

# Emisjoner fra bygningsmaterialer og produkter – påvirker det vår helse?

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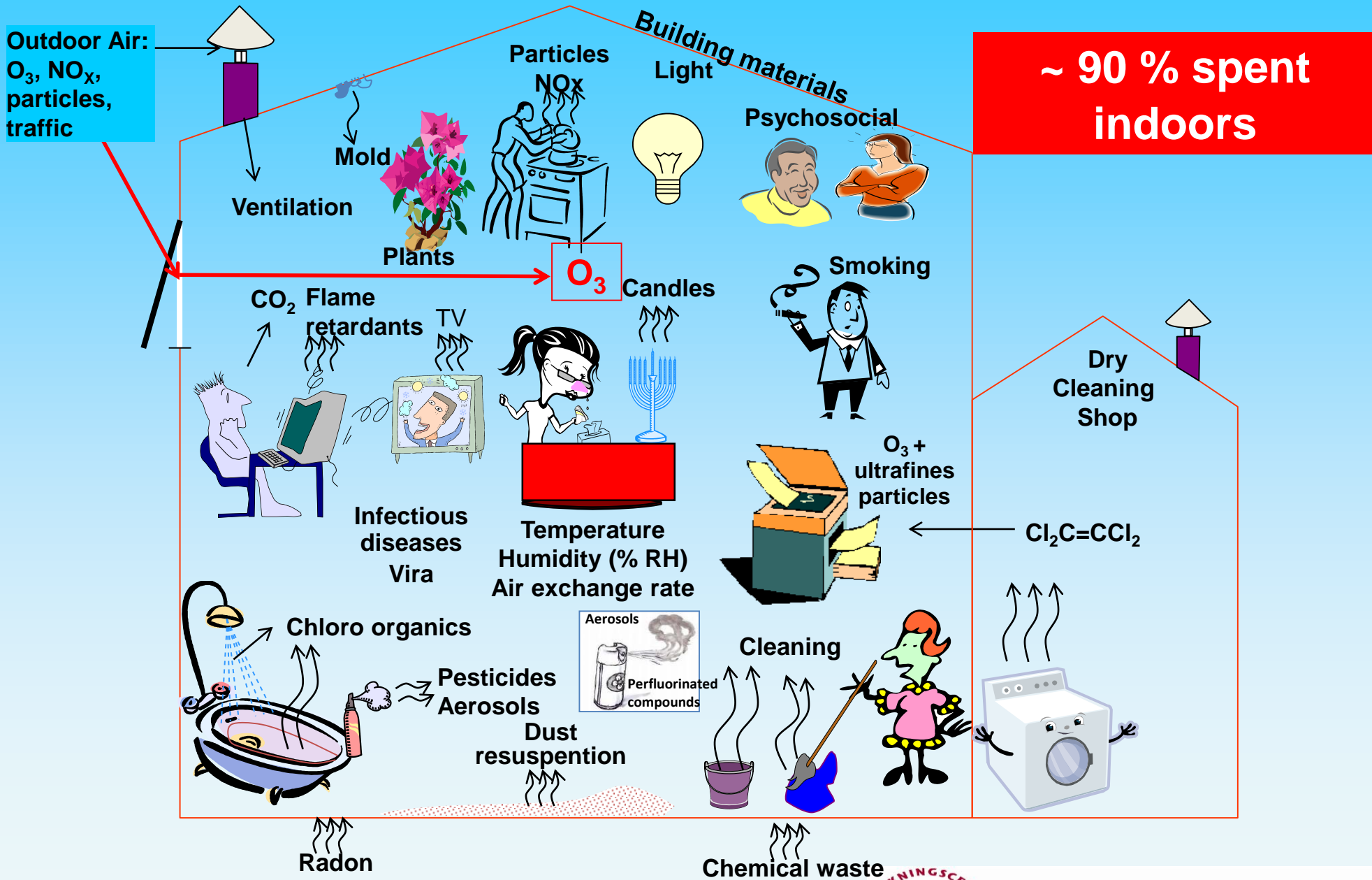


NATIONAL RESEARCH CENTRE  
FOR THE WORKING ENVIRONMENT

# Topics

- Byggematerialer og produkters emission
- Hvad er helsa? Hvilken tidshorisont?
- Kontormiljøet - symptomer
- Sensorisk irritation versus lugt (luftkvalitet)
- Lugts (luftkvalitet) betydning for indeklima
- Ozon og relative fugtighed (øjensymptomer)
- Guidelines – Tyskland og EU-LCI konceptet
- EU tiltag (delegated act)
- Løsninger

# Volatile organic compounds are one type of indoor pollutants



Weschler, *Atmos Env* 43 (2009), chapters 6.1-6.4.

## Emissions of indoor air pollutants from six user scenarios in a model room



Eva Höllbacher<sup>a, b, \*</sup>, Thomas Ters<sup>a, b</sup>, Cornelia Rieder-Gradinger<sup>a, b</sup>, Ewald Srebotnik<sup>b</sup>

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**Table 1**

Test and material specifications as performed in the model room.

