harmonized classification is included in the table. **IRIS opinion identified but not included due to newer identified scientific expert assessments *** Identified using results from the chemical analysis, part 1 (substance not highlighted in NILU (2020), chemical analysis part 2)						

*not identified above 1 µg/m^3

Substance XX: The substance is prioritized for further hazard characterisation and risk assessment

Prioritization for further hazard and risk assessment.

The table above gives an overview in relation to exposure levels, hazard identification as well as tolerable exposure level (DNELs) for the substances. The indicated DNEL values are gathered from various sources and should be considered as rough screening levels, since the derivation of the DNEL

values have to be evaluated more thoroughly for substances considered relevant for further risk assessment.

When considering which substances should be selected for further risk assessment, the following classification categories would be prioritised:

- CMR classification in category 1A and 1B
- Resp. Sens. 1
- STOT RE 1 and 2
- Acute Tox. 1/2/3
- Skin Corr. 1
- Eye Dam. 1
- STOT SE 3, H335

These classifications cover the most critical systemic effects as well as the most relevant local effects on mucous membranes of the eyes and the respiratory tract.

Furthermore, all the substances will also be prioritised in relation to *exposure level* compared to the *screening DNEL level*:

- The ratio: *exposure level*/*screening DNEL* is in the range of 0.1 or above

Based on these screening criteria the following substances were selected for further, more detailed hazard characterisation and DNEL derivation:

- Aliphatic and alicyclic hydrocarbons C7-C13
- Ethyl benzene
- Xylenes
- D3, D4 and D5
- Cyclohexanone

Aliphatic and alicyclic hydrocarbons C7-C13

, Rather low exposure values were detected for the substances in this group. The highest level of 26 µg/m^3 at bedside was found for the individual substances 1,1-dimethyl-xyclohexane and decahydro-2,3-dimethyl naphthalene. However, when adding the contribution of the 22 aliphatic and alicyclic hydrocarbons the exposure level reached 221 µg/m on the bedside [3]. This is considered sufficiently close to the lowest DNEL-screening level of 1425 µg/m^3 to be prioritised for further evaluation.

Ethylbenzene

The highest level of 38 µg/m^3 was measured for ethyl benzene in relation to toy no. 17. This exposure level is considered sufficiently close to the lowest DNEL-screening level of 200 µg/m^3 to be prioritised for further evaluation.

Xylenes

When adding the contribution from the three isomers of xylene, the highest level of 143 µg/m^3 was measured in relation to toy no. 17. This exposure level is considered sufficiently close to the lowest DNEL-screening level of 125 µg/m^3 to be prioritised for further evaluation.

Cyclic siloxanes, D3, D4 and D5

For the cyclic siloxanes D3, D4 and D5, concentration levels up to 68 µg/m^3, 272 µg/m^3, and 71 µg/m^3 respectively were measured in the breathing zone at bedside. As a similar mode of action may be expected from these substances, the total level of these substances is considered sufficiently close to the DNEL-screening levels of the substances to be prioritised for further evaluation

Cyclohexanone

The highest level of 98 µg/m^3 was measured for cyclohexanone in the breathing zone at bedside. This exposure level is considered sufficiently close to the screening DNEL-levels of 410 µg/m^3 and 2500 µg/m^3 to be prioritised for further evaluation.

Substances that were not prioritised for further assessment

Among the aromatic hydrocarbons detected, very low levels of toluene (up to 4.5 µg/m^3) and of other C9-C10 aromatics (up to 4.7 µg/m^3) were found not to be sufficient for prioritisation.

Although **TXIB** was used by NILU (2020) to characterise the emission from the toys, this substance is not prioritized further, as the highest estimated exposure level of 2.9 µg/m^3 is far below the screening DNEL value of 1300 µg/m^3.

Also, **terpenes** and **aldehydes**, which may occur as fragrances in consumer products, are not prioritised because of the very low exposure levels (in the range of 1-10 µg/m^3 measured in the flat) compared to DNEL screening levels of 900-2500 µg/m^3. Similar conclusions are drawn for **organic acids** and **esters**.

