Survey of chemical substances in consumer products
Survey no. 32 – 2003

Emission and evaluation of chemical substances from selected electrical and electronic products

Danish Technological Institute:

Bjørn Malmgren-Hansen	Environmental and Waste Technology
Steen Olesen	Environmental and Waste Technology
Kirsten Pommer	Environmental and Waste Technology
Lis Winther Funch	Wood Technology
Eva Pedersen	Chemical Technology

Technical University of Denmark:

Ole Willum	Institute for Product Development
Stig Olsen	Institute for Product Development

Contents

PREFACE 7

SUMMARY AND CONCLUSIONS 9

1 INTRODUCTION 14

2 LITERATURE SURVEY 15

2.1 ELECTRICAL AND ELECTRONIC PRODUCTS IN DANISH HOUSEHOLDS 15
2.2 COMPONENTS AND MATERIALS IN ELECTRICAL AND ELECTRONIC PRODUCTS 18
2.3 LITERATURE SURVEYS OF THE EMISSION OF SUBSTANCES FROM ELECTRICAL AND ELECTRONIC PRODUCTS 18
2.4 LITERATURE DATA FOR MEASUREMENTS OF EMISSIONS FROM ELECTRICAL AND ELECTRONIC APPLIANCES 20
2.4.1 TV Sets 20
2.4.2 Computers and Monitors 23
2.4.3 Telephone Products 28
2.4.4 Hairdryers, Electric Shavers and Hand Mixers 29
2.4.5 Printed Circuit Boards 31
2.4.6 Other AV Products and Accessories 31
2.5 HEALTH EFFECT SCREENING OF SUBSTANCES FOUND IN THE LITERATURE SURVEY 32
2.5.1 Grouping of the Substances in Accordance With the UMP System 32
2.5.2 Selection of Substances on the Basis of Literature Data 34
2.5.3 Screening Results 35

3 MEASURING EMISSIONS OF HAZARDOUS SUBSTANCES FROM SELECTED PRODUCTS 38

3.1 SELECTION OF PRODUCTS 38
3.1.1 Monitors 38
3.1.2 Game Consoles 39
3.1.3 Kids' Toys 39
3.1.4 Lighting 39
3.1.5 TV Sets 39
3.1.6 Final Selection and Purchase of Products 39
3.2 METHODS USED WHEN MEASURING EMISSIONS OF SUBSTANCES FROM ELECTRICAL AND ELECTRONIC APPLIANCES 39
3.2.1 Field Measurement 39
3.2.2 Test Chamber Measurement 40
3.2.3 Standards for Measurements 40
3.3 CLIMATIC CHAMBER MEASUREMENTS 40
3.3.1 Experimental Investigations 40
3.3.2 Results 43
3.4 HEALTH EFFECT SCREENING OF SUBSTANCES FOUND WHEN MEASURING 50

4 REFERENCES 55

Annex A
Annex B
Annex C
Annex D

Preface

The purpose of this project is to provide an overview of the harmful substances given off by electrical and electronic appliances and to measure the emission of harmful substances from some selected products. Furthermore, the project involves a health effect screening to detect any harmful substances.

The project results contribute to the effort made by the Danish Environmental Protection Agency to reduce the load from substances that may have health-hazardous effects on the population, including particularly vulnerable groups like pregnant women, children, and elderly people.

Entity responsible for the project:
- Danish Technological Institute, Environmental and Waste Technology, Bjørn Malmgren-Hansen

Other participants from the Danish Technological Institute:
- Steen Olesen, Environmental and Waste Technology
- Kirsten Pommer, Environmental and Waste Technology
- Lis Winther Funch, Wood Technology
- Eva Pedersen, Chemical Technology

Institute for Product Development, the Technical University of Denmark:
- Ole Willum
- Stig Olsen

Summary and Conclusions

Electrical and electronic products used in Danish households fall into the following categories:

1. Computers, game consoles, and equipment for computers
2. Electrical equipment used in the kitchen/utility room
3. Audio and video systems
4. Communications equipment (telephones and related equipment)
5. Electrical equipment used in connection with personal care
6. Various electrical and electronic appliances around the home

When listing the most relevant products in order of priority as regards the risk of exposing the user to hazardous substances, we have considered the following:

- Whether the product gives off much heat
- Typical service life
- Whether the product is used in small, insufficiently ventilated rooms

This prioritized list includes the following particularly relevant products:

- Computers
- Monitors
- Game consoles
- Audio and video systems
- Chargers and voltage converters

The order of priority was based on a rough sorting by the three assumed parameters that may influence the concentration of harmful substances as well as the period of time during which persons are exposed to the substances. Therefore it may be relevant to examine the emission of potentially hazardous substances from other devices with a high power consumption level – e.g. kitchen appliances.

A literature survey aiming to identify the substances used in the production of electrical and electronic products resulted in the identification of approx. 136 substances that may be volatile under normal operating conditions. A health effect screening for substances that are unwanted or problematic from the point of view of health preservation leaves behind approx. 60 substances that may be given off by the appliances during use.

A literature survey for measurements of substances given off by electrical and electronic appliances was carried out in parallel. The measurements were made on TV sets, computers and monitors, telephone products, video recorders and laser printers, hairdryers, electric shavers, hand mixers, etc. In total, the literature specifies approx. 70 substances which are emitted at high concentration levels or which have been highlighted due to a suspected, chronic health-impairing effect.

The highest concentration levels of each substance listed in the literature have been converted into concentration levels in a 17.4 m^3 room, corresponding to a small children's room with an air change rate of 0.5 time per hour.

”In order to be able to carry out a preliminary screening and ranking of the substances as to their effects on health, the factor f_s has been calculated. The calculated f_s does not take into account substances with chronic health effects.

$$f_s = \frac{\text{room concentration}}{\text{work hygiene limit value * safety factor}}$$

No specific limits for emissions to indoor climate are available in connection with the use of consumer products (in this case electronic goods) and there are in such cases no official or guiding limit values to use as guidelines. In the absence of such values it has been decided to make a preliminary assessment of emission of substances to the indoor climate in the proportion 1/100 of the limit values in the working environment. This "safety factor" of 100 in proportion to the working environment has been chosen to take into account the fact that vulnerable groups too may be exposed (children, pregnant women or patients) and that the total exposure, which consists of a complex mixture of substances, may occur over a 24-hour period. The limit value in the working environment is determined on the basis of, in particular, irritation of eyes and respiratory passages (airways) and possibly other health effects but also technical and financial conditions are taken into account.

However, it must be stated that a number of the substances are proven to have or suspected of having chronic effects (e.g. carcinogenic, sensitising) and that a safe lower limit for "no effect" cannot, therefore, be defined. The calculation of f_s for the maximum concentration levels of substances specified in the literature shows that only formaldehyde exceeds the value f_s =1 and therefore presents an immediate health problem. Next on the list are phenol, toluene, and benzene with lower risk factors.

It must be underlined that the above assessment of the health risk does not take into account substances with chronic health effects for which a “no effect” limit cannot be defined.

The concentration of volatile substances (VOCs) such as toluene and benzene decreases during use. However, data from literature surveys indicate that some VOCs may occur at fairly high concentration levels compared to the initial levels, even after 4 months (10-20 % of the initial concentration).

Furthermore, the literature reveals the emission of a number of other substances from electrical and electronic appliances that have chronic, potentially hazardous effects, including phthalates, phosphate-based and brominated flame retardants. Some of these substances, such as certain phosphate-based flame retardants, are not found at detectable concentration levels until after some time in use and only reach maximum concentration levels after approx. 100 hours of appliance use. These concentration levels do not seem to decrease after several months of use, and as the substances will be able to condense on cold surfaces and dust in the appliances or outside the appliances due to their low vapour pressure, they will in time present the risk of inhalation together with the dust.

Following the literature survey, 4 product types were selected for subsequent measurement of emitted substances. These are a TV set, a monitor, a game console, and 5 voltage converters (using traditional transformers) for halogen lamps.

Measurements have been made to detect substance emissions from the appliances after 7 hours of use and after 9 days of use in test chambers with a controlled atmosphere.

A number of emitted substances with suspected or proven chronic hazardous effects have been found, including:

Substance	Health effect	TV set	Monitor	Game console	Convert-ers
Benzene	Carcinogenic (R45)	x	x		
Formaldehyde	Canc. (R40), sensitizing	x	x	x	x
Acetaldehyde	Carcinogenic (R40)	x	x	x	x
3-carene	Suspected sensitizing	x	x	x	
Butylhydroxytoluene (BHT)	Suspected sensitizing	x	x		x
Styrene	Metabolits are genotoxic, carc.	x	x	x	
Ethylbenzene	Suspected teratogenic	x	x		x
2-ethylhexanoic acid	Effects on reproducibility				x
Cyclohexanone	Suspected carcinogenic		x		x
Dibutyl phthalate	Suspected effects on reproducibility	x	x	x	x

Some of the highest emissions of volatile substances are:

- Trimethylbenzene 409 µg/appliance/hour (monitor)
- Toluene 307 µg/appliance/hour (voltage converter)
- Xylenes 223 µg/appliance/hour (voltage converter)
- Formaldehyde 97 µg/appliance/hour (voltage converter)

The f_s factor used to assess hazardous effects was calculated for the measured substance concentration levels using the above-mentioned safety factor of 100.

Formaldehyde makes the largest contribution for all appliances tested.

Emissions of formaldehyde	f_s, 7 hours	f_s, 9 days
TV set	0.09	0.06
Monitor	0.75	0.69
Game console	0.2	0.11
Voltage converter (transformer type) for halogen bulb	2.8	1.1

When applying the safety factor of 100, the calculated f_s values show that the voltage converter presents a potential health problem as regards formaldehyde when $f_s > 1$.

It should be mentioned that several voltage converters are often in use in each room. Thus, when using 5 voltage converters, f_s can reach a value of 15, corresponding to 15 % of the work hygiene limit value for formaldehyde.

f_s for the monitor is close to $f_s = 1$ while f_s for the game console and Tv set is approximately one decade lower than $f_s = 1$.

Furthermore, it should be noted that all appliances emit proven or suspected substances involving chronic hazardous effects and that, consequently, a safe lower “no effect” limit cannot be defined.

In addition to the substances found, literature surveys would indicate that phosphate-based or possibly brominated flame retardants could probably also be emitted from some of the products examined after prolonged use.

As regards precautionary measures, we recommend adequate room air conditioning and regular ventilation as well as high cleaning standards, including dust removal from electronic appliances.

1 Introduction

A wide range of electrical and electronic products are used in Danish households.

Electrical and electronic products are highly complex. Part components are produced at plants all over the world, and suppliers are substituted depending on their prices. The production processes involve a number of chemical products as well as most of the elemental substances. The products typically have several plastics components to which various additives have been added in order to ensure the required materials properties, e.g. plasticizers or flame retardants intended to prevent the ignition of parts exposed to excessive heat.

Add to this the many volatile substances such as the solvents used during production. The products may contain such residual substances when delivered to the consumer. The substances are then emitted gradually, and emission increases with appliance temperatures, as diffusion through the plastics components increases with temperature.

Some of the substances used in electrical and electronic products present a health risk. If released from the products at sufficiently high concentration levels, these substances may therefore cause hazardous effects on consumers exposed to them.

The aim of the project was to give a clear view of the types of products that constitute the most serious risk of health-hazardous effects from emitted substances.

The project was implemented in phases.

The first step was a literature survey identifying products considered to involve a risk of emitting hazardous substances as well as substances that can be expected to be emitted, based on our knowledge of the composition of the products. In this context, we have focused on the frequency of use of the products and whether they are likely to become hot.

The next step was a literature survey for publicized data on measurements of emissions from relevant products.

Then followed a health effect screening for potentially hazardous substances.

This was followed by the selection of relevant products to be tested in the laboratory for emission of hazardous substances. When selecting products, we have mainly focused on products frequently used by sensitive parts of the population, such as children, pregnant women, and elderly people.

Finally, the project involved a health effect screening to determine the occurrence of substances that may have a hazardous effect.

2 Literature Survey

2.1 Electrical and Electronic Products in Danish Households

Table 2.1 lists a number of electrical and electronic products found in Danish households.

Table 2.1 Electrical and electronic appliances in Danish households.

Cat.	Appliance	Typical location in the home	Typical power consumption(W)
1	CD burner	Sitting-room/children's room	12
1	Gameboy	Sitting-room/children's room	Low
1	Monitor for PC and game computer, CRT	Sitting-room/children's room	100
1	Monitor for PC and game computer, TFT	Sitting-room/children's room	30
1	Game console without monitor		100
1	PC without monitor	Sitting-room/children's room	100
1	Printer for PC	Sitting-room/children's room	50
2	Toaster	Kitchen	1,000
2	Electric cooker, conventional	Kitchen	5-10,000
2	Electric cooker, induction	Kitchen	5-10,000
2	Electric kitchen appliance	Kitchen	100-300
2	Refrigerator/freezer	Kitchen	200
2	Microwave oven	Kitchen	1,000
2	Automatic dishwasher	Kitchen	1,000
2	Automatic coffee maker	Kitchen	1,000
2	Tumbler	Scullery, cellar, or kitchen	2,000
2	Electric boiler	Kitchen	2,000
2	Laundry machine	Scullery, cellar, or kitchen	2,000
2	Exhaust hood	Kitchen	400
3	Audio system	Sitting-room/children's room	300
3	Camcorder		Low
3	CD player	Sitting-room/children's room	Low
3	CD player, portable		Low
3	Digital still camera		Low
3	DVD	Sitting-room/children's room	Low
3	Amplifier	Sitting-room/children's room	100
3	Loudspeaker	Sitting-room/children's room	Low
3	Tape recorder, portable		Low
3	Mini Disc	Sitting-room/children's room	Low
3	Mini Disc, portable		Low
3	MP3, portable		Low
3	Receiver, portable		Low
3	Receiver	Sitting-room/children's room	100
3	Tuner	Sitting-room/children's room	50
3	TV, colour	Sitting-room/children's room	100
3	Video recorder	Sitting-room/children's room	25
4	Mobile phone		Low
4	Telephone	Several possibilities	Low
4	Answering machine	Several possibilities	Low
5	Electric shaver	Bathroom	Low
5	Hairdryer	Bathroom	200
6	Charger for various mobile electronics	Several possibilities	5
6	Voltage converter for halogen bulbs	Several possibilities	75
6	Vacuum cleaner	All rooms	1,500
6	Automatics for regulation of heat/ventilation	Scullery, cellar, or kitchen	Low

The products are divided into the following 6 categories:
1. Computers, game consoles, and equipment for computers
2. Electrical equipment used in the kitchen/utility room
3. Audio and video systems
4. Communications equipment (telephones and related equipment)
5. Electrical equipment used in connection with personal care
6. Various electrical and electronic appliances around the home

Furthermore, Table 2.1 specifies the typical location of the appliances in the home as well as their estimated power consumption.

To select the most relevant products with a high risk of emitting hazardous substances to sensitive parts of the population, we assessed typical patterns of appliance use and periods of operation.

We then generated a risk score which is the product of 3 scores for power consumption, room ventilation, and period of operation. Risk score = R(power) * R(ventilation) * R(time).

The score R(power) = 2 is given for low power consumption, whereas the score R(power) = 1 is given if the consumption level is so high that the appliance may become warm.

If the appliance is located in a small room with a risk of poor ventilation (such as a children's room), the score R(ventilation) = 1 is given. If not, the score is 2. Finally, appliances with more than 1 hour of operation are given the score R(time) = 1; appliances with a shorter period of operation are given the score 2. This gives us the total risk scores indicated in Table 2.2.

The score allocation process results in the following list of relevant products:
- Computers
- Monitors
- Game consoles
- Audio and video systems
- Chargers and voltage converters

The listing is based on a rough sorting in the three parameters that may influence the concentration of harmful substances as well as the period of time during which persons are exposed to the substances. Consequently, there may be other relevant appliances among those listed in Table 2.1, which may constitute important sources of emission of hazardous substances. For instance, kitchen appliances with high power consumption and consequent heat generation may be a source of emitted substances, and if the concentration of these substances is sufficiently high, this may be of importance even though the substances are released in a relatively short period of time.

Table 2.2 Risk score for products

Appliance	Special risk of exposure for children and other “sensitive” groups	Typical period of operation (hours/day)	Risk score (1 is the highest risk)
CD burner		Short	2
Gameboy	Close to user when operated	Differs	2
Monitor for PC and game computer, CRT	Close to user when operated	2 to 6	1
Monitor for PC and game computer, TFT	Close to user when operated	2 to 6	1
Game console without monitor	Close to user when operated	2 to 6	1
PC without monitor	Close to user when operated	2 to 6	1
Printer for PC		Short	2
Toaster		Short	4
Electric cooker, conventional		1 to 2	2
Electric cooker, induction		1 to 2	2
Electric kitchen appliances		0.25	4
Refrigerator/freezer		Permanent	2
Microwave oven		Short	4
Automatic dishwasher		1 to 2	2
Automatic coffee maker		0.5	4
Tumbler		1 to 2	2
Electric boiler		0.25	4
Laundry machine		1 to 2	2
Exhaust hood		1 to 2	2
Audio system		2 to 6	1
Camcorder		Short	8
CD player		2 to 6	2
CD player, portable	Carried close to body	1 to 2	4
Digital still camera		Short	8
DVD		2 to 6	1
Amplifier		2 to 6	1
Loudspeaker		2 to 6	1
Tape recorder, portable	Carried close to body	1 to 2	2
Mini-Disc		2 to 6	1
Mini-Disc, portable	Carried close to body	1 to 2	4
MP3, portable	Carried close to body	1 to 2	4
Receiver, portable	Carried close to body	1 to 2	4
Receiver		2 to 6	1
Tuner		2 to 6	1
TV, colour		2 to 6	1
Video recorder		2 to 6	1
Mobile phone		Short	8
Telephone		Short	4
Answering machine		Short	4
Electric shaver	Used close to body	Short	8
Hairdryer	Used close to body	Short	4
Charger for various mobile electronics		Can be permanent	1
Voltage converters for halogen bulbs		Can be permanent	1
Vacuum cleaner		0.5	4
Automatics for regulation of heat/ventilation		Permanent	4

2.2 Components and Materials in Electrical and Electronic Products

Electrical and electronic products are highly complex, and they contain a wide range of the elements in the periodic table as well as a large number of organic components.

