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Survey and risk assessment of chemicals from gaming equipment

Survey of chemical substances in consumer products No. 191

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Preface

This report presents the results from survey and risk assessment of gaming equipment, carried out by the Danish Technological Institute and DHI for the Danish Environmental Protection Agency in the period April to December 2022.

The survey includes legislation, market research and identification of emission of chemicals that are relevant for gaming equipment. The market research focuses on computers, monitors, keyboards, mice, headsets, mouse pads and chairs. In connection, field studies have been carried out with air and dust measurements of chemicals and particles at schools, gaming cafés and private homes where computer games are played.

Realistic exposure scenarios have been prepared based on the survey and field investigations. These were used to create a risk assessment for gaming equipment.

Gaming equipment was selected for testing for emissions to the indoor climate and 33 articles were purchased in the period between June and July 2022. Analyses of gaming equipment were carried out by testing in climate chambers and chemical analysis of the air samples.

The results form the basis for a risk assessment of selected chemical substances from gaming equipment in a realistic worst-case scenario of young people's exposure during gaming.

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Summary

The emission of particles and volatile substances from gaming equipment has been investigated by market survey and literature research, by 7 field studies at colleges, internet cafes and private homes, as well as by 25 product tests in climate chambers of new computers, monitors, keyboards, mice, headsets, mouse pads and gaming chairs.

The literature survey shows that gaming equipment can be a pollution source of chemical substances in the indoor air and in dust. A total of 153 volatile substances (VVOCs and VOCs) have been reported as well as 90 semi-volatile substances (SVOCs) that are mainly found in the dust. The field studies identify several VOCs and SVOCs in dust and air, which may also originate from other sources than gaming equipment. Phosphorous flame retardants and phthalates are identified in dust and air, but not brominated flame retardants or elevated levels of volatile VOCs. When screening the air samples, a further 14 new SVOCs are identified, of which 7 substances probably originate from personal care products, and 3 substances may originate from plastic products: Di-n-butyl adipate (DnBA), dioctyl terephthalate (DOTP) and Irganox 1076. During gaming for 5 hours, increased temperatures due to heat release and CO_2 increases due to human metabolism were measured, while the level of ultrafine particles remained unchanged.

Based on the survey and the field analyses, an initial hazard screening of the chemical substances was carried out in terms of prioritizing the toxicologically most problematic substances that should be analysed for further testing of gaming equipment. As emissions of volatile substances are dependent on climatic conditions such as temperature and humidity, an exposure scenario is drawn up. The following substances identified in the survey and field studies are prioritized in the analysis of gaming equipment emissions in climate chambers:

- Aldehydes: Formaldehyde, acetaldehyde, butyraldehyde/butanal, hexanal
- VOC: 2-ethylhexanoic acid, 2-ethyl-1-hexanol, dimethylformamide, triethylenediamine, furan, tetramethylbutanedinitrile, phenol, cyclic siloxanes (D3, D4, D5, D6)
- Brominated flame retardants: BDE 47, BDE 99, BDE 100
- Other: Acrylamide, formamide

Based on the field studies, a worst-case scenario for a gamer reference room was concluded to be:

Room volume per gaming device:	17.4 m^3
Air change:	0.2 h^{-1}
Climate conditions:	25°C / 50 % RH

Based on the market research, new gaming equipment in different materials and makes was selected, which were identified as being the most popular with the target group by the retailers. For analysis, a complete gaming set was purchased with PC, screen, keyboard, mouse, headset, mouse pad, also four different variants of each type of equipment, i.e., a total of 33 products.

The gaming equipment's emission of particles and volatile substances into the air has been investigated by 25 analyses in climate chambers was computers, monitors, keyboards, mice, headsets, mouse pads and gaming chairs. Gaming PCs and screens were stress tested by gaming in a large climate chamber for 2 time periods with air samples taken for analysis for volatile substances. Hence, 67 substances were identified, including formaldehyde, dimethylformamide, siloxanes, hydrocarbons, polyaromatic hydrocarbons (PAHs), organophosphorus

flame retardants (OPFR) and phthalates, but no brominated flame retardants (BFR). Thirty-four (34) new substances have been identified, and not previously reported in the literature for chemical emissions from gaming equipment. Two complete sets of gaming equipment with all small parts resulted in the highest emissions, with the gaming chairs being identified as the equipment that released the most substances into the indoor air. As a result of heat generation from the computers and monitors, a significant temperature increase, up to 25-30°C occurs, while the number of ultrafine airborne particles decreased slightly during gaming. The measurements confirm the observations from the field studies, that the electronic equipment does not emit particles into the indoor air.

To achieve a focused approach to the risk assessment of the gaming equipment, the measurement results from the climate chamber tests were screened to identify the most problematic substances in the emissions, considering the toxicological effects of the substances and the measured levels.
Based on this screening, several substances of concern in relation to health were identified, and based on a more detailed assessment of the toxicological data for the substances, a tolerable exposure level was determined for each of the substances for use in a subsequent risk assessment, see TABLE I.

TABLE I. Priority substances and tolerable exposure levels

Chemical Name	CAS RN	Tolerable exposure level (DNEL value): critical effect
Formaldehyde	50-00-0	50 µg/m^3: Irritation of the eyes, airway, and nasal mucosa
Acetic acid	64-19-7	1200 µg/m^3: Irritation
2-Ethylhexanoic acid	149-57-5	880 µg/m^3: Developmental effects
2-Ethyl-1-hexanol	104-76-7	800 µg/m^3: Irritation
N,N-Dimethylformamide (DMF)	68-12-2	170 µg/m^3: Liver effects 700 µg/m^3: Irritation
Methylnaphthalene Dimethylnaphthalene Triethylnaphthalene	- 1051-00-0 1052-00-0	58 µg/m^3: Irritation Applicable at individual substance level and the sum of the three substances
Dodecamethylcyclohexasiloxane (D6)	540-97-6	70 µg/m^3: Liver effects / lung effects
2,2'-Azobis(2-methylpropanenitrile)	78-67-1	Data not sufficient for reporting a value
Safrole	94-59-7	0.8 µg/m^3 (relevant to 10^{-6} cancer risk for lifetime exposure)
Dibutylphthalate DBP	84-74-2	23 µg/m^3: Endocrine disrupting effects
Diisobutylphthalate DiBP	84-69-5	29 µg/m^3: Endocrine distrupting effects

Risk assessment of the emission was carried out by calculating the risk characterization ratio (RCR) for the individual priority substances, where the RCR is calculated as:

$$R\text{(chemical x)} = \textit{Measured exposure}\text{ (chemical x)}/\ \textit{DNEL value}\text{ (chemical x)}$$

If the measured exposure to a substance exceeds the DNEL value, and the RCR thus becomes greater than 1, the exposure is considered to constitute an unacceptable risk. To assess the risk of simultaneous exposure to several substances with the same type of effect, summation of the individual RCR-values was done (i.e., the risk contributions for substances with the same effect are added): An example of a risk calculation for gaming chair ID 33 is given in TABLE II.

$$R(sum) = RCR(1) + RCR(2) + \ldots RCR(n)$$

TABLE II. Risk assessment of emissions from gaming chair ID-33. RCR-values in bold indicate risk

ID-33	Measured value	DNEL/critical effect	RCR
Formaldehyde	120 µg/m³	50 µg/m³ eye-airway irritation	**2.4***
Acetic acid	260 µg/m³	1200 µg/m³ eye-airway irritation	0.22*
2-Ethylhexansyre	-	-	-
2-Ethyl-1-hexanol	13 µg/m³	800 µg/m³ eye-airway irritation	0.02*
N,N-Dimethylformamide (DMF)	15 µg/m³	170 µg/m³ liver effects	0.09
		700 µg/m³ eye-airway irritation	0.02*
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalenes, sum	-	-	-
Dodecamethylcyclohexasiloxane (D6)	-	-	-
Safrole	-	-	-
*RCR(sum) irritation			**2.7**

* Substances with the same mechanism of action that are added to a total RCR-value.

Overall assessment of the risk calculations

The emissions from the keyboard, mouse, headset, and mouse pad were extremely low and without risk, as the levels for all the priority substances were below 10 µg/m3, i.e., significantly below the DNEL values.

Very low, but slightly higher emissions were found from PC + monitors. Here, emissions of acetic acid and dodecamethylcyclohexasiloxane (D6) was found, but the calculated RCR-values of 0.03 for acetic acid and 0.21 for D6 are not considered to pose a risk.

By far the highest emissions were found from gaming chairs, where a risk of eye and respiratory irritation was found for the chairs ID-22 and ID-33, primarily because of emission of formaldehyde, as the RCR-values for this substance were respectively 2.6 (ID-22) and 2.4 (ID-33).

Although the RCR-value for gamer's chair ID-27 was below 1, this chair cannot be ruled out as causing a risk of eye and respiratory irritation, as increased temperature from the gamer's body heat during use of the chair will cause somewhat higher emissions than the measured levels at 25 °C.

For the measurements of the two gaming sets, it was assessed that the chemical emissions are close to posing a risk as eye and respiratory irritants. The relatively high RCR-values for formaldehyde of 0.7 and 0.62 for the sets were assessed as originating from the gaming chairs, as the largest formaldehyde emissions were found in the separate measurements of gaming chairs. The two sets cannot therefore be ruled out as causing a risk of eye and respiratory irritation, as increased temperatures from body heat during use of the chair will cause somewhat higher emissions than in the climate chamber where the sets were measured.

Dodecamethylcyclohexasiloxane (D6) was also measured with an RCR-value of 0.19 from one of the gaming sets, and here the source may be the PC or the screen, as D6 was also found in the separate measurements for PC + screen.

Overall, it is worth noting that high emissions of eye and respiratory irritant substances of concern takes place from gaming chairs, while the electronic gaming equipment covered by this project was not found to cause emission that poses any risk.

It must be noted that although the very low air concentrations of SVOC measured from the electronic equipment are not considered to pose a risk by inhalation, the exposure to these substances may be significantly higher as SVOCs tend to adhere quickly to surfaces and dust, so the vapours in the air only make up a small part of the total amount of SVOCs in the room. Therefore, a person's SVOC exposure will mainly come from contact with surfaces and contact with textiles, e.g., bedding and furniture that are present in the room.

Abbreviations

CAS	Chemical Abstracts Service
CLP	Classification, Labelling and Packaging of substances
CMR	Carcinogenic, mutagenic and reproductive toxic substances
BFR	Brominated flame retardant
DNEL	Derived No-Effect Level
DP	Dechlorane Plus, isomer syn- and anti-DP
ECHA	European Chemicals Agency
ECMA	European Computer Manufacturers Association
FR	Fire retardant
GC/MS	Gas chromatography coupled with mass spectrometry
HPLC	High pressure liquid chromatography
Højskole	School for teenagers and young adults (in danish “Højskole”)
LCM	Liquid crystal monomer
LOQ	Limit of Quantification
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MST	Miljøstyrelsen, Danish Environmental Protection Agency
NIST	National Institute of Standards and Technology
NOAEL/LOAEL	No Observed Adverse Effect Level/ Lowest Observed Adverse Effect Level
OPFR	Organophosphorous flame retardants
PAH	Polyaromatic hydrocarbon
PBDE	Polybrominated diphenyl ether
PC	Personal computer (Computer)
PCB	Polychlorinated biphenyl
POP	Persistent organic pollutant
PTFE	Polytetrafluoroethylene
PU	Polyurethane
PVC	Polyvinylchloride
RCR	Risk characterisation ratio
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
RoHS	Restriction of Hazardous Substances in Electrical and Electronic Equipment
RH	Relative humidity
RSD	Relative standard deviation
SCCP	Short-chained chlorinated paraffins
STOT RE	Specific Target Organ Toxicity Repeated Exposure
STOT SE	Specific Target Organ Toxicity Single Exposure
SVHC	Substances of Very High Concern
SVOC	Semi-volatile organic compound, bp > 287°C (n-hexadecane C16)
TDS	Thermal desorption system
TVOC	Sum of volatile organic compounds (C6-C16) as toluene equivalents
VOC	Volatile organic compound, bp 68–287°C (C6-C16)
VVOC	Very volatile organic compound, bp < 68°C (n-hexane C6)

1. Introduction

Esport and gaming have become a large part of young people's everyday lives (Christensen et al., 2017), where computer games are played in private homes, schools and at competitive level. Sales of gaming equipment in Denmark are expected to increase (Vækstfonden, 2019), where computers and accessories are continuously upgraded to keep up with the performance requirements of new games that are launched. Gaming equipment consists of many materials and electronics that may contain problematic chemistry. Since electronics are heated during use, gaming equipment can emit volatile and semi-volatile chemicals into the air that can be harmful to human health, such as brominated flame retardants and phthalates.

1.1 Purpose

This study aims to:

- Survey supply and sales of gaming equipment and use by young people
- Conduct field surveys to clarify indoor climate conditions in places where games are played, in private homes, gaming cafes and institutions
- Measure the heat output of gaming equipment during tests in climate chambers
- Analyse emissions of volatile substances from gaming equipment, e.g., computers, monitors, keyboards, mice, mouse pads, gaming chairs and headsets
- Evaluate potential health risk for the target group

It is expected that the study can lead to recommendations to reduce potential exposure from the chemicals that can be released from gaming equipment.

1.2 Limitations

The survey and analyses include a screening of volatile and semi-volatile substances which may be released from gaming equipment and are present in the air as vapor or very fine particles that can settle in dust or on surfaces. The primary focus is on flame retardants and plasticisers, and 32 selected SVOCs (phthalates, brominated and organophosphorus flame retardants). Other SVOC fluorine substances, PCBs and bisphenol-A are not included in the analyses. Analyses of air have been carried out in both field studies and laboratory tests of equipment, while dust has only been analysed in the field studies.

The market research is limited to PC equipment and does not include gaming consoles.

This study deals with exposure to chemical substances from gaming equipment by inhaling air, and thus no other routes of exposure such as oral (through the mouth) or dermal (through the skin). The focus is on young people's exposure to gaming equipment, as this group typically spends the most time gaming.

2. Survey

The purpose of the survey is to gather knowledge from existing literature regarding emissions of particles and chemical substances from gaming equipment, and to identify gaming equipment popular with the target group, by conducting a market survey in Denmark. In parallel with the field surveys, a list of gaming products on the market is prepared by searching Danish online stores. This forms the basis for a plan for field surveys, purchases, and analyses of gaming equipment respectively.

This section deals with the results of the survey of gaming equipment in the period May – June 2022. The survey consists of the following activities:

- Examination of legislation for chemicals relevant to gaming equipment
- Markings and manufacturing standards for chemical safety of electronic equipment
- Survey of chemicals that can be released form gaming equipment
- Market research of gaming equipment with contact to retailers and organizations

2.1 Legislation and regulation of gaming equipment

Gaming equipment that contains electronics, including PC, screen, mouse, keyboard, headset, and chair, is covered by the Danish RoHS order, BEK no. 338 of 17 March 2022, which implements the EU's RoHS directive (no. 65/2011) restricting hazardous substances in electrical and electronic equipment: Lead, mercury, cadmium, hexavalent chromium (chromium VI), polybrominated biphenyls (PBB), polybrominated diphenyl ethers (PBDE), di(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate and diisobutyl phthalate (DIBP).

All types of gaming equipment included in this survey is subject to restrictions on the chemical content of their materials according to the EU's REACH regulation (no. 1907/2006), Annex XVII. There is also an obligation to provide information for the content of particularly problematic chemicals (SVHC) on the candidate list of more than 0.1% by weight, according to Article 33, subsection 1.

The restrictions in the REACH regulation and the RoHS executive order include limit values for the chemical content in products, but not limit values for emission/outgassing. The EU's proposal for the revision of REACH Annex XVII (G/TBT/N/EU/888 (2022), concerning the restriction of formaldehyde release from articles used indoors, with limit values in air on non-wood-based articles of 0.080 mg/m3, has been accepted in 2022 by the World Trade Organization (WTO 2022)[1].

2.2 Labelling schemes for electronic equipment

Gaming equipment and other electronic equipment were examined for markings concerning chemical safety. Three brands were identified which have requirements for limiting chemicals in electronic equipment.

[1] https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/G/TBTN22/EU888.pdf&Open=True

TCO Certified is the most widespread sustainability certification for IT products. The latest generation of TCO certification, TCO Edge, includes requirements for material safety and sustainability. TCO contains requirements for halogen-free monitors, use of recycled plastic in electronic components and a list of approved flame retardants and plasticizers (TCO certified, 2022).

The CE mark affirms that a product complies with certain EU requirements for safety, health, and environmental protection. The CE mark is mandatory for electronic devices and other products that are subject to EU specifications for safety. CE marking is also required to affirm compliance with the RoHS Directive. Since 2003, the EU has restricted the use of dangerous chemicals in electronic equipment and the directive is continuously updated.

Electronic equipment is produced and imported primarily from China, where the Chinese government requires an electrical safety label, CCC, which is in accordance with the EU Commission's rules. This regulation was last updated in 2020 and prohibits all heavy metals, organotin compounds, formaldehyde, as well as specific VOCs: BPA, halogenated solvents, aniline, alkylphenols and alkylphenol ethoxylates, perfluorinated and polyfluorinated chemicals (PFOS/PFAS). In addition, some flame retardants, some polycyclic aromatic hydrocarbons (PAHs), dimethyl fumarate (DMFu) and N-nitrosamine are prohibited.

2.3 Survey of gaming equipment on the market

The purpose of this market research is to find out which equipment is popular for gaming, so that equipment that is widespread in use can be selected for analysis. In the Nordic countries, gaming on computers is most popular, therefore the survey does not include game consoles or mobile phones.

According to the Baltic Game Industry[2], which is an EU-supported interest organization for the promotion of the gaming industry in the Baltic countries, there are 162 companies in Denmark with around 800 employees that deal with gaming equipment (Sünner & Rische, 2018). These companies are suppliers of gaming equipment, software developers of video games, and gamer café locations. According to a wholesaler of gaming equipment, which covers the entire Nordic region, 1 million headsets, keyboards, mouse pads, gaming chairs were sold in 2020 (personal communication 2022).

A market survey was carried out in Denmark. Suppliers of gaming equipment were primarily found using search engines on the internet. A search was made for suppliers of gaming equipment in general and more specifically for the most popular items sold including PCs, monitors, and other accessories such as keyboards, mice, mouse pads, headsets, and chairs. This search resulted in 15 major retailers of gaming equipment. Products for sale from these suppliers are imported either as finished goods or as components that are assembled in Denmark. Some companies sell their own branded and fully assembled gaming equipment.

Gamers and retailers were asked which PC setups with monitors (screens) are most popular. Three categories were identified:

- Desktop PC with single monitor which is either flat or curved format
- Desktop PC with two monitors with flat screens are preferred here
- Laptop gaming PCs are often used with an additional screen, either curved or flat

Curved screens have a wider format, which is good for immersive gaming including adventure games, while flat screens are preferred for shooting games.

[2] https://baltic-games.eu/171/

The most popular products for each category (PC, monitor, keyboard, mouse, mouse pad, headset, and chair) were identified on the various suppliers' websites. The websites sort by the popularity of the products based on both the number of clicks and the number of sales of the product in question and varies from day to day.

Potential gaming setups to purchase for chamber testing were selected based on each vendor's popularity list within the product categories as well as on variety of products and materials. No specific chemical information could be found about the materials in gaming equipment when searching these product pages.

The selection of gaming equipment also considered the price of the equipment, so that the examined equipment is in a price range that can be purchased by the broadest target group.

Complete packages of gaming equipment are sold by some vendors, containing a PC, screen, keyboard, mouse, mouse pad, headset, and chair. These are popular and were selected for testing. Additionally, various retailers were contacted to learn about their methodology for analysing their most popular products. Most retailers would not provide information on which specific gaming equipment was the best seller over a given period.

2.4 Identified substances that are potentially released from gaming equipment

The survey started with a search for publications concerning chemicals used in the manufacturing of electronics and other gaming specific equipment, focusing on emissions of particles and chemicals to air and dust. Knowledge databases and citation databases including Elsevier-Science direct, SpringerLink, SciVerse Scopus, Google Scholar and the Danish Royal Library were used. Relevant references from the identified literature were further explored. Relevant research from the Danish Environmental Protection Agency is also included in the survey.

Gaming equipment is composed of several different categories of materials and electronics. Different types of hard plastic, metal, printed circuit boards etc. are used in electronic equipment such as computers (plugs, chargers, transformers), monitors , keyboards, mice, headsets, and gaming chairs. Soft plastic and metal are used in wiring that connects the equipment. Foam is used in mouse pads, headsets, and gaming chairs, including polyurethane foam (PU foam). Textiles are used in cords, headsets, and gaming chairs. Batteries, either replaceable or rechargeable, are found in laptops, wireless headsets, keyboards, gaming chairs and mice.

Electronic products and cables develop heat during use, and to avoid fire, fire-retardant chemicals are added to the plastics, foams, and textile materials. Hard plastics are typically used in enclosures for electronic equipment such as ABS (acrylonitrile butadiene styrene) and PS (polystyrene), which can contain high amounts of brominated flame retardants (Pivnenko 2017, Harju 2009).

PU foam in gaming chairs, headsets and mouse pads may also contain brominated flame retardants (Harju 2009) as well as formamide (EU 2015/2115), dimethylaminoethanol (DMAE) (Klinke et al., 2018), dimethylformamide (DMF), cyclosiloxanes, formaldehyde, and VOCs (Poulsen, 2020).

The plastic insulation of wires is often PVC (polyvinyl chloride) with softening chemicals such as phthalates added to maintain flexibility in use. A recent study of PVC-containing consumer products showed content of phthalates in a phone charger (Kastberg et al., 2020) and several phthalates are mentioned in connection with PVC and electronics (Mikkelsen et al., 2014).

The amount of available literature on emissions of chemical substances from gaming computers and gaming equipment is limited. Therefore, the starting point is publications regarding the investigation of emissions from general electronic equipment such as computers and monitors (both PC and TV monitors) and investigations from gaming-like environments, such as office areas with PCs and monitors, and other rooms with many computers, e.g., computer workshops and schools. A total of 17 relevant publications have been found that report results from chemical analyses in air and dust during field investigations and chamber tests. This project focuses on SVOCs such as organophosphates and brominated flame retardants, phthalates, and PCBs, as well as VOCs.

Based on the literature search, more than 240 different chemicals have been found in air and dust, relevant to gaming equipment. Further information on the naming of the chemicals and physical parameters, e.g., boiling point and melting point, is obtained in the PubChem database. The complete list of identified chemicals and abbreviations used appears in Appendix 2. In the following section, the abbreviations for the chemicals will be used.

2.4.1 Chemicals measured in the air

Emissions from computers and similar equipment to air were investigated in 12 publications by collection of VOCs on Tenax TA and SVOCs on PUF (polyurethane foam), where 7 have found VOCs, and 7 have found SVOCs.

VOCs

VOCs such as aldehydes, alcohols, aliphatic hydrocarbons, as well as a few ketones, esters, acids, and terpenes have been found in the literature. The review article Cacho et al. (2013) have investigated emissions in office environments in Europe. The five VOCs with the highest concentration (EU average) were dichloromethane (50.2 µg/m^3), toluene (48.7 µg/m^3), xylene (18.9 µg/m^3), acetone (18.5 µg /m^3) and formaldehyde (16.8 µg/m^3).

A Danish Environmental Protection Agency study from 2005 examined emissions from electronic products, including computers and TV sets (MST, 2005). The five VOCs with the highest emission rate are phenol, butanal, xylene, ethylbenzene, and formaldehyde. In 2020, the Swedish Environmental Protection Agency has further investigated emissions from PU foam, which can also be present in gaming chairs, mouse pads, and headsets. VOCs have been analysed and DMF has been found in a high concentration of 1500 µg/m^3. In addition, cyclic siloxanes were found in the concentration range 7-190 µg/m^3. Measurements from Davis et al. (2021) of emissions from upholstered chairs, report the top ten VOCs found. The 5 VOCs with the highest concentrations are mentioned here: hexanal, propanoic acid, 1-butanol, propylene carbonate, and pentanal.

Destaillats et al. (2008) have written a review on emissions from office equipment referring to 3 studies which have found that computers and laptops both emit VOCs and SVOCs. The highest emission concentrations were from a laptop including the following VOCs: Methyl carbonate (223 µg/m^3), 2-Butoxyethanol (217 µg/m^3), ethyl carbonate (112 µg/m^3), cyclohexyl benzene (50 µg/m^3) and 2-Ethyl-1-hexanol (34 µg/m^3). The latter is registered under REACH regulation and is a harmful chemical (ECHA).

Liu and Abbat (2021) have investigated emissions from LCD monitors (computer, laptop, and TV screens) by air analysis and found some of the same chemicals as Ca-cho et al. (2013). The substance furan has been found in the emissions. Furan is of toxicological interest as it is classified as a carcinogenic, mutagenic, and toxic to reproduction (CMR) substance. In addition, some liquid crystal monomers (LCM) have been detected, which are classified as persistent organic pollutants (POP) (Su et al., 2019).

SVOCs

The review article by Destaillats et al. (2008) have found the following SVOCs from computers and laptops in the concentration range 1-446 ng/m^3: HBBZ, RDP, BDP, TPP, BDE-47, BDE-100, BD-99, TBBPA. HBBZ is also found in the study by Sun et al. (2018), who further found HBCD in computer cases and printed circuit boards. Kemmlein et al. (2003) have performed a chamber test of a complete set of computer, monitor, mouse, keyboard, and printer for emissions of SVOCs and have found HBBZ, RDP and BDP in the concentration range of 1-20 ng/m^3. All of the above SVOCs found in the air are commonly used brominated flame retardants.

In addition to brominated flame retardants, organophosphate flame retardants (OPFR) are also used in several types of products. Davis et al. (2021) and Kemmlein et al. (2003) have measured emissions of TPP/TPHP on resp. 0.9 ng/m^3 and 85 ng/m^3. Sakhi et al. (2019) found OPFRs in air measurements in Norwegian homes (average of all OPFRs 56 ng/m^3).

Reche et al. (2019) have also found polychlorinated flame retardants such as Syn-DP, anti-DP, DP (0.2-14 pg/m^3) in the air measured in office spaces.

Seo et al. (2022) found 2-25 times higher concentrations of 16 PAHs (sum PAH: 29-46 ng/m^3) in indoor climates with many computers in offices, computer rooms and server rooms. Naphtalene (10-25 ng/m^3) and phenanthrene (7-13 ng/m^3) were measured at the highest concentrations. Computers were verified as a source of PAHs by measuring inside computer cabinets and from the isolated components: printed circuit board, PVC cable and transistor. PAH concentrations were highest in new computers and decreased with age. In air, PAHs with low molecular weight were found in highest concentrations in the gas phase and PAHs with high molecular weight were found in highest concentrations in the particle phase. Chamber tests of computers under load (Maddalena et al., 2006) emitted low concentrations of the PAHs naphthalene (3 ng/m^3) and acenaphthylene (1 ng/m^3).

Wei et al. (2021) have carried out air measurements in schools and have found SVOCs such as PCBs and phthalates. Phthalates have been found in concentrations in the range 48-3800 ng/m^3, where DiBP has been found with the highest concentration (3800 ng/m^3). PCBs have been found in concentrations of 0.1-1.1 ng/m^3, with PCB 105 and PCB 138 found to have the lowest concentration. Phthalates (DMP, DEP, DiBP, DnBP) have been found in the air of Norwegian homes in concentrations of 42-459 ng/m^3 (Sakhi et al., 2019).

2.4.2 Chemicals measured in dust

SVOCs are semi volatile substances with a low vapor pressure, which are in equilibrium with the gas phase and particles in the air and accumulate in dust and other surfaces in the indoor environment (Wei et al., 2016). As a result, higher SVOC concentrations are measured in dust than in the air. Several studies have found SVOCs such as OPFRs, PCBs, phthalates and especially BFR in the dust in office areas, computer workshops, schools, and homes.

Genisoglu et al. (2019) investigated brominated flame retardants in settled dust in computer workshops and found 19 BFRs, of which BDE-209 (1802 ng/g) and BEH-TEBP (993 ng/g) were found at the highest concentrations. The other BFRs are found in concentrations below 100 ng/g, except for EH-TBB which is found at 136 ng/g. Reche et al. (2019) found PBDEs in a total concentration of 978 ng/g in dust collected in office spaces. In addition, 4 different BDEs have been found in dust measurements in schools (18-96 ng/g) (Wei et al., 2021). Additionally, the following BFRs have been found in collected dust in Chinese homes in the concentration range 0.45 ng/g-419.4 ng/g: PBT, PBEB, HBB, EHTBB, BTBPE, BEHTEBP, DBDPE (Niu et al., 2019).

Phthalates have been found in high concentrations in dust in schools studied by Wei et al. (2021). These are phthalates such as BBP, DBP, DEHP, DEP, DiBP, DiNP in concentrations from 21,700 ng/g to 9,690,000 ng/g. The same study found 10 PCBs in the concentration range 19-119 ng/g. The same phthalates, including DMP, have been found in the dust collected in office spaces and homes in concentrations ranging from 202 ng/g to 557,000 ng/g (He et al., 2015).

In addition to BFRs and phthalates, Su et al. (2019) found LCM in dust collected in laboratories, hotels, electronics workshops, and schools. Both Genisoglu et al. (2019) and Reche et al. (2019) have found DP in dust measurements in 15-22 ng/g and 169-1060 ng/g. Organophosphate flame retardants (TCEP, TCPP, TDCPP, TPP/TPHP) have been found in the dust collected in offices and homes at concentrations of 630-2850 ng/g (He et al., 2015). Organophosphate flame retardants are added to PU products (Lu et al., 2021).

The survey's literature study concludes that computers and computer equipment release volatile chemicals into the indoor air. Several of the chemicals found to be emitted by this equipment have a hazard classification indicating a potential health risk when inhaled, specifically:

- VVOCs: Aldehydes (formaldehyde)
- VOCs: 2-Ethyl-1-hexanol, dimethylformamide (DMF), furan and cyclic siloxanes
- SVOCs: Flame retardants (BFR, OPFR, PAH, PCB) and phthalates

2.5 Analysis methods for measuring emissions from gaming equipment

During the survey, several different methods were identified that can be used to measure emissions from gaming equipment during field surveys and chamber analyses. In the following, those methods are summarised.

2.5.1 Methods for measuring chemical substances in air and dust

Analytical principles for measuring volatile substances in air consist of active collection of a volume of air via controlled flow with a pump. During collection, the substances are absorbed onto a test tube (with an absorptive medium) which is subject to laboratory analysis. Sample tubes are extracted either with solvent or by thermal desorption (TDS), analysed by liquid chromatography (HPLC) or gas chromatography (GC), and the substances are detected by spectroscopy (UV, MS, or MS/MS).

Aldehydes and ketones (VVOC/VOC carbonyls) are determined by collecting approx. 10-100 L of air on DNPH tubes and analysis by HPLC-UV (ISO 16000-3). Volatile organic substances (VOC) are collected on Tenax TA (approx. 1-6 L of air) and analysed on TDS-GC/MS (ISO 16000-6). The detection limit is approx. 1 $\mu g/m^3$. ISO 16000-6 can be used for screening for SVOCs, up to the boiling point of docosane (C22) approx. 369°C, which is however not optimal.

For the analysis of semi-volatile SVOCs, special methods are required which are suitable for measuring low concentrations below 0.1 ng/m^3 (0.0001 ug/m^3) in air or 0.1 ng/g in dust (Lucattini et al. 2018, Raffy et al. 2016). A larger volume of air, typically 0.5 – 10 m^3, is collected on high-capacity media such as PU foam or OVS/XAD, which is extracted with solvent. Many different SVOC analysis methods published in the literature refer to the survey in section 2.4. SVOCs are quantified as substance-specific target analyses with internal standards and chromatographic analysis coupled with tandem-MS detection, either GC/MS-MS or LC/MS-MS, or other specialised instruments that are optimal for the detection of the different substance groups. SVOCs with polar groups (alcohols, phenols, acids) can be derivatized before analysis by GC/MS.

2.5.2 Methods for measuring emissions from gaming equipment

Methods for analyses of emissions from gaming equipment were not identified. Emissions of chemical substances from gaming accessories can be measured in climate chambers by standardised methods derived from ISO 16000-9. Emissions of particles and volatile substances from office equipment such as monitors, computers, and portable computers (laptops) can be tested according to the standards ECMA-328-2 (2017) and ISO/IEC 28360-2 (2018). The standards specify the conditions for determining emission rates from electronic equipment during intended operation. New computer equipment's packaging must be removed, and the chamber test started no later than 24 hours after. The equipment must not have been switched on for more than 3 days before the start of the test. The standard describes a typical usage scenario for the computer equipment: That it is switched on for 8 hours at a time for 3 days in "idle mode", corresponding to 24 hours. Test conditions in climate chambers must be 23 ± 2 °C and 50 ± 5% relative humidity (RH), with ventilation rate of 0.5–2 h^{-1}. Ozone is monitored and air samples (Tenax and DNPH) are taken between 3 to 4 air changes after the equipment is placed and switched on in the climate chamber. Analyses of VOCs are covered by ISO 16000-6 and carbonyls are relevant to ISO 16000-3.

Tests of computer equipment in climate chambers (Maddalena et al., 2006) showed that ozone or ultrafine particles (UFP) are not emitted, while printers and copiers emit ozone and particles. Based on this finding ozone is not measured when testing gaming equipment in the present study.

The horizontal reference method EN 16516, entitled "Construction products: Assessment of release of dangerous substances - Determination of emissions into indoor air", specifies a reference room, emission test in climate chambers, collection of air samples and chemical analysis of volatile substances by reference to ISO 16000-9/6/3 the methods mentioned in section 2.5.1. According to EN16516, VOCs and aldehydes are only reported in concentrations above 5 μg/m^3, except for carcinogenic substances Cat. 1A and 1B, which are reported as low as 1 μg/m^3.

3. Field survey

The purpose of the field survey is to gather knowledge about the indoor climate conditions that exist in homes, in internet cafes and in schools, as well as to investigate the young people's exposure to chemical substances under realistic worst-case conditions. In addition, the purpose is to register gaming equipment and the parameters that are relevant to the air quality in the room, such as temperature, building materials used, other furniture and fixtures and the number of people and PCs. The results of the field surveys are included in the survey and are used to determine the measurement program and select products for chamber testing.

This chapter describes the method and results of the field surveys, which took place in June 2022. Analysis of data and collected samples took place in June and July 2022.

The case studies consisted of the following activities:

- Registration of the equipment used
- Registration of general conditions such as room characteristics, number of people and age, playing frequency and games etc.
- Registration of the climatic conditions under which games are played, temperature, relative humidity, CO_2 concentrations and ultrafine particles
- Collection and analysis of the air quality for a wide spectrum of chemical substances
- Collection and analysis of dust for heavy volatile substances (SVOC)

3.1 Methods and materials

For the field study, a total of 7 sites were selected, where young people game either alone or with several people in the same room. The study includes 4 cases in private homes, 1 case at an internet café and 2 cases at a "højskole" (danish, meaning school for teenagers and young adults) that has Esport as a main subject. All cases were located on Zealand in Denmark. The private homes were recruited through personal contacts, while the businesses and schools were contacted directly and asked about participation in the project.

The field measurements were carried out over a period of 14 days in June 2022. During the field investigations, several different measurements and registrations were carried out. TABLE 1 shows which parameters have been investigated, as well as the measurement methods used.

TABLE 1. Overview of measured and recorded parameters, and associated methods

Type	Parameter	Measurement	Method and equipment
Air	VOCs	Screening of volatile substances (VOC, SVOC) in air, including flame retardants	ISO 16000-6: VOC (Tenax)
Air	Aldehydes	Formaldehyde, acetaldehyde, propanal, butanal, acrolein	ISO 16000-3: C1-C4 aldehydes (DNPH)
Air	SVOCs	Semi volatile brominated flame retardants, phthalates, organophosphorus	GC/MS-MS Special analysis (PUF)
Air	Ultrafine particles	Particle diameter 0.02 µm to 1 µm	TSI P-Trak 8525 Particle meter

Type	Parameter	Measurement	Method and equipment
Air	Temperature/Relative humidity	Air quality	IC-meter (Indoor climate meter)
Air	Carbon dioxide (CO_2)	Measurement of personal load. Indicator for air change/persons/room size	IC-meter (Indoor climate meter)
Air	Air quality	Odour and acceptability	Subjective perception of air quality
Dust	SVOCs in deposited dust	Dust diameter > 0.7 µm selected SVOCs: semi volatile brominated flame retardants, phthalates, organophosphorus	Collection on filter when vacuuming. Extraction with subsequent GC/MS-MS Special analysis
Gaming equipment	Temperature	Temperature of gaming equipment: PC, monitor under stress testing	IR Infrared thermometer Testo 830-T1, measured at 15-20 cm from the subject
Record	Participants	Number of people and ages	Asking participants ages
Record	Exposure time	Daily/weekly exposure/gaming	Asking participants for daily hours played
Record	Measurement conditions	Physical data: gamer room in relation to air quality and dust quantities	Building data, windows, ventilation, ventilation conditions, mechanical ventilation, gamer room description, including frequency of cleaning, visible dust.
Record	Spatial variables (density)	Equipment quantity and type	Number of gaming stations, accessories, room size. Desktop/laptop, monitor screen size, 1 or 2 monitors per PC
Record	Equipment documentation	Gaming products: make and age for mapping	Photographs of gaming setups and chairs (Note: label/make)
Record	Computer game	Note: Games that strain the PC and can cause extra heat development	The 3 most common games played

Measurement of chemical substances and ultrafine particles in the air and collection of sedimented dust on surfaces for analysis were carried out. The measurement points were chosen to be as representative as possible in relation to the air inhaled by the person(s) using the gaming equipment and without being in the person's exhalation zone. As the period for the air collection for analysis of the semi volatile chemical substances was 5 hours, the room was typically not used for gaming prior to the measurements, when this took place at home.

In cases with no mechanical ventilation, the rooms were ventilated before measurements. This was done to minimise the impact of the emissions from building materials and fixtures. Venting prior to the measurements was performed in six out of the seven cases. Prior to the measurements, it was recommended that no cleaning be carried out in the affected rooms for at least one week prior to the measurements. This was done both to avoid unnecessary chemical deposits resulting from of the use of cleaning agents, but primarily to ensure sufficient deposited dust on surfaces. The windows in the premises were kept closed during the entire measurement. In the internet café and the højskole, the same conditioning was aimed for before the measurements, as well as a high occupancy in relation to the number of gamers.

The sampling of volatile organic compounds was carried out as late as possible in the measurement period in the hope of being able to detect as many substances as possible. In order not to influence the measurements of VOCs, measurement of aldehydes and ultrafine particles was carried out after the VOC collection, as DNPH tubes can release acetonitrile and as ethanol is released from the used particle counter. The order of the measurements can be seen from FIGURE 1. The collection of dust was carried out after the end of air sampling and particle measurement, in order not to affect the air quality due to the release of chemicals, particles, and heat from the vacuum cleaner.