References

Danish EPA (2016). Survey and risk assessment of toluene and other neurotoxic substances in children's rooms. Survey of chemical substances in consumer products No. 145. https://www2.mst.dk/Udgiv/publications/2016/02/978-87-93435-42-1.pdf

Danish EPA (2018). Analysis and risk assessment of fragrances and other organic substances in squishy toys. Survey of chemical substances in consumer products No. 165.

Danish EPA (2021). Survey and risk assessment of siloxanes in cosmetic products. Survey of chemical substances in consumer products No. 185. https://www2.mst.dk/Udgiv/publications/2021/05/978-87-7038-317-2.pdf

EU-LCI (2020). Agreed EU-LCI values – substances with their established EU-LCI values and summary fact sheets. https://ec.europa.eu/docsroom/documents/44905

NILU (2020). Survey of emissions of volatile organic chemicals from handheld toys for children above 3 years. NILU report 12/2020.

SCHEER (2021). Toxicological reference values for certain organic chemicals emitted from squishy toys with regard to adopting limit values under the Toy Safety Directive 2009/48/EC 'Chemicals in squishy toys'. Adopted on 3 June 2021.

Appendix D

Derivation of DNELs

When deriving relevant DNEL values for inhalation exposure to substances emitted from handheld toys, the following statements from SCHEER (2021) in relation to the assessment of squishies have to be considered:

- *"SCHEER agrees with the differentiation between the risks associated to local effects and to systemic exposure"*.

- *Considering that exposure scenarios are limited in time and definitely shorter than the life span, the SCHEER considers the use of short-term reference values (rather than the TDI or a chronic DNEL) as sufficiently protective"*

This means that it is relevant to derive an inhalation DNEL for local effects ($DNEL_{local}$) as well as for systemic effects ($DNEL_{systemic}$) and that the DNEL values should be applicable for short-term exposure.

How SCHEER applied these principles in practice can be seen in the specific derivations of eight DNEL values in the SCHEER opinion.

In the following these principles have been used in combination with the methodology of DNEL derivation in relation to REACH given by ECHA (2012).

Aliphatic and alicyclic hydrocarbons (C8-C13)

WHO/IPCS (1996), SCOEL (2007) and ECHA (2011) have made assessments regarding the organic solvent *"white spirit",* which is an UVCB substance consisting of hydrocarbons mainly in the C8-C13 range. The assessments all agree on chronic neurotoxicity as the most critical endpoint, which covers qualities of white spirit with an aromatic hydrocarbon content of up to 25% as well as de-aromatized qualities only containing aliphatic and alicyclic hydrocarbons.

According to SCOEL (2007), the NOAEL/LOAEL range for chronic neurotoxic effects after prolonged occupational exposure to white spirit is in the range of 40 to 90 ppm. On this basis and after applying a safety factor of 2, SCOEL recommended an Occupational Exposure Level (OEL) of 116 mg/m^3 (20 ppm) in order to prevent subtle chronic nervous system effects and organic brain damage as well as to prevent acute irritation in the eyes and the respiratory tract. The OEL covered both white spirit with aromatic content as well as de-aromatized white spirit.

DNEL, Systemic effects

Based on these data, a NOAEC of 20 ppm (116 mg/m^3) from the SCOEL evaluation is taken as a starting point for the $DNEL_{systemic}$ derivation.

The NOAEC should first be converted from exposure in an 8-h working day (inhalation volume of worker of 10m3) to continuous 24-h exposure (inhalation volume of 20 m3) according to ECHA (2012):

NOAEC (continuous) = 116 mg/m^3 x 10 m^3/20m^3 x 5 days/7 days = 41 mg/m^3

From this value, the $DNEL_{systemic}$ can be calculated:

DNEL = NOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 1

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (LOAEL to NOAEL) = 1, because a no-effect-level is the starting point.