The substances and materials identified when examining the literature and other available sources can be divided into three main groups:

- Group 1 consists of materials and substances that will not evaporate at the temperatures occurring under even extreme operating conditions. These are typically metals, salts, and ceramics. This group is irrelevant in this context, as we focus on health-hazardous effects; materials and substances in group 1 have therefore been left out. However, some of these substances – such as heavy metals – may have environmental effects when the appliances are disposed of
- Group 2 consists of substances that may be volatile under normal or extreme operating conditions
- Group 3 consists of materials (typically polymers) which are not particularly volatile as such, but which may emit substances as a result of decomposition or the release of monomers or additives. We have assumed that this release mainly occurs in connection with thermal loading of the components or mechanical parts during use

Materials in group 3 are mainly used as casing materials in the electronic components, as "carrier materials" in PCBs, and as construction materials, e.g. for cabinets and mechanical parts. Those component parts of an electronic product that are exposed to particularly high thermal loads include power supply units, resistors, transistors, integrated circuits, PCBs as well as cabinets and mechanical parts close to hot components.

The substances in group 2 and those that may be emitted from group 3 materials are examined in Annex A. We have found approx. 136 substances and substance groups occurring in the form of monomers of plastics, flame retardants, plasticizers, solvents, and inorganic substances with such low boiling points that, in theory, they may evaporate.
The table includes the substance name, its CAS no., its origin or typical application, as well as polymers that may emit the substance.

2.3 Literature Surveys of the Emission of Substances From Electrical and Electronic Products

Surveys of the emission of hazardous substances from electrical and electronic products is a relatively new discipline, which began with the examination of photocopiers.

Ref. 22 provides an outline of measurements made on office equipment up until approx. 1999.

In the 1950's the photocopiers invaded the office environment. By the end of the 1960's they were assumed to be the main reason for complaints concerning indoor climate and health. The high concentration of ozone which occurs during the copying process was blamed for the many complaints, and therefore focus was mainly on measuring ozone for the first number of years. Not until the 1990's did researchers start to focus on VOCs and other components and on finding answers as to what can be done to minimise emission of these many different compounds in future products.

As TV screens, computers, and monitors have become more and more widespread, they have also been examined to detect emission levels. In 1989, the German ministry of the environment published a report that fuelled the discussion about chemical emissions from computers. Among other substances, researchers found PBDF (polybrominated dibenzofuran), which has toxic properties like those of dioxin, in emissions from the rear side of TV screens.

In a survey of monitors from 1990 made by IBM, researchers listed the functions of the individual chemical substances and the concentration levels at which they are emitted – see Table 2.3.

Table 2.3 Emissions of substances from monitors

Emission	Source [1]	Substance
100 μg/m³	D	Phenol
	A	2,6-bis(1,1-dimethyl)-4-methylphenol (BHT)
	S	Toluene
	S	2-ethoxyethyl acetate
		Lactic acid, butylester
	D	Cresole
	S	Xylene
	S	Ethylbenzene
	S,D	Ethylenbenzene (styrene)
	S	1-(2-buthoxy)ethoxyethanol
	A	2-tert-butylazo-2-methoxy-4-methylpentane
	D	Benzaldehyde
	S	Trimethylbenzene
		Acrylic acid, ethylester
		4-hydroxy-4-methylpentane
	S	Nonan
	S	Dedecane
	S	Undecane
	S	Dodecane
	D	Octamethyl cyclotetrasiloxane
	D	Dodecamethyl cyclohexasiloxane
		2-hydroxybenzaldehyde
10 μg/m³		Hydroxytoluene
		o-methylhydroxytoluene
	S,A	Aceticacid, butylester
	A	Acetophenone
	D	Caprolactam
	S	2-buthoxyethanol
	A	Heptadecane
	A	Butyl isobutyl phthalate
	A	Butyl octyl phthalate
	S	Propylbenzene
	S	Cyclohexanone
		Benzoic acid, pentylester
	A	2,6-bis(1,1-dimethylethyl)-4-ethylphenol
	A	2,6-bis(1,1-dimethylethyl)-4-butylphenol
	A	3-(1,1-dimethylethyl)phenol
	A	Hexandioicacid
	A	Tributylphosphate
1 μg/m³	A	Triphenyl phosphate

[1] D – decomposition/contamination, A – additive, S – solvent (From Ref. 22).

Since 1990, a number of surveys on electrical and electronic appliances have been published. The main results from these surveys will be examined below.

2.4 Literature Data for Measurements of Emissions From Electrical and Electronic Appliances

Measurements were made on a number of electrical and electronic appliances. Table 2.4 lists the appliances subjected to measurements up until now as well as the main substance types targeted in the measurements.

The table is followed by a more detailed description of the results from the surveys, specified by product group.

Table 2.4. Products subjected to measurements.

Product	Year	Reference	TVOC [1]	Most important VOCs [2]	Selected SVOCs [3]
TV sets					
10 TV sets		Ref. 1, 3, 6, 13	x	x	x
Computers and monitors					
19 monitors		Ref. 4	x	(x)	
Monitors		Ref. 12			x
3 computers (excl. monitor)		Ref. 9	x	x	
Computers		Ref. 11		(x)	
Computers incl. monitor		Ref. 10	x	(x)	
Telephone products					
Telephone		Ref. 7	x	x	x
Mobile telephone		Ref. 7	x	x	x
Digital answering machine		Ref. 7	x	x	x
Answering machine (tape)		Ref. 7	x	x	x
Hairdryers, electric shavers and hand mixers					
Hairdryer		Ref. 7	x	x	x
Electric shaver (Germany)		Ref. 7	x	x	x
Electric shaver (China)		Ref. 7	x	x	x
Electric hand mixer		Ref. 7	x	x	x
Printed circuit boards					
Phenol/paper-based PCBs		Ref. 17			
Epoxy/glass-based PCBs		Ref. 17			
Other AV equipment					
Portable CD player		Ref. 7	x	x	x
10 video recorders		Ref. 1	x	x	x
14 laser printers		Ref. 4	x		
Computer mouse		Ref. 7	x	x	x
Gameboy		Ref. 7	x	x	x

If the "Most important VOCs" field is checked, at least the 5 highest VOC concentration levels are listed in the reference. If a check is in brackets, less than the 5 highest concentration levels are listed.

[1] TVOC: Total content of Volatile Organic Components.

[2] VOC: Volatile Organic Components.

[3] SVOC: Semi-Volatile Organic Components.

2.4.1 TV Sets

2.4.1.1 TV sets (VOCs, SVOCs, flame retardants) (Ref. 1, Ref. 4, and Ref. 13, 1999-2002)

Measuring method

The measurements made on the 10 TV sets are described in Ref. 1, Ref. 4, and Ref. 13. The emissions from the TV sets were collected in test chambers, cf. draft CEN standard, CEN TC 264 WQ 7, defining the emission test chamber requirements.

VOCs were collected on TENAX TA tubes, and SVOCs were collected by condensation on cold glass tubes inside the test chambers as well as in air samples. The samples were subsequently analysed using GC/MS techniques. The temperature in the test chambers was 23°C, and the relative air humidity was 50 %. However, dry air corresponding to 0 % relative air humidity was used when determining the SVOCs. The air change rate in the chambers was 0.5 time per hour.

The SVOC level was determined by adding the amount of SVOCs measured in the outlet air from the test chamber and the amount of SVOCs condensed on a specially developed condensation unit in 14 days. The condensation unit consisted of an aluminium block with high-polished stainless steel plates measuring 15*15 cm which could be set to the required surface temperature. When measuring SVOCs emitted from electronic appliances, the temperature was set to -10°C, causing the SVOCs emitted from the appliances to condensate. To avoid condensation of water vapour from the air in the test chamber, dry air (relative humidity = 0 %) was introduced when measuring SVOCs.

Phthalates were analysed in the air samples through absorption on TENAX TA tubes with 10 litres passing at a flow rate of 100 ml/min. Subsequently analysis were performed using GC/MS after thermal desorption and ice-trap injection.

Phosphate-based flame retardants were collected on XAD-2 (special version with a low content of this type of substances).

Organophosphate-based flame retardants and chlorinated paraffins were adsorbed on XAD-2, and the substances were then extracted using dichloromethane, whereas polybrominated flame retardants and decomposition products from these were concentrated on XAD-2 and extracted by means of toluene using Soxhlet.

Results

Table 2.5 shows selected measuring results for 10 TV sets from Ref. 1.

Table 2.5 Emissions from 10 TV sets (1999).

Substance	TV sets (µg/set*hour)	
	New sets	After approx. 4 months of ageing
TVOC (toluene equivalents)	189–2.036	< 25–157
Vinyl chloride	< 0.1	< 0.1
Benzene	0.3 – 7.1	< 0.1–1.2
Toluene	1–203	0.2–6.4
Sum of o,m,p-xylene	1.2–5.7	0. –7.5
Styrene	1–7.6	< 0.1–1.1
Phenol	12–236	1.6–35
Sum of o,m,p-cresols	0.9–19	0.5–4.2
Dichloromethane	< 0.2–2.1	< 0.2–3.0
Trichlorethene	< 0.2–59	< 0.2–19
Tetrachlorethene	< 0.2–2.6	< 0.2–1.1
2-butoxyethanol	1.6–31.4	< 0.5–1.1
Formaldehyde	< 0.5–9.9	< 0.5–6.6
n-nitrosdibutylamine	< 0.1–0.2	< 0.1
Bis-(2-ethyl)-hexylphthalate	0.3–1.4	< 0.1–1.4
Dibutyl phthalate	0.1–11.1	< 0.1–4.4
PCB (sum of 6 PCBs)	0.001–0.003	0.001–0.002
Pentabromotoluene	< 0.00005–0.0002	< 0.00005
TCEP (Tri-(2-chloroethyl)-phosphate)	< 0.01	< 0.01–0.30

The table shows that the highest emissions of VOCs consist of phenol and toluene.

As seen in the table, the emissions of VOCs decreases with time.
To get an estimate of how fast the concentrations decrease, the mean substance emission values for new appliances and appliances after 4 months of use has been calculated respectively. This shows that the emitted concentrations of selected substances decrease to the following values after 4 months:

- TVOC: 8 %
- Phenol: 14 %
- Toluene: 3 %
- Formaldehyde: 68 %
- Benzene: 18 %
- Styrene: 14 %

The calculations indicate that the emissions of most of the substances decreases to 5-20 % of the initial emission after approx. 4 months. However, the formaldehyde emission appears to decrease at a lower rate.

In Ref. 1, 3, flame retardant levels were measured in 10 TV sets – new sets and sets in use for up to 600 hours.

Several measurements carried out over time reveal that the concentration of phosphate-based flame retardants in the air samples increases slowly. For instance, TBP (tributyl phosphate) reaches an equilibrium concentration of approx. 250 ng/m^3 after 100 hours, and TCEP (tri-(2-chloroethyl)-phosphate) and TCPP (tri-(dichloropropyl)-phosphate) reach at least 75 % of the equilibrium concentration after 100 hours. This is unlike the VOC emissions, which typically reaches a maximum after about 6 hours of use.

The instances of TCEP, TCPP and TPP (triphenyl phosphate) found in the condensation analyses from the TV sets appear from Table 2.6.

Table 2.6 Flame retardants detected in emissions from 10 different TV sets (measured using condensation unit).

Substance	Found in new TV sets	Found in used TV sets (600 hours)
TCEP (Tri(2-chlorethyl)-phosphate)		2 pcs.
TCPP (Tri(chlorpropyl)-phosphate)	5 pcs.	8 pcs.
TPP (Triphenyl phosfate)	5 pcs.	1 pcs.

As regards one of the TV sets, the following concentrations of phosphate-based flame retardants were measured in the test chamber air after 500 hours of operation:

- TBP: 31 ng/m^3
- TCEP: 102ng/m^3 (TCEP is suspected to be carcinogenic)
- TCPP: 1.725ng/m^3

The concentration of TBP, TCEP, and TCPP flame retardants increased very slowly, reaching approx. 75 % of the concentration at 600 hours (25 days) after 100 hours. It can be assumed that the concentration levels will begin to decrease again at some point, but when decrease will start is not known. The measured constant concentrations indicate that the emission of flame retardants will continue for many months (years).

Other measurements of phosphate-based flame retardants from screens are described under monitors.

After 600 hours of operation, a hexabromobenzene concentration of 2 ng/m^3 was found in the test chamber air.

2.4.1.2 TV sets (flame retardants) (Ref. 6, 1991)

In Ref. 6, measurements were made of PBDE (polybrominated diphenyl ethers) emissions as well as dioxin and furan emissions from two TV sets.

The TV sets emitted 4 and 192 ng PBDE/unit, respectively, in the course of 3 days, corresponding to a maximum of 2.7 ng/appliance/hour.

This test is relatively old, and the PBDEs have probably been substituted in more recently produced appliances – for instance by phosphate-based flame retardants.

2.4.2 Computers and Monitors

2.4.2.1 Monitors (TVOC and flame retardants) (Ref. 3, Ref. 4, 2002)

Measuring methods

In Ref. 4, 19 different monitors were examined using the test chamber method followed by GC/MS analysis as described above under TV sets.

For each appliance, the emission rates have been calculated and theoretically related to a standard office environment (17.4 m^3, ENV 13419-1, 1999) to allow the values to be compared to indicative concentration levels in air of an acceptable quality.

The monitors were supplied in mint condition to TÜV Nord in Hamburg, Germany. Upon reception, the monitors were sealed in aluminium-coated PE foil and stored in an air-conditioned room at 23°C and a relative humidity of RH 50 % until the tests were carried out.

Each monitor was tested in a 1 m^3 electropolished stainless steel test chamber, which meets the requirements of ENV 13419-1 (1999). The test process largely met the requirements of the ECMA standard (ECMA, 2001).

The monitors were kept in standby mode in the chambers for 16 hours at 23°C, RH 50 % and an air change rate of 0.5 m^3/hour. The monitors were then switched on. After 6 hours of operation, air samples were taken in order to determine the VOC concentration. In addition, long-term tests were carried out on some of the monitors.

The determination of VOC levels (by means of screening) was carried out by collecting substances using a TENAX TA tube (5 l, 0.5 l/min.), thermal desorption (PE-ATD 400) and GC/MS (HP5890/HP5970) with a DB-5MS input splitter fitted.

The TVOC value was found by adding the VOCs, C_6 to C_{16}, from the gas chromatograms.

Results
The tests carried out in Ref. 4 show that – in all cases – the concentration level peaks 6 hours after the switch from standby mode to operation mode. The concentration of most VOCs appears to decrease exponentially with time.

Table 2.7 shows TVOC and toluene levels after 6 hours for the 19 monitors tested in Ref. 4. It appears that the emission of toluene varies from 64 to 1,045 µg/hour for new products.

Table 2.7 Total amount of volatile organic components (TVOC) og toluene emitted from monitors.

Monitor no.	TVOC (µg/monitor*hour)	Toluene (µg/monitor*hour)
M-1	526	64
M-2	1,376	321
M-3	1,545	600
M-4	2,231	780
M-5	771	231
M-6	1,025	538
M-7	2,427	1,045
M-8	2,534	219
M-9	1,455	146
M-10	1,713	758
M-11	1,136	210
M-12	1,607	189
M-13[1)]	11,099	207
M-14[2)]	253	11
M-15[2)]	301	35
M-16[2)]	214	32
M-17[2)]	36	1
M-18	701	147
M-19	732	91

[1)] Mainly limonen.
[2)] Used monitors – number of operating hours before measuring not known.

The concentration of flame retardants in the test chamber air was measured after 12-14 days for 3 monitors tested in Ref. 3. Conditions were: T = 23°C, RF = 50 %, air change ACH = 0.5 h^{-1}. The concentration levels measured vary within the intervals specified in Table 2.8.

Table 2.8 Concentrations of flame retardants in TV sets.

Flame retardant		Concentration (ng/m³)
TBP	(Tributyl phosphate)	< 10-18
TKP	(Trikresyl phosphate)	< 10-13
TPP	(Triphenyl phosphate)	54-254
TBEP	(Tri(2-butoxyethyl)-phosphate)	< 10
TCEP	(Tri(2-chlorethyl)-phosphate)	11-121
TCPP	(Tri(chlorpropyl)-phosphate)	< 10-45
TDCPP	(Tri(dichloropropyl)-phosphate)	< 10
TEHP	(Tri(2-ethylhexyl)-phosphate)	< 10

Table 2.8 shows that TPP, TCEP, and TCPP have the highest concentration levels in the test chamber air.