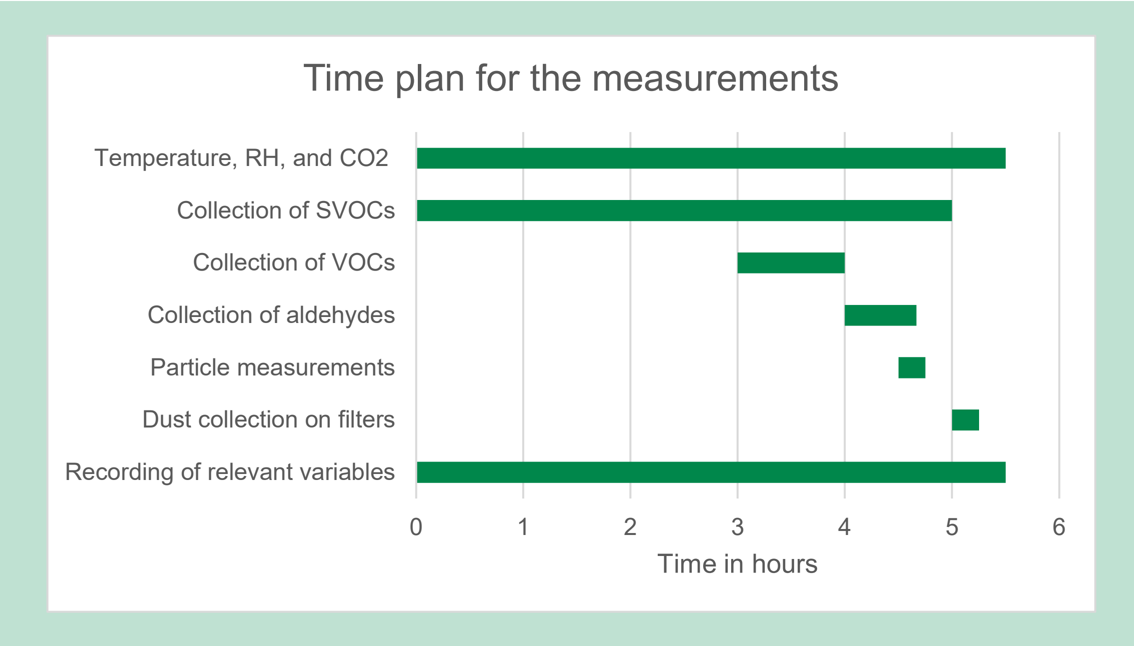

FIGURE 1. The sequence and timing of the measurements performed

Room characteristics were recorded and appear in the table in Appendix 3. Materials, fixtures, and other objects in the room have an impact on air quality and were therefore recorded in all field measurements. Building-related data relevant to the measurements were registered, as well as conditions such as room size, ventilation, cleaning frequency and cleaning products. The computer type, brand, model, as well as other gaming equipment and the age of the equipment were recorded if possible. The recorded information about the equipment was used during the purchase process of gaming equipment for climate chamber tests. The equipment and the premises were visually inspected for cleanliness.

During the entire sampling, temperature, relative humidity, and the concentration of CO_2 was recorded, which indicates the users' impact on air quality. Recordings were made every 5 minutes.

3.1.1 Chemical analysis of air and dust samples

Air samples of volatile chemical substances were collected on media for VOC on Tenax, VVOC C1-C4 aldehydes on DNPH and SVOC on PUF. The analysis strategy was determined in consultation with the Danish Environmental Protection Agency. The reporting criteria given in EN 16516 are used.

Determination of volatile organic compounds (VOC) in air by TDS-GC/MS

Six liters of air were sampled at a flow of 100 ml/min. The VOCs collected on Tenax were thermally desorbed, separated by gas chromatography (GC) and detected by mass spectrometry (MS) according to ISO 16000-6. VOCs were quantified by calibration with pure reference, substances and otherwise using toluene equivalents, where concentrations above 5 µg/m^3 are reported according to EN 16516. The measurement uncertainty was not determined for all individual substances. The analysis is a broad screening. The expanded analytical measurement uncertainty of the validated method is 30%. The samples are analysed at Fraunhofer WKI.

Determination of carbonyls in air (VVOC C1-C4 aldehydes) by HPLC-UV

The aldehydes were collected by a volume of 40 L with a flow of 1000 ml/min on 2,4-dinitrophenylhydrazine (DNPH) filter by derivatization. Collection tubes were sent to the analysis laboratory cooled. The collected carbonyls are eluted with acetonitrile and analysed by HPLC according to ISO 16000-3. Identified by retention time and UV spectrum, and quantified using calibrated reference substances: Formaldehyde, acetaldehyde, propanal, butanal and acrolein. The results are reported within 1 decimal place down to 1.0 µg/m^3, which is lower than the EN 16516 reporting limit of 5 µg/m^3. Expanded analytical measurement uncertainty is 15%. The samples were analysed at Danish Technological Institute.

Determination of heavy volatile organic compounds (SVOC) in air by GC/MS/MS

The airborne compounds were collected by continuously pumping air at a flow rate of 2000 ml/min through a URG sampler made of two parts: a 76 mm polyurethane foam (PUF) for sampling the gas phase and a 25 mm quartz fiber filter (QFF) mounted in front of the PUF to collect the particle phase. A volume of 600 L was collected. Collection tubes were sent to the analysis laboratory cooled. More details on sample preparation and storage of sampling media are available in Raffy et al. (2017). For analysis, the selected compounds were extracted from PUF and QFF together by adding dichloromethane and using pressurised liquid extraction (PLE) ASE (Accelerated Solvent Extractor) 350. Extracts from the air samples were then concentrated to 0.5 ml at 30°C under a flow of nitrogen and then stored at -18°C until the actual analysis. The analysis by GC/MS/MS was performed on an Agilent Technologies 7890B GC System gas chromatograph coupled to a 7010B Triple Quad mass spectrometer operating in electron ionization (EI) mode (70 eV). The same sample extraction and analysis method was used as reported previously (Mercier et al., 2014; Raffy et al., 2017). The samples were analysed at the Ecole des hautes études en santé pub-lique (EHESP).

Determination of heavy volatile organic compounds (SVOC) in dust by GC/MS/MS

The dust samples were taken from vertical surfaces, i.e., furniture, panels, back/fans of PCs and monitors. In some of the cases, it was necessary to vacuum the floor to get enough dust. Dust was collected by vacuuming with a specially designed nozzle with a filter holder. The dust is collected on a filter with a pore diameter of 0.7 µm. The loose dust, which can be shaken and knocked off the filter, was transferred to a glass vial. Glass vials were previously cleaned in dichloromethane and weighed. Vials with dust samples were weighed before being sent to the analysis laboratory. In the laboratory, the samples were sieved at < 100 µm. 50 mg of dust was extracted in dichloromethane using ASE 350, as for the air samples. The extracts were purified on a Chromabond® NH2 glass column (Mercier, 2014). Extracts from the dust samples were then concentrated to 0.5 ml at 30°C under a flow of nitrogen and then stored at -18°C until the actual analysis. The GC/MS/MS analysis was performed on an Agilent Technologies 7890B GC System gas chromatograph coupled to a 7010B Triple Quad mass spectrometer operating in electron ionization (EI) mode (70 eV). The same sample extraction and analysis method was used as reported previously (Mercier et al., 2014; Raffy et al., 2017). The samples were analysed at the Ecole des hautes études en santé publique (EHESP).
List of analysed SVOCs in dust and air and the LOQ is given in Appendix 6.

Screening of SVOC in air with GC/MS
Air collected on Tenax (6 L) and PUF (600 L) was screened for SVOCs by full-scan GC/MS. Tenax tubes are analysed by TDS-GC/MS according to ISO 16000-6. The PUF extracts from air samples are analysed by GC/MS and pulsed splitless liquid injection (2 µL) on GC column HP5 (30 m x 250 µm x 0.25 µm). Data analysis in both cases using Mass Hunter Unknown analysis software (Agilent), spectral deconvolution and searching in the MS libraries Wiley W9N11 and NIST20.

3.1.2 Description of measurement sites

Case 1 – Private home #1
A teenager's room on the first floor of a brick house from 1946, with sloping walls. The room has been recently renovated and has a window with a painted wood frame with a slit ventilation valve, which was open during the measurement. The window faces south. The room is sparsely furnished, with a bed (box mattress with metal legs), a desk with a melamine tabletop and steel legs, an office chair with a chair base in PET and urethane plastic, and a small wooden bookcase. The room is easy to clean, but with cables on the floor under the table. The room appears clean despite the room not being cleaned for 14 days. The PC is approx. 8 months old and appears relatively clean of dust. Air was vented shortly before the measurement. During the measurement, the temperature rose, and the air quality deteriorated over time. At one point during the measurement, dinner was eaten in the room.

Case 2 - Private home #2
A teenager's room on the first floor of a brick house from 1946, with sloping walls. The room has been recently renovated and has a French balcony with a double balcony door with painted wood frame. The window faces north. There are no ventilation openings in the window in the room. The room has a built-in cupboard with sliding doors, this volume/area is not included in the size of the room. The room is furnished with a bed (box mattress with wooden legs), a desk with plastic-covered chipboard and powder-coated steel legs, an upholstered office chair with a mesh back and an older small flat-screen TV and a small cotton carpet. The room is furnished with a few plants and other objects. The room is relatively easy to clean and appears with a bit of dust on the floor under the bed and on the skirting boards. This case is the only one of the private homes where the gaming equipment consisted of a portable gaming PC. Prior to the measurement, the room had not been cleaned for 10 days. An air change was carried out prior to the measurement. During the measurement, the temperature rose sharply and the air quality deteriorated. The PC is approx. 2 years old and appears clean of dust. Dinner was eaten in the room during the measurement. During the measurement, the teenager expresses a desire to open the balcony door to vent the room.

Case 3 - Private home #3
A children's room in a single-story house from 1979. The room was refurbished earlier in 2022. The windowpanes made of painted wood has a slit ventilation valve. The window faces west. The room is furnished with a bed in painted wood, desk with melamine tabletop and powder-coated steel legs, gaming chair, and older flat-screen TV. In addition, the room is furnished with a bookcase with books, trophies and there are loose items including an electric guitar, keyboard etc. The room is relatively easy to clean and appears with dust on the floor under the bed and on the skirting boards, as due to the measurement it had not been cleaned for 2 weeks. The room was aired out prior to the measurement. During the measurement, the temperature rose sharply and the air quality deteriorated. The PC is approx. 2 years old, while the other equipment (screen, keyboard, mouse, mouse pad and gaming chair) is approx. 6 months old.

Case 4 – Private home #4
A basement room in an aerated concrete home with 1st floor and basement from 1959 is set up for gaming. The room is not used for overnight stays. There is a newer unpainted wooden window without a slit ventilation valve. The window faces east. There is an exchange of air with the other basement rooms through doorways. A table was present with steel legs and solid wooden tabletop, which has been treated with stain and wax. There is a bookcase in steel and the same wood as the desk with books and alcohol bottles. In addition, there are plastic boxes for storage. For the gaming setup, there is a gaming chair, two monitors, keyboard, mouse, and mouse pad. The gaming PC is from 2022. The room is also furnished with two older leather armchairs and a fabric armchair. In addition, there is a guest visiting with his complete gaming equipment. The room is cleaned as needed, but not cleaned 3 weeks before the measurement. A dog was present in the room during the measurements. In addition, two cats live in the home. The air quality and temperature did not deteriorate during the measurement. However, the weather was humid and rainy, and the humidity during the measurement was high.

Case 5 – Gamer Cafe
The café is located on the 1st floor of a sports hall complex made of concrete with a flat roof from 1979. There are several windows facing northeast and southwest. The café was refurbished a few years ago and furnished with 24 identical complete gaming PC setups. The equipment is from 2019 or newer. During the measurements, there were 23 PCs in the room. In addition, there were four PlayStation 5 with associated flat screens. There were also two virtual reality glasses that were not in use. All PCs are equipped with gaming table, gaming chair, headset, keyboard, mouse, and large mouse pad. In addition, there are three tables, two leather sofas, and some armchairs. PC cabinets are either placed on tables or shelves and do not stand on the floor, as in the other cases. The room is mechanically ventilated with balanced ventilation. There were very few visitors on the day of the measurement, it was a Friday evening. This might be due to good weather on the day. The few visitors played either PlayStation or on PCs for shorter periods. All the equipment was switched on, and some PCs were starting to update or running a game. The café is cleaned daily, and it was not possible to put the cleaning on hold in the days leading up to the measurement. The dust sample therefore had to be collected by prolonged vacuuming and behind sofas etc. The PCs appeared with only a little dust. Due to the mechanical ventilation, air quality did not deteriorate during the measurement period.

Case 6 – Højskole Esport room
The Esport room used for teaching is located on the 1st floor of a teaching building which was originally used as a hospital. The building dates from 1907. The windows in this room face south. The room is furnished with 21 identical complete gaming PC setups. The equipment is from 2016 or newer. All PCs include a gaming chair, headset, keyboard, mouse, and large mouse pad. PC cabinets are located under the tables. Tables are made from painted plywood with a laminate floor as tabletop surface. In addition, there was an adjustable motorised standing desk for the teacher. The room has slit valves in the older painted wooden windows with two sets of panes. The windows were open before the measurements. There was no teaching on the day of the measurement, and therefore only average daily game play by the students. Only PCs that were in use were switched on. The room is cleaned several times a week, and it was not possible to put the cleaning on hold in the days leading up to the measurement. Under the PC cabinets, which were placed on the floor, dust was visible. The built-in dust filter was detached from the cabinet and vacuumed. During the measurements the room became warmer, and the air quality deteriorated over time, but mainly it was the heat that affected the comfort for the playing students. A seasoned student who plays at a high level stated that he would not normally play in those conditions as you cannot perform well when the temperature is high.

Case 7 - Højskole gamer room

The gamer room, which is used by the students for gaming in their spare time, is located on the ground floor of an educational building from 1907. The windows in this room face south. The room is furnished with the students' own different PCs with random components. Some have several monitors connected to their PCs, and some PCs are portable. There are different chairs, both gaming chairs and office chairs, but also ordinary chairs. All headsets, keyboards, mice, and mousepads are different. Some PC cabinets are placed under the tables and others on the table. The pupils themselves are responsible for cleaning the room, which appears dirty and with full rubbish bins. The room does not appear cleaning-friendly, due to the tight space and 'cable spaghetti' on the floor. There are slit valves in the older, painted wooden windows with two sets of panes. Only PCs in use were switched on. The windows were open prior to the measurements. It was so hot on the day of the measurement that many left the room, but several students persevered for the sake of the measurement, despite the heat. Air quality also deteriorated over time in this case.

3.2 Results

In the following, the results of the field investigations during gaming are presented.

3.2.1 Recording of temperature, relative humidity, CO_2 concentration and ultrafine particles

FIGURE 2 and FIGURE 3 show graphs of the air temperature and the relative humidity during the measurements in cases 1 and 3. The figures show that the temperature increases several degrees during the measurement, while the relative humidity remains constant or decreases slightly due to the increasing temperature.

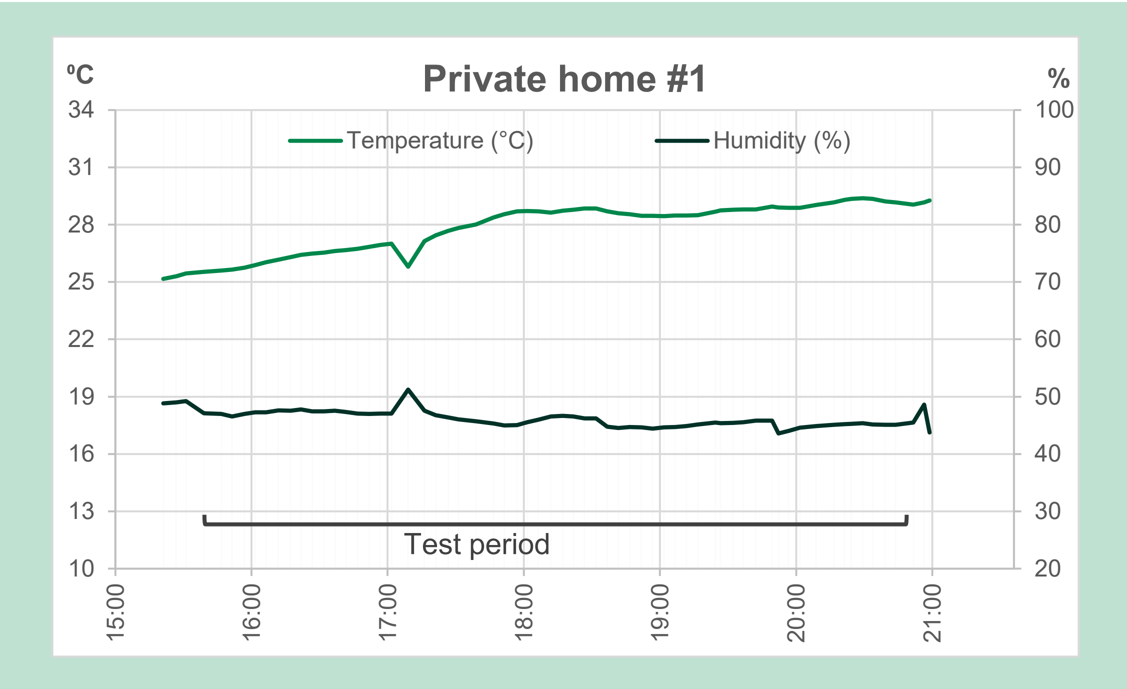

FIGURE 2. Temperature and relative humidity for Case 1

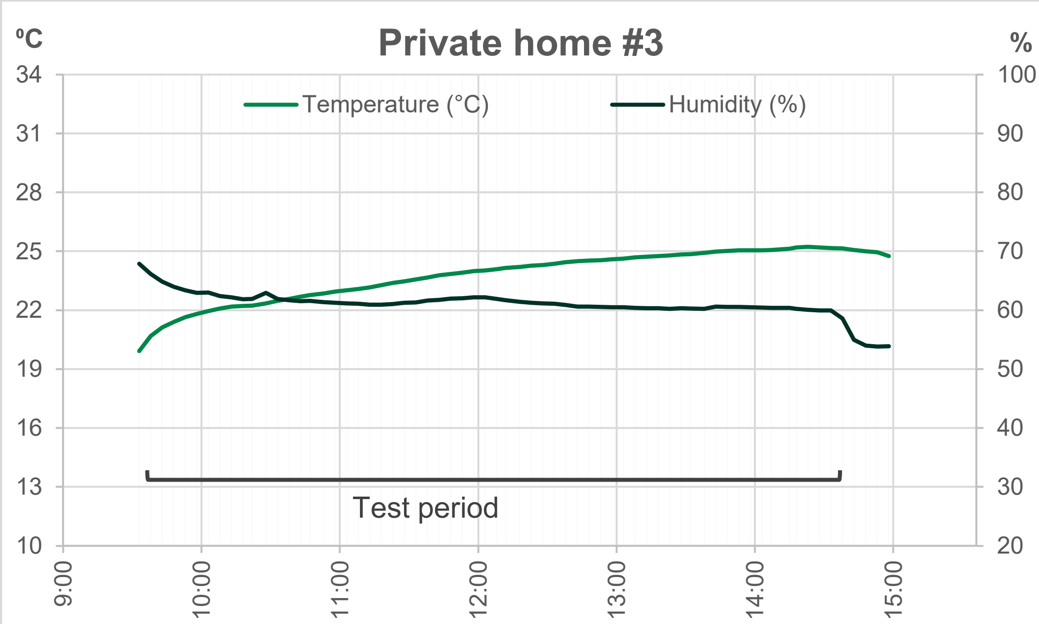

FIGURE 3. Temperature and relative humidity for Case 3

In Appendix 4 all graphs of the 7 cases can be seen. The trend of increasing temperature applies in 5 of the 7 cases. Only in cases 4 and 5 the temperature remained moderate and did not increase quickly during the measurement. In case 4, the measurements took place in a basement on a day with rainy weather, while case 5 was an internet café with mechanical ventilation and cooling. The rising temperatures in the other cases can be due to warm initial temperature in the building, and the temperature outdoors was relatively high, with direct sunlight entering the rooms in some cases, as well as the heat release of the person/s and the equipment. In addition, windows and doors were kept closed during the measurements. In several cases, the temperature was close to or above 25 degrees at the start of the measurement.

The figure below (FIGURE 4) shows an overview of what percentage of the time during the measurement the temperature lies in different intervals.

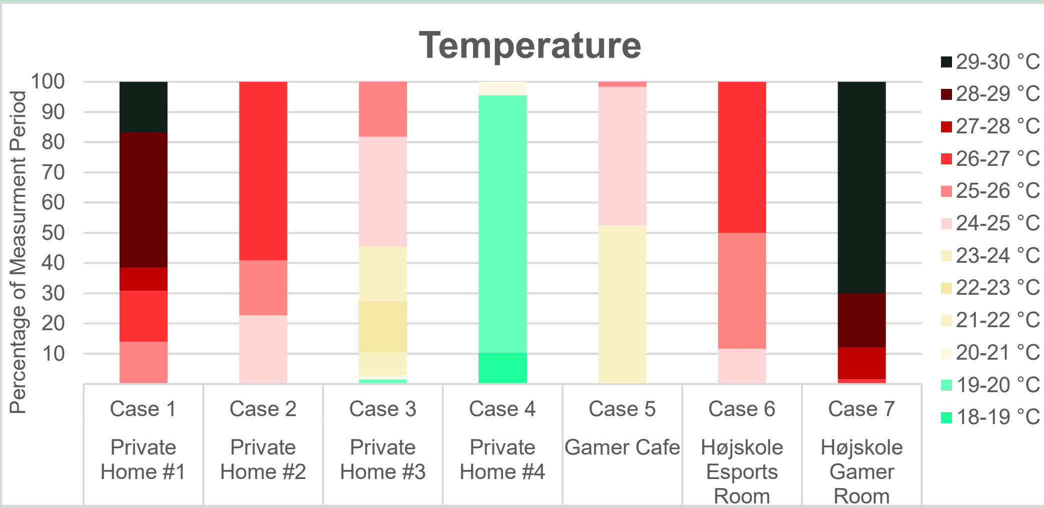

FIGURE 4. Overview of percentage of time in different temperature ranges

As can be seen from FIGURE 4, Case 4 stands out from the other cases in that there were low temperatures throughout the measurement period. This is because the measurement was made in an unheated basement. In case 5, as previously described, there was mechanical ventilation and cooling, and the temperature was relatively stable during the measurement period. In case 3, the temperature is lower than the other cases, despite the temperature rising during the measurement period. This is because the measurement started at a lower temperature.

In the cases where the temperature reached 25-30 degrees (Case 1, 2, 3, 6 and 7), several of the young people who played computer games expressed a desire to get some air. This was not possible due to the ongoing air quality survey. For that reason, the measured temperatures of over 25 degrees are considered unrealistically high, as the temperature would have dropped significantly during ventilation. After the measurement was completed, the rooms were ventilated, resulting in a drop in temperature.

For comparison, it can be stated that according to the standard DS 474 "Standard for specification of thermal indoor climate" (2017), the optimal temperature in the winter period is 20-24 °C and in the summer period 23-26 °C. The Danish Working Environment Authority recommends that the temperature be kept at 20-22 °C and that it not exceeds 25 °C in rooms with sedentary work (AT guidance A.1.2. 2018). Based on research into people's productivity and comfort at different temperatures, the Norwegian Institute of Technology typically recommends that the temperature in rooms with sedentary work be kept at 21-22 °C (Seppänen et al. 2006).

During the field studies, the CO_2 concentration was recorded over the entire measurement period. In Appendix 4 all graphs of the CO_2 concentration in the 7 cases can be seen. FIGURE 5 and FIGURE 6 show graphs of the CO_2 concentration during the measurements in cases 2 and 6. The CO_2 concentration increases over the course of the measurement. In most of the measurements, the windows were opened at the end of the measurement period after air and dust samples had been collected, which resulted in a decrease in the CO_2 concentrations as well as the temperature

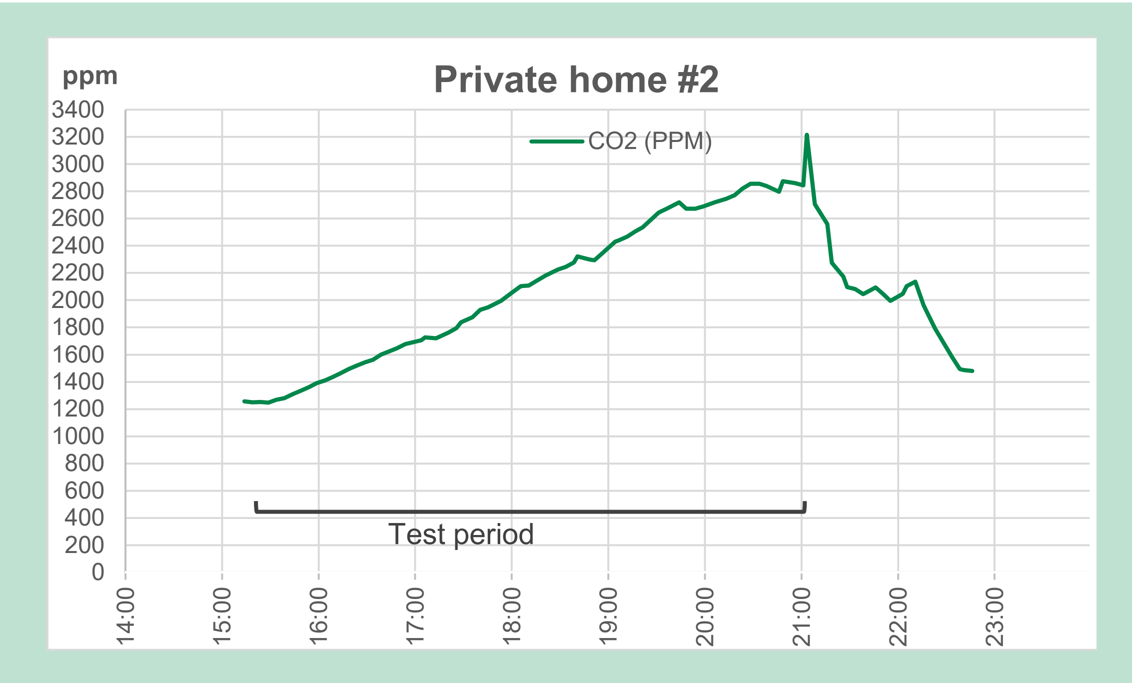

FIGURE 5. CO_2-concentration in Case 2

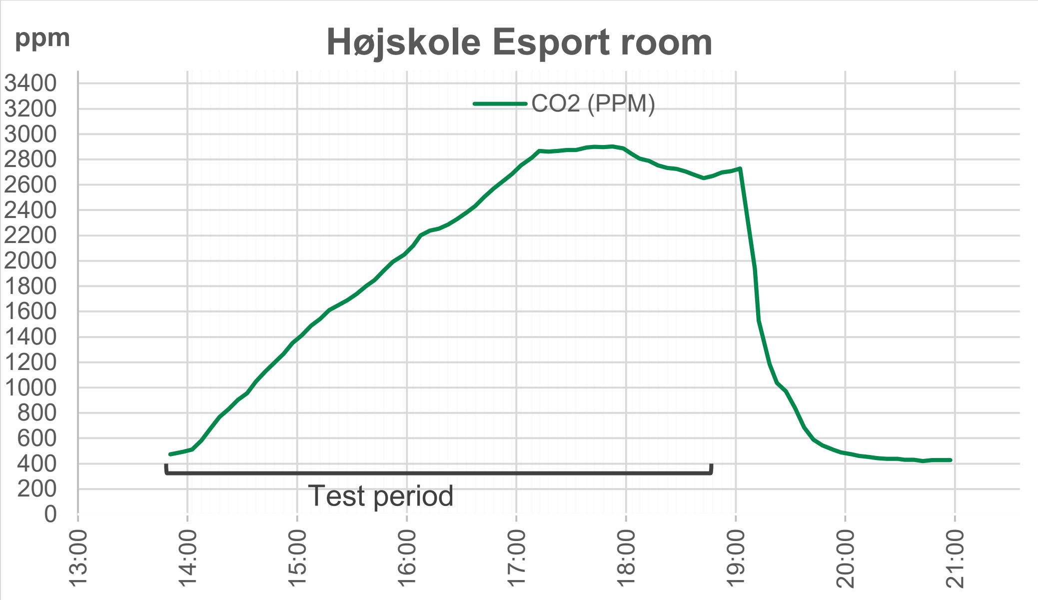

FIGURE 6. CO_2-concentration in Case 6

The trend of increasing CO_2-concentration is evident in 6 out of the 7 cases. Only in a single case, case 5 the internet café with mechanical ventilation, the CO_2 concentration was constant during the measurement. The internet café also had a low occupancy load on the day of the measurement.

FIGURE 7 shows an overview of the percentage distribution and concentration of CO_2 during the measurement period.

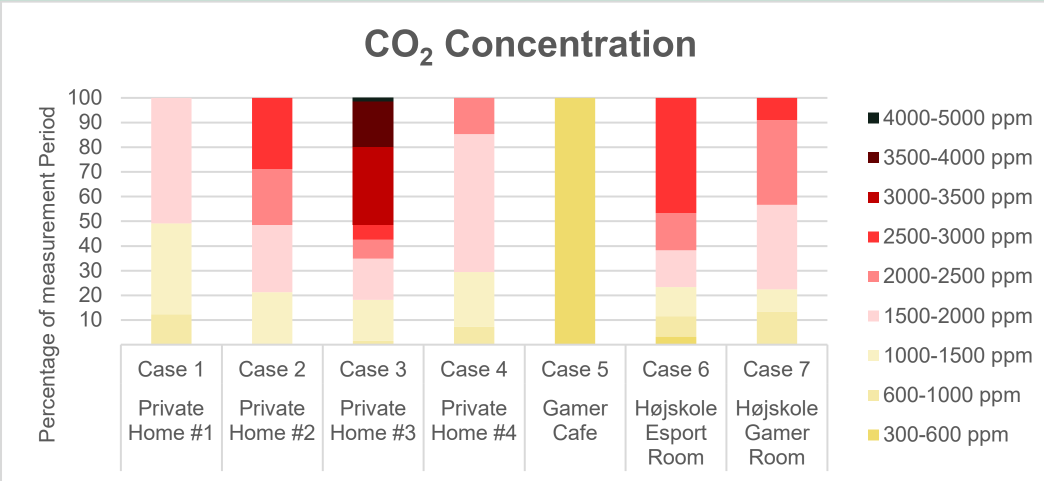

FIGURE 7. Overview of CO_2 concentration during measurements

As can be seen from the graph, case 5 stands out from the other cases with low CO_2 concentrations throughout the measurement period. In case 5, there was mechanical ventilation, and the CO_2 concentration was relatively stable during the measurement period. In the other cases, the CO_2 concentration is above 1500 ppm for more than half of the time. This is an expression of an insufficient ventilation rate in relation to the person load. It is to be expected that in the 6 cases with relatively high or decidedly high CO_2 concentrations, the persons have a significant impact on the air quality, as CO_2 is a product of human metabolism and can be used as a proxy for the VOC emission from human metabolism.

For comparison, it is noted in the Danish Building Research Institute (Statens Byggeforskningsinstitut, SBi) instruction book 196 'Indoor Climate Handbook (Danish)', 2nd edition (2000), that CO_2 concentrations below 700 ppm are considered a 'low' load. Concentrations between 700 and 1,000 ppm are assessed as 'medium', over 1,000 ppm are assessed as 'high' exposure. The Danish Working Environment Authority recommends in At-guideline A.1.2-1 (2018) that the CO_2 concentration does not exceed 0.1% for longer periods, which in this context corresponds to a concentration below approx. 1,000 ppm. Due to rounding, the concentration can go up to approx. 1,500 ppm, without the Danish Working Environment Authority's recommendation being exceeded. The results support an earlier study of air quality in private homes, which found CO_2 concentrations above 1000 ppm in children's and teenagers' rooms (Heide et al., 2021).

TABLE 2 provides an overview of the measurement results. This shows the surface temperatures measured on the electronic gaming equipment. There was a tendency for the equipment to run hotter when used in higher air temperatures than when the room temperature was lower. In addition, there was a tendency for monitor screens and parts of the PC to get hotter when playing graphics-intensive games. From the measured surface temperatures, it can be assessed that the equipment contributes significantly to the heating of the room.

TABLE 2. Overview of field study measurement results: Temperature, relative humidity (RH), CO_2 concentration and ultrafine particle concentration

Parameter	Private home #1	Private home #2	Private home #3	Private home #4	Netcafé #5	Esport room #6	Gamer room #7
Temperature Avg (min-max) [°C]	27.9 (25.1-29.9)	25.8 (24.3-26.7)	23.8 (19.9 – 25.2)	19.3 (18.9 – 20.2)	24 (23.8-25.8)	25.5 (23.3 – 26.5)	29.1 (27 – 29.9)
Relative humidity (RH) Avg (min-maks) [%]	46.1 (43.6-51.2)	49.7 (47.8-53.8)	61 (53.8 – 67.9)	70.9 (64.9 – 72)	41.3 (40 – 41.9)	46.9 (37.9 – 54.7)	42 (32.3 – 45.9)
CO_2-concentration Avg (min-max) [PPM]	1450 (750 – 1900)	2050 (1250 -2900)	2650 (1000 – 4000)	1650 (900 – 2200)	500 (500-550)	1700 (400 – 2900)	1850 (700 – 2800)
PC-temperature inside cabinet [°C]	36.5	-	34	26-28	30-31	28-32	26-32
PC-temperature inside transparent cabinet [°C]	34-41	-	35-45	29-33	33-34	-	28-35 Some PCs have extra cooling
Monitor temperature front [°C]	36	37 (laptop PC)	36	27-28	29-31	31-36	31-40
Monitor temperature back [°C]	32	35 (laptop PC)	31	24-26	28-30	28-30	28-35
Keyboard temperature [°C]	30.5	33 (laptop PC)	28	25-26	24-25	27-29	40 (For a laptop PC)
Ultra-fine particles (UFP) Indoors per cm^3 [pt/cm^3]	In the room 2975 In the building 3230	In the room 3200 In the building 3230	In the room 7450 In the building 10.200	In the cellar 5170 In the building 8500	In the cafe 2030 In the building 4090	In the room 2460 In the hall 4360	In the room 2690 In the hall 4360
UFP Outdoors [pt/cm^3]	3500	3500	8090	2340	8620	3570	3570

TABLE 2 also shows the results of the measurements of ultrafine particles. In two of the private homes (cases 3 and 4), food was prepared at the end of the measurement period, and that is reflected in the measured number of ultrafine particles. In these cases, there was a clear tendency for the particle level in the rooms where the game was played to be lower than the surroundings. One explanation could be that the air cooling of the PCs helps to filter the air by causing dust to collect in the machine. However, the measurements are too few to be able to conclude this with certainty. For comparison, a study carried out by the Danish Technological Institute (Heebøll and Lyng, 2020) found the indoor concentrations in homes without particle-generating activity to be 3,700 ultra-fine particles per cm^3 (pt/cm^3) average based on 65 measurements. Correspondingly, the average concentration during activity was 29,600 pt/cm^3 in 38 homes. The concentration outdoors was 7,200 pt/cm^3. The measurements in these field studies do not vary significantly from values found in the previous study (Heebøll and Lyng, 2020).

3.2.2 Results of the air quality survey

In total, 75 different substances have been detected in the VVOC and VOC range, as shown in TABLE 3. Two of the substances found are not identified by CAS number. They are categorised as a ketone and a carboxylic acid ester, and are found in low concentrations, below 5 µg/m3. The 75 substances detected are divided into 9 substance groups. The substances are listed in these groups. Within each group they are listed by retention time. Concentrations found on blind pipes are subtracted from the results. Substances which are only found in concentrations of 1-2 µg/m3 were not found across the different cases

An overview of the substances found is given in the following. Internal databases of previously measured concentrations in the indoor air or in the emissions from building materials are used to assess whether the identified substances originate from the equipment or other sources. These databases are based on over 1000 measurements carried out by the Danish Technological Institute.

A large part of the detected substances in the field investigations can be attributed to the emissions from building materials and fixtures and has been seen in studies of particle and vapor emissions from humans. The emissions from humans occur either as a direct result of human metabolism through exhalation, e.g., when eating or drinking, as well as release from the skin or because of care and beauty products used on the body or released from clothing.

In general, concentrations of VVOCs and VOCs are lower in case 5 than in the other cases. This was expected since case 5 is the only case with mechanical ventilation. In case 4, which is the basement of the private home, the concentrations are also lower than the other cases. This is probably due to the walls, floor, and ceiling being made of concrete and that there is air circulation with the other rooms in the basement. The only noteworthy substance found is toluene, which is found in a concentration of 101 $µg/m^3$. The substance is estimated to originate from a former oil boiler and possible oil tank in the basement. The concentration does not exceed the German health authorities' recommended indoor climate guideline value of 300 $µg/m^3$. ("Guide values for the concentration of specific substances in indoor air" from 02.10.2022).

In the group of aldehydes, formaldehyde was found in three of the homes (cases 1-3) in concentrations of between 44 and 67 ug/m^3, which is slightly above what the Danish Technological Institute normally finds in naturally ventilated homes in Denmark. However, the temperature, which in all three cases was high during sampling, probably affected the emission of formaldehyde. The emission of formaldehyde increases at higher temperatures. Formaldehyde is known to emit from building materials such as chipboard and plywood, and wherever urea glue is used. In addition, formaldehyde has been found to emit from mineral wool, coatings, foam, and furniture. It is estimated that there are several possible sources in the three studied children's rooms (Case 1, 2 and 3). The concentration of formaldehyde is in all cases below the WHO's recommended limit value of 0.1 mg/m^3.

Acetaldehyde has been found in concentrations of between 20 and 47 µg/m^3 in the children's rooms (cases 1-3) and of 11-21 µg/m^3 at the højskole (cases 6-7). The substance is both known to degas from building materials such as paint, aerated concrete, wooden furniture and wood-based panels such as chipboard, plywood and OSB boards. The substance is also endogenous and found in human breath. Acetaldehyde is formed when metabolism breaks down ethanol or by ketosis. Ethanol can be found in small amounts in fermented foods such as bread, fruit, juice, yogurt, and alcoholic beverages. It is not possible to conclude whether the concentrations found are due to the presence of building materials and fixtures or the presence of people. The levels are not elevated compared to what Danish Technological Institute typically measures in rooms without mechanical ventilation.

In general, the number of aldehydes and the concentrations in cases 1-3 and 6-7 are slightly elevated compared to what Danish Technological Institute typically finds in non-mechanically ventilated rooms. This may be due to a contribution from the gaming equipment, but it cannot be ruled out that it is solely due to the elevated temperatures and, in the case of some of the aldehydes found, the presence of people.

1,2-Propanediol has been found in cases 1-3 and 6-7 in concentrations of between 27 and 69 µg/m^3. In addition, either TXIB or texanol have been found in concentrations of 43-143 µg/m^3 in cases 1-3. The substances belong to the group of glycols and are considered to originate from paint. The three children's rooms (cases 1-3) have been refurbished and painted within the last six months.

In addition to acetaldehyde, the following substances have been found which are seen in the emissions from humans; isoprene and acetone, in cases 2, 3, 4, 6 and 7. This is consistent with the relatively high CO_2 levels in these cases. Isoprene is not found in emissions from building materials and fixtures. The substance has been found in concentrations of 3-10 µg/m^3. In the 5 cases, acetone was found in concentrations of 28-49 µg/m^3. Emission rates from human exhalation are approx. 3 times higher for acetone than for isoprene (Wang et al. 2022). In addition, acetone is also known to emit from building materials and fixtures.