ID	Test	Materials	Applied quantities	Test procedure
T1	Cleaning agent	Liquid cleaning agent All-purpose cleaner, phosphate-free, citrus scent	25 ml Dilution in water: 1:10	10 min cleaning
T2	Electric air freshener	Scent oil in a glass flask Magnolia and cherry blossom scent Electric vaporizer with adjustable intensity	0.03 g scent oil	30 min operating time at highest intensity, left in the room deactivated
T3	Cigarette smoke	Filter tipped cigarette	2 pieces	Smoked within 30 min by one person
T4	Peeling oranges	Oranges, pesticide-free	3 pieces	Peeling within 10 min, peels left in the room
T5	Cosmetics	Hair spray, perfume Sprayed together	5 sprays each 0.795 g hair spray 0.185 g perfume	Sprayed within 2 min, sprayed directly into room air
T6	Ethanol fireplace	Decorative ethanol fireplace, liquid fuel (96,6% ethanol, contains 2-butanone)	100 ml liquid fuel	Extinguished manually after 30 min burning time, left in the room extinguished

**Table 3**

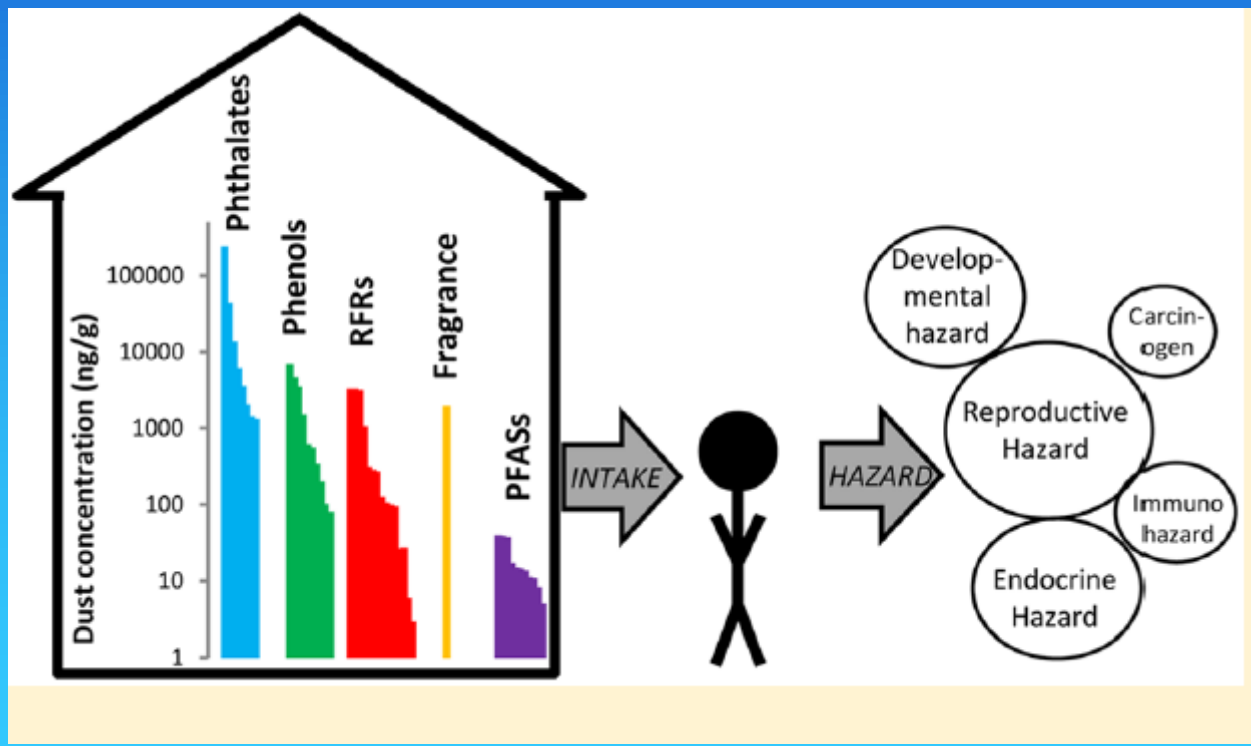
Most abundant VOC identified during each of the test scenarios T1 through T6.