2.4.2.2 Monitors (flame retardants) (Ref. 6, 1991)

In Ref. 6, measurements were made of PBDE (polybrominated diphenyl ether) emissions from two monitors.

The monitors emitted 9 and 889 ng/unit, respectively, corresponding to a maximum of 12 ng/appliance/hour. The emissions mainly consisted of tetra- and penta-BDE.

This test is relatively old, and the PBDEs have probably been substituted in more recently produced appliances – for instance by phosphate-based flame retardants.

2.4.2.3 Computers incl. monitors (sick building syndrome) (Ref. 8, 2002)

In this survey, the "perceived" air quality and sick building syndrome (SBS) symptoms were examined in a slightly contaminated office environment with an air change rate of 2 times per hour, corresponding to 10 l/s per person when 6 persons are present. The tests were carried out with and without PCs present. All other parameters were kept constant.

30 women did ordinary office work on 6-year old PCs, from which all volatile substances are presumed to have evaporated. The tests were carried out both with and without the presence of six 3-month old PCs switched on and with their monitors placed behind a curtain so that the test persons could not detect the presence of these appliances.

The test persons assessed the air quality by means of intensity scales, and their efficiency was measured by recording the number of errors made and the time of execution of the tasks presented to them.

The results show that the six relatively new PCs had a significant influence on the test persons' perception of the air quality (typically 14 % complaining when the PCs were not present, and 41 % complaining when they were present). In addition, a negative effect on the working efficiency could be registered when the relatively new PCs were present in the room.

2.4.2.4 Computers excl. monitors (VOCS) (Ref. 9, 2000)

This test involved the examination of three computers in order to determine the VOC emission levels. The computers were placed in 283-litre electropolished stainless steel test chambers at a temperature of 24-29°C. The computers were connected to mains by leading the cables through a narrow opening in the test chamber. The test chamber was conditioned before starting the tests.

A total of 48 VOCs were positively identified during these tests. The amount of toluene emitted was the single largest contributor to the overall emission – up to 300 ug/h.

In addition, the following substances were found (sorted by emission level):

- Toluene
- Undecane
- Xylenes
- Styrene
- Decane
- Dodecane
- Benzaldehyde
- Ethyl benzene
- 1,2,4-trimethylcyclohexane
- Butyraldehyde
- Alfa-metylstyrene
- Trichlorethene
- Acrylonitrile

2.4.2.5 Computers incl. monitors (Ref. 10, 1999)

Photocopiers, laser printers, and computers were tested to determine the emission of VOCs, ozone, and particles.

These tests were carried out in a 6 m^3 test chamber made of stainless steel. The air supplied was cleaned to remove all measurable concentrations of formaldehyde and VOCs, particles, and ozone before use, so that the background concentration from the air supplied was < 2 $\mu g/m^3$ TVOC, < 10 $\mu g/m^3$ particles in total, < 2 $\mu g/m^3$ formaldehyde, and < 0.01 ppm ozone. During the tests, the air supply to the chamber was kept at 23 ± 2°C, and the relative air humidity was 50 ± 5 % RH. The air was changed once per hour.

The sampling time was 4 hours and 45 minutes, corresponding to the total test period. The VOCc were collected on “multisorbent” tubes in accordance with EPA method IP-1B. These tubes were subsequently analysed by means of thermal desorption/gas chromatography/mass spectroscopy (TD/GC/MS) with a mass selective detector. The total TVOC level as well as the identifiable VOCs were determined. Generally speaking, this technique makes it possible to see compounds from C_5-C_{16} with a detection limit of 1 $\mu g/m^3$ for TVOC and for most VOCs for the sample size in question.

The test results for the 6 computers showed that the average TVOC concentration is 0.28 mg/hour, varying from 0.05 to 24.2 mg/hour, corresponding to a converted effect of 0.28 mg/m^3 in an office environment.

Listed in alphabetical order, the most important VOCs were:

- 1-phenylethanone
- 2-ethyl-1-hexanol
- Ethylbenzene
- Ethylhexylpropenoic ester
- Hexamethylcyclotrisiloxan
- Methyl acrylate

- Phenol
- Trichloroethane
- Toluene
- Xylenes

2.4.2.6 Computers and monitors (VOCs) (Ref. 11, 1993)
This article describes how VOC emissions from computers, monitors, and other electronic equipment may irritate the mucous membranes, etc.

Two office employees had all their IT equipment replaced in order to remedy certain problems concerning the indoor climate. Unfortunately, the problems simply got much worse. In the first instance, the reason for the problems was a lack of air change in the office. Consequently, the new office machines only made it all worse. In this case the problem was solved by increasing the room ventilation and leaving the equipment switched on for a couple of weeks before use. Therefore the authors recommend that, if possible, electronic equipment should be commissioned over a period of time to allow the highest VOC concentrations to evaporate.

The following typical VOC emissions are highlighted as emissions originating from monitors (in alphabetical order):

- n-butanol
- 2-butanone
- 2-buthoxyethanol
- Butyl-2-methyl-propyl-phthalate
- Caprolactam
- Cresol
- Cyclosiloxane
- Diisooctyl phthalate
- 2-ethoxyethyl acetate
- Ethyl benzene
- Ozone
- Phenol
- Toluene
- Xylene

2.4.2.7 Monitors (flame retardants) (Ref. 12, 2000)
Triphenyl phosphate – a flame retardant with a well-documented allergic effect in contact with skin – was found in an office environment with computers, monitors, and printers. The source of the emissions was localized in the CRT monitors.

18 different monitors were examined, and it appeared that the outer plastics covers contained up to 10 weight percent of triphenyl phosphate.

When brand new PC equipment was used in a smaller office, examinations revealed that after the first 24 hours the triphenyl phosphate concentration peaked at close to 100 ng/m^3.

The samples were taken in that area of the room where the users would normally have to breathe.

After one week of continuous operation the triphenyl phosphate concentration had dropped to 50 % of the value measured after 24 hours. After 183 days of operation, corresponding to 2 years of operation in normal working hours, the concentration had dropped to 10 % of the initial concentration. The fact that the triphenyl phosfate concentration decreases with time is in line with the qualitative results in Table 2.6. Please note that the results in section 2.4.1.1 show that the concentration of other phosphate-based flame retardants does not peak until after 100 hours and only decreases very slowly.

2.4.3 Telephone Products

Product analyses in this section were taken from Ref. 7, 1997.

Measuring methods
The appliances were switched on 3 hours before measuring. A glass container was used as measuring chamber. Prior to each test the glass container was cleaned and dried in a conventional dishwasher. A control experiment was carried out before each test to ensure that the glass container did not contain VOC. The product was then placed in the container, which was sealed and had pure nitrogen blown through it 3 times in order to remove the atmospheric air. Some of the nitrogen/air blown out was then extracted through a ceramic pipe containing active coal. The VOCs were then adsorbed on the active coal. The sampling time was 30 min., and the tests were carried out at room temperature.

In order to release the compounds properly from the pipes it proved necessary to insert the pipes in a microwave desorption device (Analyst MW 1).

The desorbed compounds were then analysed using GC/MS (Hewlett Packard (HP) 5890, column HP Ultra 2 & HP GCD). This equipment made it possible to find the most non-polar and slightly polar organic compounds with a molar weight (g/mol) of 20 - 400, which corresponds to a boiling point of 60°C - 400°C. The system was calibrated by means of standardized mixtures of n-alkanes and aromatic solvents.

Results
The tables below show the main VOCs and substances with a potentially hazardous effect. The VOCs are listed in order of diminishing concentration, so that VOC no. 1 has the highest measured concentration.

2.4.3.1 Telephone

Substance	Concentration (µg/hour)	High concentration of VOCs
TVOC	34	
Toluene	4.7 Suspected teratogenic	1
2-ethylhexanol		2
n-pentadecane		3
Ethylmethylbenzene		4
n-tetradecane		5
Naphtalene	Suspected carcinogenic	
Tetrachlorethene	Suspected carcinogenic	
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	

2.4.3.2 Mobile phone

Substance	Concentration (µg/hour)	High concentration of VOCs
TVOC	5.9	
Diethyl phthalate	1.6	1
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	2
Ethylbenzene		3
Xylenes		4
Benzene	Carcinogenic	5
3-carene	Sensitizing	6

2.4.3.3 Digital answering machine

Substance	Concentration (µg/hour)	High concentration of VOCs
TVOC	27	
2-ethylhexanol	2.5	1
Toluene	Suspected teratogenic	2
Xylenes		3
Silicones		4
n-tetradecane		5
n-dodecane		6
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	

2.4.3.4 Answering machine (Tape)

Substance	Concentration (µg/hour)	High concentration of VOCs
TVOC	51	
2-ethylhexanol	2.5	1
Trimethylbenzene		2
Several n-alkanes		3
Xylenes		4
Phenol		5
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	6
N,N-dimethylformamide	Teratogenic	
Benzophenone	Suspected endocrine disruptor	

The total amount of organic substances emitted (TVOC) is approx. 1-2 decades lower than for TV sets (section 2.4.1.1). Several of the substances emitted have suspected or proven chronic hazardous effects for which no lower "no effect" limit can be established.

2.4.4 Hairdryers, Electric Shavers and Hand Mixers

Analyses of the products in this section were taken from Ref. 7 (1997). See 2.4.3 for measuring methods. The appliances were switched on 15 minutes before measuring.
The tables below specify the main VOCs and substances with a potentially hazardous effect.

2.4.4.1 *Hairdryers*

Substance	Concentration (µg/hour)	High concen-tration of VOCs
TVOC	14	
n-tetradecane	3.4	1
n-pentadecane		2
n-hexadecane		3
2-ethylhexanol		4
Naphtalene	Suspected carcinogenic	5
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	

2.4.4.2 *Electric shavers (Germany)*

Substance	Concentration (µg/hour)	High concen-tration of VOCs
TVOC	13.2	
1-ethoxy-2-propanol	2.4	1
Cyclohexanone		2
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	3
Toluene	Suspected teratogenic	4
2-ethylhexanol		5
Several n-alkanes		6
Cyclohexanone	Suspected carcinogenic	

2.4.4.3 *Electric shavers (China)*

Substance	Concentration (µg/hour)	High concen-tration of VOCs
TVOC	27 (½ hour, not in operation) 206 (17 hours, in operation)	
Naphtalene	3.8 (½ hour not in operation) 23 (17 hours, in operation), suspected carcinogenic	1
Methylnaphtalenes		2
Mange alkylbenzenes		3
Mange n-alkanes		4
Cyclohexanone	Suspected carcinogenic	5
Benzene	Carcinogenic	

2.4.4.4 *Electric hand mixers*

Substance	Concentration (µg/hour)	High concen-tration of VOCs
TVOC	20	
2,6 di-tert-butyl-4-methylphenol (BHT)	1.1 Suspected sensitizing	1
Nonanal		2
Several n-alkanes		3
Tert-butyl-methylphenol		4
Styrene	Genotoxicity of metabolites	5
Toluene	Suspected teratogenic	6
Trichlorethylene	Suspected carcinogenic	
Cyclohexanone	Suspected carcinogenic	

The total amount of organic substances emitted (TVOC) is approx. 1-2 decades lower than for TV sets (section 2.4.1.1), except for the electric shaver from China. Several of the substances emitted have suspected or proven chronic hazardous effects for which no lower "no effect" limit can be specified.

2.4.5 Printed Circuit Boards

Ref. 17 includes analyses of a number of different types of printed circuit boards (PCB)s to determine the emission of VOCs.

The report shows that phenol/paper-based PCBs emit much higher amounts of aldehydes and ketones (including formaldehyde) than glass-/epoxy-based PCBs (approx. 5 % of the value for phenol/paper-based PCBs, and this also applies to the total amount of VOCs). However, the emission rate decreases with time; for instance, the formaldehyde emission rate was about 10 % of the initial concentration after 336 hours (14 days).

2.4.6 Other AV Products and Accessories

The analyses of products in this section were taken from Ref. 7 (1997). The tables below show the main VOCs and substances with a potentially hazardous effect. The measuring methods relating to Ref. 7 are described in section 2.4.3. The appliances were switched on 3 hours before measuring.

2.4.6.1 Portable CD player (Ref. 7)

Substance	Concentration (μg/hour)	High concentration of VOCs
TVOC	61	
Trimethylbenzene	5.5	1
Several alkylbenzenes		2
Several n-alkanes		3
2-ethylhexanol		4
Toluene		5
Cyclohexanone	Suspected carcinogenic	6

2.4.6.2 Computer mouse (Ref. 7)

Substance	Concentration (μg/hour)	High concentration of VOCs
TVOC	26	
2-ethylhexanol	6.9	1
Limonen		2
2-ethylhexanal		3
Trimethylbenzene		4
n-tetradecane		5
Styrene	Genotoxicity of metabolites	

2.4.6.3 Gameboy (Ref. 7)

Substance	Concentration (μg/hour)	High concentration of VOCs
TVOC	5.7	
Several silicones	0.7	1
2,6 di-tert-butyl-4-methylphenol (BHT)	Suspected sensitizing	2
Several n-alkanes		3

The total amount of organic substances emitted (TVOC) is approx. 1-2 decades lower than for TV sets (section 2.4.1.1). Several of the substances emitted have suspected or proven chronic hazardous effects for which no lower "no effect" limit can be specified.

2.4.6.4 Video recorders (VOCs) (Ref. 1,1999)

Ref. 1 specifies measurements of VOCs for 10 video recorders. The measuring methods are the same as described in section 2.4.1.1.

Table 2.9 Emissions from 10 video recorders.

Substance	Video recorder (µg/unit*hour)	
	New unit	After approx. 4 months
TVOC (toluene equivalents)	116–391	32–119
Vinyl chloride	< 0.1	< 0.1
Benzene	< 0.1–1.2	< 0.1–1.0
Toluene	2.5–67	0.4–5.3
Sum of o, m, p-xylenes	0.4–19	0.1–0.6
Styrene	0.2–6.6	< 0.1–0.2
Phenol	18–65	2.8–36
Sum of o, m, p-cresoles	1.0–7.6	< 0.2–1.0
Dichloromethane	< 0.2–1.0	< 0.2
Trichlorethene	< 0.2–4.1	< 0.2–1.0
Tetrachlorethene	< 0.2–2.1	< 0.2–0.5
2-butoxyethanol	< 0.1–2.3	< 0.1–0.9
Formaldehyde	8.0–40	2.4–19
n-nitrosdibutylamine	< 0.1	< 0.1
Bis-(2-ethyl)-hexylphthalate	0.2–1.1	0.4–0.9
Dibutylphthalate	< 0.1–1.7	0.2–0.9
PCB (sum of 6 PCBs)	0.001–0.002	0.001–0.003
Pentabromotoluene	< 0.00005	< 0.0005
TCEP (Tri-(2-chloroethyl)-phosphate)	< 0.01	< 0.01–0.08

Compared to TV sets, the total VOC emission levels are somewhat lower (approx. 2-6 times). Several of the substances emitted have suspected or proven chronic hazardous effects for which no lower “no effect” limit can be established. Formaldehyde is found in higher concentration levels than in the examination of TV sets (2.4.1.1). Furthermore, like in the case of the TV sets, the measurements indicate that the formaldehyde concentration does not decrease as fast as e.g. the toluene concentrations.

2.4.6.5 Laser printers (Ref. 4)

Ref. 4 describes measurements of VOCs from 14 laser printers. The measuring methods are the same as in section 2.4.2.1.

The total VOC concentrations measured range from 76 to 5.365 µg/unit/hour. No details are available about emission of substances with a hazardous effect.

2.5 Health Effect Screening of Substances Found in the Literature Survey

2.5.1 Grouping of the Substances in Accordance With the UMP System

A health effect screening based on the UMP system has been carried out for the 136 possibly hazardous substances emitted from electronic appliances found in section 2.2. This is described in Ref. 24, the Danish Environmental Protection Agency’s Environment Project no. 381, 1998, which corresponds to the EU’s classification criteria for chemical products, Directive 67/548/EEC, incl. amendment no. 26:

U: Unwanted (very toxic)
P: Problematic (moderately toxic)
M: Manageable (relatively low toxicity or non-toxic)
N: No data (little or no knowledge of the substance)

The results of the health effect screenings for the substances in relation to the UMP system are shown for unwanted substances (U) in Table 2.10 and for problematic substances (P) in Table 2.11.

TABLE 2.10 UNWANTED SUBSTANCES IN ELECTRIC AND ELECTRONIC EQUIPMENT ACCORDING TO THE UMP SYSTEM.