Decamethylcyclopentasiloxane (D5) has also been found in a slightly elevated concentration compared to what Danish Technological Institute typically sees in the indoor climate. In cases 2, 3, 6 and 7, the substance was found in concentrations of between 76 and 117 µg/m^3, while the concentration in case 1 was 19 µg/m^3. On average, data in the database of measurements made in 315 homes and offices show an average concentration for this substance of 26 µg/m^3. The substance has been found in limited amounts in the emissions from furniture, especially from upholstered furniture. In studies of the emissions from humans, the substance has also been found and assessed to originate from personal care and beauty products. A contribution from gaming equipment may also occur.

Menthol has been found in low concentrations (3-5 µg/m^3) in cases 3, 6 and 7. The substance is normally not found in the indoor air. It is estimated that the substance found in these cases may be due to the use of chewing gum. In case 2, tetrachloroethene was found in a concentration of 3 µg/m^3, the substance is estimated to originate from clothes that have been dry cleaned.

Air samples collected on two types of sample media Tenax and PUF was screened for SVOCs, and the results appear in TABLE 4. More SVOCs are identified in the PUF extract than from Tenax, which is probably due to a larger sample volume and that SVOCs are not efficiently analysed by thermal desorption from Tenax by the ISO 16000-6 method (Uhde et al., 2019). The substances found; galaxolide, octisalate, isopropyl myristate, dioctyl disulphide, N-butylbenzenesulfonamide, as well as linear alkanes and alkanols can originate from personal care products such as skin lotions and perfumes. Di-n-butyl adipate (DnBA) and dioctyl terephthalate (DOTP) are used as a substitute for phthalates as plasticizers and may originate from gaming equipment. Irganox 1076 is used as an antioxidant in plastics, and the sources of several of the identified SVOCs are described in Salthammer (2020). In addition to diethyl phthalate (DEP), several phthalates were also identified during the screening, but reference is made to more valid results from quantitative target analysis in TABLE 5. In all PUF extracts, fluorine-containing VOCs and SVOCs are identified, but CAS numbers and substance identity cannot be verified. The PAHs anthracene and phenanthrene can originate from several sources, including smoke, tar, or oil. Seo et al. (2022) demonstrated the emission of PAHs from computers, and in the gas phase naphthalene (VOC) was present in the highest concentration and to a lesser extent phenanthrene and anthracene. Naphthalene is not identified in the VOC or SVOC analyses, and therefore it is considered unlikely that gaming equipment is the source.

In the analysis for 32 selected SVOCs in air, 12 different substances were detected (TABLE 5). The substances belong to the substance groups phthalates, bromophenols, and organophosphates. The phthalates are the substance group found in the highest concentrations. The four phthalates found are dibutyl phthalate (DnBP), diethyl phthalate (DEP), diisobutyl phthalate (DiBP), dimethyl phthalate (DMP). DnBP and DiBP were found in all cases and were found in the highest concentrations of the phthalates. DnBP has been found in concentrations between 94 and 587 ng/m^3 with an average of 243 ng/m^3. While DiBP has been found in concentrations between 40 and 402 ng/m3 and with an average of 195 ng/m^3.
According to Kocbach Bolling et al. (2013), median indoor air concentrations reported in various countries for DnBP are between 200 and 2700 ng/m3 and for DiBP between 50 and 800 ng/m^3, and here the measured concentrations in this study are at the low to medium end of the range.
DEP was found in 5 out of the 7 cases in concentrations between 87 and 221 ng/m3 and with an average of 160 ng/m3. According to Kocbach Bolling et. eel. (2013), median concentrations of DEP are between 50 and 2700 ng/m3. Thus, DEP is also at the low end of the report-ed levels. In comparison, a French study of 537 classrooms found median concentrations of DnBP, DiBP and DEP of 170, 772 and 283 ng/m3 respectively.
DMP has only been found in a single case (Private home #3) in a concentration (77 ng/m3) which is close to the detection limit for this substance (67 ng/m3). This case is the only place with vinyl flooring, which may be why the fabric was found here.

A brominated phenol, 2,4,6-tribromophenol (2,4,6-TBP) has been found in two cases (Private home #1 and #3) in concentrations of 2.1 ng/m3, which is close to the detection limit (1.7 ng/m3). This substance is used as a flame retardant and fungicide. No other brominated flame retardants have been found in the air.

Seven substances have been found in the group of investigated organophosphates. Tri(1-chloro-2-propyl)phosphate (TCPP) is the substance found in the highest concentrations of the seven organophosphates found. The substance was found in all cases in concentrations of between 15 and 67 ng/m3 and in an average of 43 ng/m3. The substance has been re-ported in the emissions from both upholstery materials and electronics (Kemmlein et al. 2003) and Triethylphosphate (TEP) has been found in the second highest concentrations of between 5.5 and 65 ng/m3 and in an average of 20 ng/m3. TEP is also found in all cases.

Tributylphosphate (TBP) and Triphenylphosphate (TPP), which were also found in all cases, were however found in significantly lower concentrations of between 0.3 and 5.6 ng/m3 and in average concentrations of 3.8 and 0.8 ng/m3 respectively. The median concentration of TBP found in 583 French classrooms is 3.8 ng/m3, which agrees with the finding of TBP in this study. TPP has previously been found in the emissions from computers and laptops (Destaillats et al. 2008) and electronic equipment (Kemmlein et al. 2003).

The remaining 3 organophosphates found; 2-Ethylhexyldiphenylphosphate (EHDPP), Tri(2-chloroethyl)phosphate (TCEP) and Trimethylphosphate (TMP) have been found in 3, 2, and 1 case(s) respectively. All measured concentrations were found in low concentrations of up to 2.7 ng/m3. Trimethyl phosphate has only been found in a single case in a concentration of 1 ng/m3, which is close to the detection limit of 0.8 ng/m3.

TABLE 3. Results of the VOC screening and the measurement of compounds in µg/m³ for air samples

Substance	CAS RN	Private Home #1	Private Home #2	Private Home #3	Private Home #4	Internet café	Højskole Esport room	Højskole Gamer room
Aldehydes								
Formaldehyde (VVOC)	50-00-0	44	60	67	4	6	25	21
Acetaldehyde (VVOC)	75-07-0	20	32	47	3	3	11	21
Propanal (VVOC)	123-38-6	6	9	14	n.d.	1	3	6
Butanal (VVOC)	123-72-8	4	5	8	n.d.	1	3	3
Pentanal	110-62-3	8	9	17	n.d.	n.d.	6	3
Hexanal	66-25-1	18	27	42	5	2	16	11
2-Furaldehyde	98-01-1	n.d.	3	n.d.	n.d.	n.d.	n.d.	n.d.
Heptanal	111-71-7	4	6	9	n.d.	n.d.	4	3
Benzaldehyde (aromatic)	100-52-7	7	9	17	n.d.	2	6	3
Octanal	124-13-0	11	14	18	n.d.	2	11	12
Nonanal	124-19-6	29	31	36	1	7	25	30
Decanal	112-31-2	16	17	22	n.d.	4	18	25
Ketones								
Acetone (VVOC)	67-64-1	n.d.	49	28	14	2	35	31
2,3-Butandione (VVOC)	431-03-8	n.d.	n.d.	3	n.d.	n.d.	6	5
2-Butanone (MEK)	78-93-3	n.d.	n.d.	3	3	n.d.	1	n.d.
Methylisobutylketone (MIBK)	108-10-1	n.d.	n.d.	n.d.	8	n.d.	n.d.	n.d.
3-Hydroxy-2-butanone	513-86-0	n.d.	n.d.	n.d.	n.d.	n.d.	9	4
2-Methyl-2-hepten-6-one	110-93-0	9	13	14	n.d.	n.d.	11	14

Substance	CAS RN	Private Home #1	Private Home #2	Private Home #3	Private Home #4	Internet café	Højskole Esport room	Højskole Gamer room
Ketone		n.d.	n.d.	5	n.d.	n.d.	n.d.	n.d.
Alcohols								
Ethanol (VVOC)	64-17-5	n.d.	28	46	n.d.	7	33	17
2-Propanol (VVOC)	67-63-0	n.d.	8	9	43	1	7	21
iso-Butanol	78-83-1	n.d.	n.d.	n.d.	3	n.d.	n.d.	n.d.
n-Butanol	71-36-3	n.d.	18	13	12	n.d.	21	9
Pentanol	71-41-0	5	6	9	n.d.	n.d.	n.d.	n.d.
2-Ethyl-1-hexanol	104-76-7	n.d.	9	15	n.d.	n.d.	2	1
Benzylalcohol	100-51-6	n.d.	2	3	n.d.	n.d.	n.d.	n.d.
Linalool	78-70-6	n.d.	n.d.	4	n.d.	n.d.	n.d.	n.d.
Dodecanol	112-53-8	3	4	5	2	n.d.	1	1
Glycols, Ethers, Esters								
Ethylacetate (VVOC)	141-78-6	9	37	4	n.d.	n.d.	n.d.	n.d.
1,2-Propandiol (propylene glycol)	57-55-6	69	53	59	n.d.	n.d.	60	27
Carboxylsyreester		n.d.	n.d.	n.d.	n.d.	n.d.	3	1
Butyl acetate	123-86-4	n.d.	27	48	n.d.	n.d.	n.d.	n.d.
Buylglycol	111-76-2	3	5	15	n.d.	n.d.	n.d.	n.d.
Hexylene glycol	107-41-5	n.d.	16	n.d.	n.d.	n.d.	n.d.	n.d.
1-Butoxy-2-propanol	5131-66-8	n.d.	4	n.d.	n.d.	n.d.	n.d.	n.d.
Ethoxy diglycol	111-90-0	n.d.	n.d.	n.d.	n.d.	3	n.d.	n.d.
DPGMME (mix af isomere)	34590-94-8	n.d.	n.d.	15	n.d.	n.d.	n.d.	n.d.
Dimethyl glutarate	1119-40-0	n.d.	5	n.d.	n.d.	n.d.	n.d.	n.d.

Substance	CAS RN	Private Home #1	Private Home #2	Private Home #3	Private Home #4	Internet café	Højskole Esport room	Højskole Gamer room
Butyldiglycol	112-34-5	n.d.	n.d.	19	n.d.	n.d.	n.d.	n.d.
2-Phenoxyethanol	122-99-6	n.d.	2	6	n.d.	1	2	2
Dipropylenglycol butylether	29911-28-2	5	2	n.d.	n.d.	n.d.	n.d.	n.d.
Texanol	25265-77-4	4	3	43	3	n.d.	3	n.d.
TXIB	6846-50-0	143	76	4	2	n.d.	n.d.	n.d.
Aliphatic hydrocarbons								
Isoprene (VVOC)	78-79-5	n.d.	3	6	5	n.d.	10	7
3-Methylhexane	589-34-4	n.d.	13	n.d.	4	n.d.	n.d.	n.d.
Heptane (C7)	142-82-5	1	2	n.d.	7	n.d.	n.d.	n.d.
2,2,4,6,6-Pentamethylheptane	13475-82-6	3	3	17	n.d.	n.d.	n.d.	n.d.
Undecane (C11)	1120-21-4	n.d.	2	n.d.	n.d.	n.d.	2	6
Dodecane (C12)	112-40-3	n.d.	2	n.d.	n.d.	n.d.	2	3
Cykloalkanes								
Methylcyclohexane	108-87-2	n.d.	n.d.	n.d.	4	n.d.	n.d.	n.d.
Cyclohexanone	108-94-1	3	6	17	n.d.	n.d.	n.d.	n.d.
Aromatic hydrocarbons								
Toluene	108-88-3	4	3	3	101	n.d.	n.d.	n.d.
m,p-Xylene	1330-20-7	3	2	2	1	n.d.	n.d.	n.d.
Styrene	100-42-5	n.d.	n.d.	2	n.d.	n.d.	n.d.	n.d.
Terpenes								
α-Pinene	80-56-8	10	11	48	64	2	5	3
Camphene	79-92-5	n.d.	n.d.	n.d.	3	n.d.	n.d.	n.d.

Substance	CAS RN	Private Home #1	Private Home #2	Private Home #3	Private Home #4	Internet café	Højskole Esport room	Højskole Gamer room
(-)-β-Pinene	18172-67-3	n.d.	n.d.	2	4	n.d.	n.d.	n.d.
Myrcene (β-myrcene)	123-35-3	n.d.	n.d.	1	1	n.d.	n.d.	n.d.
3-Carene	498-15-7	5	5	26	25	n.d.	2	1
Limonene	5989-27-5	7	8	12	13	n.d.	29	16
Menthol	89-78-1	n.d.	n.d.	4	n.d.	n.d.	5	3
Organic Acids								
Acetic acid	64-19-7	96	144	115	n.d.	19	104	49
Propanoic acid	79-09-4	11	13	n.d.	n.d.	n.d.	15	8
Butanoicacid	107-92-6	n.d.	n.d.	n.d.	n.d.	n.d.	4	2
Pentanoic acid	109-52-4	2	2	5	n.d.	n.d.	3	2
Hexanoic acid	142-62-1	n.d.	11	29	n.d.	n.d.	12	7
Benzoic acid	65-85-0	n.d.	n.d.	n.d.	n.d.	4	2	2
Octanoic acid	124-07-2	3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Nonanoic acid	112-05-0	n.d.	n.d.	n.d.	n.d.	1	4	4
Siloxanes								
Hexamethylcyclotrisiloxane (D3)	541-05-9	n.d.	3	3	n.d.	n.d.	n.d.	n.d.
Octamethylcyclotetrasiloxane (D4)	556-67-2	5	61	6	4	n.d.	2	n.d.
Decamethylcyclopentasiloxane (D5)	541-02-6	19	76	85	5	1	117	84
Dodecamethylcyclohexasiloxane (D6)	540-97-6	2	13	5	2	n.d.	61	12
Chlorinated compounds								
Tetrachloroethene	127-18-4	n.d.	3	n.d.	n.d.	n.d.	n.d.	n.d.
Sum of other iso-alcohols:	(108-88-3)	n.d.	n.d.	3	n.d.	n.d.	n.d.	n.d.

Substance	**CAS RN**	**Private Home #1**	**Private Home #2**	**Private Home #3**	**Private Home #4**	**Internet café**	**Højskole Esport room**	**Højskole Gamer room**
Sum of other iso/cyclo-alkanes:	(13475-82-6)	1	2	29	14	n.d.	4	5
Sum of VVOCs		83	231	232	69	21	133	132
Sum of VOCs (TVOC)		510	746	855	293	48	572	353
Sum of SVOCs		-	-	-	-	-	-	-

(n.d.): not detected

TABLE 4. Results of SVOC screening of air samples collected on Tenax and PUF media

Substance	CAS RN	Private home #1	Private home #2	Private home #3	Private home #4	Internet café	Højskole Esport room	Højskole Gamer room
1,2-Benzenedicarboxylic acid, diethyl ester (DEP)	84-66-2	b	b	ab	a	n.d.	b	b
Dioctyl disulphide	822-27-5	ab	ab	n.d.	n.d.	b	ab	b
1-Hexadecanol (linear alkane C16)	36653-82-4	b	n.d.	ab	n.d.	b	n.d.	n.d.
2-Ethylhexyl salicylate (octisalate)	118-60-5	b	b	ab	n.d.	n.d.	b	b
Isopropyl myristate	110-27-0	b	ab	ab	n.d.	b	b	b
Galaxolide	1222-05-5	n.d.	n.d.	ab	n.d.	n.d.	n.d.	n.d.
Homosalate	118-56-9	n.d.	n.d.	ab	n.d.	n.d.	n.d.	n.d.
N-butyl-benzenesulfonamide	3622-84-2	n.d.	n.d.	n.d.	a	n.d.	n.d.	n.d.
Linear alkanes (C17-C22)	(multiple)	ab	ab	b	ab	b	ab	b
Linear alcohols (C16-C18)	(multiple)	ab	b	ab	b	b	b	b
Anthracen	120-12-7	b	n.d.	n.d.	n.d.	n.d.	b	n.d.
Phenanthrene	85-01-8	n.d.	n.d.	n.d.	n.d.	n.d.	b	n.d.
di-n-Butyl-adipate	105-99-7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	b
Dioctyl terephthalate (DOTP)	6422-86-2	b	b	b	n.d.	b	n.d.	n.d.
Irganox 1076	2082-79-3	n.d.	n.d.	b	n.d.	n.d.	n.d.	n.d.

Detected in air samples collected on Tenax (a), PUF (b), as well as Tenax and PUF (ab). Detected with match factor > 85% in the MS libraries: Wiley and NIST.
i.d.: Not detected.

TABLE 5. Results of the SVOC analysis in ng/m³ for air sampled on PUF media[1]

Substance	Abbreviation	CAS-no.	Private home #1	Private home #2	Private home #3	Private home #4	Internet café	Højskole Esport room	Højskole Gamer room
Dibutylphthalate	DnBP	84-74-2	182	151	243	145	94	29	587
Diethylphthalate	DEP	84-66-2	144	221	207	<67	<67	87	141
Diisobutylphthalate	DiBP	84-69-5	312	241	231	402	122	153	230.1
Dimethylphthalate	DMP	131-11-3	<67	<67	76.7	<67	<67	<67	<67
2.4.6-tribromophenol	2.4.6-TBP	118-79-6	2.1	<1.7	2.1	<1.7	<1.7	2.1	2.1
2-ethylhexyldifenylphosphate	EHDPP	1241-94-7	1.9	1.1	<0.83	<0.83	<0.83	<0.83	1.2
Tributhylphosphate	TBP	126-73-8	5.6	3.7	5.0	1.9	1.3	4.0	5.2
Tri(2-chloroethyl)phosphate	TCEP	115–96-8	<0.83	<0.83	<0.83	<0.83	2.7	<0.83	1.4
Tri(1-chloro-2-propyl)phosphate	TCPP	13674-84-5	67.0	46.8	39.8	15.1	48.9	25.5	54.5
Triethylphosphate	TEP	78–40-0	12.6	20.6	65.7	11.5	5.5	9.9	13.8
Trimethylphosphate	TMP	512–56-1	<0.08	<0.08	<0.08	0.1	<0.08	<0.08	<0.08
Triphenylphosphate	TPP	115–86-6	0.4	0.4	0.4	0.3	1.9	0.9	1.5

[1] The table indicates the identified SVOCs in air, where detection limits and substance list can be found in Appendix 6. Concentrations indicated with < signs mean the substance has not been found above its limit of detection (LOD) in the analyzed air volume.

3.2.3 Results from the dust analysis

In each of the seven cases, a dust sample was taken and analysed for the same 32 selected SVOCs that were analysed in this air quality study. See TABLE 6. It should be noted that the amount of dust (weight in g) varies between 0.11 and 0.50 g (average 0.35 g), which is why the detection limit is different for each of the samples. Therefore, substances have been detected in some dust samples in concentrations that are below the detection limit for other dust samples with a lower weight. The reason for the difference in the weight of the dust samples is due to the variation of cleanliness of the premises.

Overall, a total of 17 substances have been detected, divided into the groups: phthalates, brominated flame retardants, and organophosphates. In the four cases with dust samples over 0.5 g, the highest number of substances (15-16 substances) was detected, probably due to the lower detection limits. While between 4 and 10 substances have been detected in the three remaining dust samples.

Among the phthalates, the highest concentrations of between 888 and 446,821 ng/g have been found.
DEHP has been found in concentrations of between 44,047 and 273,751 ng/g and DiNP has been found in concentrations of 45,332 and 446,821 ng/g. Both substances were found in all dust samples, while neither substance was found in the air samples. BBP, was also only found in dust in three cases in concentrations between 888 and 10,340 ng/g. DnBP and DiBP, which were both found in the air in all cases, were found in five and four of the dust samples in concentrations between 1.241 and 14.394 ng/g. The finding of the mentioned phthalates in the dust samples is supported by findings in other countries with concentrations of up to several hundreds of thousands of ng/g (Wei et al. 2021, He et al., 2015).

Brominated flame retardants were found in two cases (Esport room #6 and Gamer room #7). It is BDE-47 and -99 that have been found in concentrations between 10 and 39 ng/g. Wei et al. (2021) have also found BDE-47 and -99 in classrooms in France at up to 10 ng/g (95th percentile). No bromophenols were found in any of the dust samples.

Ten organophosphates were detected. Among them, EHDPP, TBEP, and TPP were the most dominant, being found in 6-7 of the cases with the highest concentrations up to 11,648 ng/g. In addition, TBP, TCEP, TCPP, TDCPP, TEHP, TEP, and TMCP have been found in concentrations of up to 3783 ng/m^3. The measured levels of TBP, TCEP, TCPP, TDCPP, TBEP, and TPP do not differ from measured levels (median) in other countries (New Zealand, Belgium, USA, Japan, Sweden) found around homes or public places, shops, children's institutions, and workplaces (N. Ali et al. 2012).

The reason why some substances that are more prevalent in the dust samples in relation to the air samples is attributed to the substances' physio-chemical properties. They determine the extent to which the semi volatile substances bind to the dust or are found in the air in gaseous form. An easy way to determine whether the substance binds to the dust is to look at the substance's boiling point. At a higher boiling point, the substance has a greater tendency to bind to deposited dust or particles in the air compared to occurring in gas phase.

TABLE 6. Results of the SVOC analysis in ng/g for dust samples[1]

Substance	Abbreviation	CAS RN	Private home #1	Private home #2	Private home #3	Private home #4	Netcafé	Højskole Esport room	Højskole Gamer room
Dust sample weight (g)			**0.02402**	**0.01064**	**0.05010**	**0.05048**	**0.01524**	**0.05030**	**0.05004**
Benzylbutylphthalate	BBP	85-68-7	<1665	<3759	<798	888	<2625	6775	10340
Dibutylphthalate	DBP	84-74-2	3769	<3759	8499	5816	<2625	8049	14294
Diethylhexylphthalate	DEHP	117-81-7	44047	93589	102329	77345	50490	133321	273751
Diisobutylphthalate	DiBP	84-69-5	<1665	<3759	1859	1840	<2625	1241	1862
Disionynylphthalate	DiNP	28553-12-0	45332	61529	141332	35569	152441	235059	446821
2,2',4,4',5-Pentabromodiphenylether	BDE-99	60348-60-9	<20.8	<47	<10	<9.9	<32.8	39.0	10.4
2-Ethylhexyldifenylphosphate	EHDPP	1241-94-7	4630	3691	453	157	890	5010	11648
Tri(2-butoxyethyl)phosphate	TBEP	78-51-3	4140	<235	1280	132	11124	1273	837
Tributhylphosphate	TBP	126-73-8	<20.8	<47	25.8	24.7	<32.8	38.4	35.2
Tri(2-chloroethyl)phosphate	TCEP	115–96-8	<20.8	<47	20.4	25.4	365	86.9	144
Tri(1-chloro-2-propyl)phosphate	TCPP	13674-84-5	2127	<470	3713	2468	<328	888	1923
Tri(1,3-dichloro-2-propyl)phosphate	TDCPP	13674-87-8	310	<94	96.6	3783	1189	287	1280
Tri(2-ethylhexyl)phosphate	TEHP	78–42-2	667	<235	2397.0	188	<164	225	149
Triethylphosphate	TEP	78–40-0	<10.4	<23.5	5.6	6.4	<16.4	<5	<5
Tri-m-cresylphosphate	TMCP	563–04-2	22.9	<9.4	57.2	21.4	24.8	108	47.0
Triphenylphosphate	TPP	115–86-6	230	277	217	337	2443	5965	2800

[1] The table only indicates the identified SVOCs, where detection limits and substance list can be found in Appendix 6. Concentrations indicated with < signs mean that the substance has not been detected above its detection limit (LOD) at the analyzed amount of dust.

4. Initial hazard assessment and exposure scenario

Based on the survey and field analyses, an initial hazard screening of the chemical substances is carried out in terms of prioritizing the toxicologically most problematic substances that should be analysed in subsequent testing of gaming equipment. As emissions of volatile substances are dependent on climatic conditions such as temperature and humidity, an exposure scenario will be established.

4.1 Preliminary hazard screening of chemicals

The screening is based on the following criteria:

- Hazard classification of the substances and general knowledge about the substances from e.g., previous projects for the Danish EPA
- Quantitative data (e.g., disregarding very low measured levels)

Overall, the identification of the most critical substances as potential hazards prioritises critical systemic effects, such as CMR effects and STOT RE classifications. Respiratory sensitizers, respiratory irritants, and corrosive substances were also prioritised.

The following substances identified in the survey and field studies are prioritised for further analyses of gaming equipment:

- Aldehydes: Formaldehyde, acetaldehyde, butyraldehyde/butanal, hexanal
- VOCs: 2-ethylhexanoic acid, 2-ethyl-1-hexanol, dimethylformamide, triethylendiamine, furan, tetramethylbutanedinitrile, phenol, cyclic siloxanes (D3, D4, D5, D6)
- Brominated flame retardants: BDE 47, BDE 99, BDE 100
- Others: Acrylamide, formamide

It should be noted that very low levels of phthalates were found in the air in the field studies, as the sum of the seven phthalates measured was below 1 μg/m³, whereas relatively high concentrations were found in dust. A possible exposure by inhalation cannot be ruled out, hence phthalates in air were considered relevant for continued measurements. Correspondingly, brominated flame retardants remain a priority for quantification, as the literature connects these compounds to adverse health effects.

4.2 Initial assessment of exposure

Based on the information from the survey for expected use of gaming equipment, the exposure scenarios for young people's exposure to substances released during gaming are described next.

In private homes in Denmark, gaming often happens in bedrooms, thus providing many hours of daily exposure. Gaming happens during shorter or longer periods of time depending on free time, weekdays, and weekends. Typical gaming lasts 2-6 hours per day. At events such as

LAN-party[3], gaming lasts approx. 9-24 hours overnight or 2 days if the event is taking place during weekends.

4.3 Exposure scenarios

The cubic volume of the gamer rooms in the 4 private homes where field research was carried out, was between 17 – 24 m^3, and considering the space per gaming setup, the average volume is 18 m^3 per gaming setup. In the school's (højskole) gamer room, there was only 8-9 m^3 room per gaming setup and poor ventilation. At the gamer cafe, there was 18 m^3 room per gaming setup.

The European reference room is 30 m^3 at a standard climate of 23°C and 50% RH, with an air exchange per hour of 0.5 h^{-1} (EN 16516, 2017). In the international standard for climate chamber testing (ISO 16000-9, 2006), the standard room is defined as 17.4 m^3 with an air change rate of 0.5 h^{-1}. Room size varies according to function in homes, schools, and public places. Children's and young people's rooms are smaller than shared living spaces, and children's rooms are indicated to be on average 17.4 m^3 with an air exchange of 0.35 h^{-1} in single-family houses (SCHEER 2016, Bornehag 2005).

The average ventilation rate in poorly ventilated rooms has recently been measured in Denmark to be 0.2 h^{-1} (Hansen et al. 2020), and especially children's and teenager's rooms are often poorly ventilated (Heide et al., 2021).

During the field investigations, an average temperature of 25°C and relative humidity of 51% RH were observed. When gaming, the equipment will get warm due to heat release from electronics and from people, so the temperature in a room will typically be a few degrees higher than in a standard room.

Based on the field studies, a worst-case scenario for a gamer reference room was concluded to be:

Room volume per gaming setup:	17.4 m^3
Air change rate:	0.2 h^{-1}
Climate conditions:	25°C / 50 % RH

These climate and ventilation conditions will be used in the testing of gaming equipment. If analyses are carried out during a different air exchange change rate or material load, the results will be corrected by a factor so that the concentrations of the chemicals in air correspond to a realistic worst-case scenario for exposure.

[3] LAN party: All-night event over several days on weekends and holidays where several people bring their own computers and play competitive multiplayer games. Can take place in private homes or in larger places, such as schools and sports halls.

5. Analysis of gaming equipment emissions

The purpose of this part of the study is to determine the emissions of volatile chemical substances from selected gaming products, which will form the basis of the subsequent health and risk assessments. Tests were carried out in the period between July and August 2022.

5.1 Selection of products for analysis

Based on products identified during the survey, 33 products were selected for climate chamber testing based on the following criteria:

- Availability and price on the Danish market
- Purchasing from a variety of Danish websites
- Variety in brands, manufacturers, and materials
- Most sold (popular) in June and July 2022

The 33 new products were selected within the following categories: Computer, screen, keyboard, mouse, mouse pad, headset, and gaming chair.

TABLE 7. contains an overview of products selected and purchased for analysis. All electrical products come with soft cables and in some cases a power supply. Mouse pads (ID 5, 12, 21, 31), wireless mice (ID 24) and three gaming chairs (ID 7, 14, 22) do not have power cables.

TABLE 7. Overview of gaming equipment selected for analysis

ID	Product type	Specifications and materials
1	PC	Cabinet: Plastic, steel, tempered glass, RGB lights Graphic card: GTX 1660Ti, 6GB DDR6 RAM CPU: IntelCore i5 10400F, 2.90GHz (4,3GHz Turbo Boost) RAM: 16GB DDR4 RGB Hard disk: 500 GB M.2 NVMe SSD
2	Screen	24" Full HD (1080p) 1920 x 1080 Refresh rate: 144 Hz Response time: 1 ms (MPRT) LED – backlit LCD screen
3	Keyboard	Plastic, RGB-lighting
4	Mouse	Plastic, RGB-lighting
5	Mousepad	Textile, rubber, 900x500x3mm, water resistant
6	Headset	Plastic, aluminium, PU-leather, foam
7	Gaming chair	Plastic, foam, PU-leather, wooden frame, plastic legs, pillow headrest, leather coated armrest (13 kg)
8	PC/laptop	Screen: Full HD 144Hz IPS-screen 15.6" Graphics card: GTX 3060, 16GB DDR5 RAM CPU: Intel Core i7-12650H, 2,30 GHz RAM: 2x8 GB DDR5

		Hard disk: 1000 GB M.2 NVMe SSD
9	Screen	24" Full HD (1080p) 1920 x 1080 Refresh rate: 144 Hz Response time: 1 ms (MPRT) LED screen
10	Keyboard	Plastic, RGB-lighting, USB cable, wrist rest
11	Mouse	Plastic, USB cable, RGB-backlighting
12	Mouse mat	Textile, rubber, nonslip, 350x300 mm
13	Headset	Plastic, stainless steel, PU leather, foam
14	Gaming chair	Plastic, metal, wooden frame, PU foam, textile, plastic legs, leather coated armrest (18.5 kg)
15	PC	Cabinet: Plast, metal, glas, RGB Grafikkort: GTX 1650 D6, 2x4 GB DDR4 CPU: Intel Core i5-11400, 260 GHz RAM: 2x4 GB DDR4 Hard disk: 1000 GB M.2 NVMe SSD
16	Screen	34" curved WQHD (1440 p) Refresh rate: 144 Hz Response time: 1 ms (MPRT) LED – backlit LCD screen
17	PC	Cabinet: Plastic, metal, glass, RGB-lighting Graphics card: RTX 3070, 8GB LHR CPU: AMD Ryzen 7 5800X, 3.8 GHz RAM: 16 GB DDR4 Hard disk: 1024 GB M.2 NVMe SSD
18	Monitor (2x)	27" QHD (1440 p) Refresh rate: 165 Hz Response time: 1 ms (MPRT) LED – backlit LCD screen
19	Keyboard	Plastic, RGB-lighting, USB cable
20	Mouse	Plastic, USB cable, RGB-lighting
21	Mouse pad	Textile, rubber, 450x400mm
22	Gaming chair	PU leather upholstery, metal frame, pillows head- and backrest, leather coated plastic armrest, plastic legs (16 kg)
23	Keyboard	Wireless, plastic, RGB-lighting
24	Mouse	Wireless, plastic, RGB-lighting, PTFE
25	Mouse pad	Polypropylene, polystyrene, rubber base 340 mm x 280 mm
26	Headset	Wireless, aluminium, artificial leather, memory foam, steel
27	Gaming chair	PU – leather, nylon, RGB lighting, plastic armrest, plastic legs, pillows head- and backrest (20 kg)
28	Headset	Wireless, plastic, aluminum and steel, foam, textile
29	Keyboard	Plastic, cord, wrist rest

30	Mouse	Plastic, USB cable, RGB-backlighting
31	Mouse pad	Rubber, textile
32	Headset	Plastic, aluminium, artificial leather, foam
33	Gaming chair	Plastic, aluminium, textile, steel, moulded foam, plastic armrest, plastic legs, pillows head- and backrest. Heavy chair (28 kg)

5.2 Analysis program

The European standard ECMA-328-2 (2017) provides an appropriate procedure for testing electronic equipment. It refers to ISO 16000-3/-6/-9 which deals with chamber tests and analysis of carbonyls and VOCs. To obtain concentration measurements that can be used for realistic exposure scenarios, the equipment is unpacked and conditioned for 3 days to avoid initially high emissions. Air samples are collected to determine concentrations of VOCs and aldehydes at the end of a gaming period. As a large volume of air must be collected for SVOC analysis, air is collected on PUF samplers during the entire gaming period of 24 hours.

The products are divided into three test setups: two gaming setups are tested separately. Each setup contains a computer, monitor and accessories and is tested under gaming stress via simulation software. Testing of one of the two sets is divided into two phases; the accessories are first tested individually and then together in a climate chamber with PC and monitor. In this way, it can be assessed whether the emissions are derived from either the accessories or the PC and the screen. The next two setups each consist of a computer and a monitor while gaming is simulated. An overview of the test plan can be seen in FIGURE 8.

Additionally, 20 gaming accessories are tested within the following categories: keyboard, mouse, mouse pad, headset and gaming chairs.

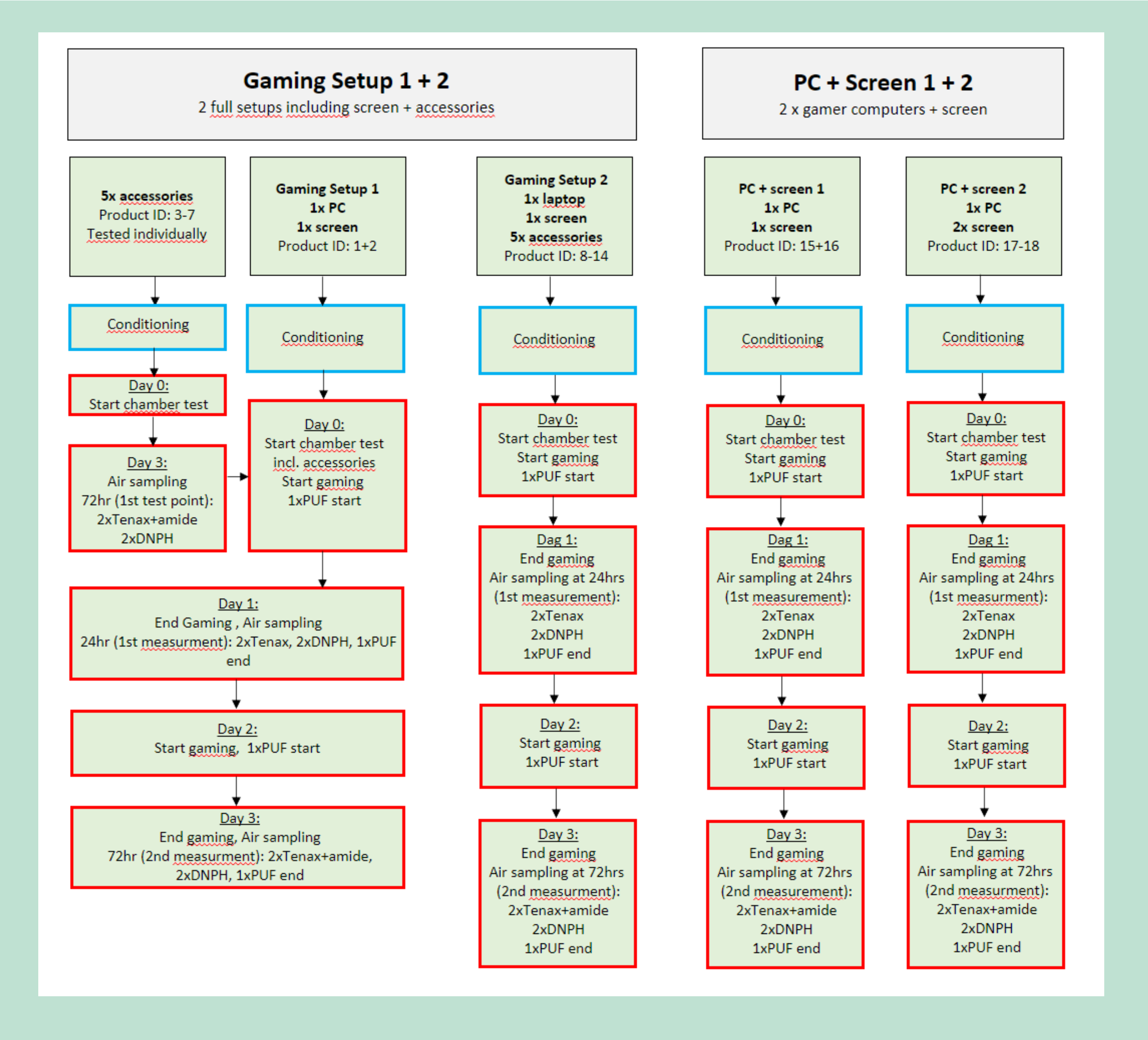

FIGURE 8. Overview of analysis plan for testing of “gaming setup 1+2”, and “PC + screen 1+2” (screen = monitor)

5.2.1 Test conditions for climate chamber tests

The test conditions are chosen based on the exposure scenarios for gaming equipment, see section 4.3, where realistic worst-case conditions during gaming are 25 °C and 50% RH in a room of 17.4 m^3 and air change 0.2 h^{-1}. Before the newly purchased equipment is placed in the test chamber, it is unpacked and left for conditioning for 3 days at 20-25 °C and 50% RH, so that substances from packaging and production degas before the test begins. An overview of the climate conditions appears in TABLE 8.

The gaming equipment is tested in climate chambers in the sizes 0.25 m^3, 6 m^3 and 24 m^3. Chamber size used depends on the size of the gaming equipment. The air exchange is set within the possible limits for the selected climate conditions in the respective chambers. All accessories, except chairs, are tested in 0.25m^3 chambers. Gaming chairs are tested in 24 m^3 or 6 m^3 chambers. The four gaming setups with PCs are tested in a 6 m^3 chamber. The chambers are suitable for testing electronic equipment and where possible the products were connected to power and switched on. The small gaming products are placed on a metal stand in the middle of the climate chamber. Gaming setups are placed on a glass table with steel frame. There were two large mouse mats, which were broken down to fit the size of the climate chamber.