T1	T2	T3	T4	T5	T6
Limonene (59%) 3-Carene (22%) $\alpha$ -Pinene (7%) $\beta$ -Pinene (5%) $\gamma$ -Terpinene (2%) Dihydromyrcenol (2%) p-Cymene (1%) Hexanal (1%) Pentanal (1%)	Linalool (36%) Dipropylene glycol methyl ether (16%) Ethyl 2-methylpentanoate (9%) Limonene (8%) Benzyl acetate (7%) 1-(2-Methoxy-1-methylethoxy)-2-propanol (7%) $\alpha$ -Terpineol (4%) Hexanal (4%) 3-Carene (3%) $\alpha$ -Pinene (3%)	Limonene (20%) Furfural (18%) $\gamma$ -Terpinene (14%) Toluene (6%) Nicotine (6%) Syrene (6%) Benzene (4%) Benzofuran (4%) Ethylbenzene (3%) Acetophenone (2%)	Limonene (94%) $\beta$ -Myrcene (4%) $\alpha$ -Pinene (1%) Sabinene (1%)	Linalool (37%) Linalyl acetate (21%) Limonene (15%) $\gamma$ -Terpinene (7%) 3-Carene (3%) Seychellene (2%) Hexanal (2%) Benzyl acetate (2%) $\beta$ -Ionone (2%) $\alpha$ -Patchoulene (2%)	2-Butanone (90%)

SVOCs

Consumer Product Chemicals in Indoor Dust: A Quantitative Meta-analysis of U.S. Studies

Susanna D. Mitro, Robin E. Dodson, Veena Singla, Gary Adamkiewicz, Angelo F. Elmi, Monica K. Tilly, and Ami R. Zota



# Vår helse i indeklimaet?

## ”Tidsaspektet”

### Arbejdsmiljø – kontor/skolemiljø

#### Akutte effekter:

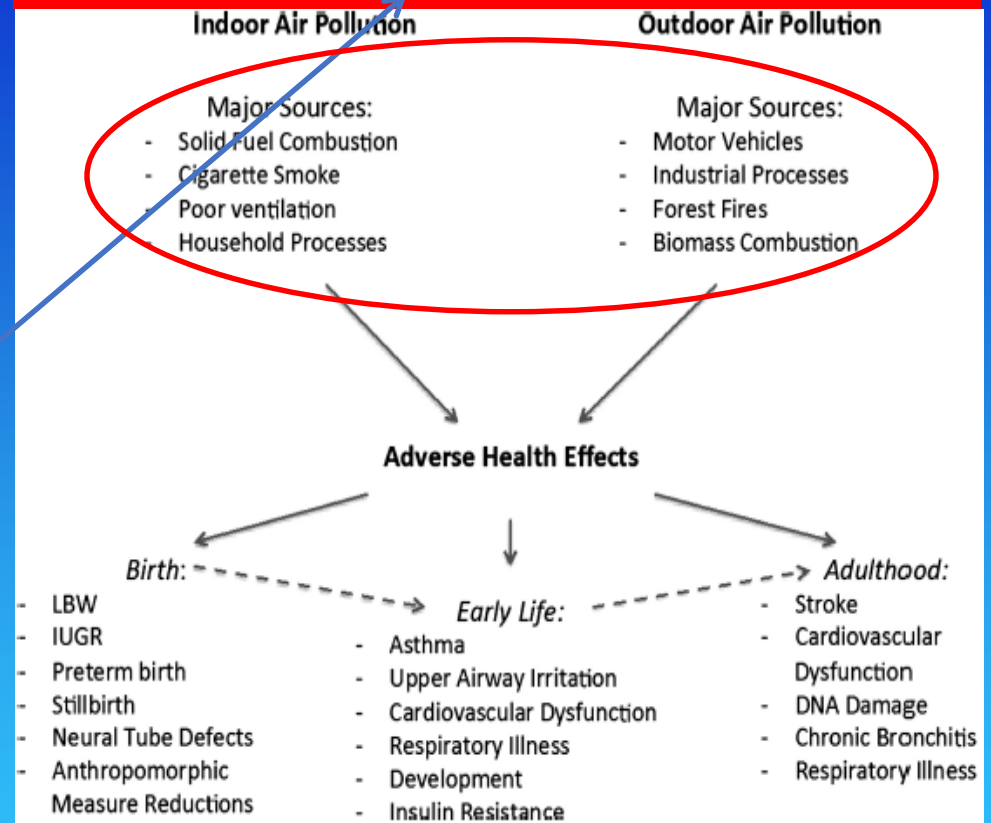
- Oplevet luftkvalitet
- Symptomer (sick-building syndrome)
- Signs (objektive tegn)

### Bolig

#### Længere-varende effekter (kroniske):

- Luftvejslidelser
  - Astma / forværret astma
  - Lungeeffekter
- Kardiovaskulære effekter
- Ototoksicitet

### Kritisk (kronisk) eksponering



Farmer et al. *Am J Physiol Heart Circ Physiol* 307 (2014) H467-H476.

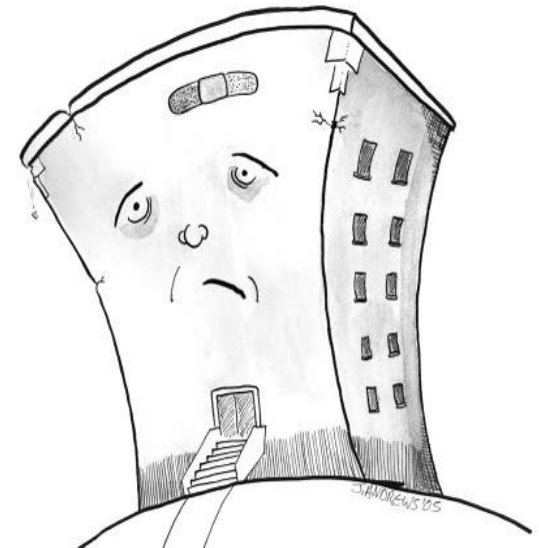
Akut (og temporær) versus længerevarende (kontinuerlig - livsvarig) eksponering

Børn versus voksne?