DNEL = 41 mg/m³ / (1 x 10) = 4.1 mg/m³ = 4100 µg/m³

DNEL, Local effects

In the WHO/IPCS (1996) monograph on white spirit volunteer studies were reported in which exposure to 600 mg/m3 and above caused dose-related increased eye irritation. No irritation was reported at 300 mg/m3.

When a NOAEC of 300 mg/m3 is taken as a starting point the following DNEL can be calculated:

DNEL = NOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 1

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (from single exposure to repeated = 3

DNEL = 300 mg/m³ / (1 x 10 x 3 x 1) = 10 mg/m³ =10000 µg/m³

References

ECHA (2011). RAC Opinion proposing harmonised classification and labelling at Community level of white spirit. Committee for Risk Assessment. https://echa.europa.eu/documents/10162/a81dbedb-e9bc-4e53-6853-92e0ba2dec4a

ECHA (2012). Characterisation of dose [concentration] - response for human health (Chapter R.8) (28/11/2012).

SCHEER (2021). Toxicological reference values for certain organic chemicals emitted from squishy toys with regard to adopting limit values under the Toy Safety Directive 2009/48/EC 'Chemicals in squishy toys'. Adopted on 3 June 2021.

SCOEL (2007). Recommendation of the Scientific Committee on Occupational Exposure Limits for "White Spirit". SCOEL/SUM/87, August 2007.

WHO/IPCS (1996). White Spirit. (Stoddard Solvent). INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY. ENVIRONMENTAL HEALTH CRITERIA 187. http://www.inchem.org/documents/ehc/ehc/ehc187.htm#SubSectionNumber:8.1.1

Ethylbenzene

The background documentation from 2013 for derivation of the LCI value (EU-LCI 2020) and the MAK background documentation from 2012 in relation to OEL derivation (MAK 2012) are considered the best starting point for DNEL derivation of ethylbenzene.

DNEL, systemic effects

A LOAEC of 867 mg/m3 in relation to ototoxicity was used as a starting point for driving an LCI value for ethylbenzene. This was the lowest exposure level used in a 90-day rat study and at this level moderate to severe ototoxicity in rats was observed.

When deriving the LCI value the exposure in the animal study was converted to 24 hours continuous exposure of 184 mg/m3 by a factor of 4.7 (24h/6h x 7d/6d = 4.7).

The LCI was then calculated using the following assessment factors:

LCI = LOAEC/(AF1 x AF2 x AF3 x AF4)

AF1 (interspecies animals to human) = 1.44* x 2.5 = 3.6

*The difference in pulmonary absorption between rats and humans for ethylbenzene is considered by the ratio of the rat absorption percentage of 45%, divided by the human absorption percentage after inhalation of 65% ethylbenzene.

AF2 (intraspecies) = 10

AF3 (LOAEC to NOAEC) = 3

AF4 (subchronic to chronic) = 2

LCI = 184 mg/m3 / (3.6 x 10 x 3 x 2) = 851 µg/m³

When transforming this LCI to a $DNEL_{systemic}$ value according to the methodology used by SCHEER (2021), a AF4 with the value of 2 should not be used for extrapolation to chronic exposure. Thus, a $DNEL_{systemic}$ below chronic exposure can be set at 1700 µg/m³

DNEL, local effects

No data regarding local effects are given in the LCI documentation. However, in the MAK documentation for an OEL value it is indicated that in a human volunteer study mucosal irritation occurred at an exposure level of 25 ppm (110 mg/m3) (MAK 2012).

When a LOAEC of 110 mg/m3 is taken as a starting point the following DNEL local can be calculated:

DNEL = LOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 1

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (LOAEL to NOAEL) = 3

DNEL = 110 mg/m³ / (1 x 10 x 3 x 1) = 3.7 mg/m³ = 3700 µg/m³

References

EU-LCI (2020). Agreed EU-LCI values – substances with their established EU-LCI values and summary fact sheets. https://ec.europa.eu/docsroom/documents/44905

MAK (2012). Ethylbenzene. ttps://onlinelibrary.wiley.com/doi/epdf/10.1002/3527600418.mb10041e5214

SCHEER (2021). Toxicological reference values for certain organic chemicals emitted from squishy toys with regard to adopting limit values under the Toy Safety Directive 2009/48/EC ‘Chemicals in squishy toys’. Adopted on 3 June 2021.