Substance	CAS no.
1,2-Dichloroethane	107-06-2
1,3,5-Triglycidyl isocyanurate (TGIC)	2451-62-9
2,4,5-Trimethylaniline	137-17-7
2,4-Toluylenediamine (Toluene-2,4-Diamine)	95-80-7
2-Bromobiphenyl	2052-07-5
2-ethoxyethanol	110-80-5
2-ethoxyethyl acetate	111-15-9
2-Methoxyethanol	109-86-4
2-Methoxyethyl acetate	110-49-6
2-Naphthylamine	91-59-8
2-phenyl-propenal (CAS no. is for 3-phenylpropenal)	104-55-2
3,3'-Dimethylbenzidene	119-93-7
3,3'-Dichlorobenzidene	91-94-1
3,3'-Dimethyl-4,4' diaminodiphenylmethane	838-88-0
3,3'-Dimethoxybenzidine	119-90-4
3-Bromobiphenyl	2113-57-7
4,4'Methylenebis-(2-chloroaniline)	101-14-4
4,4'-Thiodianilene (4,4'-thiobisbenzenamine)	139-65-1
4,4'-Dibromodiphenylether	2050-47-7
4-Bromobiphenyl	92-66-0
4-Bromophenyl phenyl ether	101-55-3
4-Chloro-o-toluidine (4-chloro-2-methylaniline)	95-69-2
Azodicarbonamide	123-77-3
Benzene	71-43-2
Benzidene and its salts	92-87-5
Bisphenol A	80-05-7
Bromine	7726-95-6
Butadien	106-99-0
Chloroform	67-66-3
Coal tar	8007-45-2
Diethylentriamine	111-40-0
Diphenylmethandiamine	101-77-9
Epichlorohydrin	106-89-8
Formaldehyde	50-00-0
n-Hexane	110-54-3
o-Aminoazotoluene	97-56-3
Octylphenol	27193-28-8
o-Toluidine	95-53-4
p,p'-dibromobiphenyl	92-86-4
p-Chloroaniline	106-47-8
Pentabromodiphenyl ether	32534-81-9
Pentachloro phenol (PCP)	87-86-5
phosgen (carbonylchlorid)	75-44-5
Phthalic anhydride	85-44-9
Styrene oxide	96-09-3
Tetrabromobisphenol-A (TBBA)	79-94-7
Vinyl chloride	75-01-4

Table 2.11 Problematic substances in electric and electronic products according to the UMP system.

Substance	CAS no.
2,4-Diaminoanisole	615-05-4
Benzal chloride	98-87-3
Caprolactam	105-60-2
Diphenylamine	122-39-4
Acetic acid	64-19-7
Hexamethylendiamine	124-09-4
Methyl-anilines	100-61-8
p-Cresidene (5-Methyl-o-Anisidine)	120-71-8
Phenol	108-95-2
Polychlorinated biphenyls	1336-36-3
Tetrachloroethylene	127-18-4
Thiocarbamide	62-56-6
Trichloroethylene	79-01-6

It should be noted that some of the substances in the above list of problematic substances are presumably not relevant as substances with a potentially hazardous effect occurring in electrical and electronic products, such as acetic acid.

2.5.2 Selection of Substances on the Basis of Literature Data

The literature survey of emissions from tested electronic appliances (sections 2.3 and 2.4) revealed a wide range of substances. As regards the substances for which emissions have been found in the literature – either with a specified concentration or highlighted in the literature as a potentially hazardous substance – CAS numbers have been found, as far as possible. It has then been checked whether the substances in question are included on the list of hazardous substances with a danger symbol and R phrases. Finally, a limit value on the Danish list of limit values (At-list 2000, Ref. 27) has been found, if applicable.

As regards some of the substances, on which information is not included on the At-list, specifications of health-related effects have been retrieved from abroad.

In addition, the score of the substances in question have been checked in the UMP system. The substances appear from Annex B.

In Annex B we have chosen to mark the substance emissions found in the literature having a potential hazardous effect by means of the codes h1, h2, h3, or possibly h4, if it is probable that the substances have chronic, hazardous effects. The codes h1, h2 includes carcinogenic, mutagenic, damaging to the reproductive ability, teratogenic, and sensitizing properties:

h1 = R40,42,45,46,48,49,60-64 proven
h2 = R40,42,45,46,48,49,60-64 suspected
h3 = EU toxicity list (UMP system); U: Unwanted substance or P: Problematic substance
h4 = Other literature sources of potential chronically health-hazardous effect.

In addition to the approx. 70 substances in Annex B found by means of measuring, there is a number of substances in Table 2.10 and Table 2.11 which on the basis of the assessment based on our knowledge of the contents of the electronics products might be emitted from electrical and electronic products.

2.5.3 Screening Results

Table 2.12 shows the number of literature references found that include a substance with the code h1, h2 or h3. The purpose of the table is to give a rough outline of the most frequently found substances.

Table 2.12 Number of literature references found for substances with a possible health effect emitted from electric and electronic equipment.

Substance	Number of literature references
Toluene	13
Xylenes	10
Phenol	8
BHT	7
Styrene	7
Benzene	6
Tetrachlorethene	5
Trichlorethene	5
bis-(2-ethyl)-hexylphthalate	4
Cyclohexanone	4
Dibutyl phthalate	4
Dichloromethane	4
Formaldehyde	4
PCB	4
Naphtalene	3
TCEP	3
Trimethylbenzene	3
Ethylbenzene	2
2-ethoxyethyl acetate	1
3-carene	1
BDE-209	1
Benzophenone	1
Caprolactam	1
Ethylmethylbenzene	1
Methylacrylate	1
N,N-dimetylformamide	1
Trichlorethylene	1
Triphenyl phosphate	1
2-buthoxyethanol	1
Acrylonitrile	1
Ethylhexylpropenoic ester	1
Methylnaphtalene	1

The most frequently found substances are toluene, xylenes, phenol, BHT, styrene, and benzene.

The maximum emitted substance concentrations found in the literature, which are specified in Annex B, have then been assessed from a health protection point of view in the following way:

The measuring results in the literature are specified as emissions (e) measured in µg/unit/hour and therefore depend on the room into which the substances are emitted. A health effect assessment of the concentrations in any given room requires knowledge of the room size and the air change rate in it. As focus is on sensitive groups, the calculations have been made for a small room with a volume (V) = 17.4 m^3 and an air change rate (L) of 0.5 time per hour, corresponding to a small children's room or office measuring 8 m^2. Furthermore, these figures have been used in Ref. 4. The room concentration is calculated as follows on the basis of the measured concentrations:

c_R [µg/m^3] =e [µg/unit/hour] / (V [m^3] * L [$hour^{-1}$])

"In order to be able to carry out a preliminary screening and ranking of the substances as to their effects on health, the factor f_s has been calculated. The calculated f_s does not take into account substances with chronic health effects.

$$f_s = \frac{\text{room concentration}}{\text{work hygiene limit value * safety factor}}$$

No specific limits for emissions to indoor climate are available in connection with the use of consumer products (in this case electronic goods) and there are in such cases no official or guiding limit values to use as guidelines. In the absence of such values it has been decided to make a preliminary assessment of emission of substances to the indoor climate in the proportion 1/100 of the limit values in the working environment. This "safety factor" of 100 in proportion to the working environment has been chosen to take into account the fact that vulnerable groups too may be exposed (children, pregnant women or patients) and that the total exposure, which consists of a complex mixture of substances, may occur over a 24-hour period. The limit value in the working environment is determined on the basis of, in particular, irritation of eyes and respiratory passages (airways) and possibly other health effects but also technical and financial conditions are taken into account.

However, it must be stated that a number of the substances are proven to have or suspected of having chronic effects (e.g. carcinogenic, sensitising) and that a safe lower limit for "no effect" cannot, therefore, be defined. The f_s values calculated for the literature data are specified in Table 2.13.

Table 2.13 Screening for health effects of maximum concentrations of substances emitted from electrical and electronic equipment found in literature survey.

Substance	$f_s = c_R/(g*S)$
Formaldehyde	1.84
Phenol	0.49
Toluene	0.064
Benzene	0.027
Dibutylphthalate	0.021
Acrylonitrile	0.0092
Trichloroethene	0.0062
Diethyl phthalate	0.0061
Naphtalene	0.0053
Triphenyl phosphate	0.0031
PCB	0.0023
Styrene	0.0018
Xylenes	0.0010
Decane	0.00059
Trimethylbenzene	0.00053
Alfa-methylstyrene	0.00031
Ethylbenzene	0.00030
Tetrachlorethene	0.00023

Dichloromethane	0.00015

The only substance that exceeds $f_s = 1$ is formaldehyde – followed by phenol, toluene, benzene and dibutyl phthalate.

The assessment indicated does not take into account substances with chronic hazardous effects for which a "no effect" limit cannot be specified.

Furthermore, it should be noted that certain assessments made abroad recommend the use of indoor limit values for e.g. the total content of organic substances (TVOC) (0.3 mg/m^3 – long-term value, Seifert 1999, Ref. 25 mentioned in Ref. 4) and likewise 0.3 mg/m^3 (Sagunski, 1996, Ref. 26 mentioned in Ref. 4). With the maximum toluene content found in the literature, the value reaches approx. 20 % of the recommended limit value for toluene mentioned above, whereas the maximum amount of TVOC found exceeds the above recommended limit value for TVOC 4.5 times.

A number of other SVOCs, such as plasticizers, phosphate-based flame retardants, and brominated flame retardants, have been found in the literature, and their very low concentration levels are presumed to be safely below the risk factor f_s. It is assumed that such substances will have a tendency to condense on cold surfaces in the appliances after several months of use and subsequently be emitted at higher concentration levels together with dust, which is inhaled, and this may result in chronic health-related effects.

3 Measuring Emissions of Hazardous Substances from Selected Products

3.1 Selection of Products

The following criteria were applied when selecting products:
- Appliances that are used frequently by Danish consumers, including particularly children, pregnant and senior citizens
- Appliance that give off heat and therefore may cause evaporation of hazardous substances

As described in section 2.1 above, relevant products were defined as:
- Computers
- Monitors
- Game consoles
- Audio and video systems
- Chargers and voltage converters

Moreover, in section 2.4 it becomes evident that of all the appliances that have been measured, monitors and TV sets have the highest emission levels, whereas video recorders have lower emission levels.

No measuring data have been identified for powerful, modern game consoles that are very popular with children and youths; similarly, no data have been identified for chargers and voltage converters, which are plentiful in many homes today.

Owing to the limited budget available for the analysing work, a survey was conducted to identify the best selling products of the above-mentioned types before the final prioritising. As it can be seen in section 2.1, there may be many other relevant products that emit hazardous substances.

3.1.1 Monitors

Monitors are used by all age groups and can be found in many households and in most organisations.

The literature survey described in section 2.4.2 shows that monitors represent one of the most significant emission sources for potentially hazardous substances; one of the reasons is that during operation they consume significant levels of energy and therefore give off substantial heat.

In order to select a representative monitor, a large Danish company was contacted and data collected on the three best selling 17” and 19” monitors.

3.1.2 Game Consoles

Today, several game consoles dominate the world market. Children and youths use these products very much, and it is therefore relevant to examine them.

3.1.3 Kids' Toys

In order to identify a product that best represents the group of electrical and electronic kids' toys, a large Danish company was contacted. On the Danish market, the best selling product in the category of electrical and electronic toys – apart from the above-mentioned game consoles – was a keyboard. A keyboard consumes a low level of power, and therefore it was prioritized somewhat lower than the other products.

3.1.4 Lighting

Power converters for halogen lamps (using traditional transformers) become very hot and are very often low-cost products manufactured in the Far East. It was decided that this product group was relevant for examination. In order to identify products that sell well, 2 large companies were contacted.

3.1.5 TV Sets

As described in section 2.4.1, TV sets are one of the most significant sources of emission of potentially hazardous substances. It was therefore decided that it would be relevant to test one of the best selling products. Again, one of Denmark's biggest suppliers was helpful with data on products that currently sell in large volumes and therefore may be relevant for this study. Data have been collected on the four best selling 28" TV sets.

3.1.6 Final Selection and Purchase of Products

Following consultations with the Danish Environmental Protection Agency, the following four products were bought and subsequently tested:

- One of the best selling monitors
- One of the best selling 28" TV sets
- One of the best selling game consoles
- Five voltage converters (using traditional transformers) for halogen lamps (two from one manufacturer, and three from a different manufacturer)

The appliances were bought in Denmark in the week ending 22nd September, 2002.

3.2 Methods Used When Measuring Emissions of Substances From Electrical and Electronic Appliances

3.2.1 Field Measurement

Concentrations can be measured directly in the room where emissions are generated. However, it may be difficult to identify the emission sources when performing the measurements; a host of other sources may emit substances such as furniture, paints, printed matter, etc. Add to this that air flow, temperature, air humidity, etc. may vary.

3.2.2 Test Chamber Measurement

There is general agreement that test chamber (climatic chamber) measurement produces the best results because all parameters such a temperature, air quality, air humidity, air change, etc. can be controlled. A test chamber may be a minor chamber (300-1000 litres) or a climatic chamber that allows the testing of the impact of emitted substances on test persons (Cf. Ref. 8). Figure 1 shows a sample test chamber setup.

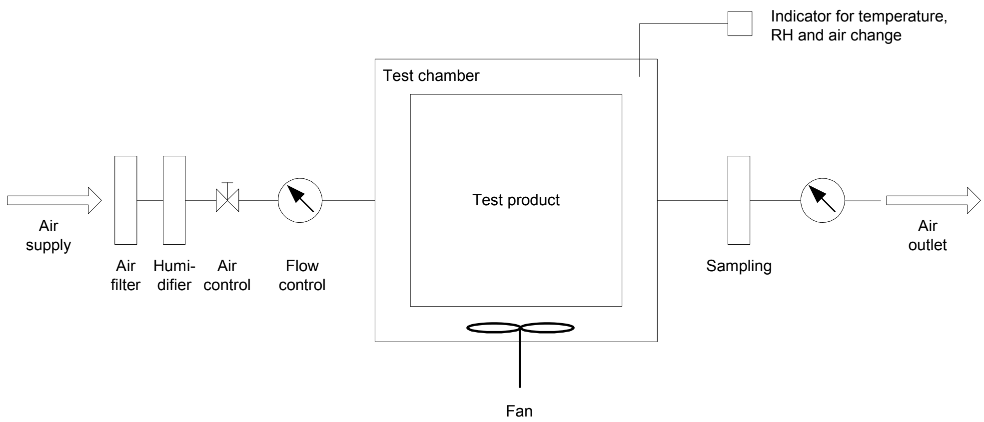

Figure 1 Example of a test chamber setup.

3.2.3 Standards for Measurements

Standards for test chambers are described in ENV 13419-1 (1999).

Standards for measurement of emissions of VOCs from electronic equipment are described in Ref. 19. These standards specify that the temperature should be kept at 23 ± 2 °C, air humidity at 50 ± 5 %, and that the air change rate should be 0.5 - 2 times per hour.

3.3 Climatic Chamber Measurements

3.3.1 Experimental Investigations

The largest appliance subjected to testing was a 28" TV set, which was tested in a 1 m^3 climatic chamber. Monitors, converters, and games consoles were tested in 320 litre chambers measuring 70*70*65 cm. The chambers are shown in Figure 2.

The TV set was fitted with an aerial cable and set to receive a TV signal. Since the TV set switches to standby mode after a certain period without a TV signal, it was only possible to operate the TV set from 7.30 in the morning on workdays and until the Danish Broadcast Corporation ends its signal around midnight. The tested TV set was in operation from 7.30 in the morning until late at night as indicated in Table 3.1.

Throughout the testing period, the monitor was switched on, showed the same screen picture, and had all economy features switched off. The monitor was hooked up to a used portable computer that was minimum four years old.

The game console was fitted with a 220V flex, a control cable, and a cable for the joystick. The game console was hooked up to a TV set that was placed outside the climatic chamber. The game console was kept operating by playing a DVD film with a playing time of 3 hours. The film was restarted three times every working day, and thus is was kept active from 7.30 am until around 6 pm every work day.

Figure 2 Climatic chambers: one 1 m^3 chamber to the right and several 320 litre chambers to the left

The converters were fitted with a 220V flex, 2 plug boxes, and 10 low-voltage cables (about 25 cm each) for the halogen lamps that were placed outside the chamber as shown in Figure 3. The converters were operating continuously throughout the testing period.

All other testing conditions appear in Table 3.1.

Table 3.1 Test conditions.

Test item	Temp.°C	Air humidity % RH	Air exchange rate n^{-1}	Period of operation
TV set	26-27	35	0.5	7.30 am until 11 pm on work days
Monitor	33	25	0.5	100%
Game console	26	35	0.5	7.30 am until 6 pm on work days
Converters	27-28	33	0.5	100%

Note: The air humidity does not comply with the prescribed 50 % RH, and the temperature is slightly higher for the monitor because of its significant heat production. These deviations for air humidity and temperature cause deviations in test volumes and hence certain concentrations that do not exceed 3-4 %. A higher temperature of 10 °C does not normally change diffusion coefficients by a factor larger than 2, and therefore the concentration deviations are expected to stay below this level.

Figure 3 Setup of halogen lamps

Prior to testing the appliances in the test chambers, blank tests were conducted on each individual climatic chamber with TENAX tubes and under operating conditions similar to those used for the testing of appliances.

The blank tests included the following equipment which is required for the operation of the appliances:

TV set	:	Power flex
Monitor	:	Older, portable PC, plug box, 30 cm cable
Game console	:	Cables and flexes for power supply, joystick, TV set, and data-logger
Converters	:	Flex, 2 plug boxes, and bits of cable connecting the lights to the converters

On the following day the appliances were switched on, and the chambers were left to acclimatize for seven hours in order to establish equilibrium before samples were taken on TENAX tubes collecting VOCs, and DNPH tubes identifying aldehydes and ketones.

The DNPH tubes are C18 polymers coated with 2,4-dinitrophenylhydrazine.

A flow of 1 litre/minute was applied when sampling by means of DNPH tubes.