# Øjen-symptomer blandt top-2 i offentlige bygninger!

- Slimhindeirritation (øjne/luftvejene)
- Respiratoriske symptomer
- Neuro-psykologiske (central-nerve) symptomer

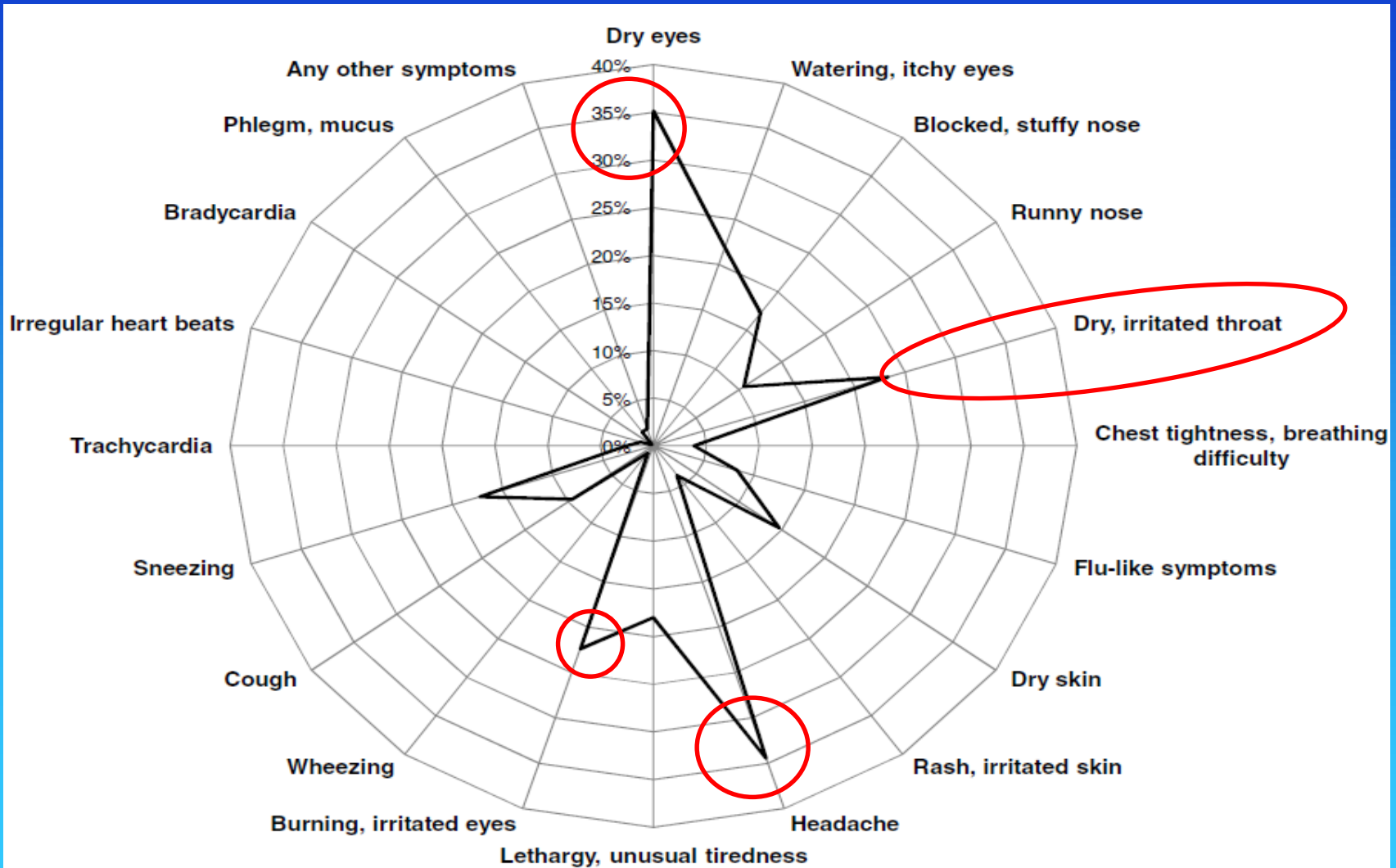
Øjen-symptomer og træthed blandt  
"top-2" i mange internationale  
studier



**US BASE study:**  
**100 public office  
buildings**

Brightman et al. Evaluating building-related symptoms using the US EPA  
BASE study results. *Indoor Air* 18 (2008) 335-345.