Xylenes

For xylenes the DNEL derivation of m-xylene provided by SCHEER (2021) will be used for this risk assessment.

Mild central nervous system effects (subjective symptoms of intoxication, headache, fatigue, and dizziness) have been observed following acute exposure of humans to m-xylene at 50 ppm and chronic occupational exposure to mixed xylene at 14 ppm.

DNEL, systemic effects

SCHEER (2021) found a 13-week inhalation study with rats as the most relevant study for DNEL derivation. In this study a LOAEC of 50 ppm (218.5 mg/m^3) for neurotoxicity was determined based on decreased performance in a rotarod performance test.

The following calculation was used by SCHEER (2021) for the calculation of the DNEL using a LOAEC of 218.5 mg/m³ as starting point and by correcting with 5 d/7d x 6 h/24h for conversion to the human exposure situation:

DNEL = LOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 10

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (LOAEL to NOAEL) = 3

DNEL = (218.5 mg/m³ x 5/7 x 6/24) / (10 x 10 x 3) = 0.13 mg/m³ = 130 µg/m³

It should be noted that data from this 13-week exposure study was used without any further adjustment for any differences in exposure duration compared to the squishy toys.

DNEL, local effects

SCHEER (2021) did not derive a DNEL for local effects.

Based on the information given by SCHEER (2021), a LOAEC of 50 ppm in relation to local effects may be used as a precautious starting point for a DNEL derivation, as this exposure level in humans caused irritant effects on the eyes, skin, and mucous membranes.

DNEL = NOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 1

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (LOAEL to NOAEL) = 3

DNEL = 218.5 mg/m³ / (1 x 10 x 3x 1) = 7 mg/m³ = 7000 µg/m³

References

SCHEER (2021). Toxicological reference values for certain organic chemicals emitted from squishy toys with regard to adopting limit values under the Toy Safety Directive 2009/48/EC ‘Chemicals in squishy toys’. Adopted on 3 June 2021.

Hexamethyl cyclotrisiloxane (D3)

For DNEL derivation of the cyclic siloxanes, the recent assessment by the Danish EPA (2021) will be used.

For D3 no expert assessments were found using web-based search. However, D3 is REACH registered at an annual tonnage above 1000 tonnes, and thus data from the REACH registration were used by the Danish EPA (2021) for the hazard assessment of the substance.

DNEL, Systemic effects

In a 90-day OECD TG 413 inhalation test (from 2001) rats were exposed to 0, 15, 150, 600, 2500 ppm D3, 6 hours/day, 5 days per week. Increased liver weight was observed at all exposure levels. In male rats at all exposure levels histopathological changes (centrilobular hypertrophy) were seen. This was also observed in female rats at 150 ppm and dose levels above. These effects were considered as an adaptive non-adverse response by the REACH registrant, as the effects were reversible after an exposure free period of 28 days. The REACH registrant determined the NOAEC to 150 ppm (corresponding to 1365 mg/m3) based on impact on the body weight in males at higher dosage levels.

As D3 after repeated exposure results in induction of the liver, increased liver weight and histopathological changes, this is in the context of this project considered as an adverse effect even though the effects after an exposure free period was found to be reversible. Thus, a LOAEC of 15 ppm (corresponding to 136 mg/m3) can be set for these effects.