A flow of 80 ml/minute was applied when sampling by means of two TENAX tubes; two different sampling periods were used in order to achieve optimum sensitivity in the detection of emitted substances from the appliances (test volumes varied from approx. 1-5 litres per tube).

Subsequent to this, the appliances were left as described under test conditions as specified in Table 3.1, and after 9 days air samples were collected on TENAX and DNPH tubes. Samples were also collected on XAD-2 tubes with a flow of 1 litre/minute. These tubes offer a larger capacity than the TENAX tubes, and therefore it is possible to obtain higher concentrations of low-volatility substances. The higher capacity means that it is possible to process much larger air volumes than on the TENAX tubes (approx. 1000 l air).

Tests for aldehydes and ketones were performed by means of elution with acetonitrile and analysis on HPLC with UV detection with a measuring uncertainty of 5-10 % and a detection limit of 30 ng per DNPH tube. Tests were performed for the following substances: formaldehyde, acetaldehyde, acrolein, propanal, acetone, butanal, pentanal, hexanal, and benzaldehyde. With typical processed volumes of 30 litres of air and an air exchange rate of 0.5 times per hour at this detection limit, tests may be as precise as down to 0.5 µg emitted substance per device per hour.

Tests for other volatile substances from the TENAX tubes were performed by means of thermal desorption on the TENAX tubes and testing with GC/MS after addition of internal standards. The tolerance on this test is approx. 10 %. The detection limit depends on the substances tested for, but typically it will be around 2-10 ng. By typically processed volumes of 2 litres of air and an air change rate of 0.5 times per hour, the detection limit is such that best cases will provide results down to 0.5 µg emitted substance per appliance per hour.

Tests for volatile substances from the XAD-2 tubes were performed by means of extraction in dichloromethane with added deuterium-marked standards with subsequent GC/MS testing. Once again, the detection limit for the GC/MS tests depends on the substances in question, but typically it will be as low as 100-500 ng. By typically processed volumes of 1000 litres of air and an air change rate of 0.5 times per hour, the detection limit is such that best cases will provide results down to 0.05 µg emitted substance per appliance per hour.

The uncertainty is approx. 10% for GC/MS measurements.

3.3.2 Results

The chromatograms from the TENAX, DNPD, and XAD-2 tubes identify a large number of substances. The first priority of the test work was the identification and quantification of the substances with the largest concentrations. Next, a specific search for a number of hazardous substances that may exist according to the literature was performed.

The substances include:

Plastisizers
- DBP (dibutyl phthalate)
- DEHP (bis-(2-ethyl)-hexylphthalate) and others

Tin-based flame retardants
- TPP (triphenyl phosphate)
- TCEP (tri-2-chlorethyl)-phosphate

Brominated flame retardants
- Tetrabromobisphenol A, BDE-209

The lower the substances' volatility level, the harder it is to identify them. It must be noted that the least volatile substances may condense on cold parts within the appliances, including in dust deposited in TV sets, and after some time they may be emitted with the dust in a condensed form. Exact measuring of emissions of such substances necessitates the construction of condenser units for the measuring of the condensed amount of substances (cf. section 2.4.1.1), and this has not been possible within the time horizon and budget of this project.

Table 3.2-Table 3.5 show test results for TV sets, monitors, game consoles, and voltage converters for halogen lamps.

In annex D, the measured emissions are recalculated to room concentrations for a room with volume = 17,4m^3 and air exchange rate = 0,5 $time^{-1}$.

The following tables show identified substances that have been quantified. The substances appear with CAS numbers, indication of potential chronic health hazards (h1-h4, see section 2.5.2) and the key R-phrase if the substances are labelled R 40, 42, 45, 46, 48, 49 or 60-64.

Table 3.2 Emissions from TV set.

Substance	CAS no.	Health effect code	Measured emission (µg/unit/h), After 7 hours	Measured emission (µg/unit/h), After 9 days
Phenol	108-95-2	h3	22	26
Toluene	108-88-3	h2	17	19
o-xylene+styrene	0	h4	13	12
2-(2-ethoxyethoxy)ethanol (diethylenglucol-monobutyl ether)	111-90-0		8	12
2-ethylhexanol	104-76-7		6	4
Nonanal	124-19-6		5	5
Butanol	71-36-3		5	5
Propionic acid	79-09-4		5	5
m-,p-xylene	1330-20-7		3	5
Benzene	71-43-2	h1,R45	2	5
Decanal/alcohol	12-31-2/2425-77-6		4	3
1-methyl-2-pyrrolidinon	872-50-4		3	3
3-carene	13466-78-9	h4	3	2
Ethylbenzene	100-41-4	h2	2	3
Formaldehyde	50-00-0	h1, R40,R43	3	2
Acetaldehyde	75-07-0	h1,R40	2	3
Acetone	67-64-1		0	4
2-propenoic acid methyl metacrylate	80-62-6		1	3
benzaldehyde	100-52-7		2	1
BHT – Butylhydroxytoluene	128-37-0	h4	1	2
Butanal	123-72-8		2	1
Acetophenone	98-86-2		2	1
2-buthoxyethanol	111-76-2	h3	1	1
Pentanal	110-62-3		1	0
Hexanal	66-25-1		< 1	1
A-pinen	80-56-8		1	< 1
4-hydroxy-4methyl-2-pentanon	123-42-2		< 1	0
1-ethyl-2-methylcyclohexane	3728-54-9		< 1	< 1

h1 = R40,42,45,46,48,49,60-64 proven
h2 = R40,42,45,46,48,49,60-64 suspected
h3 = EU toxicity list (UMP system); U: Unwanted substance, or P: Problematic substance
h4 = Other literature source for potentially chronic health effects

Table 3.3 Emissions from monitor.

Substance	CAS no.	Health effect code	Measured emission (µg/unit/h), After 7 hours	Measured emission (µg/unit/h), After 9 days
Trimethylbenzene [1]	95-63-6	h3	409	107
Toluene [1]	108-88-3	h2	333	139.5
Phenol+trimethylbenzene [1]	Compound		197	162.5
A-pinen [1]	80-56-8		223	43
2-ethyl-1-hexanol/nonanol [1]	104-76-7		172	84.5
Butanol [1]	71-36-3		136	61.5
o-xylene+styrene [1]	Compound	h4	129	35.5
2-methyl-1-propanol [1]	78-83-1		76	40
m-,p-xylene [1]	1330-20-7		82	33
C15H24 [1]	25246-27-9		57	21
Formaldehyde	50-00-0	h1, R40,R43	26	24
Ethylbenzene [1]	100-41-4	h2	33	14
Ethanol,2-2(buthoxyethoxyacetate) [1]	124-17-4		32	14
2-methyl-phenol (cresol) [1]	95-48-7		26	18
2-butyl-1-octanol [1]	3913-02-8		27	8.5
3-carene [1]	13466-78-9	h4	30	5
Acetophenon [1]	98-86-2		20	12.5
Acetone	67-64-1		14	9
Benzaldehyde	100-52-7		14	7
Acetaldehyde	75-07-0	h1,R40	9	11
Butanal	123-72-8		11	8
Tetramethylbenzene [1]	25619-60-7		14	5
Pentanal	110-62-3		18	0
2-buthoxyethanol [1]	111-76-2	h3	14	3
BHT – Butylhydroxytoluene [1]	128-37-0	h4	9	7
Benzene [1]	71-43-2	h1,R45	7	6.5
1-methoxy-2-propanol [1]	107-98-2		13	0
Hexanal	66-25-1		6	4
Cyclohexanone [1]	108-94-1	h2	6	3
2-hexyl-1-decanol [1]	2425-77-6		6	3
Butylacetate [1]	123-86-4		7	0
Octanal [1]	124-13-0		3	3
2,4-nonadien [1]	821-74-9		4	2
1,3-diazin/pyrazin [1]	68-35-9	h4	3	1.5
Propanol	123-38-6		2	1

[1] TENAX tubes slightly over-saturated. The given emissions are minimum emissions. The discrepancy is estimated to be lower than a factor of 2.

Table 3.4 Emissions from game console.

Substance	CAS no.	Health effect code	Measured emission (µg/unit/h), After 7 hours	Measured emission (µg/unit/h), After 9 days
SUM C11-c18	Group		308	21
Styren	100-42-5	h4 (metab)	16	2
Phenol	108-95-2	h3	13	4
2-ethylhexanol	104-76-7		11	0
Formaldehyde	50-00-0	h1, R40	7	4
Acetone	67-64-1		3	3
Acetophenone	98-86-2		6	0
o-xylene	1330-20-7		6	0
Trimethylbenzene	95-63-6	h3	5	0
A-pinen	80-56-8		5	0
Toluene	108-88-3	h2	2	2
Acetaldehyde	75-07-0	h1,R40	2	2
Hexanal	66-25-1		2	2
2-methyl-1-propanol	78-83-1		1	1
3-carene	13466-78-9	h4	1	0
Benzaldehyde	100-52-7		< 1	< 1
Nonanal	124-19-6		4	< 1
Propanal	123-38-6		< 1	0
Pentanal	110-62-3		< 1	0
Octanal	124-13-0		< 1	< 1

Table 3.5 Emissions from voltage converters (using traditional transformers).

Substance	CAS no.	Health effect code	Measured emission (µg/unit/h), After 7 hours *	Measured emission (µg/unit/h), After 9 days *
Toluene [1]	108-88-3	h2	307	128.6
SUM C11-c18 [1]	Group		223.4	199.6
Trimethylbenzene [1]	95-63-6	h3	179.6	114.6
m-,p-xylene [1]	1330-20-7		156	93.6
Ethylbenzene [1]	100-41-4	h2	139	74
2-methyl-1-propanol [1]	78-83-1		92.6	55.4
Formaldehyde	50-00-0	h1, R 40	97	37.6
o-xylene [1]	1330-20-7		67	38.2
2-pentylfurane [1]	3777-69-3	h4	61	30.6
2-ethylhexanol [1]	104-76-7		52.6	33.8
2-buthoxyethanol [1]	111-76-2	h3	33.6	31
Phenol [1]	108-95-2	h3	0	36.8
Hexanal	66-25-1		18.4	5.2
Tetramethylbenzene [1]	25619-60-7		12.6	6.6
Acetaldehyde	75-07-0	h1, R 40	10.2	4.4
Decanal/alcohol [1]	12-31-2/2425-77-6		8.6	4.4
BHT – Butylhydroxytoluene [1]	128-37-0	h4	3	6.8
Cyclohexanone [1]	108-94-1	h2	6	2.4
Formic acid, butylester [1]	592-84-7		4.8	3.6
Butanal	123-72-8		5.2	1.6
2-ethylhexanoic acid [1]	149-57-5	h1, R 63	3	3.8
Pentanal	110-62-3		4.6	1.8
Formic acid, 2-methylester [1]	542-55-2		4.2	2.2
Alcohol [1]	19781-13-6		3	2.8
Acetophenon [1]	98-86-2		3.8	1.6
Acetone	67-64-1		3.6	1.2
2-hydroxybenzenethanol [1]	7768-28-7		1.4	3.2
A-pinen [1]	80-56-8		3.4	0.6
Propanal	123-38-6		3	0.8
Butylacetat [1]	123-86-4		2.4	1.2
3-methylbutanal/pentanal	590-86-3/110-62-3		2	1.4
Chlorobenzene [1]	108-90-7		1.6	1.6
Octanal [1]	124-13-0		1.2	1.4
Benzaldehyde	100-52-7		0.6	0.6

* Values are for one converter; the values have been obtained by dividing the emissions from the five tested converters by 5.
[1] TENAX tubes are somewhat over-saturated because of unexpectedly high emissions; this can be seen from the test results from tubes with the two different test sampling volumes used. The listet emissions are minimum emissions.

The largest emissions from the TV set consist of phenol and toluene.

The largest emissions from the monitor are trimethylbenzene, followed by toluene and phenol; phenol could not be fully separated from trimethylbenzene in the chromatogram.

According to the surveyed literature, the popular state-of-the-art game consoles have not previously been tested for emission of potentially hazardous substances.

The largest emissions from the game console are C11-C18 compounds, followed by styrene and phenol.

According to the surveyed literature, converters for halogen lamps and, moreover, standard household electronics have not previously been tested for emissions of potentially hazardous substances.

The tested converters which is based on traditional transformers emit unexpectedly large emissions – primarily toluene, C11-C18 compounds, trimethylbenzene, and xylene.

Formaldehyde emissions from a single voltage converter is larger than all other emissions of this substance as established through literature surveys on all types of electronic devices. Moreover, emissions of toluene from a voltage converter reach the same level as emissions from a monitor, although it is much smaller in size.

In addition to the substances listed in the tables, the tests also covered a large number of substances captured on XAD-2 tubes, including phthalates. The sensitivity on the XAD-2 measurements is vastly larger than on TENAX tubes; however, some of the identified substances – including some phthalates – are clearly attributable to background levels (contamination) since the measured concentrations are almost identical for each of the four tests, and these test results have therefore been excluded. It is believed that the test results from the tubes can be improved significantly by creating optimized test conditions.

The XAD-2 tests show two types of phthalates that vary significantly for different devices. Concentrations are largest for the TV set and the five converters, whereas they are somewhat lover for the monitor and the game console. Similarly, the two phthalates were subsequently identified on TENAX tubes, but not far from the detection limit for this type of test. When comparing the test results from nine days with the seven-hour test and the blank test (0 hours), it becomes clear that there is an increase in concentrations in some of the tests. The cause of this increase in concentrations over time may be that the test specimen becomes hot, causing the phthalates to diffuse to the surface of the plastics before they are emitted after a while. It is expected that after a period of time, the concentrations will decrease again as sufficient levels of phthalates have diffused.

The level at which concentrations of less-volatile substances such as phthalates and flame retardants reach a maximum is expected to depend on the plastics that the substances form part of as well as the heat that the plastics are subjected to. Highly volatile substances (VOCs) reach their concentration maximum within the first 24 hours (after approx. 6 hours), whereas some less-volatile substances such as certain phosphate-based flame retardants reach this maximum much later (after several months, see section 2.4.1.1). In addition, the concentration levels of the substances with a very low volatility will decrease at a slower rate when the maximum concentration has been reached. This is due to the slower rate of diffusion in the plastics material that they form a part of.

Reservations must be made as regards the following quantification of the concentration levels of the phthalates measured: Dibutyl phthalate is presumed to be emitted at a rate of approx. 0.5-5 µg/appliance/hour from the TV set and the monitor and at a rate of 0.1-1 µg/appliance/hour from the game console and the converter. In addition, another type of phthalate is emitted at somewhat lower concentration levels.

The measurements of the substance emissions from the TV set can be compared with the measurements indicated in Table 2.5. Comparable levels of benzene, toluene, xylene and styrene totals, phenol, 2-butoxyethanol, and formaldehyde have been found. Furthermore, the estimated dibutyl phthalate level is in the same range.

Much higher VOC emissions have been detected from the monitor and the converters than the TV set. The emissions decrease after a certain period of time – normally after approx. 6 hours for VOCs. As regards the monitor, the toluene emission amounts to 333 µg/unit/hour. This is a mid-range value compared with the interval for toluene emissions measured from 19 monitors (64-1045 µg/unit/hour) (see section 2.4.2).

3.4 Health Effect Screening of Substances Found When Measuring

For each substance found, CAS numbers as well as health effect information and limit values have been found as far as possible. If no Danish information has been available, the limit values and health risks have been estimated on the basis of related substances by searching in TOX databases (**Ref. 23**).

Health effect data and assessments for the substances identified in the measurements on the selected equipment are shown in Annex C.

Table 3.6 lists some of the substances found, which have either proven or suspected chronic health-damaging effects.

Table 3.6 Identified substances with chronic health effects.

Substance	Health effect	TV	Monitor	Game-Console	Trans-formers
Benzene	Carcinogenic (R 45)	x	x		
Formaldehyde	Carc. (R 40), sensitizing	x	x	x	x
Acetaldehyde	Carcinogenic (R 40)	x	x	x	x
3-carene	Suspected sensitizing	x	x	x	
Butylhydroxytoluene (BHT)	Suspected sensitizing	x	x		x
Styrene	Metabolits are genotoxic	x	x	x	
Ethylbenzene	Suspected teratogenic	x	x		x
2-ethylhexanoic acid	Effects on reproducibility				x
Cyclohexanone	Suspected carcinogenic		x		x
Dibutyl phthalate	Suspected effects on reproducibility	x	x	x	x

The test results are given as measured emissions (e) in µg per unit per hour, converted into room concentration level c_R with the same room volume and air change rate as specified in section 2.5.3 ($V = 17.4 m^3$, air change = 0.5 $hour^{-1}$).

Similarly, the health effect risk factor $f_s = c_R/(g*S)$ has been obtained as specified in section 2.5.3, S being equal to 100.

The results appear in Table 3.7-Table 3.10.

Table 3.7 TV set. Screening of health effect.