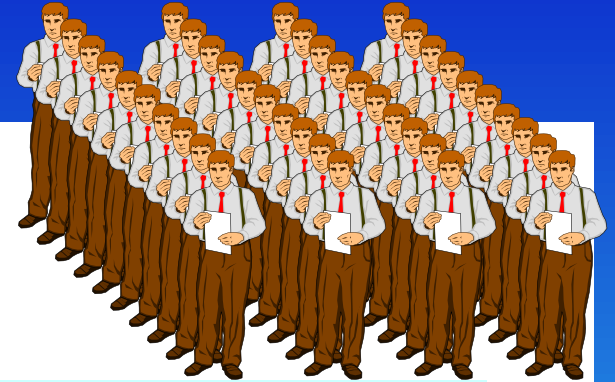
# IAQ related symptoms (last week) - OFFICAIR-projektet



Bluyssen et al. *Indoor Air* 26 (2016) 298-317.



# Good indoor air quality ASHRA\* definition



Immediate assessment of perceived air  
80 % report satisfaction

= acceptance of odour

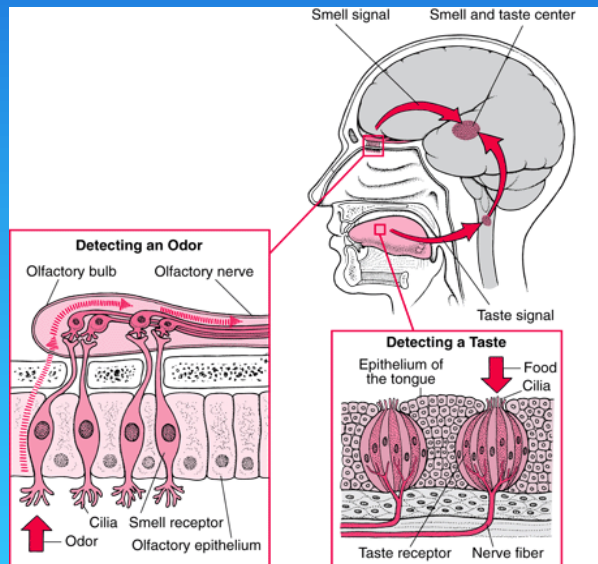
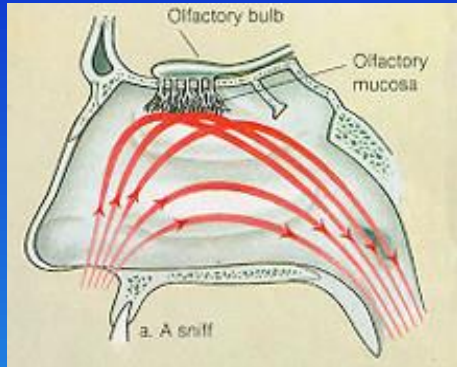
Intensity and acceptability

Does it reflect time and health effects

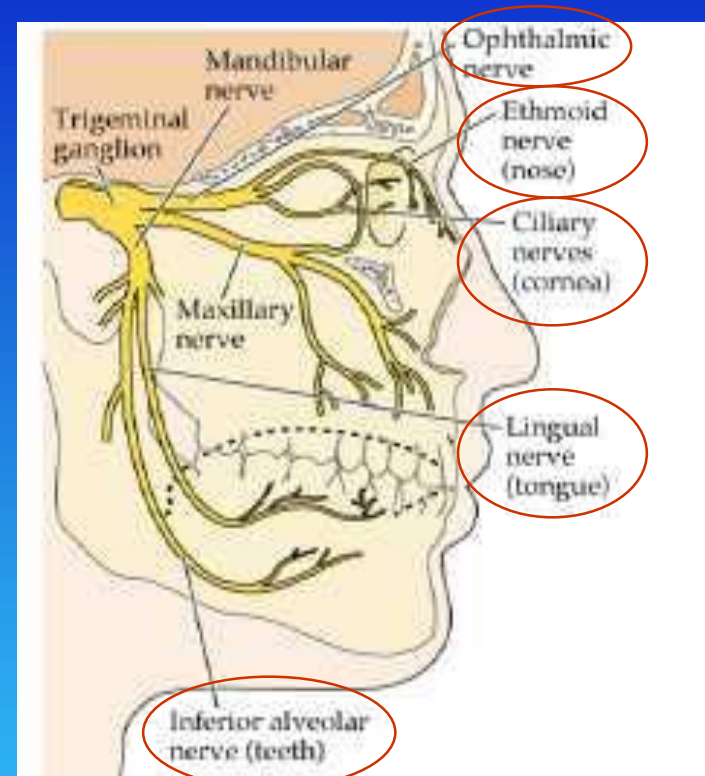


\*American Society of Heating, Refrigerating  
and Air-Conditioning Engineers

# Olfactorius and Trigenimus nervesystemer lugtesans sensorisk irritation



Øjeblikkelig perception



Karakteriseret ved en vis  
latenstid

# Estimerede tærskelværdier for sensorisk irritation i øjne og de øvre luftveje på basis af RD<sub>50</sub> værdier\*

VOC	LOAL reported by "humans"	Estimated threshold* "mouse model"
Acetaldehyde		4
Butanol	300	7
2-Ethylhexanol	53	0.2
3-Octanol		1
Acetic acid	> 25	0.5
Butyl acetate	< 700	6
<b>Formaldehyd</b>	0.3-0.8	0.04
Hexanal	> 8	3
Glutaraldehyd	1.9	0.008
Limonene	445	4.5
Peroxyacetyl nitrate	0.6	0.01
Toluene	> 100	10

mg/m<sup>3</sup>

Nielsen et al. *Reg. Tox. Pharmacol.* 48 (2007) 6-18.