Based on this the following tolerable inhalation level was calculated by the Danish EPA (2021):

From a LOAEC of 136 mg/m^3 a tolerable exposure level for inhalation can be calculated. The LOAEC was first converted from exposure 6 hours per day, 5 days per week, to a 24-hour continuous exposure:

LOAEC (continuous) = 136 mg/m^3 x 6 h/24 h x 5 days/7 days = 24 mg/m^3

From this value, a tolerable exposure level can be calculated:

$DNEL_{systemic}$ = 24 mg/m^3 / 2.5 x 10 x 3 = 0.32 mg/m^3

An uncertainty factor of 2.5 is used for extrapolation from rats to humans in connection with inhalation exposure, and a factor of 10 is used to allow for differences in human susceptibility. Further, a factor of 3 is used for the extrapolation from a LOAEC value.

DNEL, local effects

In a 28-day OECD TG 412 inhalation test (from 1992) rats were exposed to 0, 0.084, 0.945, 9.041 mg/l 6 hours a day. Four lethal outcomes were seen at the highest exposure level (out of 30 exposed animals), probably as a result of local effects and oedema in the lungs. At the two highest exposure levels histopathological signs from irritation of the tissue in the upper respiratory passages were seen, and at the highest exposure level effects in the pulmonary tissue were also observed. On this basis, a NOAEC of 84 mg/m3 was determined for local effects in the respiratory system.

Based on this a $DNEL_{local}$ for this project can be calculated:

As the local effects in the upper respiratory tract are considered the consequence of the actual concentration level rather than an average daily exposure, no conversion to an average exposure level is made. Thus, the DNEL can be calculated by:

$DNEL_{local}$= 84 mg/m^3 / 2.5 x 10 = 3.36 mg/m^3

An uncertainty factor of 2.5 is used for extrapolation from rats to humans in connection with inhalation exposure and a factor of 10 is used to allow for differences in human susceptibility.

References

Danish EPA (2021). Survey and risk assessment of siloxanes in cosmetic products. Survey of chemical substances in consumer products No. 185**.** https://www2.mst.dk/Udgiv/publications/2021/05/978-87-7038-317-2.pdf

Octamethyl cyclotetrasiloxane (D4)

For DNEL derivation of the cyclosiloxanes, the recent assessment by the Danish EPA (2021) will be used.

The Danish EPA (2021) considered the best basis for an assessment of D4 to be the expert assessment by SCCS (2010). No further data were found in the REACH registration of the substance.

The following three inhalation tests are considered relevant for the DNEL derivation.

In a 90-day inhalation test with rats exposed to 0, 35, 122, 488 or 898 ppm (0.42, 1.48, 5.91 and 10.87 mg/l) 6 hours per day, 5 days per week, increased incidences of ovarian atrophy were observed in the ovaries at the highest exposure level in female rats. From the study a NOEC of 35 ppm was observed for increased liver weight and a LOAEC of 35 ppm for adverse effects in the lungs.

In a one-generation inhalation study in rats, a reduced number of yellow bodies and increased liver and kidney weights at 35 ppm were found, but the effects were not considered as adverse, and a NOAEC of 300 ppm was determined. At 700 ppm, reduced a number of implantations and fetuses as well as increased pre- and post-implantation loss were observed. On this basis SCCS (2010) determined a NOAEC 300 ppm for reproductive toxicity.

In a carcinogenicity study with D4 in rats, inhalation at the highest exposure level of 700 ppm (8474 mg/m3) caused an increased incidence of tumors in the uterus. Furthermore, the exposure resulted in significantly increased kidney and liver weights. None of these effects were seen at 150 ppm (1816 mg/m3) that is considered as a NOAEC. As D4 is not a genotoxic substance, SCCS (2010) found that the induction of tumors is subject to a threshold value. The mode of action and the relevance to humans have not been clarified, but the effect of D4 as a dopamine agonist in rats is estimated to be a possible factor.

As basis for risk assessment of D4, SCCS (2010) determined the following values:

NOAEC for systemic effects: 150 ppm (1816 mg/m3) in relation to tumors in the uterus, and effects on kidneys and liver, based on the data from the carcinogenic study.

For local effect a LOAEC of 35 ppm (420 mg/m3) can be set.