Substance	CAS no.	Comm.	f_s, 7 hours	f_s, 9 days
Formaldehyde	50-00-0	R40,R43	0.09	0.06
Phenol	108-95-2		0.063	0.075
Benzene	71-43-2	R45	0.014	0.036
2-(2-ethoxyethoxy)ethanol (diethylenglucol-monobutyl ether)	111-90-0	est.	0.0084	0.013
Toluene	108-88-3		0.0021	0.0023
Propionic acid	79-09-4		0.0019	0.0019
BHT – Butylhydroxytoluene	128-37-0		0.0011	0.0023
1-methyl-2-pyrrolidinon	872-50-4		0.0017	0.0017
o-xylene+styrene	Compound		0.0014	0.0013
Acetaldehyde	75-07-0	R40	0.00051	0.00077
m-,p-xylene	1330-20-7		0.00032	0.00053
Butanol	71-36-3		0.00038	0.00038
Acetophenone	98-86-2		0.00047	0.00023
2-propenoic acid methyl metacrylate	80-62-6		0.00011	0.00034
Decanal/alcohol	12-31-2 / 2425-77-6	est.	0.00015	0.00011
Ethylbenzene	100-41-4		0.00011	0.00016
2-buthoxyethanol	111-76-2		0.00012	0.00012
Acetone	67-64-1		0	7,7E-05
Pentanal	110-62-3		6,6E-05	0

The abbreviation "est." indicates that the limit value, which is used to obtain f_s, is estimated.

For the TV set, the maximum health effect risk factor for formaldehyde is f_s = 0.09. Next follows phenol and benzene. The sum of calculated values are f_s=0.18. With the applied safety factors, a potential health effect cannot be established. However, it must be noted that some of the substances have been proven to be carcinogenic, are suspected to be carcinogenic, or have a sensitizing effect, etc., and therefore a safe lower limit for "no effect" cannot be established.

Table 3.8 Monitor. Screening of health effect.

Substance	CAS no.	Comm.	f_s, 7 hours	f_s, 9 days
Formaldehyde	50-00-0	R40,R43	0.75	0.69
Phenol+trimethylbenzene	Mixture	Est.	0.23	0.19
Benzene	71-43-2	R45	0.050	0.047
Toluene	108-88-3		0.041	0.017
Trimethylbenzene	95-63-6		0.039	0.010
2-methyl-phenol (cresol)	95-48-7		0.014	0.0094
A-pinen	80-56-8	est.	0.018	0.0035
BHT - Butylhydroxytoluene	128-37-0		0.010	0.0080
o-xylene+styrene	Mixture		0.014	0.0039
Butanol	71-36-3		0.010	0.0047
m-,p-xylene	1330-20-7		0.0086	0.0035
2-methyl-1-propanol	78-83-1		0.0058	0.0031
Acetophenone	98-86-2		0.0047	0.0029
2-ethyl-1-hexanol/nonanol	104-76-7	est.	0.0040	0.0019
Acetaldehyde	75-07-0	R40	0.0023	0.0028
Ethanol,2-2(buthoxyethoxyacetate)	124-17-4	est.	0.0028	0.0012
Cyclohexanone	108-94-1		0.0017	0.00086
Ethylbenzene	100-41-4		0.0017	0.00074
2-butyl-1-octanol	735273	est.	0.0016	0.00049
2-buthoxyethanol	111-76-2		0.0016	0.00035
Tetramethylbenzene	25619-60-7	est.	0.0013	0.00048
Pentanal	110-62-3		0.0012	0
1-methoxy-2-propanol	107-98-2		0.00081	0
2-hexyl-1-decanol	2425-77-6	est.	0.00034	0.00017
Acetone	67-64-1		0.00027	0.00017
Hexanal	66-25-1	est.	0.00023	0.00015
Propanal	123-38-6	est.	0.00023	0.00011
Butylacetate	123-86-4		0.00011	0
2,4-nonadien	821-74-9	est.	2,2E-05	1,1E-05

For the monitor, the highest health effect risk factor is also formaldehyde with f_s=0.75. Next follow phenol that cannot be fully separated from trimethylbenzene in the chromatogram and then benzene with f_s=0.05. The sum of calculated values are f_s=1.2. With the applied safety factors, a potential health problem can therefore not be established for a single substance. However, it must be noted that some of the substances have been proven to be carcinogenic, are suspected to be carcinogenic, or have a sensitizing effect, etc., and therefore a safe lower limit for "no effect" cannot be established.

Table 3.9 Game console. Screening of health effect.

Substance	CAS no.	Comm.	f_s, 7 hours	f_s, 9 days
Formaldehyde	50-00-0	R40,R43	0.2	0.11
Phenol	108-95-2		0.037	0.011
o-xylene	1330-20-7		0.0055	0
Styrene	100-42-5		0.0018	0.00022
Acetophenone	98-86-2		0.0014	0
Acetaldehyde	75-07-0	R40	0.00051	0.00051
Toluene	108-88-3		0.00024	0.00024
Trimethylbenzene	95-63-6		0.00048	0
A-pinen	80-56-8	est.	0.00041	0
Hexanal	66-25-1	est.	7,7E-05	7,7E-05
2-methyl-1-propanol	78-83-1		7,7E-05	7,7E-05
Acetone	67-64-1		5,7E-05	5,7E-05

For the game console, the highest health effect risk factor is also formaldehyde with f_s=0.2. The next substance is once again phenol. The sum of calculated values are f_s=0.24. With the applied safety factors, a potential health problem can therefore not be established. However, it must be noted that some of the substances have been proven to be carcinogenic, are suspected to be carcinogenic, or have a sensitizing effect, etc., and therefore a safe lower limit for “no effect” cannot be established.

Table 3.10 Voltage converter. Screening of health effect.

Substance	CAS no.	Comm.	f_s, 7 hours	f_s, 9 days
Formaldehyde	50-00-0	R 40, R 43	2.8	1.1
Phenol	108-95-2		0	0.11
2-pentylfuran	3777-69-3	est.	0.070	0.035
Toluene	108-88-3		0.038	0.016
Trimethylbenzene	95-63-6		0.017	0.011
m-,p-xylene	1330-20-7		0.016	0.0099
2-methyl-1-propanol	78-83-1		0.0071	0.0042
Ethylbenzene	100-41-4		0.0074	0.0039
BHT - Butylhydroxytoluene	128-37-0		0.0034	0.0078
o-xylene	1330-20-7		0.0071	0.0040
2-buthoxyethanol	111-76-2		0.0039	0.0036
2-hydroxybenzenethanol	7768-28-7	est.	0.0016	0.0037
Acetaldehyde	75-07-0	R 40	0.0026	0.0011
Cyclohexanone	108-94-1		0.0017	0.00069
Tetramethylbenzene	25619-60-7	est.	0.0012	0.00063
Acetophenon	98-86-2		0.00089	0.00038
Hexanal	66-25-1	est.	0.00070	0.00020
Chlorobenzene	108-90-7		0.00040	0.00040
2-ethylhexane acid	149-57-5	est.	0.00034	0.00044
Decanal/alcohol	12-31-2/2425-77-6	est.	0.00033	0.00017
Propanal	123-38-6	est.	0.00034	9,2E-05
Pentanal	110-62-3		0.00030	0.00012
A-pinen	80-56-8	est.	0.00028	4,9E-05
Acetone	67-64-1		6,9E-05	2,3E-05
Butylacetate	123-86-4		3,9E-05	1,9E-05

For the converters, the highest health effect risk factor obtained for one converter is once again formaldehyde, but with f_s = 2.8. Next comes phenol, 2-pentylfuran and toluene. The sum of calculated values are f_s = 3.

Therefore, the conclusion is that the assessment shows a potential health problem, based on the performed tests and the assumed risk factors.

Add to this that some of the substances emitted are suspected of having or proven to have chronic effects.

It is not unusual to use 3-5 converters because typically a lamp comes with its own converter, and therefore there is a potential risk of reaching $f_s = 15$, or 15 % of the work hygienic limit value for formaldehyde in a work situation.

In this context it must be noted that there are a number of other formaldehyde sources in the households, including chipboard furniture and similar.

It must be remembered that the concentrations of formaldehyde and other VOCs declines over time. The tests seem to indicate a halving time of approx. 6-12 days. Based on this assumption, 5 converters will deliver $f_s = 1$ after approx. 1-2 months. However, as mentioned above the substances may still have chronic effects, even with $f_s < 1$.

4 References

Ref. 1 Wensing, M., Determination of Organic Chemical Emissions from Electronic Devices, Raw G., Aizlewood C. and Warren O. (eds) Proceedings of the 8th International Conference on Indoor Air and Climate, Edinburgh, UK, Vol.5, pp. 87-92, 1999

Ref. 2 Wensing, M. Handbook für Bioklima und Lufthygieine -5. erg Lfg. 4/ 2001 chapter III-4.4.6 Emissionen elektonischer Geräte

Ref. 3 Salthammer, T., Uhde, E., Wensing, M., Bestimmung von SVOC in Prüfkammern - Flammschutzmittel und Weichmacher KRdL im VDI und DIN (2002): Neuere Entwicklungen bei der Messung und Beurteilung der Luftqualität, VDI-Berichte Nr. 1656, VDI-Verlag, Düsseldorf

Ref. 4 Wensing, M., Kummer, T., Riemann, A., Schwampe, W., Emissions from Electronic Devices: Examinations of Computer Monitors and Laser Printers in a 1 m^3 Emission Test Champer, Accepted for Publication Indoor Conference 2002

Ref. 5 Brown, S. K., Assessment of Pollutant Emissions from Dry-Process Photocopiers, Indoor Air, 9, 259-267

Ref. 6 Ball, M., Päpke, O. und Lis, A., Weiterführende Untersuchung zur Bildung von polybrominierten Dioxinen und Furanen …Umweltforschungsplan des Bundesministers für Umwelt, Naturschutz und Reaktorsicherheit, Forschungsbericht 104 03 365/01 (1991)

Ref. 7 Braungart, M., Bujanoski, A., Schäding, J., Sinn, C., Poor design-gaseous emissions from Complex Products. Hamburger Umweltinstitut e.V., Project Report, Hamburg (1997)

Ref. 8 Bakó-Biró, Zs, Wagocki, P., Weschler, C., Fanger, Ole, P. Personal Computers pollute indoor Air: Effects on Perceived Air Quality, SBS Symptoms and Productivity in Offices: Proceedings: Indoor Air 2002 pp. 249-254

Ref. 9 Corsi R.L., Grabbs, J., VOC emissions from packaged and active computers. Poster Annual meeting of the international society for exposureanalysis 2000, Monterey, CA, 2000

Ref. 10 Black M. S., Worthan, A. W., Emissions from office equipment. Proceedings Indoor Air 1999, vol.2, pp. 454-459

Ref. 11 Brooks B. O., Utter G. M., DeBroy, J. A., Davis, W.F., Schimke, R. D., Chemical emissions from electronic products. Proceeedings of IEEE Int. Symp on Electronics and Environment 1993, pp 120-125, Arlington VA: 1993

Ref. 12 Carlsson, H., Nilsson, U., Östman, C., Video display units An emission source of the contact allergic flame retardant triphenyl phosphate in the indoor environment. Environmental Science and Technology Vol 34 (18) pp. 3885-3889

Ref. 13 Pardemann, J., Salthammer, T., Uhde, E., Wensing, M., Flame retardants in the indoor environment. Part 1: Specification of the problem and results of screening tests. Proceedings of Healthy buildings 2000, Helsinki, Finland Vol. 4, pp. 125-130

Ref. 14 Salthammer, T. ,Wensing, M., Flame retardants in the indoor environment. Part IV

Ref. 15 Sjödin A., Carlsson, H., Thuresson, K., Sjolin, S., Bergman, A., Ostman, C., Flame retardants in indoor air at an electronics recycling plant and other work environments

Ref. 16 Wargocki P., Wyon, D. P., Baik, Y. K., Clausen G., Fanger, P. O., Perceived Air quality … Indoor Air Vol. 9, pp 165-179, 1999

Ref. 17 EPA Personal Computer Monitors: A screening evaluation of volatile organic emissions from existing printed circuit board laminates and potential pollution prevention alternatives EPA-600/R-98-034 April 1998

Ref. 18 Funaki, R., Nakagawa, T., Tanaka, H., Tanake, S., Measurements of Aldehydes and VOC Emission Rate by Using a Small-scale Champer, Proc. of annual meeting of architechtural institute of Japan 2002

Ref. 19 Standard ECMA-238 Detection and measurement of chemical emissions from electronic equipment, August 2001

Ref. 20 T. Otake, J. Yoshinaga and Yukio Yanagishawa, Analysis of Organic Esters of Plasticizer in Indoor Air by GC-MS and GC-FPD Environ. Sci. Technol. 2001, 35, 3099-3102

Ref. 21 Brominated flame retardants, Danish Environmental Agency, 1999

Ref. 22 Burkhard, C., Chemical emissions from office-equipment, IVF research publication 99826, 1999

Ref. 23 Lookup in the databases National Library of Medicine with the databases Hazardous Substance Data Bank (HSDB) and Toxline which can be found on TOXNET (http://toxnet.nlm.nih.gov/)

Ref. 24 Environmental project no. 381, 1998 which corresponds to EU's criteria of classification for chemicals dir 67/548/EEC incl. 26. adaptation

Ref. 25 B. Seifert, Richtwerte für die Innenraumluft: Die Beurteilung der Innenraumluft mit hilfe der Summe der flüchtigen organischen Verbindungen (TVOC-Wert). Bundesgesundhbl.,42,270-278, 1999.

Ref. 26 H: Sagunski, Richtwerte für die Innenraumluft: Toluol, Bundesgesundhbl.; 39, 416-421, 1996.

Ref. 27 Guidance no. C.0.1 from the Danish National Working Environment Authority "Limit values for substances and materials", oct.2000.

Ref. 28 Guidance no. A.1.2 from the Danish National Working Environment Authority "Indoor Climate"

Ref. 29 Groshart, Okkerman EUROPEAN COMMISSION DG ENV, Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption, Preparation of a candidate list of substances as a basis for priority setting nov.2000.

Ref. 30 Risk assessment for dibutylphthalate ECB june 2001 (ecb.jac.it)

Ref. 31 Canadian Environmental Protection Act, Priority Substances List, Assessment Report, Dibutyl Phthalate, 1994.

Ref. 32 European Commision Risk evaluation report on Naphtalene draft oct. 2001

Ref. 33 European Commision Risk evaluation report on Toluene draft july. 2001

Ref. OW1
Blum, B.; Schadstoffe in elektrischen und elektronischen Geräten, Emissionsquellen, Toxikologie, Entsorgung und Verwertung, 1996. Isbn 3-540-60966-0 springer-verlag, berlin

Ref. OW2
PC-tool "A designer's Guide to Eco-Conscious Design of Electrical and Electronic Equipment".version 1.1. This tool includes a database with information on chemical substances in electronic components and materials which is typically used in electrical and electronic products.

Ref. OW3
Willum, O. (2001), List of 383 substances relevant to electronics and considered to be of specific concern by leading manufacturers of electrical- and electronic equipment (www.greenpack.org).

Ref. OW4
Pedersen, L. B. (2001) Plastics and Environment, Ingeniøren/Bøger, Copenhagen, ISBN 87-571-2396-9

Ref. OW5
Jensen, B., A. Schmidt; P. Wolkoff (1989) Plastbase, A database of air pollution in the plastics industry and their health effects, Arbejdsmiljøfondet, Copenhagen, ISBN 87-7359-410-5

ANNEX A

Literature Survey for Substances which may be emitted from Electric and Electronic Equipment

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
2,3',4'-Tribromodiphenyl ether	49690-94-0	Flameretardants			x													
1,2-Dichloroethane	107-06-2	Solvent and degreaser			x													
1,3,5-Triglycidyl Isocyanurate (TGIC)	2451-62-9	Monomer from polymer syntheseses			x										x			
11-amino-undecansacid		Substances released from polymers		x		x	x				x							
2,2',4,4',5,5'-Hexabromobiphenyl	59080-40-9	Flameretardants			x													
2,4-Toluenediisocyanate	584-84-9	Monomer from polymer syntheseses			x										x			
2,4,5-Trimethylaniline	137-17-7				x													
2,4-Diaminoanisole	615-05-4				x													
2,4-Toluylenediamine (Toluene-2,4-Diamine)	95-80-7	Monomer from polymer syntheseses			x										x			
2,6 Toluene diisocyanate	9016-87-9	Monomer from polymer syntheseses			x										x			
2-Amino-4-nitrotoluene	99-55-8	Monomer from polymer syntheseses			x													
2-Bromobiphenyl	2052-07-5	Flameretardants			x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
2-ethoxyethanol	110-80-5	Solvent from lacquer or liquid in electrolytic capacitors			x													
2-ethoxyethyl acetate	111-15-9	Solvent from lacquer or liquid in electrolytic capacitors			x													
2-Methoxyethanol	109-86-4	Solvent from lacquer or liquid in electrolytic capacitors			x													
2-Methoxyethyl acetate	110-49-6	Solvent from lacquer or liquid in electrolytic capacitors			x													
2-Naphthylamine	91-59-8				x													
2-phenyl-propenal (CAS-No for 3-phenylpropenal)	104-55-2	Substances released from polymers		x		x	x							x				
3,3,'-Dimethylbenzidene	119-93-7				x													
3,3'-Dichlorobenzidene	91-94-1				x													
3,3'-Dimethyl-4,4' diaminodiphenylmethane	838-88-0	Monomer from polymer syntheses			x										x			
3,3'-Dimethoxybenzidine	119-90-4				x													
3-Bromobipheny	2113-57-7	Flameretardants			x													
4,4'Methylenebis-(2-chloroaniline)	101-14-4				x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
4,4'-Thiodianilene (4,4'-thiobisbenzenamine)	139-65-1				x													
4,4'-Dibromodiphenylether	2050-47-7	Flameretardants			x													
4-Bromobiphenyl	92-66-0	Flameretardants			x													
4-Bromophenyl phenyl ether	101-55-3	Flameretardants			x													
4-Chloro-o-toluidine (4-chloro-2-methylaniline)	95-69-2				x													
4-Nonylphenol	104-40-5				x													
Acetaldehyde	75-07-0	Substances released from polymers		x		x	x		x						x		x	
Acrolein	107-02-8	Substances released from polymers		x		x	x		x			x					x	
Acrylonitril	107-13-1	Monomer from polymer syntheses	x	x		x	x											x
Adipic acid	124-04-9	Substances released from polymers		x		x	x				x							
Alkoxy radicals		Substances released from polymers		x		x	x							x			x	x
Argon			x															
Aroclor	12767-79-2				x			a)										
Aroclor 1254	11097-69-1				x			a)										
Azodicarbonamid	123-77-3	Substances released from polymers		x		x	x										x	