Wolkoff, *IJHEH* 216 (2013) 371-394.

# Forskelle i tærskler for sensorisk irritation og lugt

VOC	Odour $\mu\text{g}/\text{m}^3$	Sensory irritation $\text{mg}/\text{m}^3$	Ratio of thresholds Irritation/odour
Toluene	644	376	600
Butanol	90	300	> 3000
Acetic acid	5	> 25	> 5000
Limonene	45	445	~10000

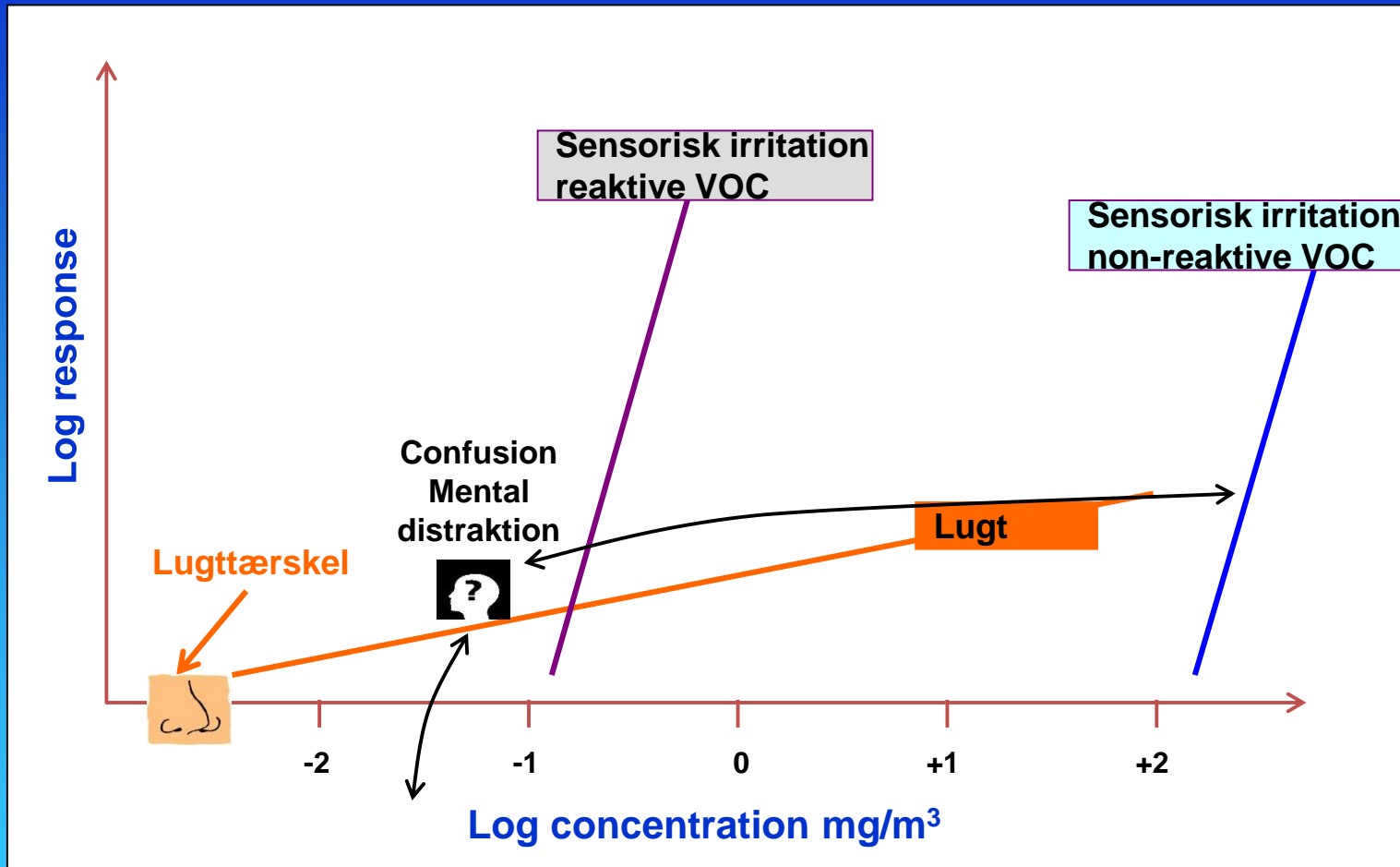
Lugttærskler er generelt mindst 10 - 1000 gange lavere end tilsvarende tærskler for sensorisk irritation