DNEL, systemic effects

The starting point is a NOAEC for systemic effects: 150 ppm (1816 mg/m3) in relation to tumors in the uterus, and effects on kidneys and liver. This dose level is converted to a 24-h average exposure level:

NOAEC (continuous) = 1816 mg/m3 x 6h/24 h x 5 days/7 days = 324 mg/m3

From this value, a tolerable exposure level can be calculated:

$DNEL_{systemic}$ = 324 mg/m3 / 2.5 x 10 = 13 mg/m3

An uncertainty factor of 2.5 is used to extrapolate from rats to humans in connection with inhalation exposure, another factor 10 is used to allow for differences in human susceptibility.

DNEL, local effects

For inhalation, the starting point is a LOAEC value of 35 ppm (420 mg/ m3) from a 90-day inhalation test based on inflammation in the lungs. As it is not known to which extent this effect is caused by the actual exposure level during 6 hours or is due to a 24-h average dose, a cautious approach is used and the exposure value is converted to 24 hours of continuous exposure:

LOAEC (continuous) = 420 mg/m3 x 6h/24 h x 5 days/7 days = 75 mg/m3

From this value, a tolerable exposure level can be calculated:

$DNEL_{local}$ = 75 mg/m3 / 2.5 x 10 x 3 = 1.0 mg/m3

An uncertainty factor of 2.5 is used to extrapolate from rats to humans in connection with inhalation exposure, another factor 10 is used to allow for differences in human susceptibility. Further a factor of 3 is used because of extrapolation from LOAEC level.

References

Danish EPA (2021). Survey and risk assessment of siloxanes in cosmetic products. Survey of chemical substances in consumer products No. 185**.** https://www2.mst.dk/Udgiv/publications/2021/05/978-87-7038-317-2.pdf

SCCS (2010). Opinion on Cyclomethicone. Octamethylcyclotetrasiloxane (Cyclotetrasiloxane, D4) and Decamethylcyclopentasiloxane (Cyclopentasiloxane, D5). SCCS/1241/10

Decamethyl cyclopentasiloxane (D5)

For DNEL derivation of D5 the recent assessment by the Danish EPA (2021) will be used.

The Danish EPA (2021) considered the best basis for assessment of D5 to be the expert assessment by SCCS (2016). No further data was found in the REACH registration of the substance.

The following inhalation tests are considered relevant for the DNEL derivation.

In a 90-day inhalation test, where rats were exposed 6 hours per day, 5 days per week, to 0, 28.6, 49.2, 87.7 and 233 ppm of D5, a NOAEC of 49.2 ppm (744 mg/m3) was found based on effects in lungs and nasal mucous membranes. In female rats, effects in the ovaries and the uterus were found at the highest exposure level of 233 ppm (3536 mg/m3). Enlarged liver was found in female rats at 49.2 ppm and above and at 233 ppm in male rats. As no histopathological changes in the liver were observed, the SCCS (2016) did not consider these effects as adverse. In connection with this project, the effects on the liver are, however, based on a precautionary approach considered to be a relevant finding for risk assessment (especially as other cyclo-siloxanes also impact the liver). Thus, LOEC of 49.2 ppm is used as a NOAEC for liver impact.

Both a one-generation and a two-generation reproduction study have been performed in rats. From these studies, SCCS (2016) determined a NOAEC value of 160 ppm (2428 mg/m3 – the highest exposure level tested) for impact on both fertility and foetal development. SCCS (2016) did however note, that exposure at 160 ppm caused increased anogenital distance in the newborn males but doubted these findings as they could not be supported by relevant data concerning hormonal effects.

In a carcinogenic study with rats, inhalation at the highest exposure level of D5 of 160 ppm caused an increased incidence of cancer in the uterus, whereas this was not seen at 40 ppm (607 mg/m3) that was determined as a NOAEC.

SCCS (2016) found that the mode of action behind these findings could not be clarified. It was considered unlikely that the effects were related to hormonal effects, as studies have shown that D5 does not have direct estrogen, anti-estrogen, androgen, anti-androgen or progesterone activity. SCCS (2016) found indications that D5 can act as a dopamine agonist, which may be significant for development of cancer in the uterus. In any case, the carcinogenic effect of D5 is considered to be subject to a threshold, as D5 is not considered to be genotoxic.