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Benzalchloride	98-87-3	Substances released from polymers		x		x	x										x	
Benzene	71-43-2	Monomer from polymer syntheses	x	x	x	x	x		x		x						x	
Benzidene and its salts	92-87-5				x													
Benzidinephenyl	??				x													
Bis(n-octyl) Phthalate (DNOP)	117-84-0				x													
Bisphenol A	80-05-7	Substances released from polymers		x		x	x		x			x						
Blystearat		Substances released from polymers		x		x	x										x	
Bromine	7726-95-6	Substances released from polymers		x		x	x											
Brominated flameretardants			x															
Brominated flameretardants other than PBB and PBDE		Flameretardants			x													
Butadien	106-99-0	Substances released from polymers		x		x	x											x
Butyl benzyl phthalate (BBP)	85-68-7	Plasticizer			x													
Caprolactam	105-60-2	Substances released from polymers		x		x	x				x							
Chlorodiphenyl (Aroclor 1260)	11096-82-5				x			a)										
Chloroform	67-66-3				x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Chloroparaffins	63449-39-8	Plasticizer			x													
Coal Tar	8007-45-2				x													
cyclohexyldicarboxylic acid anhydride		Substances released from polymers		x		x	x		x									
Cyclopentanone	120-92-3	Substances released from polymers		x		x	x				x							
Decabromobiphenyl	13654-09-6	Flameretardants			x													
Decabromodiphenyl ether	1163-19-5	Flameretardants			x													
Decansyrenitril		Substances released from polymers		x		x	x				x							
Dibutyl phthalate (DBP)	84-74-2	Plasticizer			x													
Diethylene glycol dimethyl ether	111-96-6	Solvent from lacquer or liquid in electrolytic capacitors			x													
Diethylentriamin	111-40-0	Substances released from polymers		x		x	x		x									
Diisodecyl phthalate	26761-40-0	Plasticizer			x												x	
Diisononyl Phthalate (DINP)	28553-12-0	Plasticizer			x												x	
Dimethyl phthalate	131-11-3	Plasticizer			x												x	
Diphenylamine	122-39-4				x													
Diphenylmethandiamin	101-77-9	Monomer from polymer syntheses		x	x	x	x		x						x			

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Diphenylmethandiamin	1208-52-2	Substances released from polymers		x		x	x								x			
Di-sec-octyl phthalate (DEHP)	117-81-7	Plasticizer			x												x	
Acetic acid	64-19-7	Substances released from polymers		x		x	x											
Epichlorohydrin	106-89-8	Basic substance by polymer synteheses of epoxy	x	x		x	x		x									
Ethylene Glycol	107-21-1	Plasticizer. Solvent from or liquid in electrolytic capacitors	x	x														
Formaldehyde	50-00-0	Substances released from polymers		x	x	x	x			x		x			x		x	
Glycols		Solvent from or liquid in electrolytic capacitors	x															
Halogenated flame retardants other than TBBA		Flameretardants			x													
Halogenated Polymers					x													
Helium			x															
Heptabromodiphenylether	68928-80-3	Flameretardants			x													
hexabromo-1,1'-biphenyl	36355-01-8	Flameretardants			x													
Hexabromodiphenyl ether	36483-60-0	Flameretardants			x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Hexachlorobutadiene	87-68-3				x													
Hexamethylendiamin	124-09-4	Substances released from polymers		x		x	x				x				x			
Hydrogensulfid	7783-06-04	Substances released from polymers		x		x	x						x					
Isocyanates	26471-62-5	Substances released from polymers		x		x	x								x			
Isocyanates	101-68-8	Substances released from polymers		x		x	x								x			
Isopropanol	67-63-0	Ink	x															
Kanechlor 500	27323-18-8				x			a)										
Lactam		Substances released from polymers		x		x	x				x							
Limonene	138-86-3				x													
Methacrylate	18358-13-9			x														
Methyl-aniliner	100-61-8	Substances released from polymers		x		x	x								x			
Methylcyclohexyldicarbonacid anhydride		Substances released from polymers		x		x	x		x									
Neon			x															
n-Hexane	110-54-3				x													
Nonabromodiphenyl ether	63936-56-1	Flameretardants			x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Nonenylcyanide		Substances released from polymers		x		x	x				x							
o-Aminoazotoluene	97-56-3				x													
Octabromodiphenyl	61288-13-9	Flameretardants			x													
Octabromodiphenyl Ether	32536-52-0	Flameretardants			x													
Octylphenol	27193-28-8				x													
Octylphenolethoxylates	9002-93-1				x													
o-Toluidine	95-53-4				x													
p,p'-dibromobiphenyl	92-86-4	Flameretardants			x													
p-Chloroaniline	106-47-8				x													
p-Cresidene (5-Methyl-o-Anisidine)	120-71-8				x													
Pentabromodiphenyl ether	32534-81-9	Flameretardants			x													
Pentachloro phenol (PCP)	87-86-5				x													
Pentachloro phenol, sodium (salt and other PCP salts or compounds)	131-52-2				x													
Phenol	108-95-2	Substances released from polymers		x		x	x		x	x								
Phosgen (carbonylchloride)	75-44-5	Substances released from polymers		x		x	x					x						
Phthalic anhydride	85-44-9	Substances released from polymers		x		x	x										x	

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Phthalates		Plasticizer, substances released from polymers	x	x		x	x										x	
Polybrominated biphenyl mixture (Firemaster FF-1)	67774-32-7	Flameretardants			x													
Polybrominated Biphenyls	59536-65-1	Flameretardants			x													
Polybrominated Biphenyls Ethers		Flameretardants			x													
Polychlorinated Biphenyls	1336-36-3				x			a)										
Polychlorinated naphtalenes	39450-05-0				x			a)										
Polychlorinated naphtalenes	58718-66-4				x			a)										
Polychlorinated naphtalenes	58718-67-5				x			a)										
Polychlorinated terphenyls	61788-33-8				x			a)										
p-toluidin	106-49-0	Substances released from polymers		x		x	x								x			
Styrene	100-42-5	Monomer from polymer synteheses	x	x		x	x							x				x
Styrenoxide	96-09-3	Substances released from polymers		x		x	x							x				
Terphenyls	26140-60-3				x			a)										
Tetrabromobiphenyl	40088-45-7	Flameretardants			x													
Tetrabromobisphenol-A (TBBA)	79-94-7	Flameretardants		x	x													

Substance Name	CAS-No	Origin or Application	Ref OW 1	Ref OW 2	Ref OW 3	Ref OW 4	Ref OW 5	Comm.	Polymer Releasing the Substance									
									EP	PF	PA	PC	PPS	PS	PUR	Silicones	PVC	ABS
Tetrabromodiphenyl ether	40088-47-9	Flameretardants			x													
Tetrachloroethylene	127-18-4	Solvent and degreaser			x													
Thiocarbamide	62-56-6				x													
Toluene	108-88-3	Solvent from lacquer	x															
Trichloroethylen	79-01-6	Solvent and degreaser			x													
Vinylacetate	108-05-4	Monomer from polymer synteheses	x															
Vinylchloride	75-01-4	Monomer from polymer synteheses	x	x	x	x	x										x	

a) Application in new products is expected to be very unlikely
EP: Epoxy
PF: Phenol formaldehyde resin
PA: Polyamide
PC: Polycarbonate
PPS: Polyphenylene sulphide
PS: Polystyrene
PUR: Polyurethane
Silicones: Siloxanes and Silicones
PVC: Polyvinylchloride
ABS: Acrylonitril Butadienstyrene

ANNEX B

Substances Emitted from Electrical and Electronic Products

Substance	CAS-No	Health Effect [1]	Limit Value	Maximum found Emission in Literature (µg/unit/hour)	Chronic Health Effect
1,2,4-trimethylcyclohexane		Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27	4.8	x
1-ethoxy-2-propanol	1569-02-4	Not on DK-list of haz. subst.	Tent. 100 ppm	2.4	x
1-phenylethanon	98-86-2	Xn; R 22-36	10 ppm 49 mg/m^3		
2-butanone	78-93-3	F, Xi; R 11-36-66-67	50 ppm 145 mg/m^3		
2-buthoxyethanol	111-76-2	Xn; R 20/21/22-36/38	20 ppm 98 mg/m^3		h3
2-ethoxyethylacetate	111-15-9	T; R 60-61-20/21/22	5 ppm 27 mg/m^3		h3, R 60-61
2-ethylhexanal		Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		x
2-ethylhexanol	104-76-7	Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		x
3-carene	13466-78-9	Not on DK-list of haz. subst. (sensitizing, Ref. 7)	Not on At-list 2000, Ref. 27		h4
Acrylonitrile	107-13-1	F, T, N; R 45-11-23/24/25-37/38-41-43-51/53	2 ppm 4 mg/m^3	3.2	h3, R 45
Alfa-methylstyrene	100-80-1	Xi, N; R 10/36/37-51/53	25 ppm 120 mg/m^3	3.2	
Alkylbenzenes	-	F, Xn; R 11-20	Tent. 25 ppm		x
Benzaldehyde	100-52-7	Xn; R 22	Not on At-list 2000, Ref. 27		
Benzene	71-43-2	F, T; R 45-11-48/23/24/25	0,5 ppm 1,6 mg/m^3	3.7	h1, R 45
Benzophenon	119-61-9	Not on DK-list of haz. subst. (suspected endocrine disruptor, Ref. 7)	Not on At-list 2000, Ref. 27		h4
BHT - Butylhydroxytoluen	128-37-0	Not on DK-list of haz. subst. AT: Contact allergy possibly sensitizing Ref. 7)	10 mg/m^3		h4
bis-(2-ethyl)-hexylphthalate	117-81-7	Not on DK-list of haz. subst. (possibly carc. Ref. 23)	3 mg/m^3		h2
Butanal	123-72-8	F, R 11	Not on At-list 2000, Ref. 27		

Substance	CAS-No	Health Effect [1]	Limit Value	Maximum found Emission in Literature (µg/unit/hour)	Chronic Health Effect
Caprolactame	105-60-2	Not on DK-list of haz. subst.	5 ppm 25 mg/m^3		h3
Cresoles	95-48-7	T; R 24/25-34	5 ppm 22 mg/m^3		x
Cyclohexanone	108-94-1	Xn; R 10-20 (suspected carc. , Ref. 7)	10 ppm 40 mg/m^3		h2
Cecane	124-18-5	Xn; R 65	45 ppm 250 mg/m^3	12.8	
Dibutylphthalate	84-74-2	Not on DK-list of haz. subst. (possible endocrine disruptor, risk of abortion, Ref. 7, endocrine effects cat.1: Ref. 29. Possibly reprotoxic, cat.2: Ref. 30 , damage on embryo: Ref. 31)	3 mg/m^3	5.6	h2
Dichloromethane	75-09-2	Xn; R 40	35 ppm 122 mg/m^3	1.6	h1, R 40
Diethylphthalate	84-66-2	Not on DK-list of haz. Subst., on DK-list of unwanted subst.)	3 mg/m^3	1.6	h4
Dodecane	112-40-3/93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
Ethylbenzene	100-41-4	F, Xn; R 11-20 (possible teratogen, Ref. 7)	50 ppm 217 mg/m^3	5.6	h2
Ethylhexylpropenoic ester	103-11-7	Xi; R 37/38-43	Not on At-list 2000, Ref. 27		h3
Ethylmethylbenzene	611-14-3	Xn; R 10-20/21-38 (susp. carc., Ref.7)	Not on At-list 2000, Ref. 27		h2
Formaldehyde	50-00-0	T; R 23/24/25-34-40-43	0,3 ppm 0,4 mg/m^3 0,15 mg/m^3 in Ref. 28 (indoor climate)	24	h1, R 40
Hexamethylcyclotrisiloxane		Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		x
Limonene	138-86-3	Xi, N; R 10-38-43-50/53	Not on At-list 2000, Ref. 27		x
Methylacrylate	96-33-3	F, Xn; R 11-20/21/22-36/37/38-43	2 ppm 7 mg/m^3		h2
Methylnaphtalene	1321-94-4	Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		h3
N,N-dimetylformamide	68-12-2	T; R 61-20/21-36 (teratogen, Ref.7)	10 ppm 30 mg/m^3		h1, R 61
n-alkaner	93763-35-0	Xn; R 65	25 ppm 180 mg/m^3		

Substance	CAS-No	Health Effect [1]	Limit Value	Maximum found Emission in Literature (µg/unit/hour)	Chronic Health Effect
Naphtalene	91-20-3	Xn, N; R 22-50/53 (possible carc., Ref. 7, Ref. 23, carc3, R40: ref.32)	10 ppm 50 mg/m³	23	h2
n-dodecan	93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
n-hexadecan	93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
n-nitrisodibutylamin					x
Nonanal	124-19-6	Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		
n-pentadecane	93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
n-tetradecane	93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
PCB	1336-36-3	Xn, N; R 33-50/53	0,01 mg/m³	0.002	h3
Pentabromotoluene		Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		x
Phenol	108-95-2	T; R24/25-34	1 ppm 4 mg/m³	169	h3
Phthalates		On DK-list of unwanted subst.	3 mg/m³		x
Silicones		-	-		h4
Siloxanes		-	-		x
Styrene	100-42-5	Xn; R 10-2036/38 (metabolits are genotoxic, Ref. 7) (metabolised to styreneoxides, Ref. 23 carc., R 45)	25 ppm 105 mg/m³	16	h4 (metab)
Tri-2-chloroethylphosphate (TCEP)	115-96-8	Not on DK-list of haz. subst. (possible carc., Ref. 13, Ref. 23)	-		h2
Tertiær butyl-methylphenol		Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27		x
Tetrachloroethene	127-18-4	Xn, N; R 40-51/53	10 ppm 70 mg/m³	1.4	h1, R 40
Toluene	108-88-3	F, Xn; R 11-20 (possible teratogen, Ref. 7, reprotoxic cat 3, R63 :ref.33)	25 ppm 94 mg/m³	523	h2
Trichlorethane	71-55-6	Xn, N; R 20-59	50 ppm 275 mg/m³		
Trichlorethene	79-01-6	T; R 45-36/37/38-67/68-52/53	10 ppm 55 mg/m³	29.6	h1, R 45
Trimethylbenzene	95-63-6	Xn,N; R10-20-36/37/38-51/53	25 ppm 120 mg/m³	5.5	h3
Triphenylphosphate	115-86-6	Not on DK-list of haz. subst.	3 mg/m³		h1

Substance	CAS-No	Health Effect [1]	Limit Value	Maximum found Emission in Literature (µg/unit/hour)	Chronic Health Effect
		(allergy effects Ref. 12)			
TVOC	Group	-	-	12,200	
Undecane	93763-35-0	Xn; R 65	Not on At-list 2000, Ref. 27		
Xylenes	1330-20-7	Xn; R 10-20/21-38	25 ppm 109 mg/m^3	9.7	
BDE-209 (2,2',3,3',4,4',5,5',6,6'-decabromodiphenylether)		See Ref. 15			h4
CP (chlorinated paraffins)	Group	On list of unwanted substances			h4
PBDE (polybrominated diphenylether)	Group			0.012	h4
TBBPA (tetrabromobisphenolA)	79-94-7				x
TBP (tributylphosphate)	126-73-8				x
TCPP (tri-chloropropylphosphate)	78-43-3				x
Hexabromobenzene	87-82-1	Suspected reaction product from flammeretardants			h4
DecaBDE (decabromodiphenylether)	Group				h4
OctaBDE	Group				h4
PentaBDE	Group 32534-819	DK draft for classification: Xn; R4 8/21/22/64			h4

[1] Health effects according to Danish law: List of hazardous substances (Bek. nr. 439, 2002) with addition of selected international information
h1 = R 40, 45, 46, 48, 49, 60-64 proved
h2 = R 40, 45, 46, 48, 49, 60-64 suspected
h3 = On EU toxicity list, U: Unwanted) or P: Problematic
h4 = Other literature reference for possible health effect
"x" means no found data
At: Danish National Working Environment Authority

Found Emitted Substances in Measurements on 4 Selected Electrical and Electronic Appliances