# Hvorfor lugt (luftkvalitet - lugtubehag) er så vigtig en indeklimafaktor

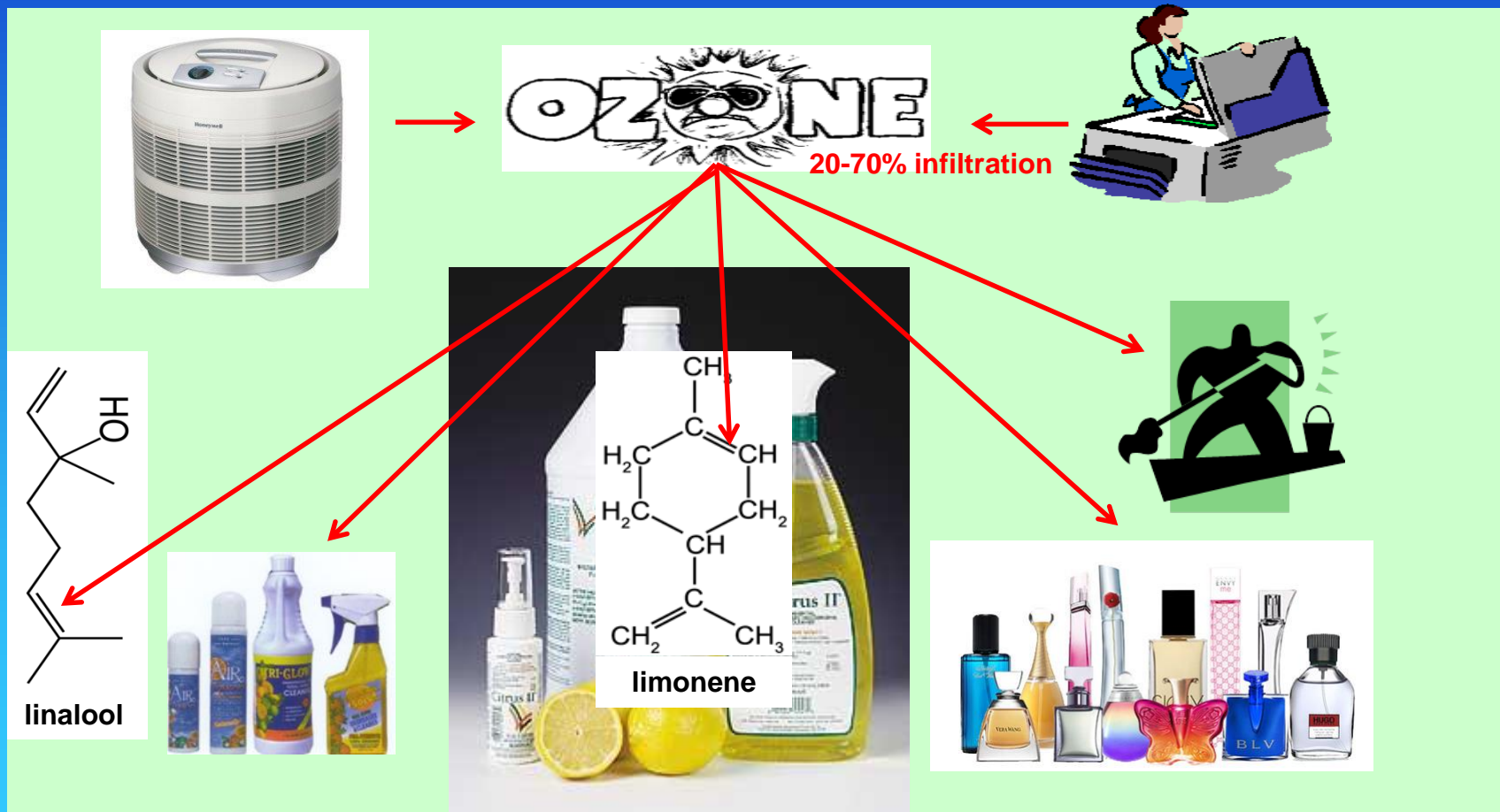
- Impact on perceived air quality – energy aspects  
ventilation
- Risk of subjective sensory irritation
- Risk of perceived "bad" health (health threat)
- Risk of deteriorated performance (mental distraction)
- Risk of physiological changes (stress pattern)  
hog farms

- Når lugten eller dens kilde er identificeret, bliver den en "ting"
- Når lugten eller dens kilde er diffus/ukendt, kan den aktivere "bekymring" og initiere psykologiske processer som "frygt og mental distraktion" og påvirke arbejdsrelateret performance