SCCS (2016) determined the following relevant values for hazard characterisation and risk assessment:

NOAEC for systemic effects, cancer in the uterus: 40 ppm (607 mg/m3).

NOAEC for local effects in the lungs: 49 ppm (744 mg/m3).

DNEL, Systemic effects

Based on a NOAEC of 607 mg/m3, the Danish EPA (2021) derived the following tolerable exposure level for systemic effects:

The NOAEC is as a first step converted to 24 hours continuous exposure:

NOAEC (continuous) = 607 mg/m3 x 6t/24 h x 5 days/7 days = 108 mg/m3

From this value, a tolerable exposure level was calculated:

$DNEL_{systemic}$ = 108 mg/m3 / 2.5 x 10 = 4.3 mg/m3

An uncertainty factor of 2.5 is used for extrapolation from rats to humans for inhalation exposure and a factor 10 is used to consider differences in human susceptibility.

DNEL, local effects

In connection with inhalation and local adverse effects in the lungs and an enlarged liver, the starting point is a NOAEC of 744 mg/m3 from exposure during 6 hours per day, 5 days per week. As it is not known to which extent this effect is caused by the actual exposure level during 6 hours or is due to a

24-h average dose, a cautious approach is used and the exposure value is converted to 24 hours of continuous exposure:

NOAEC (continuous) = 744 mg/m3 x 6h/24 h x 5 days/7 days = 133 mg/m3

From this value, a tolerable exposure level can be calculated:

tolerable exposure levels (inh, local) = 133 mg/m3 / 2.5 x 10 = 5.3 mg/m3

An uncertainty factor of 2.5 is used for extrapolation from rats to humans for inhalation exposure and a factor 10 is used to consider differences in human susceptibility.

Thus, a $DNEL_{local}$ of 5300 µg/m3 is concluded.

References

Danish EPA (2021). Survey and risk assessment of siloxanes in cosmetic products. Survey of chemical substances in consumer products No. 185. https://www2.mst.dk/Udgiv/publications/2021/05/978-87-7038-317-2.pdf

SCCS (2016). Opinion on decamethylcyclopentasiloxane (cyclopentasiloxane, D5) in cosmetic products. SCCS/1549/15. Final version of 29 July 2016

Cyclohexanone

DNEL, systemic effects

For this substance a $DNEL_{systemic}$ of 2.5 mg/m^3 was calculated in SCHEER (2021), which is adapted in this report.

A 13-week inhalation study in rats and mice was identified as the most relevant study. From this a NOAEC of 100 ppm (401 mg/m^3) was identified based on effects on liver, bile duct and kidneys at 250 and 6025 ppm.

For systemic effects the following calculation was made by SCHEER (2021):

NOAEC: 401 mg/m^3 x 5d/7d x 6 h/24h (time adjustment for human exposure situation)

DNEL = NOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 10

AF2 (intraspecies, difference in human sensitivity) = 10

$DNEL_{systemic}$ = (401mg/m^3 x 5d/7d x 6 h/24h) / (10 x 10) = 0.716 mg/m^3

DNEL, local effects

No specific $DNEL_{local}$ was calculated by SCHEER (2021), but it was indicated that the same LOAEC of 763 mg/m^3 would apply for local effects.

DNEL = NOAEC/(AF1 x AF2 x AF3)

AF1 (interspecies animals to human) = 2.5 (for local irritation effects)

AF2 (intraspecies, difference in human sensitivity) = 10

AF3 (low confidence) = 3

$DNEL_{local}$= 763 mg/m^3 / (2.5 x 10 x 3) = 10 mg/m^3

References

SCHEER (2021). Toxicological reference values for certain organic chemicals emitted from squishy toys with regard to adopting limit values under the Toy Safety Directive 2009/48/EC ‘Chemicals in squishy toys’. Adopted on 3 June 2021.