Substance	CAS-No	Health Effect [1]	Limit Value	Chronic Health Effect
1,3-diazin/pyrazin	68-35-9	Diazin = sulfadiazin, 68-35-9, Probably with health effect and probably terotogenic	Not on At-list 2000, Ref. 27	h4
1-ethyl-2-methylcyclohexane	3728-54-9	Lv probably higher than cyclohexane: 172 mg/m^3, methylcyclohexan Xn, R 65-67, Xi, R 38	est. 172 mg/m^3	
1-methoxy-2-propanol	107-98-2	R10	185 mg/m^3	
1-methyl-2-pyrrolidinon	872-50-4	Xi; R 36/38	20 mg/m^3	
2-(2-ethoxyethoxy)ethanol (diethylenglucol-monobutyl ether)	111-90-0	(Diethylenglucol-monobutyl ether like diethylenglucol 111-46-6 Xn; R 22 lv: 11 mg/m^3)	est. 11 mg/m^3	
2,4-nonadien	821-74-9	Nonan 2050 mg/m^3, probably same level of lv.	est. 2,050 mg/m^3	
2-buthoxyethanol	111-76-2	Xn; R 20/21/22-36/38	20 ppm 98 mg/m^3	h3
2-butyl-1-oktanol	3913-02-8	A branched higher alkohol, lv higher than 200 mg/m^3	est. 200 mg/m^3	
2-ethyl-1hexanol/nonanol	104-76-7	Butanol lv: 150 mg/m^3, pentanol lv: 360 mg/m^3, hexanol and nonanol with expected higher lv.	est. 500 mg/m^3	
2-ethylhexanol	104-76-7	Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27	x
2-ethylhexanoic acid	149-57-5	Xn, Rep, R 63, Effects on reproducibility lv est. from ketones of C7,C8 est. 100 mg/m^3	est. 100 mg/m^3	h1, R 63
2-hexyl-1-decanol	2425-77-6	A branched higher alkohol, lv probably higher than 200 mg/m^3	est. 200 mg/m^3	
2-hydroxybenzenethanol	7768-28-7	ethylenglycol moophenylether, probably Xn, phenol lv: 4 mg/m^3, probably lv around 10 mg/m^3	est. 10 mg/m^3	
2-methyl-1-propanol	78-83-1	Xi; R 10-37/38-41-67	150 mg/m^3	
2-methyl-phenol (cresol)	95-48-7	Same as cresol, T, R 24-25, C, R 34	22 mg/m^3	
2-pentylfuran	3777-69-3	Not on DK-list of haz. subst.: Furan (110-00-9, Fx, T; R 45). Furfural 98-	est. 10 mg/m^3	h4

Substance	CAS-No	Health Effect [1]	Limit Value	Chronic Health Effect
		01-1 lv 8 mg/m³ = Furan+ -COH Furfurylalcohol 98-00-0 lv = 20 mg/m³ cons. Est. Lv = 10 mg/m³		
2-propenoic acid methyl Metacrylate	80-62-6	F, Xi; R 11-37/38-43	102 mg/m³	
3-carene	13466-78-9	Not on DK-list of haz. subst. (sensitizing, Ref. 7)	Not on At-list 2000, Ref. 27	h4
3-methylbutanal/pentanal	590-86-3/110-62-3	Not on DK-list of haz. subst.	Not on At-list 2000, Ref. 27	
4-hydroxy-4methyl-2-pentanon	123-42-2	Xi; R 36 lv probably like pentanon 700 mg/m³	est. 700 mg/m³	
Acetaldehyde	75-07-0	Fx, Xn; R12, R 36/37, R 40	45 mg/m³	h1, R 40
Acetone	67-64-1		600 mg/m³	
Acetophenone	98-86-2	Xn; R 22-36	49 mg/m³	
Alkohol	19781-13-6	Probably higher alcohols, not very significant		
a-pinen	80-56-8	80-56-8, irritating effects, effect on organs, nervous system, lethal dosis 180 gram, lv probably like terpentine 25 ppm/140 mg/m³	est. 140 mg/m³	
Benzaldehyde	100-52-7	Xn; R 22	Not on At-list 2000, Ref. 27	
Benzene	71-43-2	F, T; R 45-11-48/23/24/25	0,5 ppm 1,6 mg/m³	h1, R 45
BHT - Butylhydroxytoluene	128-37-0	Not on DK-list of haz. subst. At: contact allergy (probably sensitizing, Ref. 7)	10 mg/m³	h4
butanal	123-72-8	F, R 11	Not on At-list 2000, Ref. 27	
Butanol	71-36-3	Xn; R 10-22-37/38-41-67	150 mg/m³	
Butylacetate	123-86-4	R 10-66-67	710 mg/m³	
$C_{15}H_{24}$	25246-27-9			
Chlorobenzene	108-90-7	R 10, R 20, R 51/53	46 mg/m³	
Cyclohexanone	108-94-1	Xn; R 10-20 (probably carc. , Ref. 7)	10 ppm 40 mg/m³	h2
Decanal/alkohol	12-31-2/2425-77-6	Lv probably higher than pentanal fx 300 mg/m³	est. 300 mg/m³	

Substance	CAS-No	Health Effect [1]	Limit Value	Chronic Health Effect
Dibutylphthalate	84-74-2	Not on DK-list of haz. subst. (possibly endocrine disruptor, risk of abortion, Ref. 7, endocrine effects cat.1: Ref. 29. Possibly reprotoxic, cat.2: Ref. 30 , damage on embryo: Ref. 31)	3 mg/m^3	h2
Ethanol, 2-2(buthoxyethoxyacetate)	124-17-4	Butyldiglycolacetat, probably like butylglycolacetat (Xn, R 20/R 21) lv: 130 mg/m^3	est. 130 mg/m^3	
Ethylbenzene	100-41-4	F, Xn; R 11-20 (possibly teratogen , Ref. 7)	50 ppm 217 mg/m^3	h2
Formaldehyde	50-00-0	T; R 23/24/25-34-40-43	0,3 ppm 0,4 mg/m^3 0,15 mg/m^3 in Ref.28 (indoor climate)	h1, R 40
Hexanal	66-25-1	Not on DK-list of haz. subst. Probably lv higher than pentanal fx 300 mg/m^3	est. 300 mg/m^3	
m-,p-xylene	1330-20-7	Xn; R 10-20/21-38	109 mg/m^3	
Formic acid, 2-methylester	542-55-2	F,Xi; R 11-36/37	Not on At-list 2000, Ref. 27	
Formic acid butylester	592-84-7	F,Xi; R 11-36/37	Not on At-list 2000, Ref. 27	
Nonanal	124-19-6	Not on DK-list of haz.subst.	Not on At-list 2000, Ref. 27	
Octanal	124-13-0	Not likely effects, used as additive in food		
o-xylene	1330-20-7	Xn; R 10-20/21-38	109 mg/m^3	
o-xylene+styrene	Group	Styrene lv = 105 mg/m^3 LHK, K = Carcinogenic	105 mg/m3	h4
Pentanal	110-62-3	Not on DK-list of haz. subst.	175 mg/m^3	
Phenol	108-95-2	T; R 24/25-34	1 ppm 4 mg/m^3	h3
Phenol+trimethylbenzene	Group	Trimethylbenzene 95-63-6, lv 120 mg/m^3; phenol 108-95-2, lv 4 mg/m^3	est.10 mg/m^3	
Propanal	123-38-6	F, Xi; R 11-36/37/38 probably lv between acetaldehyde and pentanal lv est: 100 mg/m^3	est. 100 mg/m^3	
Propionic acid	79-09-4	C; R 34	30 mg/m^3	

Substance	CAS-No	Health Effect [1]	Limit Value	Chronic Health Effect
Styrene	100-42-5	Xn; R 10-2036/38 (metabolits are genotoxic, Ref. 7 (metabolised to styrene oxides, Ref. 23 which are carc., R 45)	25 ppm 105 mg/m^3	h4 (metab. carc.)
SUM C11-c18	Group			
Tetramethylbenzene	25619-60-7	Not on DK-list of haz. subst. Probably like trimethylbenzene Xn, N; R 10-20-36/37/38, lv: 120 mg/m^3	est. 120 mg/m^3	
Toluene	108-88-3	F, Xn; R 11-20 (susp. teratogen, Ref. 7)	25 ppm 94 mg/m^3	h2
Trimethylbenzene	95-63-6	Xn,N; R 10-20-36/37/38-51/53	25 ppm 120 mg/m^3	h3

[1] Health effects according to Danish law: List of hazardous substances (Bek. nr. 439, 2002) with addition of selected international information
h1 = R 40, 45, 46, 48, 49, 60-64 proved
h2 = R 40, 45, 46, 48, 49, 60-64 suspected
h3 = On EU toxicity list, U: Unwanted or P: Problematic
h4 = Other literature reference for possible health effect
At: Danish National Working Environment Authority
Lv: Limit value

Annex D

Calculated Room Concentrations from Measured Emissions
(V = 17,4m^3, luftskifte = 0,5 $time^{-1}$)

CALCULATED ROOM CONCENTRATIONS FOR TV SET

Substance	CAS no.	Health effect code	Concentration (µg/m^3) After 7 hours	Concentration (µg/m^3) After 9 days
Phenol	108-95-2	h2	2.53	2.99
Toluene	108-88-3	h2	1.95	2.18
o-xylene+styrene	0	h4	1.49	1.38
2-(2-ethoxyethoxy)ethanol (diethylenglucol-monobutyl ether)	111-90-0		0.92	1.38
2-ethylhexanol	104-76-7		0.69	0.46
Nonanal	124-19-6		0.57	0.57
Butanol	71-36-3		0.57	0.57
Propionic acid	79-09-4		0.57	0.57
m-,p-xylene	1330-20-7		0.34	0.57
Benzene	71-43-2	h1,R45	0.23	0.57
Decanal/alcohol	12-31-2/2425-77-6		0.46	0.34
1-methyl-2-pyrrolidinon	872-50-4		0.34	0.34
3-carene	13466-78-9	h4	0.34	0.23
Ethylbenzene	100-41-4	h2	0.23	0.34
Formaldehyde	50-00-0	h1, R40,R43	0.34	0.23
Acetaldehyde	75-07-0	h1,R40	0.23	0.34
Acetone	67-64-1		0.00	0.46
2-propenoic acid methyl metacrylate	80-62-6		0.11	0.34
benzaldehyde	100-52-7		0.23	0.11
BHT – Butylhydroxytoluene	128-37-0	h4	0.11	0.23
Butanal	123-72-8		0.23	0.11
Acetophenone	98-86-2		0.23	0.11
2-buthoxyethanol	111-76-2	h3	0.11	0.11
Pentanal	110-62-3		0.11	0.00
Hexanal	66-25-1		<0.11	0.11
A-pinen	80-56-8		0.11	<0.11
4-hydroxy-4methyl-2-pentanon	123-42-2		<0.11	0.0
1-ethyl-2-methylcyclohexane	3728-54-9		<0.11	<0.11

h1 = R40,42,45,46,48,49,60-64 proven
h2 = R40,42,45,46,48,49,60-64 suspected
h3 = EU toxicity list (UMP system); U: Unwanted substance, or P: Problematic substance
h4 = Other literature source for potentially chronic health effects

Calculated room concentrations for monitor

Substance	CAS no.	Health effect code	Concentration (μg/m³) After 7 hours	Concentration (μg/m³) After 9 days
Trimethylbenzene [1]	95-63-6	h3	47.0	12.3
Toluene [1]	108-88-3	h2	38.3	16.0
Phenol+trimethylbenzene [1]	Blanding		22.6	18.7
A-pinen [1]	80-56-8		25.6	4.9
2-ethyl-1-hexanol/nonanol [1]	104-76-7		19.8	9.7
Butanol [1]	71-36-3		15.6	7.1
o-xylene+styrene [1]	Blanding	h4	14.8	4.1
2-methyl-1-propanol [1]	78-83-1		8.7	4.6
m-,p-xylene [1]	1330-20-7		9.4	3.8
C15H24 [1]	25246-27-9		6.6	2.4
Formaldehyde	50-00-0	h1, R40,R43	3.0	2.8
Ethylbenzene [1]	100-41-4	h2	3.8	1.6
Ethanol,2-2(buthoxyethoxyacetate) [1]	124-17-4		3.7	1.6
2-methyl-phenol (cresol) [1]	95-48-7		3.0	2.1
2-butyl-1-octanol [1]	3913-02-8		3.1	1.0
3-carene [1]	13466-78-9	h4	3.4	0.6
Acetophenon [1]	98-86-2		2.3	1.4
Acetone	67-64-1		1.6	1.0
Benzaldehyde	100-52-7		1.6	0.8
Acetaldehyde	75-07-0	h1,R40	1.0	1.3
Butanal	123-72-8		1.3	0.9
Tetramethylbenzene [1]	25619-60-7		1.6	0.6
Pentanal	110-62-3		2.1	0.0
2-buthoxyethanol [1]	111-76-2	h3	1.6	0.3
BHT – Butylhydroxytoluene [1]	128-37-0	h4	1.0	0.8
Benzene [1]	71-43-2	h1,R45	0.8	0.7
1-methoxy-2-propanol [1]	107-98-2		1.5	0.0
Hexanal	66-25-1		0.7	0.5
Cyclohexanone [1]	108-94-1	h2	0.7	0.3
2-hexyl-1-decanol [1]	2425-77-6		0.7	0.3
Butylacetate [1]	123-86-4		0.8	0.0
Octanal [1]	124-13-0		0.3	0.3
2,4-nonadien [1]	821-74-9		0.5	0.2
1,3-diazin/pyrazin [1]	68-35-9	h4	0.3	0.2
Propanol	123-38-6		0.2	0.1

[1] TENAX tubes slightly over-saturated. The given concentrations are minimum concentrations. The discrepancy is estimated to be lower than a factor of 2.

Calculated room concentrations for game console

Substance	CAS no.	Health effect code	Concentration ($\mu g/m^3$) After 7 hours	Concentration ($\mu g/m^3$) After 9 days
SUM C11-c18	gruppe		35.40	2.41
Styren	100-42-5	h4 (metab)	1.84	0.23
Phenol	108-95-2	h3	1.49	0.46
2-ethylhexanol	104-76-7		1.26	0.00
Formaldehyde	50-00-0	h1, R40	0.80	0.46
Acetone	67-64-1		0.34	0.34
Acetophenone	98-86-2		0.69	0.00
o-xylene	1330-20-7		0.69	0.00
Trimethylbenzene	95-63-6	h3	0.57	0.00
A-pinen	80-56-8		0.57	0.00
Toluene	108-88-3	h2	0.23	0.23
Acetaldehyde	75-07-0	h1,R40	0.23	0.23
Hexanal	66-25-1		0.23	0.23
2-methyl-1-propanol	78-83-1		0.11	0.11
3-carene	13466-78-9	h4	0.11	0.00
Benzaldehyde	100-52-7		<0.11	<0.11
Nonanal	124-19-6		0.46	<0.11
Propanal	123-38-6		<0.11	0.00
Pentanal	110-62-3		<0.11	0.00
Octanal	124-13-0		<0.11	<0.11

Calculated room concentrations for voltage converters (using traditional transformers)

Substance	CAS no.	Health effect code	Concentration (µg/m³) After 7 hours	Concentration (µg/m³) After 9 days
Toluene 1	108-88-3	h2	35.3	14.8
SUM C11-c18 1	gruppe		25.7	22.9
Trimethylbenzene [1]	95-63-6	h3	20.6	13.2
m-,p-xylene [1]	1330-20-7		17.9	10.8
Ethylbenzene [1]	100-41-4	h2	16.0	8.5
2-methyl-1-propanol [1]	78-83-1		10.6	6.4
Formaldehyde	50-00-0	h1, R 40	11.1	4.3
o-xylene [1]	1330-20-7		7.7	4.4
2-pentylfurane [1]	3777-69-3	h4	7.0	3.5
2-ethylhexanol [1]	104-76-7		6.0	3.9
2-buthoxyethanol [1]	111-76-2	h3	3.9	3.6
Phenol [1]	108-95-2	h3	0.0	4.2
Hexanal	66-25-1		2.1	0.6
Tetramethylbenzene [1]	25619-60-7		1.4	0.8
Acetaldehyde	75-07-0	h1, R 40	1.2	0.5
Decanal/alcohol [1]	12-31-2/2425-77-6		1.0	0.5
BHT – Butylhydroxytoluene [1]	128-37-0	h4	0.3	0.8
Cyclohexanone [1]	108-94-1	h2	0.7	0.3
Formic acid, butylester [1]	592-84-7		0.6	0.4
Butanal	123-72-8		0.6	0.2
2-ethylhexanoic acid [1]	149-57-5	h1, R 63	0.3	0.4
Pentanal	110-62-3		0.5	0.2
Formic acid, 2-methylester [1]	542-55-2		0.5	0.3
Alcohol [1]	19781-13-6		0.3	0.3
Acetophenon [1]	98-86-2		0.4	0.2
Acetone	67-64-1		0.4	0.1
2-hydroxybenzenethanol [1]	7768-28-7		0.2	0.4
A-pinen [1]	80-56-8		0.4	0.1
Propanal	123-38-6		0.3	0.1
Butylacetat [1]	123-86-4		0.3	0.1
3-methylbutanal/pentanal	590-86-3/110-62-3		0.2	0.2
Chlorobenzene [1]	108-90-7		0.2	0.2
Octanal [1]	124-13-0		0.1	0.2
Benzaldehyde	100-52-7		0.1	0.1

* Values are for one converter; the values have been obtained by dividing the calculated room concentrations from the five tested converters by 5.
[1] TENAX tubes are somewhat over-saturated because of unexpectedly high emissions; this can be seen from the test results from tubes with the two different test sampling volumes used. The listet concentrations are minimum concentrations.