TABLE 8. Climate chamber conditions during conditioning and testing of gaming equipment

	Temperature	Air humidity	Air change	Duration
Conditioning	20-25 °C	50 %	1.0 h^{-1}	3-4 days
Gaming accessories test	25 °C	50 %	0.25 h^{-1}/1.0 h^{-1}	3 days
Gaming setup/PC+monitor test	25-35 °C	50 %	0.38 h^{-1}	3 days

Temperature and humidity

The starting point was standardised to indoor climate conditions for tests in climate chambers: 23°C, 50% relative humidity and 0.5 air changes, refer to ISO 16000-9 and EN 16516. Based on field studies, it was observed that the average temperature in 7 gaming locations was 25°C. A relative humidity of 50% was maintained, as an average of 51% has been measured in the field studies. It was not accounted for that gaming accessories will heat up during use by people via body heat.

Measurement units

Measurements are given in the concentration unit µg/m^3, as the concentration in the reference room for gamers can thus be directly used for exposure and risk assessment. For the gaming equipment analysed in the small 0,25 m^3 climate chambers and 24 m^3 climate chamber, the concentration corresponding to the concentration in the gamer reference room was converted by a factor that considers differences in ventilation, the size of the room, and the climate chamber.

TABLE 9 indicates conversion factors. An additional factor was multiplied by the measured concentrations for the two large mouse mats, ID 4 and ID 31, which were cut to an appropriate sizes for testing, quarters and thirds respectively. The concentration measurements of gaming setups, which are measured in 6 m^3 climate chambers, was used directly, as the air change was adapted to the conditions in the gamer reference room.

TABLE 9. Factor for converting measured concentration in climate chamber to exposure in the gamer reference room of 17.4 m^3

Type of product for testing	Chamber	Conversion factor
Gaming computer setup	6 m^3	1
Gaming accessories	0.25 m^3	0.07184
Gaming chair	24 m^3	1.724

Measurement periods

Gaming equipment accessories were conditioned for 3 days, after which the test period lasts a further 3 days, after which air sampling was carried out. Air samples was collected on Tenax and DNPH collection media. The 4 gaming setups were conditioned for 3 days, and the concentration of the emissions is measured after 24 and 72 hours. Air samples was collected on Tenax, DNPH and PUF collection media.

Air change

The airchange rate for testing gaming accessories in the 0.25 m^3 chamber was set to 1 air-change per hour (1 h^{-1}) as it was not possible to set the air change to correspond to the reference room. This avoided an excessively high concentration which could result in an overloading of the collection medium. The gaming chairs were tested in 24 m^3 and 6 m^3 climate chambers and the airchange rate is set to 0.25 and 1 per hour.
Gaming setups were tested in 6 m^3 climate chamber where the air exchange is set to 3.48 m^3 per hour, so that the conditions correspond to the reference room.

Gaming

Gaming setups were tested with simulated gaming stress for two periods. The first period is from 0-24 hours and the second period is from 48-72 hours. It is simulated by a demo version of the video game Final Fantast XIV. The video game is a popular multiplayer online role-playing game. The game is chosen because, in addition to being a popular game with 25 million registered players (SQUARE ENIX, 2022), it has a demo version available and requires a high capacity of the graphics card, putting a high strain on the equipment. The program is set to run in a loop for 24 hours, which simulates the worst-case scenario of a LAN party.
During chamber tests, the chamber cannot be opened, and the gaming equipment is therefore controlled remotely with the program Team Viewer which is used to gain remote access to computer software. Temperature data is collected for the processor and graphics card with the system monitoring program SpeedFan for Microsoft Windows. Team Viewer and Speedfan were downloaded as freeware. Challenges with Team Viewer and the video game reduced the actual gaming simulation time by 24 hours, see TABLE 10. These challenges consisted of the simulation software stopping spontaneously, also Team Viewer lost connection, and gaming could not be resumed by remote access. The game and computer freeze after several hours of gaming and may be caused by increased temperatures due to heating of the equipment.

TABLE 10. Game time in hours during the first and second gaming periods

	Gaming Setup 1	Gaming Setup 2	PC+Monitor 1	PC+Monitor 2
	Gaming time (hours)			
Gaming 1st period	21	22	24.5	11.5
Gaming 2nd period	21.5	10	13	9.5

Other measurements

Ultra-fine particles (UFP) with a particle diameter of 0.02 µm to 1 µm are measured before gaming and immediately after gaming with a TSI P-Trak 8525 Particle Counter. Power consumption is measured for gaming setups in standby mode and under gaming load. Temperature and relative humidity are monitored for all climate chambers.

Air sampling

Chemical analyses of air samples are described in TABLE 11, where deviations from the methods described in section 3.1.1 are summed up. The volume of air sampling for Tenax and DNPH follows the standard for chamber tests (EN 16516). Air sampling with the PUF collection medium during chamber tests can take place for 24 hours, thereby sampling a larger volume than during the field investigations. Sampling with PUF media takes place during the gaming periods, when the product and chamber are further heated by the equipment being active.

TABLE 11. Parameters for air sampling and qualitative/quantitative method of analysis

Substance	Collection medium	Sample volume	Flow	Analysis method
Formamide	Tenax	4 L	100 mL/min	TDS-GC/MS Polar FFAP GC-column
VOC	Tenax	2-5 L	100 mL/min	TDS-GC/MS
Formaldehyde and carbonyls	DNPH coasted Silica gel	60 L	1000 mL/min	HPLC-DAD
SVOC	76 mm polyurethane foam (PUF)	2800-3100 L (ca. 24 hours)	2000 mL/min	GC/MS/MS

5.3 Results emission of volatile substances from gaming equipment

This section summarises the results of chamber tests carried out in the period between July and August 2022. The VOC results are shown in tables 13-17, where the substances are divided into chemical groups. The reporting limit is 5 µg/m^3, see reference EN 16516. Substances with concentrations between 1 µg/m^3 and 4 µg/m^3 are indicated with < 5 µg/m^3.

In Appendix 5, all detected VOC substances for gaming accessories are listed in tables down to 1 µg/m^3. The measured concentrations from the gaming accessories have been adjusted to the reference room with the factors given in table 9, i.e. several of the substances measured have concentrations lower than 1 µg/m^3. Substances in concentrations < 1 µg/m^3 are not reported in Tables 13, 14 and 15, as they will fall below the detection limit in the reference room.

For chamber tests of gaming setups with PC and monitor, the average temperature of the climate chamber, graphics card and processor are given in TABLE 12. The temperature appears both during standby mode, where the equipment is switched on, and during gaming. Further information on power consumption and UFP measurements appears in the same table. There is a clear rise in temperature for all three parameters during gaming compared to standby mode. Power consumption is also significantly higher during gaming. Measurements of UFP show a decrease in the number of particles after gaming for all setups, except PC and monitor 2. The decrease may be due to the built-in filter in the computer. The one exception of PC and monitor setup 2 showing increasing number of UFP may be due to measurement being taken approx. 14 hours after gaming, after the filter effect from the fans had stopped.

TABLE 12. Average temperature (°C) of climate chamber, graphics card and processor and power consumption (watts) in standby mode and during gaming. UFP after 24 hours and 48 hours in the chamber test period (only during gaming). Gaming setup 1 consists of products ID 1-7, Gaming setup 2 consists of products ID 8-14, PC + monitor 1 consists of products ID 15-16, PC + monitor 2 consists of products ID 17-18

	Gaming setup 1	Gaming setup 2	PC + monitor 1	PC + monitor 2
	(standby mode / **gaming**)			
Chamber temp. (°C)	25 / **29**	25 / **27**	25 / **29**	25 / **35**
Graphics card, GPU (°C)	33 / **78-84**	39-51 / **78-83**	27-39 / **67-69**	41-57 / **63-75**
Processor, CPU (°C)	14 / **49-67**	21-35 / **59-69**	34-50 / **42-62**	Ingen data[1]
Power consumption (watt)	51-56 / **200-220**	45-50 / **140-160**	60 / **200**	120 / **390**
UFP, empty chamber (pt/cm³)	240-280	100-110	50-70	66-78
UFP, 24h/72h (pt/cm³)	120-130 / 110-130	13-30 / 65-85	27-35 / 39-55	35-42 / 180-220

[1] Unable to log with Speedfan on this device

The results from testing of gaming accessories appear in TABLE 13 and TABLE 14, where the measured concentrations are converted to the gamer reference room. Emissions for gaming accessories such as keyboards, mice, mouse pads and headsets are characterised by some chemicals at low concentrations. Of the chemicals mentioned in the initial risk assessment, cyclic siloxanes (D5 and D6) and formaldehyde have been found in concentrations between 5-10 µg/m³.

TABLE 123. Results of VOC and aldehyde measurements for keyboard and mouse in µg/m³. Concentrations corresponds to the reference room

		Keyboard				Mouse			
Substance	**CAS RN**	**ID 3 [1]**	**ID 19**	**ID 23**	**ID 29**	**ID 4 [1]**	**ID 20**	**ID 24**	**ID 30**
Alcohols									
2-Phenyl-2-propanol	617-94-7	n.d.	n.d.	n.d.	5	n.d.	n.d.	n.d.	< 5
Organic acids									
Acetic acid	64-19-7	n.d.	< 5	< 5	< 5	< 5	5	< 5	< 5
Siloxanes									
Dodecamethylcyclohexasiloxane (D6)	540-97-6	< 5	< 5	< 5	7	< 5	< 5	< 5	< 5

[1] Products are tested both under single tests and as a combined tests in gaming setup 1

n.d.: not detected

TABLE 134. Results of VOC and aldehyde measurements for headset and mouse pad in µg/m³. Concentrations correspond to the reference room

		Headset				Mouse pad			
Substance	**CAS RN**	**ID 6 [1]**	**ID 26**	**ID 28**	**ID 32**	**ID 5 [1]**	**ID 21**	**ID 25**	**ID 31**
Aldehydes									
Formaldehyde (VVOC) *	50-00-0	< 5	< 5	< 5	< 5	5	< 5	< 5	< 5
Organic acids									
Acetic acid	64-19-7	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6
Siloxanes									
Decamethylcy-clopentasilox-ane (D5)	541-02-6	< 5	< 5	8	< 5	< 5	< 5	< 5	< 5
Dodecamethyl-cyclohexasilox-ane (D6)	540-97-6	< 5	< 5	9	< 5	< 5	< 5	< 5	< 5
Thiazoles									
Benzothiazole	95-16-9	< 5	< 5	< 5	< 5	< 5	< 5	< 5	5
Sum of other iso/cyclo-al-kanes:	(13475-82-6)	11	< 5	< 5	20	53	21	< 5	51
Sum af other hydrocarbons:	(108-88-3)	< 5	< 5	< 5	< 5	40	< 5	< 5	< 5

* Classified as CMR substance category 1A or 1B under Annex VI to Regulation (EC) No 1272/2008

[1] Products are tested both under single tests and as a combined tests in gaming setup 1

The analysis of emissions from gaming chairs shows several chemicals at higher concentrations, see TABLE 15. Formaldehyde emits at high concentrations from the products ID 22 and ID 33, respectively. 130 µg/m³ and 120 µg/m³. The concentration exceeds the WHO's recommended limit value of 0.1 mg/m³, which is also described in the building regulations (Bygningsreglementet BR18, 2018). In addition, the measured concentration exceeds the recently established limit value for formaldehyde in articles of 0.08 mg/m³.

Of the chemicals mentioned in the initial hazard assessment, cyclic siloxanes (D3 and D4), phenol, 2-Ethyl-1-hexanol and 2-Ethylhexanoic acid were found. The latter emits in a concentration of 36 µg/m³ from product ID 27. Acetic acid also emitted from all products in high concentrations, from 78-260 µg/m³.

In addition, chemicals with CMR effects were found in the emissions; safrole and N,N-Dimethylformamide (DMF). DMF has been found in high concentrations for ID 7 and ID 27, 38 µg/m³ and 98 µg/m³, respectively. The substances DMF, acetic acid, cyclic siloxanes and 2-ethyl-1-hexanol can be assumed to originate from PU foam, as these have previously been found in the emissions from PU foam (Poulsen, 2020).

TABLE 145. Results of VOC and aldehyde measurements for gaming chairs in µg/m³. Concentrations correspond to the reference room

		Gaming chair			
Substance	**CAS RN**	**ID 7 [1]**	**ID 22**	**ID 27**	**ID 33**
Aldehydes					
Formaldehyde (VVOC) *	50-00-0	16	130	9	120

		Gaming chair			
Substance	**CAS RN**	**ID 7 [1]**	**ID 22**	**ID 27**	**ID 33**
Hexanal	066-25-1	< 5	5	< 5	< 5
Benzaldehyde	100-52-7	< 5	< 5	< 5	5
Nonanal	124-19-6	n.d.	n.d.	n.d.	5
Alcohols					
2-Ethyl-1-hexanol	104-76-7	< 5	< 5	< 5	13
4-Methyldiphenylmethane	620-83-7	n.d.	5	n.d.	n.d.
1-Methoxy-2-propanol	107-98-2	5	n.d.	n.d.	n.d.
Glycols, Ethers, Esters					
Carboxylsyreester		< 5	5	< 5	n.d.
Safrole (Toluen) *	94-59-7	n.d.	12	n.d.	n.d.
Triacetin	102-76-1	n.d.	5	n.d.	10
Butyldiglycol acetate	124-17-4	n.d.	n.d.	n.d.	9
Ether (Toluen)		n.d.	n.d.	5	n.d.
Benzoic acid, 4-ethoxy-, ethyl ester (Toluen)	23676-09-7	9	n.d.	16	n.d.
1,2-Propylene carbonate	108-32-7	6	n.d.	9	16
Amines/Amides					
N,N-Dimethylformamide (DMF) *	68-12-2	38	n.d.	98	15
Nitriles					
2,2'-Azobis(2-methylpro-panenitrile) (AIBN)	78-67-1	n.d.	5	n.d.	n.d.
Aliphatic hydrocarbons					
C12 (Dodecane)	112-40-3	n.d.	5	n.d.	n.d.
C13 (Tridecane)	629-50-5	n.d.	9	17	n.d.
C14 (Tetradecane)	629-59-4	n.d.	< 5	5	< 5
Aromatic hydrocarbons					
Toluene	108-88-3	10	n.d.	5	< 5
Methylnaphthalene (1-Methyl-naphthalen)		n.d.	15	n.d.	n.d.
Dimethylphthalate (DMP)	131-11-3	< 5	5	n.d.	n.d.
Dimethylnaphthalene (2,6-Di-methylnaphthalen)	1051-00-0	n.d.	30	n.d.	n.d.
Methylbiphenyl (Toluen)		n.d.	15	n.d.	n.d.
Trimethylnaphthalene (2,3,5-Trimethylnaphthalen)	1052-00-0	n.d.	16	n.d.	n.d.
2,2,5,5-Tetramethylbiphenyl	3075-84-1	n.d.	5	n.d.	n.d.
Terpenes					
α-Terpineol	7785-53-7	5	n.d.	n.d.	n.d.
Longifolene	475-20-7	n.d.	29	n.d.	n.d.
Organic acids					
Acetic acid	64-19-7	110	81	78	260
2-Ethylhexanoic acid	149-57-5	5	5	36	-
Palmitic acid	57-10-3	17	n.d.	n.d.	22
Siloxanes					

		Gaming chair			
Substance	**CAS RN**	**ID 7 [1]**	**ID 22**	**ID 27**	**ID 33**
Hexamethylcyclotrisiloxane (D3)	541-05-9	9	< 5	7	5
Hexadecamethylheptasiloxane (Octamethylcyclotetrasiloxan (D4))	541-01-5	n.d.	n.d.	n.d.	5
Phenols					
Phenol	108-95-2	n.d.	n.d.	< 5	5
4-Nonylphenol (Toluen)	104-40-5	n.d.	n.d.	7	n.d.
Sum of other iso/cyclo-alkanes:	(13475-82-6)	n.d.	24	240	21
Sum of other siloxanes:	(556-67-2)	n.d.	19	n.d.	< 5
Sum af other sesquiterpenes:	(475-20-7)	n.d.	10	n.d.	n.d.
Sum of other terpenes:	(80-56-8)	< 5	37	n.d.	< 5
Sum of other hydrocarbons:	(108-88-3)	n.d.	150	n.d.	n.d.

Substances indicated in sunken brackets have been used for calibration due to the lack of a reference substance.

* Classified as CMR substance category 1A or 1B under Annex VI to the regulation (EC) No 1272/2008

[1] Products are tested both under single tests and as a combined tests in gaming setup 1

n.d.: not detected

Gaming setup 1 and 2

VOC emissions from gaming setups 1 and 2 appear in TABLE 16. From the initial hazard assessment relevant chemicals, the following substances are found in the measurements for gaming setup 1 (id 1-7): formaldehyde, cyclic siloxanes (D5, D6 and D7), phenol, 2-ethyl-1-hexanol, 2-ethylhexanoic acid and chemicals with CMR effect: DMF and N,N-dimethylacetamide. All substances, except phenol and N,N-dimethylacetamide, were also found in individual tests of accessories (ID 3-7), most of all in the gaming chair (ID7). Formaldehyde and DMF have been found in the highest concentrations of 35 µg/m^3 (3d) and 44 µg/m^3 (3d). No significant difference is seen in the concentrations measured after 1 day and 3 days. From gaming setup 2 (ID 8-14) there is formaldehyde, cyclic siloxanes (D3, D5, D6 and D7) and 2-ethyl-1-hexanol. The concentrations are slightly decreasing for the measurements after 3 days compared to 1 day.

TABLE 16. Results of VOC and aldehyde measurements for Gaming setup 1 and 2 in µg/m^3 Concentrations correspond to reference room

		Gaming setup 1 ID 1-7		Gaming setup 2 ID 8-14	
Substance	**CAS RN**	**1 d**	**3 d**	**1 d**	**3 d**
Aldehydes					
Formaldehyde (VVOC) *	50-00-0	34 [1]	35 [1]	31	24
Ketones					
Cyclohexanone	108-94-1	< 5	< 5	10	7
Ketone (toluene)		11	11	n.d.	n.d.
Alcohols					
Butanol	71-36-3	5	< 5	8	6
2-Ethyl-1-hexanol	104-76-7	10 [1]	9 [1]	5	< 5

		Gaming setup 1 ID 1-7		Gaming setup 2 ID 8-14	
Substance	**CAS RN**	**1 d**	**3 d**	**1 d**	**3 d**
Dodecanol	112-53-8	6	6	n.d.	n.d.
Glycols, Ethers, Esters					
1,2-Propylene carbonate	108-32-7	7 [1]	8 [1]	n.d.	n.d.
Ethylhexyl acrylate	103-11-7	10	9	< 5	< 5
Isobornyl acrylate	5888-33-5	7	6	10	7
Diethylene glycol dibutyl ether	112-73-2	n.d.	n.d.	10	6
Aliphatic hydrocarbons					
C14 (Tetradecane)	629-59-4	10	10	< 5	< 5
C15 (Pentadecane)	629-62-9	11	10	7	7
C16 (Hexadecane)	544-76-3	11	12	6	7
C17 (Heptadecane)	629-78-7	< 5	< 5	6	7
Aromatic hydrocarbons					
Toluene	108-88-3	9 [1]	9 [1]	6	5
m,p-Xylene	1330-20-7	< 5	< 5	6	5
Phenols					
Phenol	108-95-2	5	< 5	< 5	< 5
Amines					
N,N-Diethylmethylamine	616-39-7	6	< 5	< 5	< 5
Caprolactam	105-60-2	n.d.	n.d.	6	5
Amides					
N,N-Dimethylformamide (DMF) *	68-12-2	46 [1]	44 [1]	n.d.	n.d.
N,N-Dimethylacetamide *	127-19-5	2	2	n.d.	n.d.
Terpenes					
α-Terpineol	7785-53-7	6 [1]	7 [1]	< 5	< 5
Organic acids					
Acetic acid	64-19-7	74 [1]	83 [1]	210	160
Palmitic acid	57-10-3	n.d.	n.d.	8	11
2-Ethylhexanoic acud	149-57-5	20 [1]	22 [1]	n.d.	n.d.
Siloxanes					
Hexamethylcyclotrisiloxane (D3)	541-05-9	n.d.	n.d.	7	5
Decamethylcyclopentasilox-ane (D5)	541-02-6	< 5 [1]	< 5 [1]	5	< 5
Dodecamethylcyclohex-asiloxane (D6)	540-97-6	< 5 [1]	< 5 [1]	13	8
Tetradecamethylcyclohep-tasiloxane (D7)	107-50-6	6	< 5	6	5
Sum af other iso/cyclo-al-kanes:	(13475-82-6)	140 [1]	130 [1]	670	580
Sum of other siloxanes:	(556-67-2)	11	11	n.d.	n.d.

		Gaming setup 1 ID 1-7		Gaming setup 2 ID 8-14	
Substance	**CAS RN**	**1 d**	**3 d**	**1 d**	**3 d**
Sum af other sesquiter-penes:	(475-20-7)	5	5	n.d.	n.d.
Sum of VOCs (TVOC)		400	380	980	810

Substances indicated in sunken brackets have been used for calibration due to the lack of a reference substance. * Classified as CMR substance category 1A or 1B under Annex VI to Regulation (EC) No. 1272/2008. [1] Found in gaming equipment accessories (ID 3-7) see TABLE 13, TABLE 14, and TABLE 15 (n.d.): not detected

PC and monitor, set 1 and 2

Results for PC and monitor setups 1 and 2 are below in TABLE 17. In tests of PC and monitor 1 (ID 15-16), the following chemicals were found that are relevant from the initial hazard assessment: cyclic siloxanes (D5, D6 and D7), 2- Ethyl-1-hexanol and styrene with CMR effect. In addition to the chemicals mentioned, phenol was found from PC and monitor 2 in a concentration of 5 µg/m^3. Styrene is found in the same concentration. Siloxanes have been found in concentrations between 6 and 22 µg/m^3.

TABLE 17. Results of VOC and aldehyde measurements for PC and monitor 1 and 2 in µg/m³. Concentrations corresponds to the reference room

Substance	**CAS RN**	**PC + monitor 1 ID 15 + 16**		**PC + monitor 2 ID 17 + 18**	
		1 d	**3 d**	**1 d**	**3 d**
Ketones					
Cyclohexanone	108-94-1	8	6	< 5	< 5
Ketone (toluen)		-	-	24	9
Ketone (toluen)		21	16	23	10
Alcohols					
Butanol	71-36-3	-	-	6	5
2-Ethyl-1-hexanol	104-76-7	9	6	9	< 5
Dodecanol	112-53-8	-	-	6	< 5
Glycols, Ethers, Esters					
1,4-Dioxane	123-91-1	-	-	6	< 5
Ethylhexyl acrylate	103-11-7	16	11	< 5	< 5
Isobornyl acrylate	5888-33-5	< 5	< 5	11	< 5
Diethylene glycol dibutyl ether	112-73-2	-	-	10	< 5
Aliphatic hydrocarbons					
C14 (Tetradecane)	629-59-4	5	< 5	9	< 5
C15 (Pentadecane)	629-62-9	< 5	< 5	34	9
C16 (Hexadecane)	544-76-3	5	< 5	40	8
C17 (Heptadecane)	629-78-7	< 5	< 5	17	< 5
C18 (Octadecane)	593-45-3	-	-	5	< 5
Aromatic hydrocarbons					
Toluene	108-88-3	12	7	< 5	< 5
m,p-Xylene	1330-20-7	7	< 5	11	6

Substance	CAS RN	PC + monitor 1 ID 15 + 16		PC + monitor 2 ID 17 + 18	
		1 d	3 d	1 d	3 d
Styrene *	100-42-5	5	< 5	5	< 5
Phenols					
Phenol	108-95-2	-	-	5	< 5
Amines					
4-Acrylmorpholine	5117-12-4	-	-	7	< 5
Organic acids					
Acetic acid	64-19-7	34	41	37	25
Palmitic acid	57-10-3	-	-	5	10
Siloxanes					
Hexamethylcyclotrisiloxane (D3)	541-05-9	< 5	< 5	6	< 5
Decamethylcyclopentasiloxane (D5)	541-02-6	7	< 5	< 5	< 5
Dodecamethylcyclohexasiloxane (D6)	540-97-6	15	8	10	< 5
Tetradecamethylcycloheptasiloxane (D7)	107-50-6	19	10	22	< 5
Sum of other iso/cyclo-alkanes:	(13475-82-6)	24	17	140	51
Sum of other siloxanes:	(556-67-2)	16	11	43	5
Sum of VOCs (TVOC)		180	120	420	120
Sum of VOCs (TVOC)		400	380	980	810

Substances indicated in sunken brackets have been used for calibration due to the lack of a reference substance

* Classified as CMR substance category 1A or 1B under Annex VI to Regulation (EC) No 1272/2008

SVOC results

The result for SVOC measurements carried out in the 4 chamber tests of gaming setups and setups with just PC and monitor can be seen in TABLE 18. The substances with the highest measured concentrations are phthalates (DBP, DEP, DiBP and DMP), which were found especially from gaming setup 1 (ID 1-7) and PC and monitor 2 (ID 17-18). In gaming setup 1, most SVOCs were found at the highest concentrations measured in this study. Four SVOCs have been found in concentrations above 100 ng/m^3 (3d): DBP (589 ng/m^3), DiBP (202 ng/m^3), DMP (5434 ng/m^3) and TEP (101 ng/m^3). The concentration increases from day 1 to day 3, which may be due heating of gaming equipment and the climate chamber, resulting in higher SVOC emissions. Gaming setup 2 (ID 8-14) emitted low concentrations of SVOC after 3 days; DBP (48 ng/m^3), DiBP (28 ng/m^3), and TEP (40 ng/m^3), are highlighted. The highest SVOC emissions resulted after gaming 3 days from PC and monitor 1 (ID 15-16) are DBP (30 ng/m^3), TBP (78 ng/m^3), 2,4,6-TBP (37 ng/m^3) and TEP (326 ng/m^3). In PC and monitor 2 (ID 17-18), the following SVOCs were found in the highest concentrations: DBP (215 ng/m^3), DiBP (45 ng/m^3) and 2,4,6-TBP (73 ng/m^3). The concentrations for gaming setup 2 (ID 8-14) and PC and monitor 1 (ID 15-16) and 2 (ID 17-18) are generally decreasing over day 1 through day 3 measurements. Similar results are seen for SVOCs from the field surveys.

In the field survey, the same SVOCs have been found, where phthalates and TEP have been measured with the highest concentrations. TMP was also found in the field survey, whereas in a chamber test (gaming setup 2, ID 8-14) TDCPP and DEEP were additionally found in low concentrations of respectively 0.6 ng/m^3 (3 d) and 2.9 ng/m^3 (3 d).

TABLE 158. Results of the SVOC analysis in ng/m³ for air samples taken from chamber tests[1]

Substance	Abbreviation	CAS-nr.	Gaming setup 1 ID 1-7		Gaming setup 2 ID 8-14		PC + monitor 1 ID 15 + 16		PC + monitor 2 ID 17 + 18	
			1 d	3 d	1 d	3 d	1 d	3 d	1 d	3 d
Dibutyl phthalate	DBP	84-74-2	157	589	55	48	33	30	220	215
Diethyl phthalate	DEP	84-66-2	27	76	<14.5	<13.9	<14.5	<14.5	26	22
Diisobutyl phthalate	DiBP	84-69-5	59	202	25	28	<15.4	<15.4	59	45
Dimethyl phthalate	DMP	131-11-3	1209	5434	<15.4	<15.4	<15.4	<15.4	25	26
2.4.6-tribromophe-nol	2.4.6-TBP	118-79-6	5	25	1.0	1.1	37	37	86	73
Diethyl ethyl phos-phonate	DEEP	78-38-6	3.4	4.5	3.5	2.9	<0.07	<0.07	3.0	2.3
2-ethylhexyldiphe-nyl phsphate	EHDPP	1241-94-7	<0.18	<0.17	<0.18	0.18	<0.18	<0.18	<0.18	<0.18
Tributhyl phosphate	TBP	126-73-8	0.4	1.1	8.1	8.1	68	78	6.4	4.5
Tri(2-chloroethyl) phosphate	TCEP	115–96-8	0.8	7.1	<0.19	<0.19	<0.18	<0.18	<0.18	<0.18
Tri(1-chloro-2-pro-pyl) phosphate	TCPP	13674-84-5	9.5	32	16	8.4	27	25	37	20
Tri(1.3-dichloro-2-propyl) phosphate	TDCPP	13674-87-8	<0.35	<0.34	0.5	0.6	<0.36	<0.36	<0.36	<0.37
Triethyl phosphate	TEP	78–40-0	106	101	48	40	392	326	8.7	6.9
Triphenyl phos-phate	TPP	115–86-6	0.6	2.3	2.2	3.5	0.5	0.2	1.6	2.3

1 The table indicates the identified SVOCs in air, where detection limits and substance list can be found in appendix 6. Concentrations indicated with < signs mean that the substance has not been found above its detection limit (LOD) in the analysed air volume.

5.4 Discussion of results

The results described in the previous section indicate that the keyboard, mouse, mouse pad and headset only have low emissions of VOCs. Although the equipment has been connected to power and switched on, it has not developed heat. On the other hand, the gaming chairs emit several substances with a hazard classification, such as formaldehyde, dimethylformamide, dimethylnaphthalene, acetic acid and 2-ethylhexanoic acid in high concentrations compared to the other results measured from gaming accessories.

The chemicals that emit from gaming sets or PCs and screens/monitors vary in type and concentration. Tests of gaming sets where chair and accessories are included show emissions of more chemicals in higher concentrations than PC and screen. The combination of single test and combined test for gaming set 1 indicates that several substances from gaming set 2 may originate from the gamer's chair.

Number of hours with high temperature in the climate chamber has varied considerably between the different gaming sets due to interruptions in remote gaming. This is probably caused by the PC itself stopping the game, as temperature logging of the CPU/GPU shows very high temperatures, which may be an excess of the maximum temperature limit. Especially PC + monitor 2, have had less than 12 hours in both gaming periods. Emissions from the PC equipment will therefore be reduced, as a longer time with high temperatures is required for the release of VOCs and SVOCs from the electronics as well as from other parts that are not monitored (cabinet, cables or other).

5.4.1 Comparison of volatile substances from the survey and the substances found from the products

Emissions of volatile chemicals from all gaming products, both gaming accessories and gaming sets, found in the present field studies and climate chamber tests are summarized in TABLE 19. In the table, the 67 substances are compared with previous studies that have tested computers and similar products in climate chamber tests (air samples). No VOCs have been found in dust, but many of the chemicals measured in the air samples from climate chamber tests have also been found in the air samples from the field surveys and in the literature.

VOCs

The analysis of gaming equipment in climate chambers for VOCs shows that many of the substances have been found in the field studies and in the literature. In the field studies, the same aldehydes, some alcohols and aromatic hydrocarbons and cyclic siloxanes were found. The gaming equipment emitted these substance groups: Aldehydes, aliphatic and aromatic hydrocarbons, siloxanes, and phenols. Five amines/amides emitted from the gaming chairs but are not measured in emissions from computers in the literature, nor were they found in the field studies. The amides, dimethylformamide (DMF) and formamide are foaming agents, which have been identified in the literature survey (2.4) in polymer foams. Formamide was not identified in the emissions from gaming equipment. However, DMF is a substance of very high concern (SVHC) found in the emissions of gaming chairs (ID 7, ID 27, ID 33).

Formaldehyde (VVOC) is a known carcinogen (Carc. 1B) and was found in the emissions of all gaming chairs, and in remarkable high concentrations from chairs ID 22 and ID 33 and was not correlated to the available information of materials stated in TABLE 7. Formaldehyde has also been identified in all field surveys, however it was not possible to establish any correlation to gaming chairs, since this is ubiquitous to many indoor products.

In the field survey, siloxanes (D3, D4, D5, D6) have been found, of which D5 is most frequently found in the highest concentrations. Siloxanes have also been found in the outgassing from gamer equipment. Here D3, D5 and D6 are measured, in addition there is D7. For gaming accessories, siloxanes degas from ID 28 (headset) and ID 29 (keyboard) and from ID 7, ID

27, and ID 33 (gaming chairs). It is mostly D3 that degasses. From gaming sets, D6 and D7 are the most frequent cyclic siloxanes found. Thereby, gaming equipment can be identified as a source of siloxanes found in the field survey.

SVOCs

Brominated flame retardants previously reported in the literature have not been identified in the emissions from the gaming equipment or in the field studies, which may be due to them being phased out and replaced with organophosphorus flame retardants etc. Four of the identified organophosphorus flame retardants (TBP, TCPP, TEP and TPP) emit gases from all computer setups at levels between < 1 ng/m³ (TBP and TPP) up to 392 ng/m³ (TEP). TEP is used as a fire retardant and softener in PU foam.

The phthalates dibutyl phthalate (DBP) and diisobutyl phthalate (DiBP), as well as the organophosphorus flame retardants tri(1-chloro-2-propyl)phosphate (TCPP), triethylphosphate (TEP) and triphenylphosphate (TPP) have been found in the emission from all gaming sets and in the air in the 7 field studies in very low concentrations, which suggests that a wide use of these substances in gaming equipment.

TABLE 19. Overview of all chemicals found in climate chamber tests of gaming equipment (air), in field studies in this project (air and dust), and in literature from gaming equipment (air)

Substance	CAS RN	Field surveys		Literature
		Air (μ/m³)	Dust (ng/g)	Air (μ/m³)
Aldehydes				
Formaldehyde (VVOC)	50-00-0	Yes	No	Yes
Hexanal	66-25-1	Yes	No	Yes
Benzaldehyde	100-52-7	Yes	No	Yes
Nonanal	124-19-6	Yes	No	Yes
Ketones				
Cyclohexanone	108-94-1	No	No	Yes
Alcohols				
n-Butanol	71-36-3	Yes	No	Yes
2-Ethyl-1-hexanol	104-76-7	Yes	No	Yes
Dodecanol	112-53-8	Yes	No	No
1-Methoxy-2-propanol	107-98-2	No	No	No
2-Phenyl-2-propanol	617-94-7	No	No	Yes
Glycols, Ethers, Esters				
Safrole *	94-59-7	No	No	No
Triacetin	102-76-1	No	No	No
Butyldiglycol acetate	124-17-4	No	No	No
Benzoic acid, 4-ethoxy-, ethyl ester	23676-09-7	No	No	No
1,2-Propylene carbonate	108-32-7	No	No	Yes
1,4-Dioxane	123-91-1	No	No	No
Ethylhexyl acrylate	103-11-7	No	No	Yes
Isobornyl acrylate	5888-33-5	No	No	Yes
Diethylene glycol dibutyl ether	112-73-2	No	No	No
Aliphatic hydrocarbons				
C12 (Dodecane)	112-40-3	Yes	No	Yes
C13 (Tridecane)	629-50-5	No	No	Yes

Substance	CAS RN	Field surveys		Literature
		Air (μ/m³)	Dust (ng/g)	Air (μ/m³)
C14 (Tetradecane)	629-59-4	No	No	Yes
C15 (Pentadecane)	629-62-9	No	No	Yes
C16 (Hexadecane)	544-76-3	No	No	Yes
C17 (Heptadecane)	629-78-7	No	No	No
C18 (Octadecane)	593-45-3	No	No	Yes
Aromatic hydrocarbons				
Toluene	108-88-3	Yes	No	Yes
m,p-Xylene	1330-20-7	Yes	No	Yes
Styrene *	100-42-5	Yes	No	Yes
4-Methyldiphenylmethane	620-83-7	No	No	No
Methylnaphthalene	-	No	No	Yes
Dimethylnaphthalene	1051-00-0	No	No	No
Methylbiphenyl	-	No	No	No
Trimethylnaphthalene	1052-00-0	No	No	No
2,2,5,5-Tetramethylbiphenyl	3075-84-1	No	No	No
Terpenes				
α-Terpineol	7785-53-7	No	No	No
Longifolen	475-20-7	No	No	Yes
Organic acids				
Acetic acid	64-19-7	Yes	No	Yes
2-Ethylhexanioc acid	149-57-5	No	No	Yes
Palmitic acid	57-10-3	No	No	No
Siloxanes				
Hexamethylcyclotrisiloxan (D3)	541-05-9	Yes	No	Yes
Octamethylcyclotetrasiloxan (D4)	556-67-2	Yes	No	Yes
Decamethylcyclopentasiloxan (D5)	541-02-6	Yes	No	Yes
Dodecamethylcyclohexasiloxan (D6)	540-97-6	Yes	No	Yes
Tetradecamethylcycloheptasiloxan (D7)	107-50-6	No	No	Yes
Thiazoles				
Benzothiazole	95-16-9	No	No	No
Amines/Amides				
N,N-Dimethylformamide (DMF) *	68-12-2	No	No	Yes
N,N-Dimethylacetamide *	127-19-5	No	No	No
N,N-Diethylmethylamine	616-39-7	No	No	No
Caprolactame	105-60-2	No	No	No
4-Acrylmorpholine	5117-12-4	No	No	No
Nitriles				
2,2'-Azobis(2-methylpropanenitrile) (AIBN)	78-67-1	No	No	No
Phenoles				
Phenol	108-95-2	No	No	No
4-Nonylphenol	104-40-5	No	No	No
SVOCs				
Dibutyl phthalate (DBP)	84-74-2	Yes	Yes	No

Substance	CAS RN	Field surveys		Literature
		Air (μ/m^3)	Dust (ng/g)	Air (μ/m^3)
Diethyl phthalate (DEP)	84-66-2	Yes	No	Yes
Diisobutyl phthalate (DiBP)	84-69-5	Yes	Yes	No
Dimethyl phthalate (DMP)	131-11-3	Yes	No	No
2,4,6-tribromophenol (2,4,6-TBP)	118-79-6	Yes	No	No
Diethylethyl phosphonate (DEEP)	78-38-6	No	No	No
2-ethylhexyldifenyl phosphate (EHDPP)	1241-94-7	Yes	Yes	No
Tributhyl phosphate (TBP)	126-73-8	Yes	Yes	No
Tri(2-chloroethyl) phosphate (TCEP)	115–96-8	Yes	Yes	No
Tri(1-chloro-2-propyl) phosphate (TCPP)	13674-84-5	Yes	Yes	No
Tri(1,3-dichloro-2-propyl) phosphate (TDCPP)	13674-87-8	No	Yes	No
Triethyl phosphate (TEP)	78–40-0	Yes	Yes	Yes
Triphenyl phosphate (TPP)	115–86-6	Yes	Yes	Yes

* Classified as CMR substance category 1A or 1B under Annex VI to Regulation (EC) No 1272/2008

6. Hazard assessment

6.1 Method for prioritizing substances for further risk assessment

Before making risk assessment for the emission of the above substances, it is important to prioritize the substances that can pose a hazard to health as well as the substances that occur in concentrations that may be near hazardous levels.

In connection with prioritization, it is important to note that all measurements are given as the concentrations a gamer would be exposed to in a standard room of 17.4 m^3 with an air change of 0.2 times per hour. That is, the measured values can be directly used as exposure values and assessed in relation to known tolerable exposure values for the substances.

The prioritization/screening procedure for identification of the most critical substances among the many substances measured is described below. Details of the process and review of the measurement results in the tables are described in Appendix 7.

Step 1: The VOCs in TABLE 13, 14, 15, 16 and 17 which have measured values lower than a screening value of 10 $\mu g/m^3$ are not prioritized further, unless the substance's structure or background knowledge about the substances gave rise to concerns. For SVOCs in table 18, priority is given to chemicals measured above a screening value of 10 ng/m^3 (see explanation of the selected screening values in Appendix 7).

Step 2: For substances that remain prioritized after step 1, information is sought on the substance's hazard classification, and data is collected on already derived tolerable exposure levels, which are then used as screening values to assess whether the measured values are close to these and thus may be near a risk level. Thus, the substances are excluded from the prioritization if the measured exposure levels are less than 1/10 or, in the case of some substances, less than 1/100 of the screening values found. This ensures a very cautious approach, as it is not expected that a subsequent detailed assessment of the used screening values for the substances will result in 10-100 times lower tolerable exposure values than the screening values.

Step 3: For the substances that have passed step 1 and step 2, a more thorough literature search is carried out to obtain knowledge about the substances' critical effects (i.e., the effects that can occur at the lowest levels of the substances) and dose-response for these. It is assessed to what extent the screening values that have been used are reliable and whether they have been calculated according to the guidelines for DNEL derivation in the REACH regulation (ECHA 2012). It is thus evaluated whether the assessments behind the screening values can be used further in the risk assessment or whether they must be adjusted based on new information obtained during the search, or by recalculating the values in accordance with ECHA (2012). In the assessment of the substances, emphasis is placed on using the most recently updated expert or authority assessments of the substances. If these are not available, relevant data of the substances were for example obtained from REACH registration data.

6.2 Results of the prioritization process

Following the prioritization process method above, the chemicals below in table 20 were selected for further hazard and risk assessment.

TABLE 20. Prioritized chemicals for further hazard and risk assessment

Prioritization of VOCs (from Tables 13, 14, 15, 16 and 17)					
Substance	**CAS RN**	**Highest measured conc. µg/m³**	**Hazard Classification**	**Tolerable exposure level/ screening value µg/m³**	**Prioritized**
Formaldehyde	50-00-0	130	AcuteTox 3 H301, H311, H331 Skin Corr. 1B H314 Eye Damage 1 H318 Skin Sens 1 H317 Muta 2 H341 Carc 1B H350	100 eye and respiratory tract irritation EU-LCI 2016b WHO 2010	Yes*
Acetic Acid	64-19-7	260	Skin Corr. 1A H314	1200 respiratory tract irritation EU-LCI 2016	Yes*
2-Ethylhexanoic acid	149-57-5	36	Repr. 2 H361 Future harmonized classification Repr. 1B H360D (ECHA-RAC 2020a)	150 developmental effects EU LCI 2014	Yes*
2-Ethyl-1-hexanol	104-76-7	13	Acute Tox. 4 H332 Skin Irrit. 2 H315: Eye Irrit. 2 H319	300 respiratory tract irritation EU-LCI 2014b	Yes (Can be converted to 2-ethylhexanoic acid in the body)
N,N-Dimethylformamide (DMF)	68-12-2	98	Acute Tox. 4 H312 Eye Irrit. 2 H319 Acute Tox. 4 H332 Repr. 1B H360d	700 (eye and respiratory tract irritant) 170 (liver toxicity) SCHEER 2021	Yes*
Methylnaphthalene		15	Acute Tox. 4 H302 Carc. 2 H351 Classfication for naphthalene	10 (inflammation of respiratory tract), value for naphthalene EU-LCI 2015	Yes*
Dimethylnaphthalene	1051-00-0	30			
Triethylnaphthalene	1052-00-0	16			
Dodecamethylcyclohexasiloxane (D6)	540-97-6	15	Not classifiied	130 (Lung effects/ liver effects) MST 2021	Yes*
2,2'-Azobis(2-methylpropanenitrile)	78-67-1	5	Acute Tox. 4 H302, H332	70 DNEL (REACH-reg.)	Yes**
Safrole	94-59-7	12	Acute Tox. 4 H302 Muta. 2 H341 Carc. 1B H350	No REACH registration	Yes genotoxic carcinogen
Prioritization of SVOCs (from Table 18)					
Dibutylphthalate DBP	84-74-2	0.589	Repr. 1B H360Df	6.7 µg/kg/day or 23.5 µg/m³ endocrine disruptor RAC 2018	Yes***
Diisobutylphthalate DiBP	84-69-5	0.202	Repr. 1B H360Df	8.3 µg/kg/day or 29 µg/m³ endocrine disruptor RAC 2018	Yes***

Yes*: The measured exposure value is more than 1/10 of the tolerable exposure value, found by expert assessment
Yes**: The measured exposure value is more than 1/50-100 of the tolerable exposure value based on DNEL value from REACH registration.

Yes***: The measured exposure value is close to or more than 1/100 of the tolerable exposure value found by expert assessment

6.3 Hazard assessment of the prioritized substances

After further literature search and critical review of data for the priority substances, the below tolerable exposure levels were derived according to the REACH regulation's principles for DNEL/DMEL derivation (ECHA 2012).

TABLE 21. Prioritized substances and tolerable exposure levels

Substance	CAS RN	Tolerable Exposure Level (DNEL) / Critical effects	Comments
Formaldehyde	50-00-0	50 µg/m³ irritation of the nasal mucosa, eyes, and respiratory tract	Reassessed value differing from screening value
Acedic acid	64-19-7	1200 µg/m³ irritation	Screening value retained for the risk assessment
2-Ethylhexanoic acid	149-57-5	880 µg/m³ birth defects	Reassessed value differing from screening value
2-Ethyl-1-hexanol	104-76-7	800 µg/m³ irritation	Reassessed value differing from screening value
N,N-Dimethylformamide (DMF)	68-12-2	170 µg/m³ liver effects 700 µg/m³ irritation	Screening value retained for the risk assessment
Methylnaphthalene Dimethylnaphthalene Triethylnaphthalene	- 1051-00-0 1052-00-0	58 µg/m³ irritation Applicable at individual substance level and the sum of the three substances	Reassessed value differing from screening value
Dodecamethylcyclohexasiloxane (D6)	540-97-6	70 µg/m³ liver damage/lung damage	Reassessed value differing from screening value
2,2'-Azobis(2-methylpropanenitrile)	78-67-1	Data not sufficient for output	Based on the risk assessment
Safrole	94-59-7	0.8 µg/m³ (10^{-6} cancer risk for lifetime exposure)	Calculated cancer risk, but lack of transparency in data
Dibutylphthalate DBP	84-74-2	23 µg/m³ endocrine disruptor	Screening value retained for the risk assessment
Diisobutylphthalate DiBP	84-69-5	29 µg/m³ endocrine disruptor	Screening value retained for the risk assessment

It can be seen that the screening values have been maintained for four substances (acetic acid, N,N-dimethylformamide, dibutyl phthalate and diisobutyl phthalate), while a different value has been set for the other substances. Thus, the values have decreased by a factor of 2 for formaldehyde and dodecamethylcyclohexasiloxane (D6) in relation to the screening values, while the values for 2-ethylhexanoic acid, 2-ethylhexanol, methylnaphthalene, dimethylnaphthalene and triethylnaphthalene have increased by a factor of 5-6 in relation to the screening values. See the assessments of the individual substances in Appendix 7.

In case of simultaneous exposure to several substances, it is considered relevant to add the risk contributions (RCR-values) for substances having the same critical effect, i.e., the RCR-values for substances with irritative properties are added to a total RCR-value for irritation. The same applies to substances with hormone-disrupting effects or liver damage.

7. Exposure and risk assessment

7.1 Exposure levels

As described in chapter 4.3, the climate chamber measurements are based on a worst-case scenario of exposure in a gaming reference room:

Room volume per gaming setup: 17.4 m^3
Air change rate: 0.2 h^{-1}
Climate conditions: 25°C / 50 % RH

These parameters are thus included in the processing of the measurement results, which are corrected by a factor so that the concentrations of the chemicals in the air given in TABLES 13 to 18 correspond to the realistic worst-case concentrations for exposure. Therefore, the specified values can be directly used as exposure values.

Since in some cases young people can game over an entire weekend, it is considered realistic to assess exposure to the substances in relation to permitted concentration levels (DNEL values) applicable for 24-hour exposure. This means that the DNEL values for the substances can be used directly against the measured substance levels, as the DNEL values in accordance with the REACH guidelines are calculated as 24-hour average exposure levels.

7.2 Selection of equipment for risk assessment

Based on the prioritized substances, further prioritization was made of the equipment where the equipment having the highest and second highest measurements of the substances was found. The risk assessment of the equipment with the second highest measurements may be relevant if a risk has been found from the equipment with the highest measurements.

For VOC substances, the prioritization found no basis for further assessment of some of the substances from TABLE 13 "keyboard and mouse" or from TABLE 14 "headset and mouse pad" because of the very low measured levels (below 10 µg/m^3 for the priority substances, see Appendix 7).

For the other equipment, measurements showed priority VOCs from the measurement results in TABLE 15, 16 and 17 allowing the selection of the equipment with the greatest emissions, as indicated below in TABLE 22. The same principle applies for priority SVOCs in TABLE 18, where equipment with the higher emissions is reported in TABLE 23.

TABLE 22. Gaming equipment selected for risk assessment based on highest measurements of priority VOCs

Substance	Gaming chair	PC + monitor	Gaming setup
Formaldehyde (VVOC)	**ID22: 130 µg/m³** ID33: 120 µg/m³	-	**ID 1-7: 35 µg/m³** ID 8-14: 31 µg/m³
Acetic acid	**ID33: 260 µg/m³** ID7: 110 µg/m³	-	**ID 8-14: 210 µg/m³** ID 1-7: 83 µg/m³

Substance	Gaming chair	PC + monitor	Gaming setup
2-Ethylhexanoic acid	**ID27: 36 µg/m³** ID22: 5 µg/m³	-	**ID 1-7: 22 µg/m³**
2-Ethyl-1-hexanol	**ID33: 13 µg/m³**	**ID15+16: 9 µg/m³**	**ID 1-7: 10 µg/m³** ID 8-14: 5 µg/m³
N,N-Dimethylformamide (DMF)	**ID27: 98 µg/m³** **ID7: 38 µg/m³**	-	**ID 1-7: 46 µg/m³**
Methylnaphthalene	**ID22: 15 µg/m³**	-	-
Dimethylnaphthalene	**ID22: 30 µg/m³**	-	-
Triethylnaphthalene	**ID22: 16 µg/m³**	-	-
Dodecamethylcyclohexasilox-ane (D6)	-	**ID15+16: 15 µg/m³** **ID17+18: 10 µg/m³**	**ID 8-14: 13 µg/m³**
Safrole	**ID22: 12 µg/m³**	-	-
Equipment with the highest measurements*	**ID22, ID33, ID27**	**ID15+16**	**ID 1-7, ID 8-14**
Other equipment	ID7	ID17+18	-

TABLE 23. Gaming equipment selected for risk assessment based on highest measurements of priority SVOCs

Substance	PC + monitor	Gaming setup
Dibutylphthalate	**ID17+18: 220 ng/m³** ID15+16: 33 ng/m³	**ID1-7: 589 ng/m³** ID8-14: 55 ng/m³
Diisobutylphthalate	**ID17+18: 59 ng/m³**	**ID1-7: 202 ng/m³** ID8-14: 28 ng/m³
Equipment with the highest measurements	**ID17+18**	**ID1-7**
Other equipment	ID15+16	ID8-14

The equipment with the highest measured values (indicated in **bold**) for the priority substances will proceed to risk assessment. If a risk is calculated for this equipment, a risk assessment is also carried out for equipment with lower measurements (indicated in regular font), initially for the equipment listed as "other equipment", for which the second highest values have been found.

7.3 Risk assessment method

Assessment of risk from exposure to one or more of the priority substances is carried out based on the guidelines used in connection with the REACH chemical regulation (ECHA 2012b). Risk assessment is carried out by calculating the risk characterization ratio (RCR) for the individual priority substances, where the RCR is calculated as:

$$R(\text{substance x}) = \text{Measured exposure (substance x)}/\ \text{DNEL value (substance x)}$$

If the measured exposure to a substance exceeds the DNEL value, and the RCR thus becomes greater than 1, the exposure is considered to constitute an unacceptable risk.

To assess the risk of simultaneous exposure to several substances, summation of the individual RCR-values is used:

$$R(sum) = RCR(1) + RCR(2) + \dots RCR(n)$$

This approach can be used when the several substances having similar effects (e.g., irritation of mucous membranes in the eyes and respiratory tract, liver effects or hormone-disrupting effects) are present at the same time, and where one can therefore assume an additive effect, and the risk ratios for the individual substances are therefore added.

If the RCR(sum) exceeds 1, the total exposure to the substances with the same hazard is considered to constitute an unacceptable risk.

7.4 Risk assessment of selected gaming equipment

7.4.1 Risk calculations for the gaming equipment

7.4.1.1 Gaming chair

When calculating the risk for gaming chair ID-22 (see TABLE 24), an RCR-value of 2.6 was obtained for formaldehyde alone, which poses a risk of irritation and effects on /influence of the nasal mucosa. The sum of methylnaphthalenes also represents a corresponding risk of irritation to the respiratory tract with an RCR-value of 1.05. Overall, an RCR-value of 3.7 is obtained for exposure to respiratory tract irritants, when the RCR contribution of acetic acid is also considered.

TABLE 24. Risk assessment of VOC emission from gaming chair ID-22

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	130 µg/m³	50 µg/m³ (eye-respiratory irritation)	**2.6***
Acetic acid	81 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.07*
2-Ethylhexanoic acid	5 µg/m³	880 µg/m³ (developmental effects)	0.006
2-Ethyl-1-hexanol	-	-	-
N,N-Dimethylformamide (DMF)	-	-	-
Methylnaphthalene	15 µg/m³	58 µg/m³ (eye-respiratory irritation)	0.26*
Dimethylnaphthalene	30 µg/m³	58 µg/m³ (eye-respiratory irritation)	0.52*
Triethylnaphthalene	16 µg/m³	58 µg/m³ (eye-respiratory irritation)	0.28*
Methylnaphthalene, sum	61 µg/m³	58 µg/m³ (eye-respiratory irritation)	**1.05***
Dodecamethylcyclohexasiloxane (D6)	-	--	-
Safrole	12 µg/m³	0.8 µg/m³ (DMEL 10^{-6} risk of cancer)	**15**
*RCR(sum) irritation			**3,7**

RCR-values in bold indicates risk

* marked RCR-values indicate that the risk contributions can be added due to similar effects

An RCR-value of 15 is obtained for safrole for increased cancer risk. However, the increased cancer risk is calculated based on continuous exposure of 12 µg/m^3 throughout life, and thus, a short-term exceedance over a few days is not considered problematic. By inhaling 12 µg/m^3 over a 24-hour period, by inhaling 20 m^3 of air, a person will inhale approx. 240 µg safrole, which corresponds to approx. the same amount of safrole that a person consumes through food every day throughout lifetime.

From TABLE 25 when calculating the risk for gaming chair ID-33, an RCR-value of 2.4 is obtained for formaldehyde alone, which thus poses a risk of irritation/damage to the nasal mucosa. Including the contributions from the other respiratory irritants, a total RCR-value for irritation of 2.7 is obtained.

Formaldehyde is a carcinogenic substance in humans in terms of for the development of nasal and laryngeal cancer. It is considered that there is a threshold value for this effect, which only appears after prolonged exposure at levels where persistent irritation of the mucous membranes causes changes in the surface cells. Protection against irritation will thus also lead to protection against the cancer-causing effect. There are, however, no data available from which a specific NOAEL for the carcinogenic effect can be determined, but it is not considered likely that short-term exposure to levels that exceed the irritative limit (as for ID 22 and ID 33) will result in any increased risk of cancer from gaming chairs.

TABLE 25. Risk assessment of VOC emission from gaming chair ID-33

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	120 µg/m³	50 µg/m³ (eye-respiratory irritation)	**2.4***
Acetic acid	260 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.22*
2-Ethylhexanoic acid	-	-	-
2-Ethyl-1-hexanol	13 µg/m³	800 µg/m³ (eye-respiratory irritation)	0.02*
N,N-Dimethylformamide (DMF) +	15 µg/m³	170 µg/m³ (liver effects)	0.09
		700 µg/m³ (eye-respiratory irritation)	0.02*
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalene, sum	-	-	**-**
Dodecamethylcyclohexasiloxane (D6)	-	-	-
Safrole	-	-	-
*RCR(sum) irritation			**2.7**

RCR-values in bold indicate risk

* marked RCR-values indicate that the risk contributions can be added due to similar effects

When calculating the risk for gaming chair ID-27 (TABLE 26), the highest RCR-value of 0.58 was found for N,N-dimethylformamide related to a risk of liver damage, while the sum of respiratory irritants results in an RCR-value of 0.49. This does not immediately give rise to risk. However, since the measurements were carried out at 25 °C, additional local heating to 35 °C in contact with the body is not accounted for, such as when the gamer is sitting in a chair. With a temperature rise of 10 °C, the vapor pressure doubles, and so the air concentrations of volatile substances in the air would increase. This can cause exposures with risk factors with RCR 0.5 – 1.0 to be greater than 1.

TABLE 26. Risk assessment of VOC emission from gaming chair ID-27.

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	9 µg/m³	50 µg/m³ (eye-respiratory irritation)	0.18*
Acetic acid	78 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.07*
2-Ethylhexanonic acid	36 µg/m³	880 µg/m³ (developmental effects)	0.04
2-Ethyl-1-hexanol	-	-	-
N,N-Dimethylformamide (DMF)	98 µg/m³	170 µg/m³ (liver effects)	0.58
		700 µg/m³ (eye-respiratory irritation)	0.14*
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalener, sum	-	-	-
Dodecamethylcyclohexasiloxane (D6)	-	-	-
Safrole	-	-	-
*RCR(sum) irritation			0.49

* marked RCR-values indicate that the risk contributions can be added due to similar effects

7.4.1.2 PC and screen

For TABLE 27, when calculating the risk for PC+ screen, ID15+16, RCR-values significantly below 1 are obtained, and no risk of emissions from the products can be demonstrated.

TABLE 27. Risk assessment of VOC emission from PC+ screen, ID15+16

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	-	-	-
Eddikesyre	41 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.03*
2-Ethylhexanoic acid	-	-	-
2-Ethyl-1-hexanol	9 µg/m³	800 µg/m³ (eye-respiratory irritation)	0.01*
N,N-Dimethylformamide (DMF)	-	-	-
		-	-
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalene, sum	-	-	-
Dodecamethylcyclohexasiloxane (D6)	15 µg/m³	70 µg/m³ (liver and lung damage)	0.21
Safrole	-	-	-

Substance	Measured values	DNEL (critical effect)	RCR
*RCR(sum) irritation			0.04

* marked RCR-values indicate that the risk contributions can be added due to similar effects

7.4.1.3 Gaming sets

In TABLE 28 when the risk for gamer setup 1 (ID 1-7) was calculated, RCR-values below 1 are obtained for all substances and resulted in the RCR(sum) value of 0.85 for irritation. It is especially formaldehyde with an RCR-value of 0.7 that contributes to the emissions from this gaming setup. It must be considered most likely that the formaldehyde emissions originate from the gaming chair. As indicated for gaming chair ID-27, heating of the gaming chair from the gamer's body heat is presumed to lead to increased emissions and thus a potential risk for irritation cannot be ruled out in relation to the gaming hair included in gaming set ID 1-7.

TABLE 28. Risk assessment of VOC emission for gaming setup 1, ID1-7

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	35 µg/m³	50 µg/m³ (eye-respiratory irritation)	0.7*
Acetic acid	83 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.07*
2-Ethylhexanoic acid	22 µg/m³	880 µg/m³ Developmental effects	0.03
2-Ethyl-1-hexanol	10 µg/m³	800 µg/m³ (eye-respiratory irritation)	0.01*
N,N-Dimethylformamide (DMF)	46 µg/m³	170 µg/m³ (liver effects)	0.27
		700 µg/m³ (eye-respiratory irritation)	0.07*
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalene sum	-	-	-
Dodecamethylcyclohexasiloxane (D6)	-	-	-
Safrole	-	-	-
*RCR(sum) for irritation			0.85

* marked RCR-values indicate that the risk contributions can be added due to similar effects

As shown in TABLE 29, for the calculated risk for gaming setup 2 (ID 8-14), results in RCR-values below 1 for all substances and for the RCR(sum) value of 0.81 regarding irritation. It is especially formaldehyde with an RCR-value of 0.62 and acetic acid with an RCR-value of 0.18 that contribute to the emission from the gaming chair. It is considered most likely that the formaldehyde and acetic acid emission originates from the gaming chair, due to similar results from gaming chair ID-27, heating of the gaming chair from the gamer's body heat must be assumed to lead to increased emission and thus a potential risk of irritation, including impact on the nasal mucosa.

TABLE 29. Risk assessment of VOC emission from gaming setup 2, ID 8-14

Substance	Measured values	DNEL (critical effect)	RCR
Formaldehyde	31 µg/m³	50 µg/m³ (eye-respiratory irritation)	0.62*
Acetic acid	210 µg/m³	1200 µg/m³ (eye-respiratory irritation)	0.18*
2-Ethylhexanoic acid	-	-	-
2-Ethyl-1-hexanol	5 µg/m³	800 µg/m³ (eye-respiratory irritation)	0.006*
N,N-Dimethylformamide (DMF)	-	-	-
		-	-
Methylnaphthalene	-	-	-
Dimethylnaphthalene	-	-	-
Triethylnaphthalene	-	-	-
Methylnaphthalene, sum	-	-	-
Dodecamethylcyclohexasiloxane (D6)	13 µg/m³	70 µg/m³ (liver and lung damage)	0.19
Safrole	-	-	-
*RCR(sum) for irritation			0.81

* marked RCR-values indicate that the risk contributions can be added due to similar effects

7.4.1.4 PC and screen

The very low RCR-values in TABLE 30 indicate that inhalation of the SVOCs from the gaming equipment does not pose a risk to the gamer.

TABLE 30. Risk assessment of SVOC emission from PC and screen, ID 17+18

Substance	Measured values	DNEL (critical effect)	RCR
Dibutylphthalate	220 ng/m³	23 000 ng/m³ (endocrine disrupting effects)	0,01*
Diisobutylphthalate	59 ng/m³	29 000 ng/m³ (endocrine disrupting effects)	0,002*
*RCR(sum) for hormone disrupting effects	-	-	0,012

* marked RCR-values indicate that the risk contributions can be added due to similar effects

7.4.1.5 Gaming set

The very low RCR-values in TABLE 31 indicate that inhalation of the SVOCs from the gaming equipment does not pose a risk to the gamer.

TABLE 31. Risk assessment of SVOC emission from gaming setup 1, ID 1-7

Substance	Measured value	DNEL	RCR
Dibutylftalat	589 ng/m³	23 000 ng/m³ (endocrine disrupting effects)	0.026*
Diisobutylftalat	202 ng/m³	29 000 ng/m³ (endocrine disrupting effects)	0.007*
*RCR(sum) for hormone disrupting effects	-	-	0.033

* marked RCR-values indicate that the risk contributions can be added due to similar effects

7.5 Overall assessment

When the measurement results and risk assessments are considered together, it can be seen that the emissions from "keyboard and mouse" and "headset and mouse pad" are extremely limited and without risk, as the levels for all the prioritized substances were below 10 µg/m^3.

Slightly higher but still low emission occurs from PC + monitors. Here, emission of acetic acid and dodecamethylcyclohexasiloxane (D6) was found, but the calculated RCR-values of 0.03 for acetic acid and 0.21 for D6 are not considered to pose any risk.

By far the greatest off-gassing was found from gaming chairs, where there is a risk of eye and respiratory irritation for chairs ID-22 and ID-33, primarily as a result of off-gassing formaldehyde, as the RCR-values for this substance were respectively 2.6 (ID-22) and 2.4 (ID-33). Although the RCR-value for gamer's chair ID-27 was below 1, this chair cannot be ruled out as entailing a risk of eye and respiratory irritation, as increased temperature from the gamer's body heat during use of the chair will cause somewhat higher emissions than the measured emissions at 25 °C.

For the measured levels from the two gaming sets, these are assessed to be relatively close to posing a risk in terms of eye and respiratory irritants. The relatively high RCR-values for formaldehyde of 0.7 and 0.62 for the sets are assessed to originate from the gaming chairs, as the greatest formaldehyde degassing has just been found in the separate measurements of gaming chairs. However, the two sets cannot be ruled out as causing a risk of eye and respiratory irritation, as increased temperature from the gamer's body heat during use of the chair will cause somewhat higher emissions than in the climate chamber where the emissions from the sets were measured.

Dodecamethylcyclohexasiloxane (D6) was also measured with an RCR-value of 0.19 from one of the gaming sets, and here the source must be estimated to be the PC or the screen, as D6 was also found in the separate measurements for PC + screen.

Overall, it is worth noting that high emissions causing risk for eye and respiratory irritant substances takes place from gaming chairs, while the electronic gaming equipment in this project has not been shown to cause emissions that poses any risk.

It must be noted, however, that the very low air concentrations of SVOC measured from the electronic equipment are not considered to pose a risk by inhalation, however the exposure to these substances may be significantly higher. SVOCs tend to quickly stick to surfaces and dust, and vapours in the air only make up a small part of the total amount of SVOCs in the room. Therefore, in addition to inhalation of vapours, a person's exposure to SVOC will mainly come from contact with surfaces and contact with textiles, e.g., bedding and furniture present in the room (Eichler et al, 2021).

7.5.1 Limitations and uncertainties

As the formula for the RCR calculation states (RCR = exposure/ DNEL), the uncertainties in the risk assessment will come from the assessment (measurements) of the emissions as well as from the assessment of the toxicological data and determination of the DNEL value. In addition, there will be uncertainties/limitations in the screening process itself, where a number of substances in the emissions are deselected for further risk assessment.

Uncertainties in the exposure

In the project, the aim is to carry out the measurements of the gaming equipment in a way that best represents a user situation, and the measurements are carried out in a way so that the results can be directly converted to the air concentration of the substance to which the user will be exposed. There are therefore only relatively limited uncertainties in relation to the measurements in the project. The greatest uncertainty in the measurements must be associated with the measurements from the gaming chairs, as the measurements were carried out at 25 °C, and thus do not take into account additional local heating to 35 °C in contact with the body, such as when the gamer sits in a chair. With a temperature rise of 10 °C, the vapor pressure doubles, and thus the air concentrations of volatile substances.
Therefore, calculated RCR-values in the range of 0.5 to 1.0 may not necessarily indicate safe levels without risk.

The exposure values used are calculated on the basis of an assumed standard scenario, which is considered a worst-case scenario. It cannot be ruled out that in some cases (smaller rooms and no ventilation at all) higher values may occur, which could therefore lead to increased risk.

In addition, it is also difficult to assess whether the relatively limited number of gaming equipment that has been purchased and investigated is representative of the market in general. Equipment with higher emissions than the levels measured in this project can probably be found on the market.

Uncertainties in DNEL determination

Here, the uncertainties lie in the selection of the most relevant toxicological data for a substance and the assessment and calculation of the DNEL values, including assessment of the size of the individual uncertainty factors used in the calculation. To limit the uncertainties, data has primarily been collected on the substances based on published expert assessments or authority assessments, so that uncertainties when identifying the most critical effects and selecting relevant NOAEL/LOAEL values for calculating the DNEL values are reduced.
Next, the guidelines in relation to REACH are used to determine values for the uncertainty factors used, which also helps to achieve "standardized" values.

However, the quality of a DNEL determination is no better than the toxicological data that form the starting point for the calculation. The poorer/fewer data the greater the uncertainty factors will be. This is justified, as experience has often shown that in cases where more precise toxicological data is obtained, significantly lower NOAEL/LOAEL values for a substance are also obtained.

Limitations of the prioritization process

To identify the most problematic substances for the risk assessment, it has been necessary through a screening process to deselect a number of substances contained in the emissions. This was done partly based on very low measured values, or because of the absence of particularly critical effects in the substance's classification or by screening values for tolerable exposure levels. Based on the high number of substances excluded, it can be expected that there has been an underestimation of the toxicity of the total degassing to a certain extent. Finally, it cannot be completely ruled out that individual substances/substance groups have been deselected wrongfully.

7.5.2 Conclusions

When the measurement results and risk assessments are considered together, the emissions from "keyboard and mouse" and "headset and mouse pad" were extremely low and without risk, as the levels for all the prioritized substances were below 10 µg/m^3.

Also, very low but slightly higher degassing occurred from PC + monitors. Here, emissions of acetic acid and dodecamethylcyclohexasiloxane (D6) was found, but the calculated RCR-values of 0.03 for acetic acid and 0.21 for dodecamethylcyclohexasiloxane (D6) are not considered to indicate any risk.

By far the gaming chairs resulted in the highest emissions, where a risk of eye and respiratory irritation was found for two out of four chairs, primarily because of emitted formaldehyde, as the RCR-values for this substance were 2.6 and 2.4 respectively. Although the RCR-value for a third gamer's chair was below 1, this chair cannot be ruled out as causing a risk of eye and respiratory irritation, as increased temperature from the gamer's body heat during use of the chair will cause somewhat higher emissions than the measured emissions at 25 °C. Overall, only one out of four chairs can be concluded to be without risk.

For the measurements of the two gaming sets, these are assessed to be relatively close to posing a risk in terms of eye and respiratory irritants. The relatively high RCR-values for formaldehyde of 0.7 and 0.62 for the sets are assessed to originate from the gaming chairs, but this will immediately require further specific measurements to determine this. The two sets cannot therefore be ruled out as causing a risk of eye and respiratory irritation, as increased temperature from the gamer's body heat during use of the chairs will cause somewhat higher emissions than in the climate room where the sets were measured.

No risk was detected when inhaling SVOCs from the electronic parts of the gaming equipment (PC and monitor), as the measured levels of hormone-disrupting phthalates resulted in RCR-values of 0.033 and below.

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Appendix 1. Market Research

E-mail to distributors of equipment

I am writing to you today because our group at the Danish Technological Institute is working on a project to investigate popular gaming equipment.

Your website can be sorted by "POPULARITY" and I have a few questions:

1.Can you deduce from sorting by popularity, what are the best-selling products in a given category?

2.Is popularity based on sales over a period and which period, is it fex. 3 months?

See web page: https://www.xxxx

We will be very happy to receive your answer.

Thank you for the help

Appendix 2. Chemicals found in literature that could originate from gaming equipment

TABLE 32. Mapping of chemicals in the literature: VOC and SVOC. Field studies found in the literature have been carried out in office spaces, schools, private homes and PC workshops. The equipment tested (literature) includes computers, computer monitors, TV sets, PU foam and upholstered chairs. Air field: Found in air measurements in field surveys. Air equipment: Found in air measurements in equipment tests. Dust field: Found in dust analysis collected during field investigations. Dust equipment: Found in dust analysis collected inside computers. * decomposes

Group	Substance	CAS RN	BP (°C)	MP (°C)	Air field	Air equip-ment	Dust field	Dust equip-ment
							(yes/no)	
Acid								
	Carbonic acid, dimethyl ester	616-38-6	90.5	3	-	-	YES	-
	Acetic acid	64-19-7	118	16.6	YES	YES	-	-
	Hexanoic acid	142-62-1	205.2	-3	YES	-	-	-
	2-ethylhexanoic acid	149-57-5	228	-59	-	YES	-	-
	Octanoic acid	124-07-2	239	16.3	-	YES	-	-
	Nonanoic acid	112-05-0	254.5	12.3	-	YES	-	-
	Decanoic acid	334-48-5	268.7	31.9	-	YES	-	-

	Cyclohexanepropionic acid	701-97-3	276.5	16	-	YES	-	-
	Phthalic acid anhydride	85-44-9	295	130.8	-	YES	-	-
Alcohol								
	Butanol	110-82-7	80.7	6.6	-	YES	-	-
	1-Butanol	71-36-3	117.7	-89	YES	YES	-	-
	2-Butoxyethanol	111-76-2	168.4	-74.8	-	YES	-	-
	1-Butoxy-2-propanol	5131-66-8	171	-	YES	YES	-	-
	Eucalyptol	470-82-6	176.4	1.5	-	YES	-	-
	2-Ethyl-1-hexanol	104-76-7	184	-70	YES	YES	-	-
	1,2-Propandiol (Propylene glycol)	57-55-6	187	-60	YES	YES	-	-
	2-(2- ethoxyethoxyethanol)	111-90-0	196	-76	-	YES	-	-
	Hexylene glycol (2-methyl-2,4-pentanediol)	107-41-5	198	-50	-	YES	-	-
	2-Phenyl-2-propanol	617-94-7	202	36	-	YES	-	-
	Menthol	89-78-1	212	39	-	YES	-	-
	Texanol	25265-77-4	243.8	-50	-	YES	-	-
	2-phenoxyethanol	122-99-6	245	14	YES	-	-	-
	2-Propanol, 1-(2-propenyloxy)	21460-36-6	-	-	-	YES	-	-
	1,9-Nonanediol	3937-56-2	-	45.8	-	YES	-	-
	1,8-Octanediol	629-41-4	-	63	-	YES	-	-
Aldehyde								
	Formaldehyde	50-00-0	-19	-92	YES	YES	-	-
	Acetaldehyde	75-07-0	20.2	-123	YES	YES	-	-
	Propionaldehyde	123-38-6	48	-80	YES	YES	-	-

	Butyraldehyde	123-72-8	74.8	-99	-	YES	-	-
	Pentanal	110-62-3	103	-91.5	-	YES	-	-
	Hexanal	66-25-1	131	-56	YES	YES	-	-
	Octanal	124-13-0	171	-23	-	YES	-	-
	Benzaldehyde	100-52-7	179	-26	YES	YES	-	-
	Nonanal	124-19-6	191	-19.3	YES	YES	-	-
	Octanal	111-87-5	195	-15.5	YES	-	-	-
Amide/Amines								
DMF	Dimethylformamide	68-12-2	153	-60.4	-	YES	-	-
	Acrylamide	79-06-1	192.6	84.5	-	YES	-	-
	Propylamide	79-05-0	213	81.3	-	YES	-	-
	Butanamide	541-35-5	216	114.8	-	YES	-	-
	Pentanamide	626-97-1	225	106	-	YES	-	-
	Triethylenediamine	280-57-9	174	159	-	YES	-	-
PC	Propylene carbonate	108-32-7	242	-48.8	-	YES	-	-
Chlorinated								
DCM	Dichloromethane	75-09-2	40	-95	YES	-	-	-
EDC	Ethylene dichloride	107-06-2	83.5	-35.5	-	YES	-	-
PERC	Tetrachloroethylene	127-18-4	121.3	-22.3	-	YES	-	-
CPS	Chlorpyrifos-ethyl	2921-88-2	160	42	YES	-	YES	-
1.4-DCB	1,4-Dichlorobenzene	106-46-7	174	52.1	-	YES	-	-
1.2-DCB	1,2-Dichlorobenzene	95-50-1	180	-16.7	-	YES	-	-
DDVP	Dichlorvos	62-73-7	234.1	-60	YES	-	YES	-

Esters								
	Ethylacetate	141-78-6	77	-83.6	YES	YES	-	-
	Methylcarbonate	-	119	-	-	YES	-	-
	Diazinon	333-41-5	125	25	YES	-	YES	-
	Butyl acetate	123-86-4	126.1	-78	-	YES	-	-
	Butylacrylate	141-32-2	145	-64.6	-	YES	-	-
	Hydroxyethylmethacrylate	868-77-9	213	-99	-	YES	-	-
	2-Ethylhexyl acrylate	103-11-7	213.5	-90	-	YES	-	-
	Ethylcarbonate	-	-	-	-	YES	-	-
	Kodaflex	6846-50-0	-	-	-	YES	-	-
	Methylmethacrylate	80-62-6	100.5	-48	-	YES	-	-
	Isobornyl acrylate	5888-33-5	-	97	-	YES	-	-
Glycols and Ethers								
	Furan	110-00-9	31.5	-85.6	-	YES	-	-
THF	Tetrahydrofuran	109-99-9	65	-108.3	-	YES	-	-
	Dimethyldioxane	15176-21-3	121.5	-4.5	-	YES	-	-
	Dipropylene glycol mono-n-butylether	29911-82-2	-	-	-	YES	-	-
	Butyldiglycol	112-34-5	231	-68	-	YES	-	-
	Dipropylene glycol methyl ether	34590-94-8	-	-	-	YES	-	-
Hydrocarbons								
	Cyclopentadiene	542-92-7	41	-85	-	YES	-	-
	Hexene	592-41-6	63.4	-139.7	-	YES	-	-
	Hexane	110-54-3	68.7	-95	YES	-	-	-

Benzene	71-43-2	80	5.5	YES	-	-	-
Cyclohexadiene	592-57-4	80.5	-89	-	YES	-	-
Cyclohexene	110-83-8	82.9	-103.5	-	YES	-	-
Norbornene	498-66-8	96	45	-	YES	-	-
n-Heptane	142-82-5	98.5	-90.7	YES	YES	-	-
Methylcyclohexane	108-87-2	101	-126.6	YES	-	-	-
Methylcyclohexene	591-49-1	106	-	-	YES	-	-
Toluene	108-88-3	111	-94.9	YES	YES	-	-
Octene	111-66-0	121.2	-101.7	-	YES	-	-
3,4-Dimethylcyclohexene	2808-72-2	122.5	-	-	YES	-	-
Octane	111-65-9	126	-56	YES	-	-	-
4-Vinylcyclohexene	100-40-3	128	-109	-	YES	-	-
Allylcyclohexane	2114-42-3	132	-	-	YES	-	-
Ethylbenzene	100-41-4	136	-95	YES	YES	-	-
Xylene	106-42-3	138	13.3	YES	YES	-	-
o-xylene	95-47-6	144	-25	YES	-	-	-
Styrene	100-42-5	145	-31	-	YES	-	-
Nonene	124-11-8	146.9	-81.3	-	YES	-	-
Nonane	111-84-2	150.4	-53	YES	-	-	-
n-Propylbenzene	103-65-1	159.2	-99.5	YES	YES	-	-
α-Methylstyrene	98-83-9	165.4	-23.2	-	YES	-	-
Trimethylbenzene	95-63-6	169	-44	YES	YES	-	-
Decene	872-05-9	170.5	-66.3	-	YES	-	-

n-Decane	124-18-5	174	-29	YES	YES	-	-
Propenylbenzene	873-66-5	176.9	-28.2	-	YES	-	-
2,2,4,6,6-Pentamethylheptane	13475-82-6	177.8	-67	-	YES	-	-
Decahydronaphtalene	493-02-7	179.5	-38.7	-	YES	-	-
Butylcyclohexane	1678-93-9	180.9	-74.7	-	YES	-	-
1-Ethenyl-4-ethyl benzene	3454-07-7	192.3	-49.7	-	YES	-	-
n-Undecane	1120-21-4	195.9	-25.6	YES	YES	-	-
2,3-Dihydro-4-methyl-1H-Inden*	824-22-6	205.3	-	-	YES	-	-
n-Dodecane	112-40-3	216	-9.6	YES	YES	-	-
Naphtalene	91-20-3	217.9	80.2	-	YES	-	YES
n-Tridecane	629-50-5	235.4	-5.3	-	YES	-	-
Cyclohexyl benzene	827-52-1	240.1	7.3	-	YES	-	-
Methylnapthalene	90-12-0	244.7	-30.4	-	YES	-	-
n-Tetradecane	629-59-4	253.5	5.8	-	YES	-	-
n-Pentadecane	629-62-9	270.6	9.9	-	YES	-	-
n-Hexadecane	544-76-3	286.8	18.1	-	YES	-	-
n-Octadecane	593-45-3	316.3	28.2	-	YES	-	-
2,2,4,4-Tetramethyloctane	62183-79-3	-	-	-	YES	-	-
m,p-Xylene	179601-23-1	-	-	YES	YES	-	-
2-methyl-1-propylbenzene	768-49-0	-	-	-	YES	-	-
4'-(prop-1-en-1-yl)-[1,1'-bi(cyclohexan)]-3-ene	-	-	-	-	YES	-	-
4-(prop-1-en-1-yl)-1,1'-bi(cyclohexane)	-	-	-	-	YES	-	-
4-(prop-1-en-1-yl)cyclohexyl)benzene	-	-	-	-	YES	-	-

	4'-butyl-[1,1'-bi(cyclohexan)]-3-ene	-	-	-	-	YES	-	-
	cis-3-Methyl-endo-tricyclo[5,2,1,0(2,6)]decane	1000215-29-0	-	-	-	YES	-	-
	Longicyclene	1137-12-8	-	-	-	YES	-	-
	4'-methyl-[1,1'-bi(cyclohexan)]-3-ene	168191-95-5	-	-	-	YES	-	-
	4-propylcyclohexyl benzene	173837-35-9	-	-	-	YES	-	-
	1,1'-bi(cyclohexan)]-3-ene	500002-53-9	-	-	-	YES	-	-
	4'-ethyl-[1,1'-bi(cyclohexan)]-3-ene	615257-52-8	-	-	-	YES	-	-
	4-phenylcyclohexane-1-carboxylic acid	7494-76-0	-	-	-	YES	-	-
Ketone								
	Acetone	67-64-1	56	-95	YES	YES	-	-
	Butanone (Methylethylketone)	78-93-3	79.5	-86.6	-	YES	-	-
	2-methyl-1-propanol	78-83-1	107.8	-108	-	YES	-	-
	2-Methylcyclopentanone	1120-72-5	139	-	-	YES	-	-
	Cyclohexanone	108-94-1	155.4	-31	-	YES	-	-
	Cyclohexyl methyl ketone	823-76-7	180.5	-	-	YES	-	-
	Trimethylcyclohexenone	873-94-9	189	-	-	YES	-	-
	Cyclohexyl acetone	103-78-6	198	-	-	YES	-	-
	Acetophenone	98-86-2	202	20	-	YES	-	-
	Menthone	14073-97-3	210	-6	-	YES	-	-
	2,2',4,4',5-pentabromodiphenyl ether	60348-60-9	200	-5	-	YES	-	-
Phenol								
	Phenol	108-95-2	181.8	40.9	-	YES	-	-
	p-Cresol	106-44-5	201.9	35.5	-	YES	-	-

	Butylated hudroxytoluene	128-37-0	265	71	-	YES	-	-
Siloxane								
D3	Hexamethylcyclotrisiloxane (D3)	541-05-9	134	64.5	-	YES	-	-
D4	Octamethylcyclotetrasiloxane (D4)	556-67-2	175.8	17.5	-	YES	-	-
	Decamethyltetrasiloxane	141-62-8	194	-76	-	YES	-	-
D5	Decamethylcyclopentasiloxane (D5)	541-02-6	210	-38	-	YES	-	-
	Dodecamethylpentasiloxane	141-63-9	232	-80	-	YES	-	-
D6	Dodecamethylcyclohexasiloxane (D6)	540-97-6	245	-3	-	YES	-	-
	Hexatetradecamethylsiloxane	107-52-8	245.5	-59	-	YES	-	-
D7	Tetradecamethylcycloheptasiloxane (D7)	107-50-6	-	-26	-	YES	-	-
Terpene								
	Isoprene	78-79-5	34	-145.9	YES	YES	-	-
	alpha-pinene	80-56-8	156	-62.5	YES	YES	-	-
	beta-pinene	127-91-3	166	-61.3	-	YES	-	-
	3-carene	13466-78-9	175	25	YES	YES	-	-
	Limonene	138-86-3	176	-95	YES	YES	-	-
	Longifolene	475-20-7	258	-	-	YES	-	-
	Isolongifolene	1135-66-6	-	-	-	YES	-	-

TABLE 33. Mapping of chemicals in the literature: SVOC. Field studies found in the literature have been carried out in office spaces, schools, private homes and PC workshops. The tested equipment (liturature) includes computers, computer monitors, TV sets, PU foam and upholstered chairs. *Air field: Found in air measurements in field surveys. Air*

*equipment: Found in air measurements in equipment tests. Dust field: Found in dust analysis collected during field investigations. Dust equipment: Found in dust analysis collected inside computers. * decomposes*

Group	Substance	CAS RN	BP (°C)	MP (°C)	Luft felt	Luft udstyr	Støv felt	Støv udstyr
					(yes/no)			
BFR								
TBB	2-Ethylhexyl 2,3,4,5-tetrabromobenzoate	183658-27-7	-	-	-	-	YES	-
HBCD	Hexabromocyclododecane	3194-55-6	-	-	-	YES	YES	-
TBCO	1,2,5,6-Tetrabromocyclooctane	3194-57-8	-	-	-	-	YES	-
TBECH	1,2-Dibromo-4-(1,2-dibromoethyl)cyclohexane	3322-93-8	-	-	-	-	YES	-
DPTE	2,3-Dibromopropyl-2,4,6-tribromophenyl ether	35109-60-5	-	-	-	-	YES	-
BTBPE	1,2-bis(2,4,6 tribromophenoxy) ethane	37853-59-1	-	222	-	-	YES	-
PBEB	Pentabromoethylbenzene	85-22-3	-	-	-	-	YES	-
HBBZ	hexabromobenzene	87-82-1	-	-	-	YES	YES	-
PBDE	Pentabromotuluene	87-83-2	-	288	-	-	YES	-
TBBPA	tetrabromo bisphenol A	79-94-7	316	181	-	YES	-	-
BDE 209	BDE-209	1163-19-5	530	305	YES	-	YES	-
	HexaBDE (Sum of BDE 153 and 154)	-	-	-	YES	-	-	-
	PentaBDE (Sum of BDE 85, 99 and 100)	-	-	-	YES	-	-	-
BDE 100	1,3,5-tribromo-2-(2,4-dibromophenoxy)benzene	189084-64-8	-	97	YES	YES	YES	-
BDE 154	1,2,4-tribromo-5-(2,4,6-tribromophenoxy)benzene	207122-15-4	-	142	YES	-	YES	-
BDE 183	1,2,3,5-tetrabromo-4-(2,4,5-tribromophenoxy)benzene	207122-16-5	-	-	YES	-	YES	-
BDE 28	2,4-dibromo-1-(4-bromophenoxy)benzene	41318-75-6	-	-	YES	-	YES	-
BDE 47	2,2',4,4'-tetrabromodiphenyl ether	5436-43-1	-	82	YES	YES	YES	-
BDE 153	1,2,4-tribromo-5-(2,4,5-tribromophenoxy)benzene	68631-49-2	-	157.6	YES	-	YES	-

Group	Substance	CAS RN	BP (°C)	MP (°C)	Luft felt	Luft udstyr	Støv felt	Støv udstyr
BDE 99	2,2',4,4',5-pentabromodiphenyl ether	60348-60-9	200	-5	YES	YES	YES	-
DBDPE	Decabromodiphenyl ethane	84852-53-9	-	345	YES	-	YES	-
PFR								
TDCPP	2-propanol, 1,3-dichloro-, phosphate (3:1)	13674-87-8	236	27	-	-	YES	-
TCPP	2-propanol, 1-chloro-, phosphate (3:1)	13674-84-5	241	-40	-	-	YES	-
TEP	Triethylphosphate	78-40-0	215.5	-56.4	-	YES	-	-
TPP	triphenyl phosphate	115-86-6	370	50	-	YES	YES	-
TCEP	Tris(2-carboxyethyl)phosphine	5961-85-3	-	-	-	-	YES	-
TBP	Tributyl phosphate	126-73-8	289	-80	YES	-	YES	-
RDP	resorcinol-bis-biphenylphosphate	57583-54-7	-	-	-	YES	-	-
BDP	bisphenolA-bis-biphenylphosphate	5945-33-5	-	-	-	YES	-	-
CFR								
syn-DP	syn Dechlorane Plus	135821-03-3	-	-	-	-	YES	-
anti-DP	anti Dechlorane Plus	135821-74-8	-	-	-	-	YES	-
DP	Dechlorane Plus	13560-89-9	-	-	YES	-	YES	-
Dec 603	Dechlorane 603	13560-92-4	-	-	YES	-	-	-
Dec 602	Dechlorane 602	31107-44-5	-	-	YES	-	-	-
Chlorinated								
Alpha-HCH	Alpha-hexachlorocyclohexane	58-89-9	323	113	YES	-	YES	-
4,4'-DDE	4,4'-Dichlorodiphenyldichloroethylene	72-55-9	336	89	YES	-	YES	-
4,4'-DDT	Clofenotane	50-29-3	260 *	108.5	YES	-	YES	-
	Dieldrin	60-57-1	330 *	175	YES	-	YES	-
	Aldrin	309-00-2	*	104	YES	-	YES	-
	1,6-dichlorocyclooctadien	29480-42-0	-	-	-	YES	-	-

Group	Substance	CAS RN	BP (°C)	MP (°C)	Luft felt	Luft udstyr	Støv felt	Støv udstyr
	Alpha-endosulfan	959-98-8	-	-	YES	-	YES	-
Ketone								
	2,5-di-tert-Butyl-1,4-benzoquinone	2460-77-7	285.4	152.5	-	YES	-	-
	Galaxolide	1222-05-5	325	-5	YES	-	YES	-
	Tonalide	21145-77-7	326	54.5	YES	-	YES	-
Liquid Crystal Monomers								
LCM-18	1-ethoxy-2,3-difluoro-4-(4- (4- propylcyclohexyl)cyclohex yl)benzene	123560-48-5	-	-	-	-	YES	-
LCM-10	1-methyl-4-(4-(4- vinylcyclohexyl)cyclohexyl) benzene	155041-85-3	-	-	-	-	YES	-
LCM-5	1-ethoxy-2,3-difluoro-4-(4-propylcyclohexyl)benzene	174350-05-1	-	-	-	-	YES	-
LCM-12	4-[difluoro(3,4,5- trifluorophenoxy)methyl]- 3,5-difluoro-4'-propylbiphenyl	303186-20-1	-	-	-	-	YES	-
LCM-15	2,3-difluoro-1-methoxy-4- (4-(4- propylcyclohexyl)cyclohex yl)benzene	431947-34-1	-	-	-	-	YES	-
LCM-23	1-(4-(4- butylcyclohexyl)cyclohexyl)-4-ethoxy-2,3-difluorobenzene	473257-15-7	-	-	-	-	YES	-
LCM-13	1-methyl-4-(4-(4- propylcyclohexyl)cyclohex yl)benzene	84656-75-7	-	-	-	-	YES	-
LCM-3	1-methoxy-4-(4- propylcyclohexyl)cyclohex ane	97398-80-6	-	-	-	-	YES	-
LCM-20	1-ethoxy-2,3-difluoro-4-(4- (4-(prop-1- enyl)cyclohexyl)cy-clohexyl) benzene	-	-	-	-	-	YES	-
Nitrile								
	Tetramethylbutanedinitrile	3333-52-6	sublimes	170.5	-	YES	-	-
PAH								
	Acenaphthene	83-32-9	279	93	YES	-	YES	YES
	acenaphthylene	208-96-8	280	89	-	-	-	YES

Group	Substance	CAS RN	BP (°C)	MP (°C)	Luft felt	Luft udstyr	Støv felt	Støv udstyr
	Fluorene	86-73-7	294	114.8	YES	-	YES	YES
	Phenanthrene	85-01-8	338	99	YES	-	YES	YES
	Anthracene	120-12-7	342	218	YES	-	YES	YES
	Fluoranthene	206-44-0	384	110	YES	-	YES	YES
	Pyrene	129-00-0	404	151	YES	-	YES	YES
	benzo[a]anthracene	56-55-3	437	162	-	-	-	YES
	chrysene	218-01-9	448	255	-	-	-	YES
	benzo[k]fluoranthene	207-08-9	480	217	-	-	-	YES
	benzo[b]fluoranthene	205-99-2	481	168	-	-	-	YES
	Benzo(a)pyrene	50-32-8	495	178.1	YES	-	YES	YES
	dibenz[a,h]anthracene	53-70-3	524	269	-	-	-	YES
	indeno[1,2,3-cd]pyrene	193-39-5	536	164	-	-	-	YES
	benzo[g,h,i]perylene	191-24-2	550	278	-	-	-	YES
PCB								
	HeptaCB (sum of CB170, 180, 183, 187 and 189)	-	-	-	YES	-	-	-
	HexaCB (sum of CB128, 138, 141, 149, 153, 156, 157 and 167)	-	-	-	YES	-	-	-
	PentaCB (sum of CB 99, 101, 105, 114, 118, 122 and 123	-	-	-	YES	-	-	-
	TetraCB (sum of CB 47, 52, 66 and 74),	-	-	-	YES	-	-	-
	TriCB (sum of PCBs 18, 28, 31, 33 and 37)	-	-	-	YES	-	-	-
PCB 28	2,4-dichloro-1-(4-chlorophenyl)benzene	7012-37-5	-	-	YES	-	YES	-
PCB 31	1,4-dichloro-2-(4-chlorophenyl)benzene	16606-02-3	-	-	YES	-	YES	-
PCB 118	1,2,4-trichloro-5-(3,4-dichlorophenyl)benzene	31508-00-6	-	-	YES	-	YES	-
PCB 105	1,2,3-trichloro-4-(3,4-dichlorophenyl)benzene	32598-14-4	-	-	YES	-	YES	-

Group	Substance	CAS RN	BP (°C)	MP (°C)	Luft felt	Luft udstyr	Støv felt	Støv udstyr
PCB 153	1,2,4-trichloro-5-(2,4,5-trichlorophenyl)benzene	35065-27-1	-	-	YES	-	YES	-
PCB 138	1,2,3-trichloro-4-(2,4,5-trichlorophenyl)benzene	35065-28-2	-	-	YES	-	YES	-
PCB 52	1,4-dichloro-2-(2,5-dichlorophenyl)benzene	35693-99-3	-	-	YES	-	YES	-
PCB101	1,2,4-trichloro-5-(2,5-dichlorophenyl)benzen	37680-73-2	-	-	YES	-	YES	-
Phenol								
BPA	bisphenol A	80-05-7	360.5	153	-	YES	-	-
Phthalate								
DEHP	diethylhexyl phthalate	117-81-7	384	-55	-	-	YES	-
TBPH	Bis(2-ethylhexyl) tetrabromophthalate	26040-51-7	-	-	-	-	YES	-
DEP	Diethylphthalate	84-66-2	295	-41	YES	YES	YES	-
DiBP	di-isobutyl phthalate	84-69-5	296	-37	YES	-	YES	-
DiNP	bis(7-methyloctyl) benzene-1,2-dicarboxylate	28553-12-0	420	-43	YES	-	YES	-
DBP	dibutyl phthalate	84-74-2	340	-35	YES	-	YES	-
BBP	Benzyl butyl phthalate	85-68-7	698	-35	YES	-	YES	-
DMP	dimethyl phthalate	131-11-3	-	-	YES	-	YES	-

Appendix 3. Observations and information from field investigations

TABLE 34. Field investigations – Observations and information

	Private home #1	**Private home #2**	**Private home #3**	**Private home #4**	**Netcafé**	**Højskole Esport room**	**Højskole Gamer room**
Date	6. juni 2022	6. juni 2022	12. juni 2022	20. juni 2022	10. juni 2022	13. juni 2022	13. juni 2022
Time	15.00-21.00	15.30-21.30	9.30-15.30	16.30-22.30	16.30-22.30	15.30-21.30	14.00-19.00
Type of room	Child's bedroom	Child's bedroom	Child's bedroom	Basement living room	Hall	Computer room (Classroom)	Classroom
Number of people	1	1	1	2	2	Between 4 and 9 Av-erage: 6	Between 2 and 10 Av-erage: 9
Participant's age	14	16	12	13	10+	18+	18+
Floor space [m^2]	9.0	12.2	9.2	11.2	153.1	59.8	46.7
Ceiling height [m]	2.2	2.2	2.3	2.0	2.6	3.2	3.3
Room volume [m^3]	17.0	24.3	21.3	22.5	398.1	192.1	155.2
Room volume per PC [m^3]	17.0	24.3	21.3	11.2	17.3	9.1	6.5
Flooring material	Laquered laminate	Laquered laminate	Vinyl	Concrete	Linoleum	Older Linoleum	Older Linoleum
Wall material	Painted wallpaper	Painted wallpaper	Painted fiberglass	Concrete	Painted fiberglass	Spackled and painted	Spackled and painted

	Private home #1	Private home #2	Private home #3	Private home #4	Netcafé	Højskole Esport room	Højskole Gamer room
Ceiling material	Painted paneling	Painted paneling	Painted plaster	Painted concrete	Cement bonded wood wool panels and painted concrete beams	Suspended acoustic panel ceiling: painted mineralwool and metal rails	Suspended acoustic panel ceiling: painted mineralwool and metal rails
Cleaning schedule	Cleaning every 14 days. Vacuuming, wiping off dust with microfibre cloth and dust broom. Floor washed with Ajax.	Cleaning every 14 days. Vacuuming, wiping off dust with a microfiber cloth. Floor washed with Ajax.	Weekly vacuuming and wiping with a wet cloth or microfiber cloth. Floor washed with "minirisk" cleaner.	Cleaning as needed with vacuuming and wiping the table. No use of cleaning agents.	Daily cleaning, with vacuuming and wiping of dust. Floor washing with a machine a few times a week. Cleaning agent info not available.	Cleaning several times a week. Vacuuming and wiping tables with cleaner. Floor washing once a week with a product called "Gulvpleje".	The students themselves are responsible for the cleaning, which is sparse. The frequency is unknown.
Ventilation	Open outside air vent in the window	No outdoor air vents in windows	Closed outdoor air vents in windows	Closed outside air vents in windows, but air exchange with the other rooms allowed	Balanced mechanical ventilation	Closed outdoor air vents in windows	Closed outdoor air vents in windows
Windows Face	South	North	West	East	Northeast and southwest	South	South
Subjective notes on air quality	The air quality worsened over time, and was mostly experienced as warm and heavy air.	The air quality deteriorated over time, food smells came from meals consumed, the room became hot and stuffy by the end.	The air quality became increasingly stale and stuffy.	The air was humid and became slightly stuffy over time. The smell from popcorn was noticed at the end of the measurement.	The air quality was fresh and comfortable.	The air became warmer over time.	The air warmed over time and became increasingly stuffy. Smells came from full garbage cans and food consumption.

	Private home #1	Private home #2	Private home #3	Private home #4	Netcafé	Højskole Esport room	Højskole Gamer room
Weather conditions during the measure-ments	Solskin og enkelte byer, 16-18 grader	Solskin og enkelte byer, 16-18 grader	Blandet solskin og skyer, 14 til 18 grader	Regnvejr og fugtigt i vejret, lidt spredt sol-skin, 12 til 14 grader	Solskin, 19-20 grader	Solskin og enkelte byer, 15 til 17 grader	Solskin og enkelte byer, 15 til 17 grader
Games played dur-ing measurments	Minecraft (played dur-ing measurement) ARC Skyrim	Minecraft, (played dur-ing measurement) Valorant Among Us Phasmophobia	Paladins (played dur-ing measurement) League of Legends (played during meas-urement) Fortnite	Minecraft (played dur-ing measurement) Among Us (played during measurement) Ark Skyrim Gæst spiller Minecraft og senere Among Us	Fortnite Counter Strike GO Minecraft PlayStation Fifa	League of Legends Counter Strike GO	League of Legends Counter Strike GO
Active Gaming Hours	30 hours/week	2-3 hours/day	15-20 hours/week	3 hours/day	Active hours: 15:00-18:00 on week-days 15:00-22:00 on weekends	2-6 hours/day	2-6 hours/day
Desktop PC (#)	1	0	1	2	23	21	19 (not all in use)
Laptop PC (#)	0	1	0	0	0	0	5
Monitor (#)	2	0	1	3	24	21	23
Double screen	Yes	0	0	Yes	0	0	Yes, 2
Keyboard (#)	1	0	1	2	24	21	17
Mouse (#)	1	1	1	2	24	21	21
Mouse mat (#)	1	1	1	2	24	21	21
Headset (#)	1	1	1	2	24	21	21
Microphone (#)	1	1	0	0	0	0	2
Chair (#)	1	1	1	3	24	2	29

	Private home #1	**Private home #2**	**Private home #3**	**Private home #4**	**Netcafé**	**Højskole Esport room**	**Højskole Gamer room**
Gaming chair (#)	0	0	0	1	24	21	0
Gaming chair material	Upholstered seat with fabric cover and back in mesh.	Upholstered seat and back with fabric cover.	Artificial leather and mesh.	A chair that is upholstered with PU leather cover and one with an upholstered seat with fabric cover and back in mesh.	Upholstered seat and back with fabric cover.	Upholstered seat and back with textile cover.	Mixed – not many gaming specific chairs.

Appendix 4. Temperature, relative humidity, and CO2 concentration in the field survey

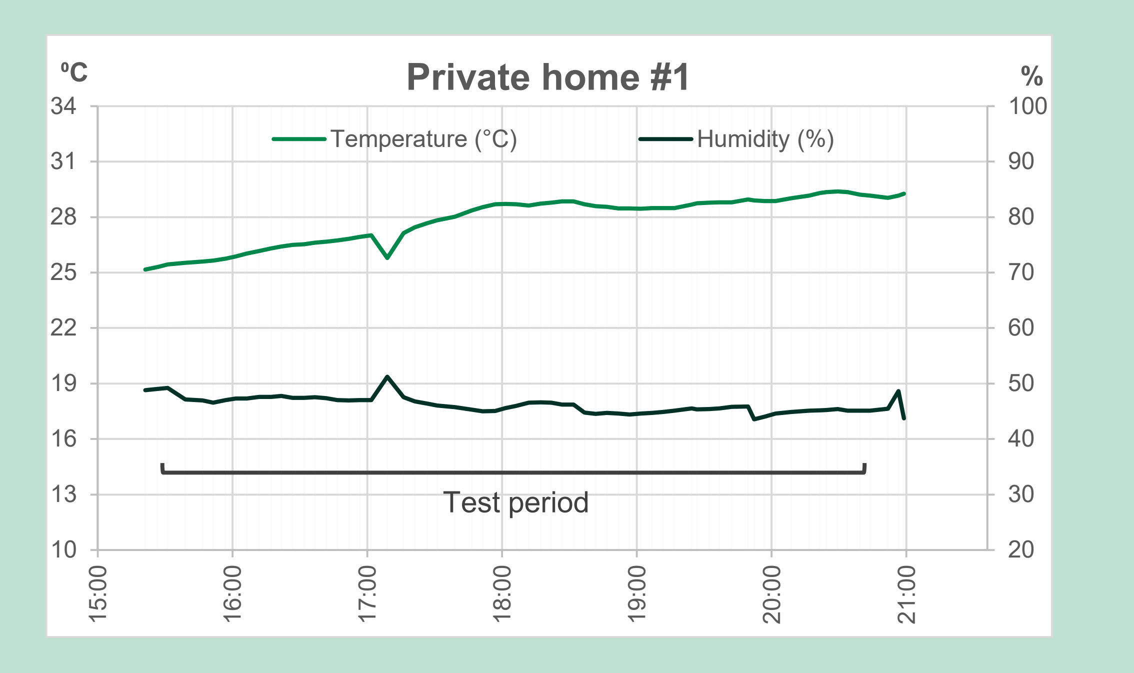

FIGURE 9. Temperature and humidity measurements in Private Home #1

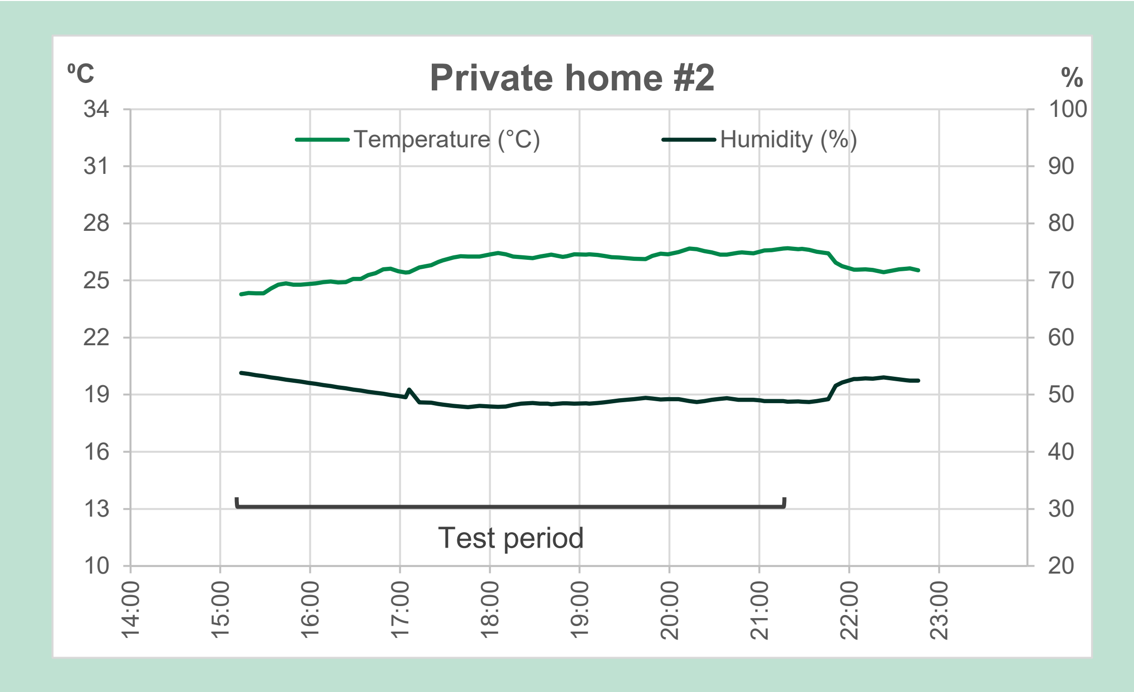

FIGURE 10. Temperature and humidity measurements in Private Home #2

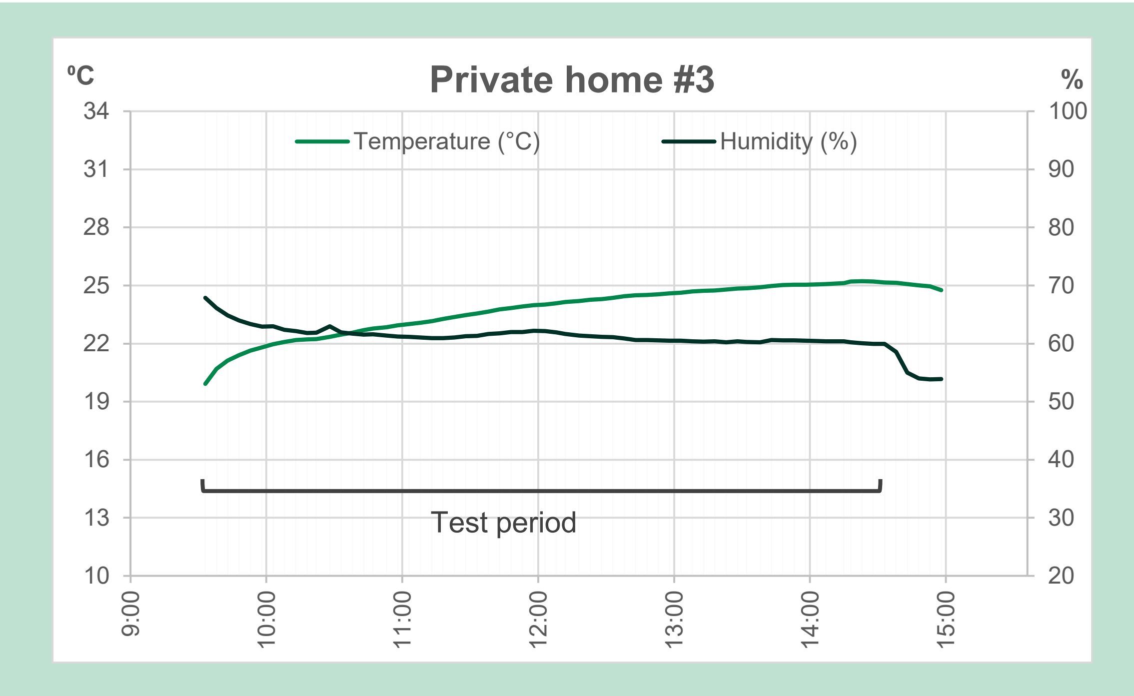

FIGURE 11. Temperature and humidity measurements in Private Home #3

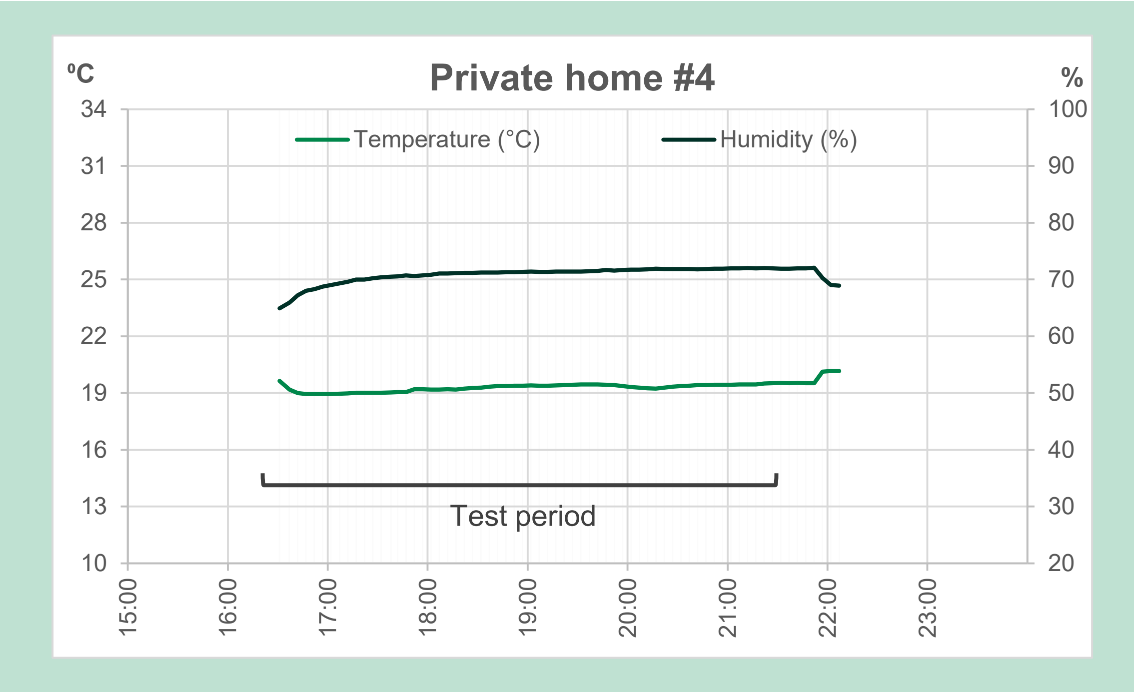

FIGURE 12. Temperature and humidity measurements in Private Home #4

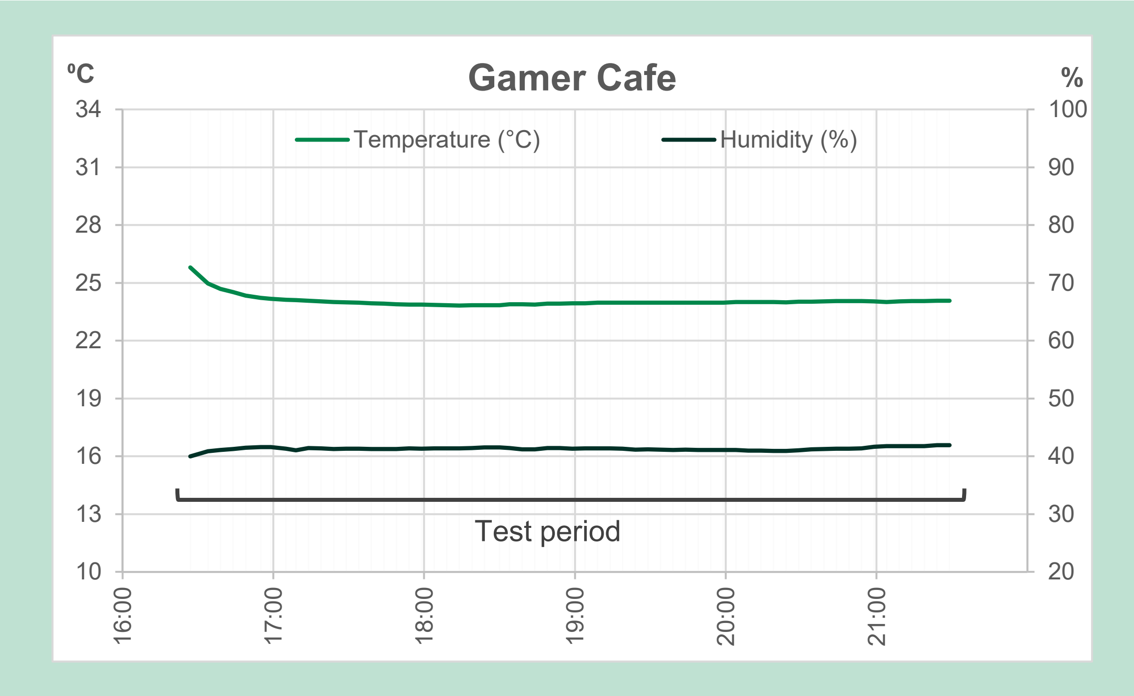

FIGURE 13. Temperature and humidity measurements in the Gamer Cafe

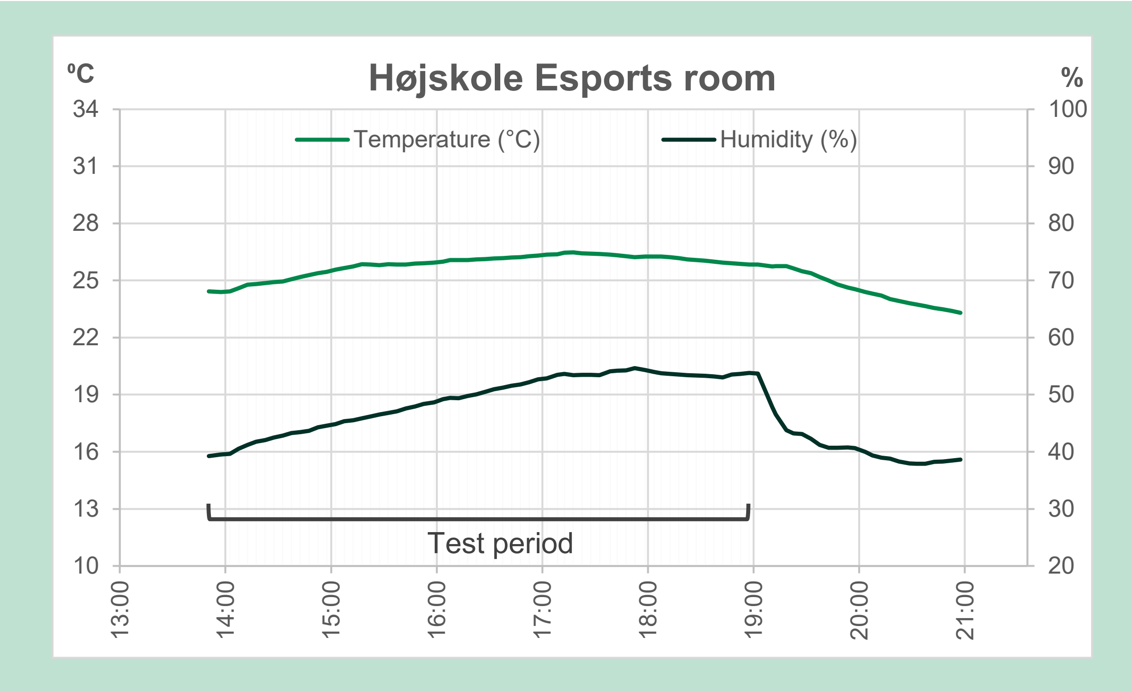

FIGURE 14. Temperature and humidity measurements in the Højskole Esport room

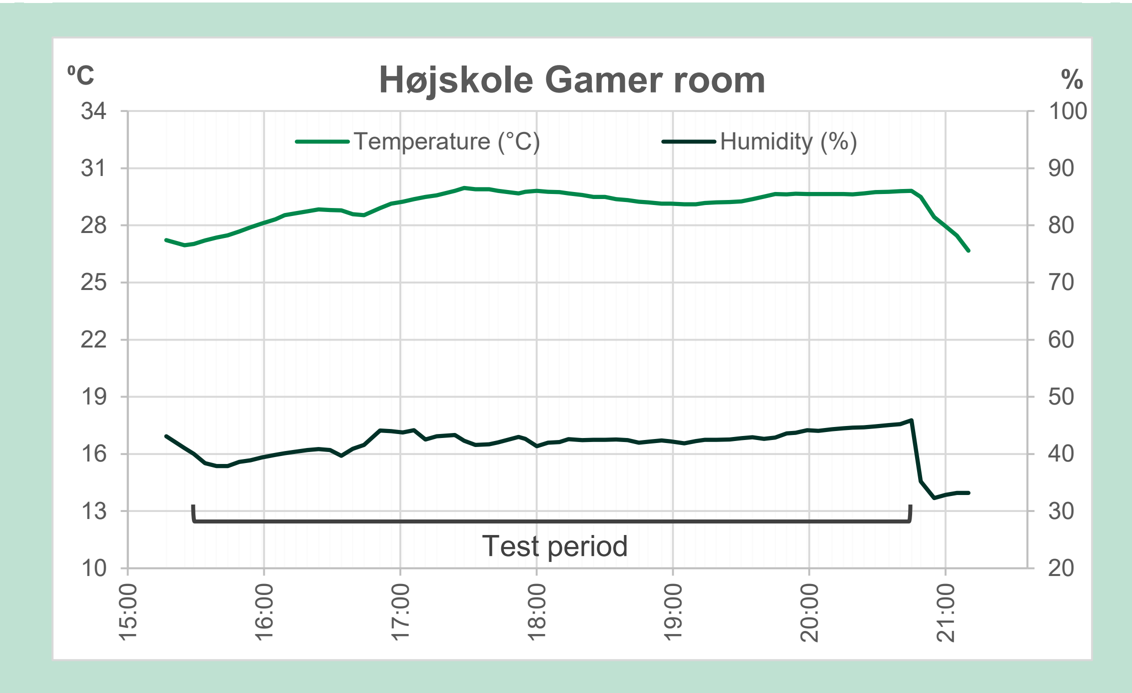

FIGURE 15. Temperature and humidity measurements in the Højskole Gamer room

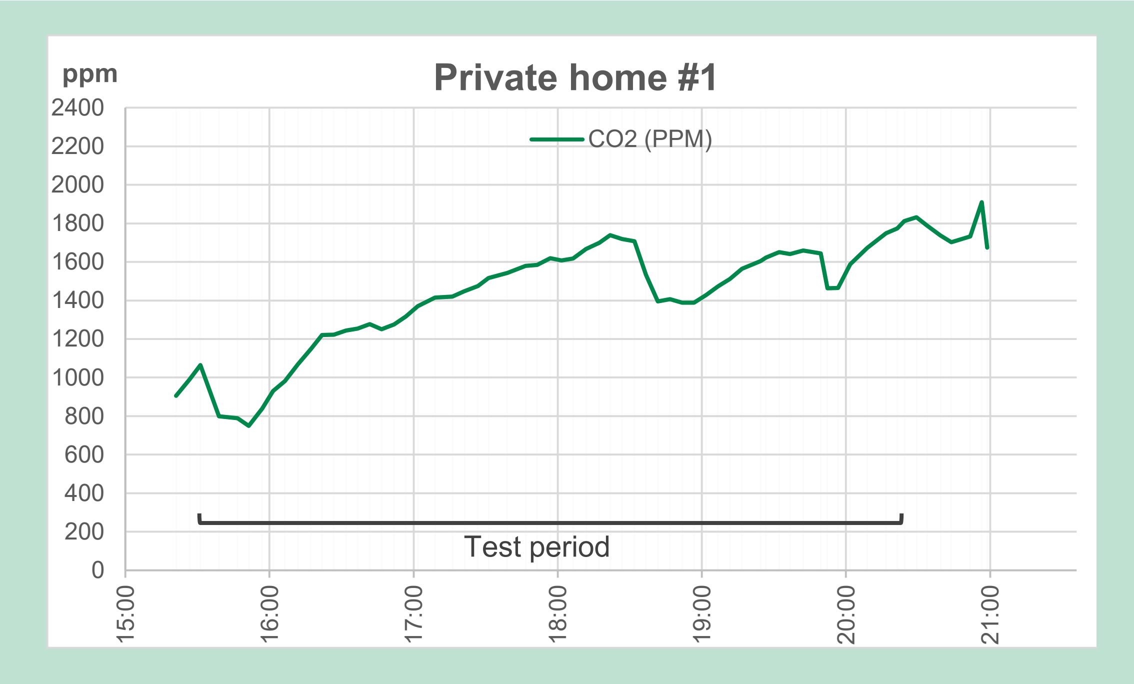

FIGURE 16. CO_2 concentration in Private Home #1

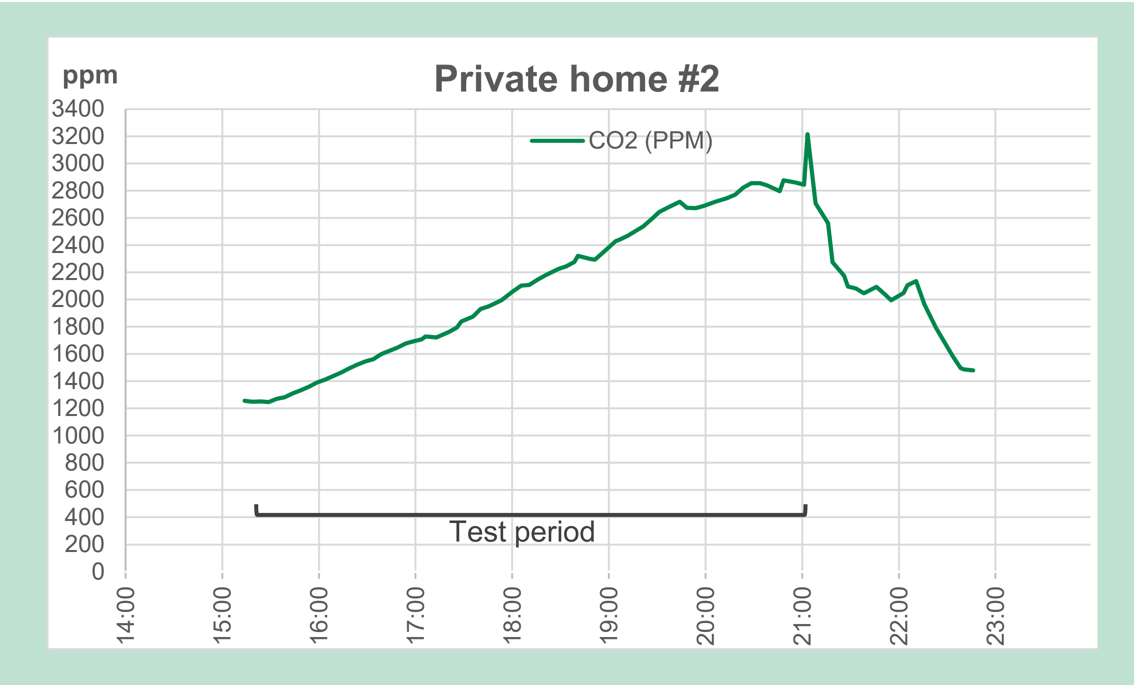

FIGURE 17. CO_2 concentration in Private Home #2

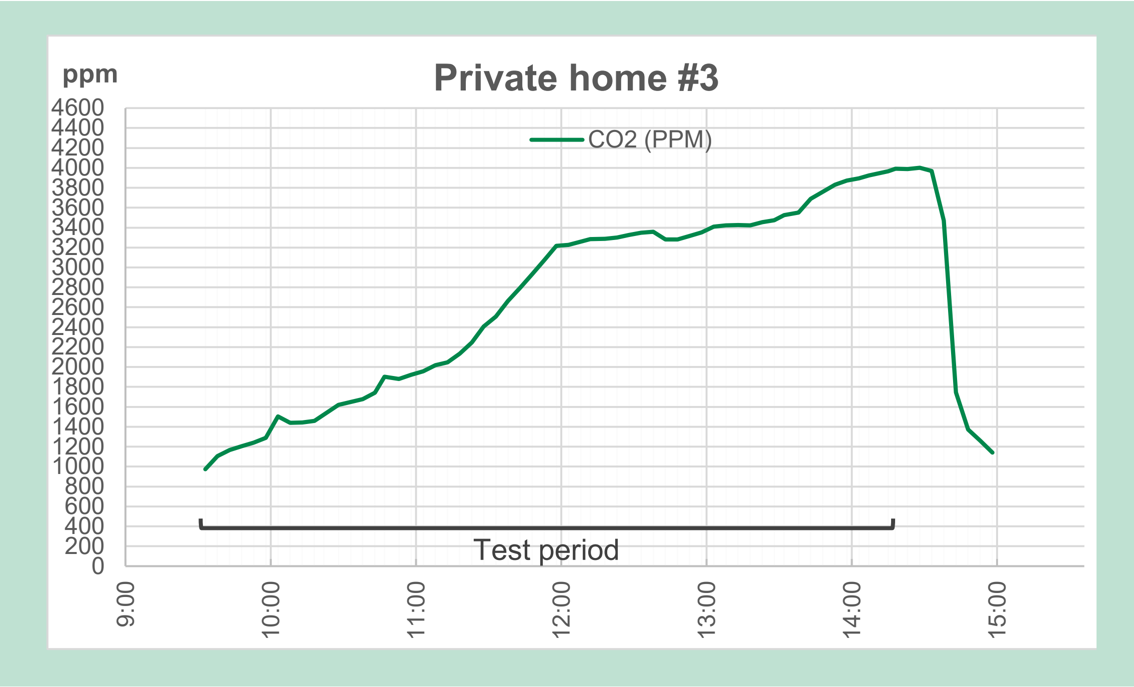

FIGURE 18. CO_2 concentration in Private Home #3

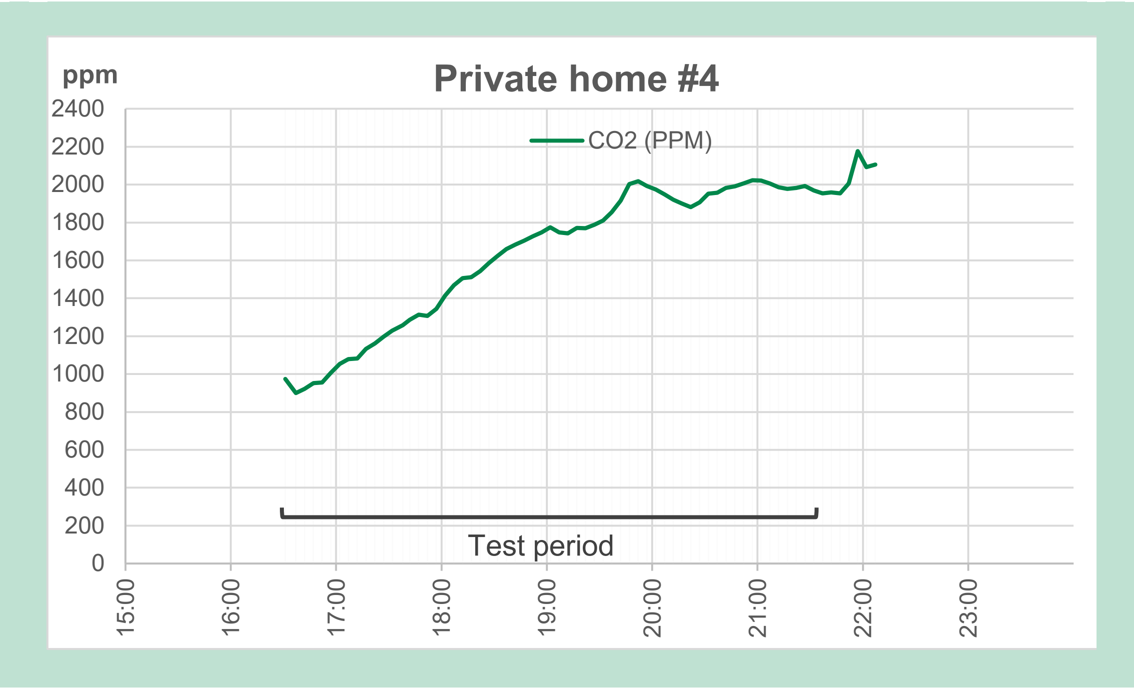

FIGURE 19. CO_2 concentration in Private Home #4

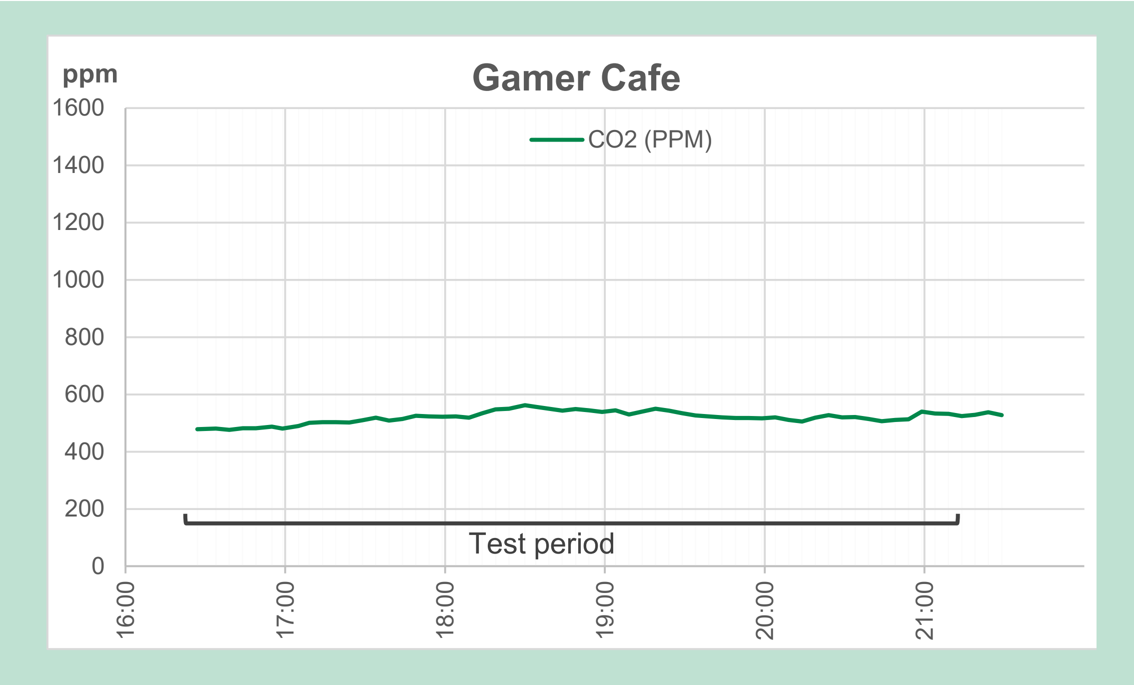

FIGURE 20. CO_2 concentration in the Gamer Café

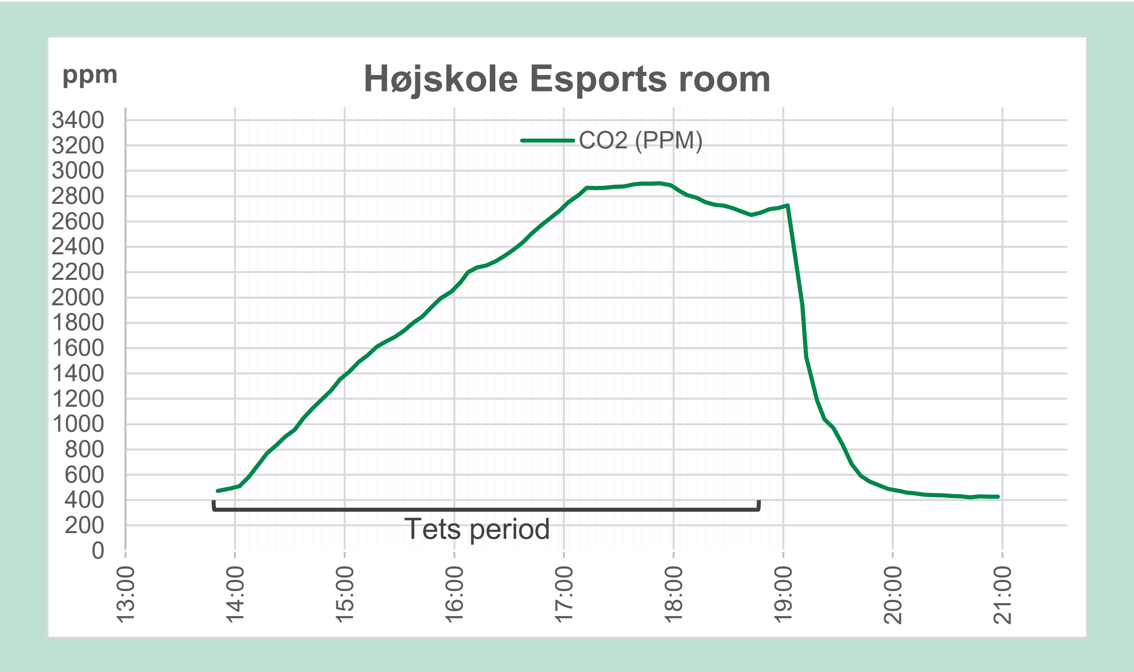

FIGURE 21. CO_2 concentration in the Højskole Esport room

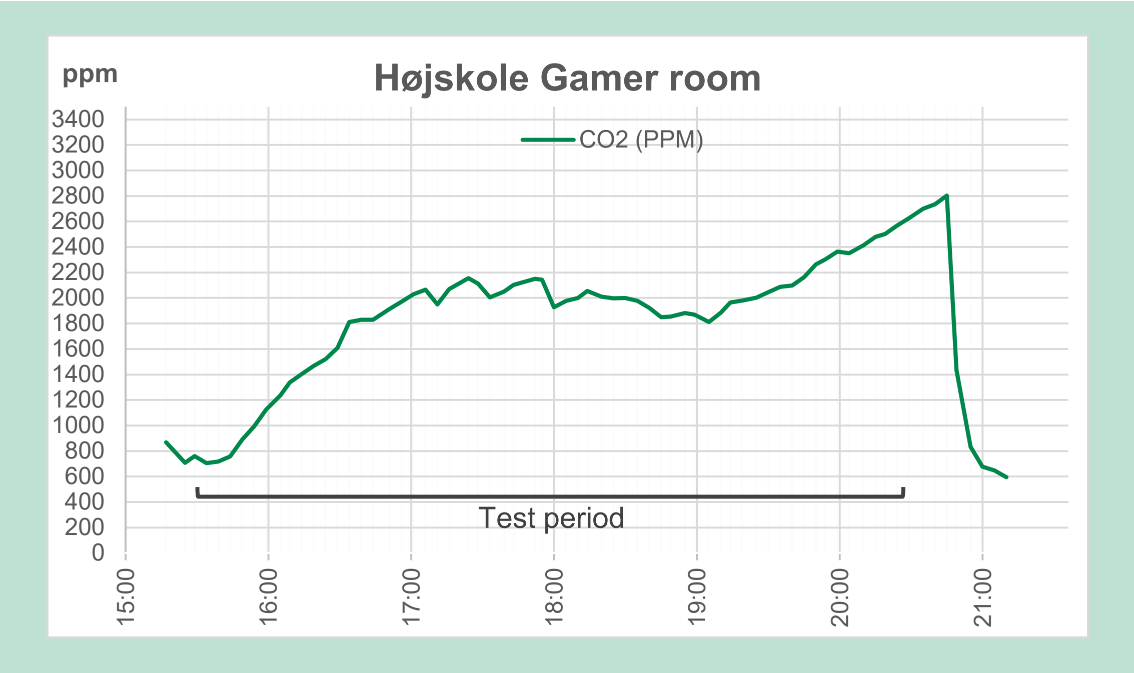

FIGURE 22. CO_2 concentration in the Højskole gamer room

Appendix 5. VOC results from climate chamber tests of gaming accessories

TABLE 35. Results of VOC and aldehyde measurements for keyboard and mouse products in µg/m³. Concentrations correspond to the reference room

		Keyboard				Mouse			
Substance	**CAS RN**	**ID 3**	**ID 19**	**ID 23**	**ID 29**	**ID 4**	**ID 20**	**ID 24**	**ID 30**
Aldehydes									
Formaldehyde (VVOC)	50-00-0	-	< 1	< 1	< 1	-	-	-	< 1
Acetaldehyde (VVOC)	75-07-0	-	< 1	-	< 1	-	< 1	-	< 1
Amines									
Caprolactam	105-60-2	-	1	1	-	-	-	-	-
Ketones									
Acetophenone	98-86-2	-	< 1	-	4	-	-	-	-
Ketone (tolu-ene)		-	-	-	2	-	-	-	-
Alcohols									
n-Butanol	71-36-3	-	-	< 1	1	-	-	-	-
2-Ethyl-1-hexa-nol	104-76-7	-	< 1	< 1	2	-	< 1	-	< 1
2-Phenyl-2-pro-panol	617-94-7	-	-	-	5	-	-	-	< 1
Glycols, Ethers, Esters									
Carboxyl-syreester		-	-	-	-	-	1	-	-
Ethylhexyl acry-late	103-11-7	-	-	1	1	-	-	< 1	-
Benzoic acid, 4-ethoxy-, ethyl ester (toluene)	23676-09-7	-	-	-	-	-	1	-	-
Aliphatic hydrocarbons									
C15 (Pentade-cane)	629-62-9	< 1	< 1	-	1	< 1	< 1	-	< 1
C16 (Hexade-cane)	544-76-3	< 1	-	-	1	< 1	< 1	< 1	< 1
Aromatic hydrocarbons									
Toluene	108-88-3	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1

		Keyboard				Mouse			
Substance	**CAS RN**	**ID 3**	**ID 19**	**ID 23**	**ID 29**	**ID 4**	**ID 20**	**ID 24**	**ID 30**
Unknown aromatic compound		-	-	-	1	-	-	-	-
Organic acid									
Acetic acid	64-19-7	-	1	1	2	1	5	2	1
Palmitic acid	57-10-3	-	< 1	-	1	-	< 1	-	1
Phenols									
Phenol	108-95-2	-	1	-	-	-	< 1	-	< 1
Siloxanes									
Decamethylcyclopentasiloxane (D5)	541-02-6	-	-	4	3	-	-	< 1	< 1
Dodecamethylcyclohexasiloxane (D6)	540-97-6	< 1	< 1	4	7	< 1	< 1	< 1	< 1
Tetradecamethylcycloheptasiloxane (D7)	107-50-6	< 1	< 1	-	2	< 1	< 1	< 1	< 1
Sum other iso/cyclo-alkanes:	(13475-82-6)	2	-	2	1	1	-	-	-
Sum other siloxanes:	(556-67-2)	-	-	1	1	< 1	< 1	< 1	< 1
Sum other sesquiterpenes:	(475-20-7)	-	-	1	< 1	-	< 1	< 1	-
Sum other hydrocarbons:	(108-88-3)	-	-	-	-	-	4	-	-

TABLE 36 Results of VOC and aldehyde measurements for headset and mouse pad products in µg/m³. Concentration corresponds to the reference volume.

		Headset				Mouse mat			
Substance	**CAS RN**	**ID 6**	**ID 26**	**ID 28**	**ID 32**	**ID 5**	**ID 21**	**ID 25**	**ID 31**
Aldehydes									
Formaldehyde (VVOC)	50-00-0	< 1	-	< 1	< 1	5	4	-	3
Acetaldehyde (VVOC)	75-07-0	-	-	< 1	< 1	-	< 1	-	< 1
Propanal (VVOC)	123-38-6	-	-	-	-	-	-	< 1	-
Amines									
Nitrogen forb-indelse		-	1	-	< 1	-	< 1	-	-
Amides									
N,N-Dimethyl-formamide (DMF) CMR	68-12-2	-	1	-	-	-	-	-	-
N,N-Dimethyla-cetamide CMR	127-19-5	-	< 1	-	-	-	-	-	-
Ketones									
Benzophenone	000119-61-9	-	-	-	-	-	-	1	-
Alcohols									
2-Ethyl-1-hexa-nol	104-76-7	< 1	< 1	1	1	-	-	-	-
Glycols, Ethers, Esters									
Ethyl acetate	141-78-6	-	2	-	-	-	-	-	-
Butylglycol	111-76-2	-	-	-	2	-	-	-	-
n-Butyl acetate	123-86-4	-	2	-	-	-	-	-	-
2,2,4-Trimethyl-1,3-pentanediol diisobutyrate (TXIB)	6846-50-0	-	< 1	-	< 1	1	< 1	1	1
Benzoic acid, 4-ethoxy-, ethyl ester (toluene)	23676-09-7	-	< 1	1	-	-	-	-	-
Aliphatic hydrocarbons									
Cyclopentane	287-92-3	-	-	-	< 1	-	-	-	1
Methylcyclohex-ane	108-87-2	-	1	-	-	-	-	-	-
C14 (Tetrade-cane)	629-59-4	-	-	< 1	< 1	1	< 1	-	< 1
C15 (Pentade-cane)	629-62-9	< 1	-	-	1	1	< 1	-	1
C16 (Hexade-cane)	544-76-3	< 1	-	-	< 1	1	< 1	-	< 1
Aromatic hydrocarbons									
Toluene	108-88-3	3	< 1	< 1	< 1	1	< 1	< 1	-

		Headset				Mouse mat			
Substance	**CAS RN**	**ID 6**	**ID 26**	**ID 28**	**ID 32**	**ID 5**	**ID 21**	**ID 25**	**ID 31**
Naphthalene derivative (toluene)		-	-	-	-	3	-	-	-
Organic acids									
Acetic acid	64-19-7	< 1	1	3	3	1	2	1	6
Palmitic acid	57-10-3	-	-	1	1	-	-	-	-
Phenols									
2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	-	< 1	-	-	-	-	-	1
BHT-derivative		-	< 1	-	-	1	-	< 1	4
Phenol, 2-(1-phenylethyl)- (Toluene)	4237-44-9	-	-	-	-	3	-	-	-
Phosphates									
Tri-ethylphosphate	78-40-0	-	-	-	1	-	-	-	-
Siloxanes									
Hexamethylcyclotrisiloxane (D3)	541-05-9	-	< 1	< 1	< 1	-	< 1	-	1
Octamethylcyclotetrasiloxane (D4)	556-67-2	< 1	< 1	1	< 1	-	< 1	< 1	-
Decamethylcyclopentasiloxan (D5)	541-02-6	-	< 1	8	< 1	-	-	-	-
Dodecamethylcyclohexasiloxan (D6)	540-97-6	-	-	9	< 1	-	-	-	-
Tetradecamethylcycloheptasiloxane (D7)	107-50-6	-	-	2	< 1	-	-	-	-
Thiazoler									
Benzothiazole	000095-16-9	-	-	-	-	2	1	-	5
Sum other iso/cyclo-alkanes:	(13475-82-6)	11	< 1	< 1	20	53	21	1	51
Sum other siloxanes:	(000556-67-2)	-	< 1	1	1	-	-	-	3
Sum other hydrocarbons:	(000108-88-3)	-	-	-	1	40	-	-	-
Sum other sesquiterpenes:	(000475-20-7)	-	-	< 1	-	1	< 1	-	1

TABLE 37 Results of VOC and aldehyde measurements for gaming chair products in µg/m³. Concentration corresponds to the reference volume.

		Gaming chair			
Substance	**CAS RN**	**ID 7**	**ID 22**	**ID 27**	**ID 33**
Aldehydes					
Formaldehyde (VVOC)	50-00-0	16	130	9	120
Propanal (VVOC)	123-38-6	2	3	2	2
Butanal (VVOC)	123-72-8	1	-	1	2
n-Hexanal	066-25-1	2	5	2	2
Benzaldehyde	100-52-7	2	2	2	5
n-Nonanal	124-19-6	-	-	-	5
Ketones					
Methyldecaline (Toluene)		2	-	2	-
2-Butanone (MEK)	78-93-3	2	-	2	2
Alcohols					
tert-Butanol	75-65-0	3	-	-	2
n-Butanol	71-36-3	2	-	2	3
Pentanol	71-41-0	-	-	2	-
2-Ethyl-1-hexanol	104-76-7	3	2	3	13
4-Methyldiphenylmethane	620-83-7	-	5	-	-
1-Methoxy-2-propanol	107-98-2	5	-	-	-
1,2-Propanediol	57-55-6	-	-	2	-
Benzyl alcohol	100-51-6	-	-	2	-
Glycols, Ethers, Esters					
Methyl benzoate	93-58-3	-	2	-	-
Carboxylsyreester		2	5	3	-
Safrole (Toluene) CMR	94-59-7	-	12	-	-
Triacetin	102-76-1	-	5	-	10
Butyldiglycol acetate	124-17-4	-	-	-	9
Ether (Toluene)		-	-	5	-
Benzoic acid, 4-ethoxy-, ethyl ester (Toluene)	23676-09-7	9	-	16	-
DPGMME (mix af isomere)	34590-94-8	3	-	-	-
Dimethylglutarat	1119-40-0	-	-	2	-
1,2-Propylene carbonate	108-32-7	6	-	9	16
Amines/Amides					
N,N-Dimethylformamide (DMF)	68-12-2	38	-	98	15
Nitrogen forbindelser (toluen)		-	3	-	3
Nitriles					
2,2'-Azobis(2-methylpropanenitrile) (AIBN)	78-67-1	-	5	-	-
Aliphatic hydrocarbons					

		Gaming chair			
Substance	**CAS RN**	**ID 7**	**ID 22**	**ID 27**	**ID 33**
C7 (Heptane)	142-82-5	2	-	-	2
Cyclohexane	110-82-7	-	3	-	-
C10 (Decane)	124-18-5	2	-	2	-
C12 (Dodecane)	112-40-3	-	5	-	-
C13 (Tridecane)	629-50-5	-	9	17	-
C14 (Tetradecane)	629-59-4	-	3	5	2
C15 (Pentadecane)	629-62-9	2	2	-	2
Aromatic hydrocarbons					
Toluene	108-88-3	10	-	5	2
Ethylbenzene	100-41-4	2	-	-	-
m,p-Xylene (m-Xylene)	1330-20-7	3	-	2	-
Styrene	100-42-5	-	2	3	2
o-Xylene (m-Xylene)	95-47-6	2	2	2	-
Pentamethylbenzene	700-12-9	-	3	-	-
Methylnaphthalene (1-Methylnaphthalene)		-	15	-	-
Dimethylphthalate	131-11-3	3	5	-	-
Dimethylnaphthalene (2,6-Dimethylnaphthalene)	1051-00-0	-	30	-	-
Methylbiphenyl (Toluene)		-	15	-	-
Trimethylnaphthalene (2,3,5-Trimethylnaphthalene)	1052-00-0	-	16	-	-
2,2,5,5-Tetramethylbiphenyl	3075-84-1	-	5	-	-
Terpenes					
α-Pinen	80-56-8	-	-	3	-
3-Carene	498-15-7	-	-	2	-
Limonene	138-86-3	2	2	-	-
α-Terpineol	7785-53-7	5	-	-	-
Longifolene	475-20-7	-	29	-	-
Organic acids					
Acetic Acid	64-19-7	110	81	78	260
Hexanoic acid	142-62-1	-	-	3	-
2-Ethylhexanoic acid	149-57-5	5	5	36	-
Palmitic acid	57-10-3	17	-	-	22
Siloxanes					
Hexamethylcyclotrisiloxan (D3)	541-05-9	9	3	7	5
Octamethylcyclotetrasiloxan (D4)	556-67-2	3	3	3	3
Decamethylcyclopentasiloxan (D5)	541-02-6	2	2	2	-

		Gaming chair			
Substance	**CAS RN**	**ID 7**	**ID 22**	**ID 27**	**ID 33**
Tetradecamethylhexasilox-ane	107-52-8	-	-	-	3
Hexadecamethylheptasilox-ane (Octamethylcyclotetra-siloxane (D4))	541-01-5	-	-	-	5
Phenols					
Phenol	108-95-2	-	-	2	5
BHT-derivat		2	-	-	2
2,6-Di-tert-butyl-4-methylphenol (BHT)	128-37-0	-	-	-	3
4-Nonylphenol (Toluene) #	104-40-5	-	-	7	-
Sum other iso/cyclo-al-kanes:	(13475-82-6)	-	24	240	21
Sum other siloxanes:	(556-67-2)	-	19	-	2
Sum other sesquiterpenes:	(475-20-7)	-	10	-	-
Sum other terpenes:	(80-56-8)	2	37	-	3
Sum other hydrocarbons:	(108-88-3)	-	150	-	-
Sum other C3-benzenes:	(108-67-8)	2	-	-	-

Appendix 6. LOQ for SVOCs

TABLE 38 Limits of quantification (LOQ) for SVOC analyses in field studies (dust and air) and chamber tests (air). PTHAL: Phthalate, PBDE: Polybrominated diphenyl ether, OPFR: Organophosphate flame retardant.

Sub-stance	CAS RN	Abbrev.	Substance	Field LOQ 0.05 g dust (ng/g)	Field LOQ 0.6 m^3 air (ng/m^3)	Chamber LOQ 2.6 m^3 air (ng/m^3)
PHTAL	85-68-7	BBP	2-O-benzyl 1-O-butyl benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	84-74-2	DBP	dibutyl benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	117-81-7	DEHP	bis(2-ethylhexyl) benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	84-66-2	DEP	diethyl benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	84-69-5	DiBP	bis(2-methylpropyl) benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	28553-12-0	DiNP	bis(7-methyloctyl) benzene-1,2-dicarboxylate	800	67	15.4
PHTAL	131-11-3	DMP	dimethyl benzene-1,2-dicarboxylate	800	67	15.4
PBDE	189084-64-8	BDE 100	1,3,5-tribromo-2-(2,4-dibromophenoxy)benzene	10	0.83	0.19
PBDE	189084-66-0	BDE 119	1,3,5-tribromo-2-(3,4-dibromophenoxy)benzene	20	1.7	0.38
PBDE	68631-49-2	BDE 153	1,2,4-tribromo-5-(2,4,5-tribromophenoxy)benzene	100	8.3	1.9
PBDE	207122-15-4	BDE 154	1,2,4-tribromo-5-(2,4,6-tribromophenoxy)benzene	40	3.3	0.77
PBDE	41318-75-6	BDE 28	2,4-dibromo-1-(4-bromophenoxy)benzene	2	0.17	0.04
PBDE	5436-43-1	BDE 47	2,2',4,4'-tetrabromodiphenyl ether	4	0.33	0.08
PBDE	182346-21-0	BDE 85	1,2,3-tribromo-4-(2,4-dibromophenoxy)benzene	40	3.3	0.77
PBDE	60348-60-9	BDE 99	2,2',4,4',5-pentabromodiphenyl ether	10	0.83	0.19
OPFR	118-79-6	2,4,6-TBP	2,4,6-tribromophenol	20	1.7	0.38
OPFR	3278-89-5	ATE	1,3,5-tribromo-2-prop-2-enoxybenzene	200	17	3.8
OPFR	78-38-6	DEEP	diethyl ethyl phosphonate	4	0.33	0.08
OPFR	1241-94-7	EHDPP	2-ethylhexyl diphenyl phosphate	10	0.83	0.19
OPFR	78-51-3	TBEP	tri(2-butoxyethyl) phosphate	50	4.2	0.96
OPFR	126-73-8	TBP	tributyl phosphate	10	0.83	0.19
OPFR	115–96-8	TCEP	tris(2-chloroethyl) phosphate	10	0.83	0.19
OPFR	13674-84-5	TCPP	2-propanol, 1-chloro-, phosphate (3:1)	100	8.3	1.9
OPFR	13674-87-8	TDCPP	2-propanol, 1,3-dichloro-, phosphate (3:1)	20	1.7	0.38
OPFR	78–42-2	TEHP	tri(2-ethylhexyl) phosphate	50	4.2	0.96
OPFR	78–40-0	TEP	triethyl phosphate	5	0.42	0.1
OPFR	513–02-0	TIPP	triisopropyl phosphate	1	0.08	0.02
OPFR	563–04-2	TMCP	tri-m-cresyl phosphate	2	0.17	0.04
OPFR	512–56-1	TMP	trimethyl phosphate	1	0.08	0.02
OPFR	78–30-8	TOCP	tri-o-cresyl phosphate (Tri-o-tolyl phosphate)	3	0.25	0.06
OPFR	115–86-6	TPP	triphenyl phosphate	2	0.17	0.04
OPFR	25653-16-1	TXP	tris(3,5-xylenyl)phosphate	100	8.3	1.9

Appendix 7. Prioritization of substances for further risk assessment

In the screening phase, Tables 13-18 were the starting point with the measurement results of emissions from the various gaming equipment. For the prioritization, it is important to note that all measurements are given as the concentration levels a user will be exposed to in a standard room of 17.4 m^3 with an air change of 0.2 times per hour.

The values can be used directly as exposure values. It was useful in the prioritization to compare this exposure to the hazardous properties of the substances. An important part of the prioritization was to obtain knowledge of the substance's hazard classification as well as to obtain knowledge of tolerable exposure levels, as this allows one to see how close the measured values are to the tolerable exposure levels.

1) As a first step in the prioritization, the measured exposure levels were assessed since substances with very low measured values will be sorted out since the exposure is considered insignificant. In this process, an exposure level of less than 10 $\mu g/m^3$ was considered insignificant for all the volatile substances. This value is considered relevant as a cut-off point as only highly potent toxic substances will achieve a tolerable exposure level below this level. Thus, among the total of 176 EU-LCI values, there were only 13 substances with values in the range 1-10 $\mu g/m^3$, of which ten were specific aldehydes, one was an isothiazole compound, one was a diacrylate compound and one was an aromatic hydrocarbon (naphthalene).

2) In the next step, the hazard classification of the substances was researched, the information was obtained on ECHA's website, as the classification given in the REACH registration of the substances will reproduce partly the EU harmonized classification (i.e. the classification given in Annex VI of Regulation (EC) no. 1272/2008 on classification, labelling and packaging (CLP)) + the classification for other harmful health effects that may not be covered by the harmonized classification, but which the registrant considers as relevant based on the data available on the substance. It was considered too uncertain to consider the notified classification also included on ECHA´s website, as there is no documentation on these, and as they have proven to be misleading in many cases.
   Where classification data is not available, the substance is assessed based on a (Q)SAR printout from the Danish DTU/MST (Q)SAR database (https://qsar.food.dtu.dk/), where the substance is included in the prioritization if there are positive predictions for mutagenicity / carcinogenicity.

3) Next, information on the substances' tolerable exposure levels was obtained, as far as possible, from independent expert assessments, e.g., from the expert groups under the auspices of the EU (e.g., ECHA's Risk Assessment Committee RAC, the EU Commission's scientific expert group SCHEER, or other expert groups that prepare toxicological assessments.

A significant contribution to this was the expert assessments that form the basis for the EU's LCI values for emissions to the indoor climate. LCI, which is short for Lowest Concentration of Interest, is a concentration set to limit the emission of chemical substances from building materials.

LCI values are derived based on similar methods as used under REACH when tolerable exposure levels, DNEL values (Derived No Effect Level), arere derived, and therefore an LCI value will be a good tool for prioritization. A list of the adopted LCI values and the expert assessments behind them can be found at the link: Agreed EU-LCI values : Agreed EU-LCI values (December 2021).

An additional source is the Danish Environmental Protection Agency's previous publications, were toxicological assessments and derivation of tolerable exposure levels have been carried out.

Values from the above sources are considered reliable. If the highest measured exposure level for a chemical substance is below 1/10 of a tolerable exposure level from these sources, then the substance will not be prioritized for further risk assessment.

Finally, DNEL values from the substances' REACH registrations are used, in cases where the above is not available. However, these values stated by the registrant may be associated with potentially large uncertainty regarding the assessment method and the calculation of the values, which must be considered in the prioritization process.

DNEL values derived by the registrant are considered less reliable and if the highest measured exposure level for a chemical substance is a factor of 50-100 below the DNEL value, the substance is not prioritized for further risk assessment.

Thus, it was considered relevant to use an exposure level of less than 10 µg/m^3 as an exclusion criterion in the first step of the prioritization, as this step will already exclude part of the substances measured, so that the subsequent focus is on substances with a higher exposure level.

Tables 13-18 are reproduced below, however, the substances with measured values below 10 µg/m^3 are removed, and for the remaining substances only the highest measured level is included in this first step. In some cases, substances with measured values of 10 µg/m^3 will be retained in the tables, in cases where the chemical structure of the substances is assessed as toxicologically questionable based on experience/prior knowledge of the substances and the reactivity of their chemical structure.

For the substances that are retained in the tables, the hazard classification is given and the tolerable exposure levels as screening values are given in separate columns. An extra column has been added indicating whether the substance is still prioritized for further hazard and risk assessment.

Prioritization from **TABLE 13** Results of VOC and aldehyde measurements for keyboard and mouse in µg/m^3

		Keyboard				Mouse				Further prioritization
Substance	**CAS RN**	**ID 3**	**ID 19**	**ID 23**	**ID 29**	**ID 4**	**ID 20**	**ID 24**	**ID 30**	
		None of the measured chemical concentrations exceeded 10 µg/m^3								No substances here are included in the further prioritization

Prioritization from **TABLE 14** Results of VOC and aldehyde measurements for headset and mouse mat in µg/m³

Substance	CAS RN	Highest measurements for headsets and mouse mats	Classification	Tolerable exposure level in µg/m³ (Effect) Reference	Further prioritization
Decamethylcyclopenta-siloxane (D5)	541-02-6	8	Not classified	4300 (tumors in the uterus, lung and liver effects) MST 2021	No
Dodecamethylcyclohexa-siloxane (D6)	540-97-6	9	Not classified	130 (lung and liver damage) MST 2021	No
Sum of other iso/cyclo-alkanes:	(13475-82-6)	53	Asp. Tox 1 STOT RE1 H372 Classification for white spirit	5700 (white spirit neurotoxicity) MST 2016	No
Sum of other hydrocarbons:	(108-88-3)	40			

Prioritization from **TABLE 15** Results of VOC and aldehyde measurements for gaming chairs in µg/m³

Substance	CAS RN	Highest measurements for gaming chairs	Classification	Tolerable exposure level in µg/m³ (Effect) Reference	Further prioritization
Aldehydes					
Formaldehyde (VVOC) *	50-00-0	130	Acute Tox.3 H301; H311, H331 Skin Corr. 1B H314 Eye Damage 1 H318 Skin Sens 1 H317 Muta 2 H341 Carc 1B H350	100 (eye and airway irritation) EU-LCI 2016b WHO 2010	Yes*
Alcohols					
2-Ethyl-1-hexanol	104-76-7	13	Acute Tox. 4 H332 Skin Irrit. 2 H315: Eye Irrit. 2 H319	300 (airway irritation) EU-LCI 2014b Note: can be converted to 2-ethylhexanoic acid in the organism	(Yes)
Safrole	94-59-7	12	Acute Tox. 4 H302 Muta. 2 H341 Carc. 1B H350	No REACH registration	Yes Genotoxic carcinogen
Triacetin (glycerol triacetate)	102-76-1	10	Not classified	No DNEL value due to the chemical's low toxicity	No
Benzoic acid, 4-ethoxy-, ethyl ester	23676-09-7	16	Not classified	No REACH registration	No (QSAR)
1,2-Propylene carbonate	108-32-7	16	Eye Irrit. 2 H319	1800 (eye irritation)	No

				EU-LCI 2021	
Amines/Amides					
N,N-Dimethylformamide (DMF)	68-12-2	98	Acute Tox. 4, H312 Eye Irrit. 2, H319 Acute Tox. 4, H332 Repr. 1B H360d	700 (eye and airway irriation) 170 (liver toxicity) SCHEER 2021	Yes*
Nitriles					
2,2'-Azobis(2-methylpropanenitrile) (AIBN)	78-67-1	5	Acute Tox. 4 H302, H332	70 DNEL (REACH-reg.)	Yes**
Aliphatic hydrocarbons					
Sum C12; C13; C14 alkanes		22	Asp. Tox 1 STOT RE1 H372 Classification for white spirit	5700 (Neurotoxic) value for white spirit MST 2016	No
Aromatic hydrocarbons					
Toluene	108-88-3	10	Skin Irrit. 2 H315 Skin Irrit. 2 H315 Asp. Tox 1 H304 STOT SE 3 H336 STOT RE2 H373 Repr. 2 H316d	2900 MST 2016	No
Methylbiphenyl		15	Not classified	No REACH registration	No QSAR
Methylnaphthalene		15	Acute Tox. 4 H302 Carc. 2 H351 Classification for naphthalene	10 (inflammation of the airway) value for napthalene EU-LCI 2015	Yes*
Dimethylnaphthalene	1051-00-0	30			
Trimethylnaphthalene	1052-00-0	16			
Sum alkylnaphthalenes		66			
Terpener					
Longifolene	475-20-7	29	Skin Irrit. 2 H315: Skin Sens. 1B H317:	No DNEL 1400 value for "other terpenes" (no effect specified) EU-LCI 2013e	No
Organic acids					
Acetic acid	64-19-7	260	Skin Corr. 1A H314	1200 (airway irritation) EU-LCI 2016	Yes*
2-Ethylhexanoic acid	149-57-5	36	Repr. 2 H361 Future harmonized classification: Repr. 1B H360D (ECHA-RAC 2020a)	150 (birth defects) EU LCI 2014	Yes*
Palmitic acid	57-10-3	22	Not classified	4348 DNEL (REACH-reg.)	No
Siloxanes					

Hexamethylcyclotrisiloxane (D3)	541-05-9	9	Not classified	320 (liver effects) MST 2021	No
Sum of other iso/cyclo-alkanes:	(13475-82-6)	240	Asp. Tox 1 STOT RE1 H372 Classification for mineral terpentine	5700 (neurotoxic) Value for mineral terpentine MST 2016	No
Sum of other siloxanes:	Ingen specifik ID	19	-		No
Sum of other sesquiterpenes:		10		1400, value for "other terpenes" (no effect specified) EU-LCI 2013e	No
Sum of other terpenes:		37	-	1400 value for "other terpenes" (no effect specified) EU-LCI 2013e	No
Sum of other hydrocarbons:		150	Asp. Tox 1 STOT RE1 H372	5700 (neurotoxic) MST 2016	No

Yes*: the measured exposure value is more than 1/10 of the tolerable exposure value based on expert judgment

Yes**: the measured exposure value is more than 1/50-100 of the tolerable exposure value based on DNEL value from REACH registration

Prioritization from **TABLE 16** Results of VOC and aldehyde measurements for gaming setups 1 and 2 in µg/m³

		Highest measured values for the gaming set-ups 1+2		Classification	Tolerable exposure level in µg/m³ (Effect) Reference	Further prioritization
Substances	**CAS RN**	**1 d**	**3 d**			
Aldehydes						
Formaldehyde (VVOC)*	50-00-0	34	35	Acute Tox 3 H301; H311, H331 Skin Corr. 1B H314 Eye Damage 1 H318 Skin Sens 1 H317 Muta 2 H341 Carc 1B H350	100 (eye and airway irritation) EU-LCI 2016b WHO 2010	Yes*
Ketones						
Cyclohexanone	108-94-1	10	7	Acute Tox.4 H332	716 (liver toxicity) SCHEER 2021	No
Alkohols						
2-Ethyl-1-hexanol	104-76-7	10	9	Acute Tox. 4 H332 Skin Irrit. 2 H315 Eye Irrit. 2 H319	300 (airway irritation) EU-LCI 2014b Note: Can be converted to 2-ethylhexanoic acid in the organism	(Yes)
Glycols, Ethers, Esters						
Ethylhexyl acrylate	103-11-7	10	9	Skin Irrit. 2 H315 Skin Sens.1 H317 STOT SE 3 H335	380 effect not stated EU-LCI 2013a	No
Isobornyl acrylate	5888-33-5	10	7	Skin Irrit. 2 H315 Eye Irrit. 2 H319 Skin Sens.1 H317 STOT SE 3 H335	110 value for "other acrylic acid esters", (effect not stated) EU-LCI 2013b	No
Diethylene glycol dibutyl ether	112-73-2	10	6	Not classified	70 000 DNEL value in REACH reg. for workers	No
Aliphatic hydrocarbons						
C14 (Tetradecane)	629-59-4	10	10	Not classified	6000 for the sum of C9-C16 saturated hydrocarbons (effect not stated) EU-LCI 2013d (OECD 2011 indicates lung toxicity related to inhalation of aerosols)	No
C15 (Pentadecane)	629-62-9	11	10			
C16 (Hexadecane)	544-76-3	11	12			
Amides						

		Highest measured values for the gaming set-ups 1+2		Classification	Tolerable exposure level in µg/m³ (Effect) Reference	Further prioritization
N,N-Dimethylformamide (DMF)	68-12-2	46	44	Acute Tox.4, H312 Eye Irrit. 2, H319 Acute Tox.4, H332 Repr. 1B H360d	700 (eye and airway irritation) 170 (liver toxicity) SCHEER 2021	Yes*
Organic acids						
Acetic acid	64-19-7	210	160	Skin Corr. 1A H314	1200 (airway irritation) EU-LCI 2016a	Yes*
Palmitic acid	57-10-3	8	11	Ikke klassificeret	4348 DNEL, REACH-reg.	No
2-Ethylhexanoic acid	149-57-5	20	22	Repr. 2 H361 Future harmonized classification: Repr. 1B H360D (ECHA-RAC 2020a)	150 (birth defects) EU LCI 2014a	Yes*
Siloxanes						
Dodecamethylcyclohexasiloxane (D6)	540-97-6	13	8	Not classified	130 (lung/ liver damage) MST 2021	Yes*
Sum of other iso/cyclo-alkanes:	(13475-82-6)	670	580	Asp. Tox 1 STOT RE1 H372 Classification for white spirit	5700 (neurotoxic) Value for white spirit MST 2016	No
Sum of other siloxanes	No specific chemical id	11	11			No
Sum of VOCs (TVOC)		980	810			

Yes*: the measured exposure value is more than 1/10 of the tolerable exposure value based on expert judgment

Prioritization from **TABLE 17** Results of VOC and aldehyde measurements for PC and monitors 1 and 2 in µg/m³

		Highest measured values for the PC + monitor sets		**Classification**	**Tolerable exposure level in µg/m³ (Effect) Reference**	**Further prioritization**
Substances	**CAS RN**	**1 d**	**3 d**			
Ethylhexyl acrylat	103-11-7	16	11	Skin Irrit. 2 H315 Skin Sens 1 H317 STOT SE 3 H335	380 (effect not stated) EU-LCI 2013a	No
Isobornyl acrylat	5888-33-5	11	< 5	Skin Irrit. 2 H315 Skin Sens 1 H317 Eye Irrit 2 H319 STOT SE 3 H335	110 value for "other acrylic acid esters", (effect not stated) EU-LCI 2013b	No
Diethylene glycol dibutyl ether	112-73-2	10	< 5	Not classified	70 000 DNEL-value for workers	No
Aliphatic hydrocarbons						
C14 (Tetradecane)	629-59-4	9	< 5		6000 EU-LCI 2013d for the sum of the substances (effects not listed)	No
C15 (Pentadecane)	629-62-9	34	9			
C16 (Hexadecane)	544-76-3	40	8			
C17 (Heptadecane)	629-78-7	17	< 5			
C18 (Octadecane)	593-45-3	5	< 5			
Sum af andre iso/cyclo-alkanes:	(13475-82-6)	140	51	Asp. Tox 1 H304 STOT RE1 H372	5700 (neurotoxicity) MST 2016	No
Aromatic hydrocarbons						
Toluene	108-88-3	12	7	Skin Irrit. 2 H315 Skin Irrit. 2 H315 Asp. Tox 1 H304 STOT SE 3 H336 STOT RE2 H373 Repr. 2 H316d	2900 (neurotoxicity) EU-LCI 2013c	No
m,p-Xylene	1330-20-7	11	6	Acute Tox. 4 H312, H332 Skin Irrit. 2 H315	500 (neurotoxicity) EU-LCI 2013d 130 (neurotoxicity) SCHEER 2021	No
Organic acids						
Acetic acid	64-19-7	37	41	Skin Corr. 1A H314	1200 (airway irritation) EU-LCI 2016	No
Palmitic acid	57-10-3	5	10	Not classified	4348 DNEL, REACH-reg.	No
Siloxanes						
Dodecamethylcyclohexasiloxane (D6)	540-97-6	15	8	Not classified	130 (lung and liver effects) MST 2021	Yes*
Tetradecamethylcycloheptasiloxane (D7)	107-50-6	22	10	Not classified	No REACH registration	No

		Highest measured values for the PC + monitor sets		Classification	Tolerable exposure level in µg/m³ (Effect) Reference	Further prioritization
Sum of other siloxanes	No specific chemical id	43	11	-	-	No
Sum of VOCs (TVOC)		420	120	-	-	No
Sum of VOCs (TVOC)		980	810	-	-	No

Yes*: the measured exposure value is more than 1/10 of the tolerable exposure value based on expert judgment

Based on the above, the following volatile substances were selected for further hazard and risk assessment:

formaldehyde
acetic acid
2-ethylhexanoic acid
2-ethyl-1-hexanol
N,N-dimethylformamide (DMF)
methylnaphthalene
dimethylnaphthalene
triethylnaphthalene
dodecamethylcyclohexasiloxane (D6)
2,2'-Azobis(2-methylpropanenitrile)
safrole

When prioritizing the semi-volatile substances, a more cautious strategy was used, as even relatively low levels in the air not necessarily reflect the total exposure to the substances. Semi-volatile substances will tend to quickly stick to surfaces and dust so that vapours in the air only make up a small part of the total SVOC quantity in the room. In addition to inhaling vapours, a person's exposure will come from contact with surfaces and e.g., contact with clothing and textiles, e.g., bedding which is present in the room (This aspect is described in detail in a re-view on exposure to SVOCs by Eichler et al. 2021). For SVOCs, exposure levels higher than 1/100 of the tolerable exposure level therefore proceed to hazard and risk assessment.

Prioritization from **TABLE 18.** Results of the SVOC analysis in ng/m³ for air samples taken from chamber tests

		Highest measured values for the gaming setups		Classification	Tolerable Exposure Level (Effect) Reference	Further prioritization
Substance	**CAS RN.**	**1 d**	**3 d**			
Dibutylphthalate DBP	84-74-2	157	589	Repr. 1B H360Df	6700 ng/kg/day or 23450 ng/m³ (hormone disrupting effects) RAC 2018	Yes***
Diethylphthalate DEP	84-66-2	27	76	Not classified	2600 000 DNEL	No
Diisobutylphthalate DiBP	84-69-5	59	202	Repr. 1B H360Df	8300 ng/kg/day or 29050 ng/m³ (hormone disrupting effects) RAC 2018	Yes***
Dimethylphthalate DMP	131-11-3	1209	5434	Not classified	16300 000 DNEL	No
2.4.6-tribromophenol 2.4.6-TBP	118-79-6	37	37	Acute Tox. 4 H302 Eye Irrit. 2 H319	580 000 (liver and kidney damage) DNEL	No

				Skin Sens. 1 H317		
Tributhylphosphate TBP	126-73-8	68	78	Acute Tox. 4 H302 Skin Irrit. 2 H315 Carc. 2 H351	300 000 (bladder damage) EU-LCI 2016a	No
Tri(1-chloro-2-propyl)phosphate TCPP	13674-84-5	27	32	Acute Tox. 4 H302	840 000 ng/kg/day or 2940 000 ng/m^3 (thyroid gland damage) EU-RAR 2008	No
Triethylphosphate TEP	78–40-0	392	326	Acute Tox. 4 H302 Eye Irrit. 2 H319	1700 000 (liver toxicity) EU-LCI 2021b	No

Yes***: the measured exposure value is more than 1/100 of the tolerable exposure value

Based on the above, the following semi-volatile substances are selected for further hazard and risk assessment:

dibutyl phthalate
diisobutyl phthalate

Condensed hazard assessment of the priority substances

For the priority substances, a brief description is provided below with respect to the substances' harmful effects on health and the derivation of the substances' tolerable exposure levels. The tolerable exposure values (DNEL) were calculated according to the guidelines specified in REACH guidance R8 (ECHA 2012).

Formaldehyde

Sources: WHO (2010). EU-LCI (2016b). ECHA-RAC (2020b)

Formaldehyde is a corrosive, skin sensitizing, carcinogenic and mutagenic substance.

The EU-LCI value for formaldehyde of 100 µg/m^3 is based on WHO (2010), which in their assessment derives an air quality criterion for indoor air of 100 µg/m^3.

In humans, formaldehyde can cause cancer of the upper respiratory tract at exposure levels down to about 1.25 mg/m^3 as an average exposure and with peak concentrations around 5 mg/m^3. Higher levels may cause leukemia. In mouse and rat experiments, cancer of the upper respiratory tract is seen as the most sensitive form of cancer. The carcinogenic effect, which is considered to be a consequence of the substance's irritating and mutagenic properties, is considered to have a lower threshold value and occurs in rats at chronic exposure levels of 7.5 mg/m^3 and above. Irritating changes to the nasal mucosa are seen at lower levels down to a NOAEL of 1.25 mg/m^3.

WHO (2010) assessed that exposure levels below 2.5 mg/m^3 in humans only have marginal significance for the formaldehyde level in the blood, which is formed naturally by the organism's normal metabolism. It is also estimated that protection against the irritative effects that can occur at lower exposure levels will also protect against the carcinogenic effect.

Based on several human studies, it has been shown that eye and respiratory tract irritation can occur down to levels of 0.63 mg/m3 and 0.38 mg/m^3 respectively. A NOAEL of 0.6 mg/m^3 for effects on the eyeblink reflex was assessed as the best objective basis for calculating a limit value and, using a factor of 5 to account for uncertainties in the respiratory irritation threshold, a tolerable exposure level of 0.12 mg/m^3, which was then rounded to 100 µg/m^3 by WHO (2010)

Since the value is for acute irritation, WHO (2010) states that the value applies to a value measured as an average over ½ hour, which limits the durations for exceedance of the value.

ECHA-RAC (2020) re-evaluated the data and, in connection with a proposal to restrict the use of formaldehyde and formaldehyde releasers in articles, assessed that the value of 100 µg/m^3 did not provide sufficient protection for consumers.

For acute irritant effects, the RAC used a NOAEC of 0.6 mg/m^3 in volunteer subjects and, using a factor of 10 to account for differences in sensitivity in the population, a DNEL value of 0.06 mg/m^3 was obtained.

For chronic exposure, the RAC established a long-term DNEL of 0.05 mg/m^3 based on a 26-week inhalation study with monkeys exposed 22 hours/day, 7 days a week, and where a LOAEC level of 1.25 mg/m^3 could be established for effects on the tissue in the nasal mucosa. By applying a factor of 2.5 to convert from monkeys to humans and a factor of 3.16 to account for particularly sensitive individuals among humans, and a factor of 3 to extrapolate to a no-effect level, the RAC obtained a DNEL value of 0.05 mg/m^3.

Comment and determination of DNEL value according to ECHA/RAC (2012):

In this project, the further risk assessment will be based on RAC's latest assessment, where the DNEL value is calculated in accordance with the principles from the ECHA guidance ECHA (2012).
For this project, a DNEL of 0.05 mg/m^3 for long-term exposure was considered the most relevant to use in the risk assessment, as the measurement results more reflect an average 24-hour value than short-term peak loads, where a DNEL value of 0.06 mg/m^3 for acute irritation effects would be more relevant.

Acetic Acid

Sources: EU-LCI (2016a).

Acetic acid in concentrated form is classified as a corrosive substance that has been assigned an LCI value of 1200 µg/m^3 because of eye and respiratory irritant properties in vapor form. In connection with the preparation of the LCI value, acute irritation of the eyes and respiratory tract was considered the most critical effect of the substance.

The starting point for the calculated value was two trials with volunteer subjects exposed to 0; 5 and 10 ppm acetic acid vapours (10 ppm corresponding to 24.7 mg/m^3) for a duration of two and four hours respectively. In these experiments, the subjects observed slight signs of irritation at 10 ppm.

With a LOAEL of 24.7 mg/m^3 as a starting point, an LCI value of 1.235 mg/m^3 was calculated, using an uncertainty factor of 2 to extrapolate from very slight effects to a no-effect level, as well as an uncertainty factor of 10 to protect particularly sensitive individuals in the population. For practical reasons, this value was then rounded up to 1200 µg/m^3.

Comment and determination of DNEL value according to ECHA (2012):

The calculation of the assessment is consistent with the principles for calculating DNEL values in the REACH guidance for DNEL calculation, the value of 1200 µg/m^3 will be used in this project.

2-Ethylhexanoic acid

Sources: EU-LCI (2014a); ECHA-RAC (2020a)

2-Ethylhexanoic acid and its salts have recently been assessed by ECHA's Risk Assessment Committee, where it was decided that the substance should be classified as toxic for reproduction in category 1B because of fetal damage to the skeleton, heart and brain observed in rat experiments (ECHA-RAC 2021).

The LCI value, which was set at 150 µg/m^3, was similarly set on the basis of a rat experiments where 100 mg/kg bw/day was considered a NOAEL in a developmental toxicity study where the pregnant female rats were exposed to 0, 100, 250 and 500 mg/kg bw/day orally on days 6-15. day during the gestation period.
For the oral dose of 100 mg/kg bw/day, an uncertainty factor of 10 was then used to extrapolate from rats to humans and an uncertainty factor of 10 to account for particularly sensitive groups in the population. In addition, an uncertainty factor of 6 was used to extrapolate from subacute exposure to chronic exposure, as well as an uncertainty factor of 2 due to the severity of the effects and an uncertainty factor of 2 due to a lack of inhalation data. Finally, an additional factor of 3.5 was used to convert from oral dose to inhalation concentration (70 kg/20m^3/day) as an adult person of 70 kg inhales approx. 20 m^3 of air per day, i.e., 100 mg/kg bw/day x 70 kg/20 m^3.

LCI = 100 mg/kg bw/dag x 3,5 / (10 x 10 x 6 x 2 x 2) = 0,146 mg/m^3 (rounded to 150 µg/m^3).

Comment and determination of DNEL value according to ECHA (2012):

The calculation above is considered to deviate at certain points from the REACH guidance for the DNEL calculation, as according to this guidance the following DNEL value can be calculated:

DNEL = LCI = 100 mg/kg bw/day x 3.5 / (10 x 10 x 2 x2) = 0.88 mg/m^3 or 880 µg/m^3

This calculation does not use an uncertainty factor of 6 to extrapolate from sub-acute to chronic exposure, as the developmental toxicity is in relation to exposure only during a short-term period during the development of the fetus. Furthermore, in the REACH registration of the substance, a NOAEL of 200 mg/kg bw/day is achieved in a 90-day experiment with rats, which indicates that the fetuses are more sensitive than the adult animals.
Finally, a factor of 2 is retained for the severity of the effects and a factor of 2 for uncertainty regarding the degree of absorption by inhalation and conversion from oral dose.

The DNEL in connection with this report is set at 880 µg/m^3.

2-Ethyl-1-hexanol

Sources: EU-LCI (2014b)

EU-LCI (2014) indicates acute irritation effects as the most critical effect of 2-Ethyl-1-hexanol. An LCI value of 300 µg/m^3 was calculated from an experiment where volunteers were exposed to 2-Ethyl-1-hexanol vapours in concentrations of 1.5, 5 and 10 ppm for four hours. For eye and respiratory tract irritation, a clear dose-response was seen with a NOAEL of 1.5 ppm corresponding to 8 mg/m^3.

The LCI of 300 µg/m^3 was then calculated using a factor of 6 to extrapolate to long-term exposure and a factor of 5 to extrapolate from volunteer subjects to the general population.

Comment and determination of DNEL value according to ECHA (2012):

As the substance's critical effect is assessed to be an acute irritation response, it is not assessed to be relevant to use a factor 6 for extrapolation to chronic exposure. This corresponds to the approach indicated for acetic acid where the critical effect was also acute irritation.

On the other hand, an uncertainty factor of 10 should be used to protect particularly sensitive groups in the population and not a factor of 5 as stated above.

The DNEL in connection with this report is therefore set at 8 mg/m^3 / 10 = 0.8 mg/m^3 or 800 µg/m^3.

It should be noted that 2-Ethyl-1-hexanol can be converted in the body to 2-ethylhexanoic acid, that may cause developmental toxicity. However, the DNEL of 800 µg/m^3 for irritation will also protect against possible harmful effect to the fetus as the DNEL value for 2-Ethylhexanoic acid is 880 µg/m^3.

N,N-Dimethylformamide (DMF)

Source: SCHEER (2021)

Although the substance is classified as reproductive toxic (harmful to the fetus) and is therefore on the REACH candidate list as a SVHC substances, the most critical effects at low exposure levels to the substance are considered to be eye and respiratory irritation and liver damage, as these effects occur at lower exposure levels than fetal effects.

Based on a LOAEC of 22 mg/m^3 for eye and respiratory irritation from an occupational study, SCHEER (2021) calculated a DNEL value for these effects of 0.7 mg/m^3, using an uncertainty factor of 3 to extrapolate to a no-effect level and an additional factor of 10 to take account of particularly sensitive individuals in the population.

In the same study, a LOAEC of 22 mg/m^3 could also be determined for liver effects, and SCHEER (2021) calculated from this a DNEL of 0.17 mg/m^3. In addition to the uncertainty factors as indicated above, corrections were made for continuous exposure over 24 hours by multiplying by the factors 8h/24h and 5d/7d, since the workers were only exposed 8 hours a day, 5 days a week.

(This conversion to an average 24 hour level was not used to protect against irritation, as the effects here are in relation to the actual concentration in the air and not in relation to the inhaled amount of the substance, which is considered to be important for the liver effects.)

Comment and determination of DNEL value according to ECHA (2012):

The derivation of the DNEL value of 0.17 mg/m^3 is in accordance with ECHA's guidelines and the value is subsequently used in the risk assessment in the project.

Methylnaphthalene, dimethylnaphthalene, triethylnaphthalene

Source: EU-LCI (2015); WHO (2010); Kim et al. (2020), Lin et al. (2009)

A PubMed search only found toxicologically relevant data for methylnaphthalene, while no data could be found for dimethylnaphthalene and trimethylnaphthalene. There are, however, several expert assessments for naphthalene, with the EU-LCI (2015) assessment being the most up to date. From a 90-day rat inhalation study (a 2012 study not included in WHO (2010)), a NOAEC of 0.1 ppm was found, as effects on the respiratory tract mucosa observed at higher levels. From this NOAEC, an LCI value of 10 µg/m^3 was calculated. This is the same value that WHO (2010) arrived at from another, older rat study.

In a publication by Lin et al (2009), the toxicity of naphthalene is compared with methylnaphthalene. Based on oral cancer tests with 1-methylnaphthalene and 2-methylnaphthalene, it is concluded that these do not possess the same carcinogenic properties as seen for naphthalene in similar studies. However, inhalation studies show comparable effects as for naphthalene, as the changes in the mucous membranes of the respiratory tract wasalso seen for methylnaphthalene.

Rather than relying on data for naphthalene, the specific DNEL calculation for methylnaphthalene can be made based on a recent 90-day inhalation experiment in which rats were exposed to 0, 0.5, 4 and 30 ppm 1-methylnaphthalene in the air 6h/day, 5 days/week (Kim et al 2020). Here, effects (hyperplasia) were found on the mucous membrane in the upper respiratory tract of the animals. The effects were termed "minimal" effects at the lowest exposure level and gradually increased over "slight" to "moderate" effects at the highest dose level. Since the effects at the two lowest dose levels were judged to be "minimal" or "slight", the authors concluded 4 ppm (equivalent to 23 mg/m^3) to be a NOAEC level.

Comment and determination of DNEL value cf. ECHA (2012):

When calculating a DNEL value, it is considered more cautious to use a NOAEC of 0.5 ppm (corresponding to 2.9 mg/m^3), as 15 out of 20 animals at 4 ppm had developed hyperplasia in lighter degree. Based on a NOAEC of 2.9 mg/m^3, the DNEL value is calculated:

DNEL = 2.9 mg/m^3*/ 2.5 x 10 x 2 = 0.058 mg/m^3 or 58 µg/m^3

*As irritative effects are considered to be a concentration-related effect, conversion to a 24-hour average level is not carried out before the DNEL calculation.

A factor of 2.5 is then applied to extrapolate from rats to humans (starting value for local irritation effects), a factor of 10 to protect particularly sensitive in the population and a factor of 2 to extrapolate from sub-chronic to chronic exposure.

Dodecamethylcyclohexasiloxane (D6)

Source: MST (2021)

In the assessment of the substance carried out in MST (2021), data from the REACH registration of the substance has been used. The REACH registration has since been updated, but not with data that influence the previous assessment.

MST (2021) found a 90-day inhalation test with rats to be the most suitable data for deriving an inhalation DNEL value. In this experiment, rats were exposed to 18.2, 182 and 546 mg/m3 D6 for 6 hours per day, 5 days per week for 13 weeks (90 days). The NOAEC was set at 18.2 mg/m^3, due to adverse effects on the nasal mucosa and milder effects on the lungs and liver at the higher exposure levels.

Comment and determination of DNEL value according ECHA (2012):

In connection with inhalation and local harmful effects in the lungs, the starting point is a NO-AEC of 18.2 mg/m^3 for an exposure of 6 hours a day for 5 days. This value can be converted to 24 hours of continuous exposure, as the systemic effects (liver effects) must be considered to be a consequence of the total daily exposure rather than the actual concentration of the substance:

NOAEC (continuous) = 18,2 mg/m^3 x (6 h/24 h)* x 5 day/7 day = 3,3 mg/m^3

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

DNEL = 3,3 mg/m^3 / 2,5 x 10 x 2* = 0,07 mg/m^3 or 70 $µg/m^3$

As an uncertainty factor of 2.5 is used to extrapolate from rats to humans in terms of inhalation exposure and an additional factor of 10 to account for differences in human sensitivity and an uncertainty factor of 2 to extrapolate from subchronic exposure to chronic exposure.

*In MST (2021) the tolerable exposure level is calculated for the substance in cosmetics. In safety assessment of cosmetics, a factor of 2 is not used when the NOAEL is from a a 90-study.

2,2'-Azobis(2-methylpropanenitrile), CAS 78-67-1

A literature search of (PubMed, PubChem, Google, ECHA-database) found very little validated and relvant data on the substance.

A toxicological data sheet for the substance stated that the substance is used as a catalyst in the formation of polyvinyl polymers and in connection with the production of resin, plastic, and fumigants. The substance is very reactive, and inhalation of the substance causes irritation of the respiratory tract. Furthermore, it is stated that the substance can damage the liver and kidneys (HSFS 1998).

Azo and nitrile compounds are very reactive, and a number of these compounds have been included on the Danish Working Environment Authority's list of limit values (BEK nr 1054 from 28/06/2022), often with very low values of around 1 mg/m^3 in the working environment, which indicates that these substances can be potent harmful substances.

Since no information has been found on specific exposure levels and harmful effects of tue-substance, no further hazard and risk assessment can be carried out for the substance.

Safrole

Sources: EFSA (2002); Cal EPA (1992)

Several expert assessments of safrole have been found, with the most recent and most comprehensive assessment carried out by EFSA (2002).

As a natural flavouring substance, safrole occurs in spices such as nutmeg, cinnamon, pepper and basil and is indicated to occur in foods in general at an average level of approx. 0.5 mg/kg (a level of 2 mg/kg is indicated for products with cinnamon and 20 mg/kg for canned fish (EFSA (2002)). Since safrole is a flavouring substance in food, the toxicological studies were primarily carried out with oral (in some cases subcutaneous) dosing, and therefore no inhalation data have been found with the substance.

The harmonized EU classification according to CLP (Reg. No. 1272/2008) states that the substance is carcinogenic and mutagenic and EFSA (2002) considers safrole as a carcinogen without any lower threshold value due to its direct mutagenic properties.

In connection with a number of different oral cancer tests in mice, an increased incidence of liver cancer has been found at dose levels from 150 – 300 mg/kg bw/day and higher. In rats dosed with safrole in the feed at a content between 0.01% and 0.5% safrole, liver effects have been seen at the lowest dosage and significantly increased incidence of liver cancer at higher dosage levels.

Neither EFSA (2002) nor other expert assessments consider that a tolerable and safe exposure level can be set for safrole as a result of its carcinogenic and mutagenic properties. EFSA (2002) does not provide any calculations regarding cancer risk for consumers, but states that the carcinogenic potency of safrole is considered relatively low, i.e., the substance is considered a weak carcinogen. At the same time, it is stated that the population in the EU is on average exposed to a daily dose of approx. 0.3 mg safrole from daily intake of food and spices.

Based on analysis of the many cancer trials, the California Environmental Agency has calculated that a lifetime average dose of 3 µg/day leads to an increased lifetime cancer risk of 10^{-5} (corresponding to an extra case of cancer among 100,000 people exposed to 3 µg safrole/day throughout life) (Cal EPA 1992).

The American Carcinogenic Potency Database (CPDB), which is continuously updated, collects data from cancer trials and from the data a TD50 exposure value is estimated corresponding to the dose of a substance that in animal experiments will cause tumours in half of the experimental animals with daily, lifelong dosing of the animals. When determining the TD50 value, the starting point is the type of tumours that occur at the lowest dose is converted to a lifetime dose if the experiment has been of shorter duration. In the case of several tests in the same animal species, the average of the TD50 value is calculated. For safrole, a TD50 value for rats of 441 mg/kg bw/day is given, while for mice a TD50 value of 51.3 mg/kg bw/day is given. In both cases, the values are calculated based on the occurrence of living tumors. It is stated that the value for rats is calculated based on several experiments, while the value calculated for mice is based on only one experiment and a greater uncertainty is indicated for this experiment.

Comment and determination of DNEL value according to ECHA (2012):

It is not possible to assess whether the method used by the Californian authorities corresponds to the method specified by ECHA (2012) for calculating DMEL values. But the California risk level of 10^{-5} at a daily lifetime exposure of 3 µg/day would mean that the population in the EU with an average exposure of 0.3 mg/day is exposed to a 10^{-3} risk of developing liver cancer as a result of this exposure – which seems unrealistically high for a weak carcinogen.

In Denmark, the Danish Environmental Protection Agency often uses a 10^{-6} lifetime risk as a tolerable risk level for exposure to genotoxic carcinogens. This would then correspond to a daily exposure of 0.3 µg/day if the Californian value is taken as a starting point.

The TD50 value of 441 mg/kg bw/day from the CPDB is considered more reliable for calculating risk levels for safrole.
According to ECHA (2012), the value can be converted to an inhalation dose for the rat, as a rat inhale 1.15 m^3 of air/kg bw/day. Thus, an oral exposure of 441 mg/kg bw/day bw. a concentration in the air of 441 mg/kg bw/day /1.15 m^3/day = 383 mg/m^3.

Since TD50 expresses a lifetime risk of 0.5, the following concentration can be calculated by linear extrapolation down to 10^{-6} lifetime risk:

Concentration corresponding to 10^{-6} lifetime risk = 383 mg/m^3 / 0.5 x 10^{-6} = 0.0008 mg/m^3 or 0.8 µg/m^3

This value of 0.8 µg/m^3 as a dose corresponding to 10^{-6} lifetime risk is subsequently used for risk assessment in this report.

Dibutylphthalate and diisobutylphthalate

Source: ECHA-RAC (2017)

Dibutyl phthalate (DBP) and Diisobutyl phthalate (DiBP), which are reproductive and endocrine-disrupting substances, have been assessed by ECHA's Risk Assessment Committee. In a study with rats where the dams were exposed to DBP from day 15 during the gestation period and during the subsequent lactation period, an effect on the offspring was found in the form of an effect on the development of the mammary glands in the female rats and an effect on the testes in the male rats with a LOAEL of 2 mg/kg bw/day.

From this, a DNEL value of 0.0067 mg/kg bw/day was then calculated, using an uncertainty factor of 3 to extrapolate to a no-effect level and a factor of 10 to extrapolate from rats to humans and finally a factor of 10 for to consider special sensitivities in the population.
As corresponding data were not available for DiBP but other data pointed to comparable effects as for DBP, a DNEL value of 0.0083 mg/kg bw/day was set for this substance, see FIGURE 23.

	NOAEL (mg/ kg bw/day)	**LOAEL (mg/ kg bw/day)**	**Endpoint and study reference**	**AFs #**	**Correction for absorption §**	**DNEL internal dose (mg/ kg bw/day)**
DBP	-	2	Reduced spermatocyte development at postnatal day 21, and mammary gland changes (vacuolar degeneration and alveolar atrophy) in adult male offspring in Lee et al. (2004)	4*2.5*10*3 = 300	1	0.0067
DIBP	-	2.5	Read-across from DBP	4*2.5*10*3 = 300	1	0.0083

FIGURE 23. Description for NOAEL/LOAEL for DBP and DIBP from ECHA-RAC (2017)

Comment and determination of DNEL value according to ECHA (2012):

The stated DNEL values can be directly converted to an inhalation concentration assuming that an adult person (70 kg bw) inhales 20 m^3 of air per day. ECHA-RAC (2017) considers that absorption from oral exposure is 100% and that the same applies to inhalation, which is why no correction for different absorption between the two routes of exposure is to be made. That is:

DNEL-inhalation (DBP) = 0.0067 mg/kg bw/day x 70 kg bw/ 20 m^3
DNEL-inhalation (DBP) = 0.023 mg/m^3 or 23 µg/m^3

DNEL-inhalation (DiBP) = 0.0083 mg/kg bw/day x 70 kg bw/ 20 m^3
DNEL-inhalation (DiBP) = 0.029 mg/m^3 ot 29 µg/m^3

Summary

For the following substances toxicological assessments have been made and tolerable exposure levels have been derived for further use in risk assessment in this project, see TABLE 39.

TABLE 39. Conclusion of prioritization of substances for risk assessment

Substance	CAS RN	Tolerable exposure level and critical effect
Formaldehyde	50-00-0	50 µg/m^3 irritation of or damage to the nasal mucosa
Acetic acid	64-19-7	1200 µg/m^3 irritation
2-Ethylhexanoic acid	149-57-5	880 µg/m^3 developmental effects
2-Ethyl-1-hexanol	104-76-7	800 µg/m^3 irritation
N,N-Dimethylformamide (DMF)	68-12-2	170 µg/m^3 liver effects 700 µg/m^3 irritation
Methylnaphthalene Dimethylnaphthalene Triethylnaphthalene	- 1051-00-0 1052-00-0	58 µg/m^3 irritation applicable at individual substance level and for the sum of the three substances
Dodecamethylcyclohexasiloxane (D6)	540-97-6	70 µg/m^3 liver effects/lung effects
2,2'-Azobis(2-methylpropanenitrile)	78-67-1	Data not sufficient for derivation of value
Safrole	94-59-7	0.8 µg/m^3 (corr. 10^{-6} cancer risk for lifetime exposure)
Dibutylphthalate DBP	84-74-2	23 µg/m^3 endocrine disrupting effects
Diisobutylphthalate DiBP	84-69-5	29 µg/m^3 endocrine disrupting effects

In case of simultaneous exposure to several substances at once, it is considered relevant to add the RCR-values for substances with the same critical effect, i.e., that the RCR-values for the substances with irritative properties are added to a total RCR-value for irritation. The same applies to substances with hormone-disrupting effects or liver effects.

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Survey and risk assessment of chemicals from gaming equipment

Gaming have become a substantial part of the everyday life of many young people. Computer games are played in private homes, institutions and on a competitive level. Gaming equipment can emit volatile and semi-volatile organic compounds into the air that can be harmful to human health.
In a literature survey, the Danish Environmental Protection Agency identified 153 volatile substances (VVOCs and VOCs) and 90 semi-volatile substances (SVOCs) related to gaming equipment.
In this study, 14 additional SVOCs was identified from 7 field studies. Based on the literature survey and field analyses, an initial hazard screening was prepared to prioritize toxicologically problematic substances which were analyzed in subsequent tests of gaming equipment in climate chambers.
When analyzing 33 products in a climate chamber, 67 substances were identified, including formaldehyde, dimethylformamide, siloxanes, hydrocarbons, polyaromatic hydrocarbons (PAHs), organophosphorus flame-retardants (OPFR) and phthalates. 34 of these substances have not previously been identified to emit from gaming equipment. 11 of the 67 substances were prioritized for hazard assessment and 10 of these substances were selected for risk assessment. Based on a realistic worst-case scenario, two of the 35 products posed a risk to the consumer. The risk is associated with gaming chairs that have high emissions of formaldehyde that may cause eye- and respiratory irritation.

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