# Lugt versus sensorisk irritation



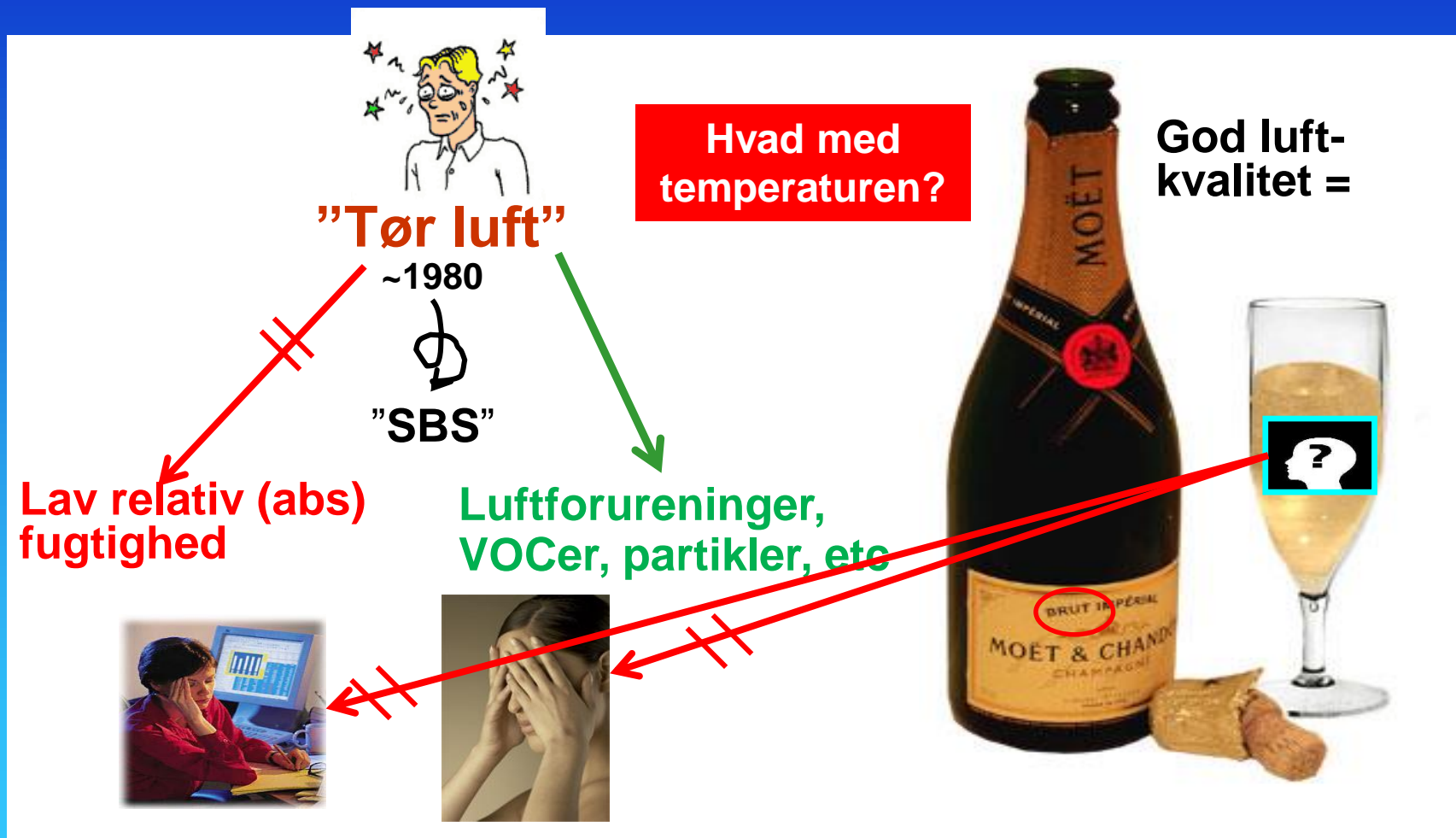
# Realistic emission testing of consumer products: formaldehyde, other oxidation products, and ultrafine particles



# "Sick building syndrome"

## Hvorfor luftforurening

## Hvorfor ikke fugt



Wolkoff/Kjærgaard *Environ Int* 33 (2007) 850-857.

Wolkoff et al. *JOEM* 54 (2012) 621-631.

Wolkoff *IJHEH* 216 (2013) 371-394.



# Betydningen for tårefilmens (PTF) stabilitet: rel. fugt, temperatur, højde, luftforureninger

	Vand tab	BUT	Film tykkelse	Wetness receptor medieret	Surfaktant egenskaber	Stabilitet af PTF
Øget relativ fugtighed	↓	↑	↑			😊
Høj temperatur Cornea	↑	↓	(↓)	↓	↓	😞
Lavt tryk (højde)	↑	↓				😞
VOCer indoors • Non-reaktiv • Reaktiv	nej	nej	nej			😐 [😞]
Inde-partikler Aggressive aerosoler (OH <sup>-</sup> )	?	?	?			😐 😞

**EPI studier og eksponerings-studier peger på at lav fugt og høj temperatur er detrimental for PTF stabiliteten**

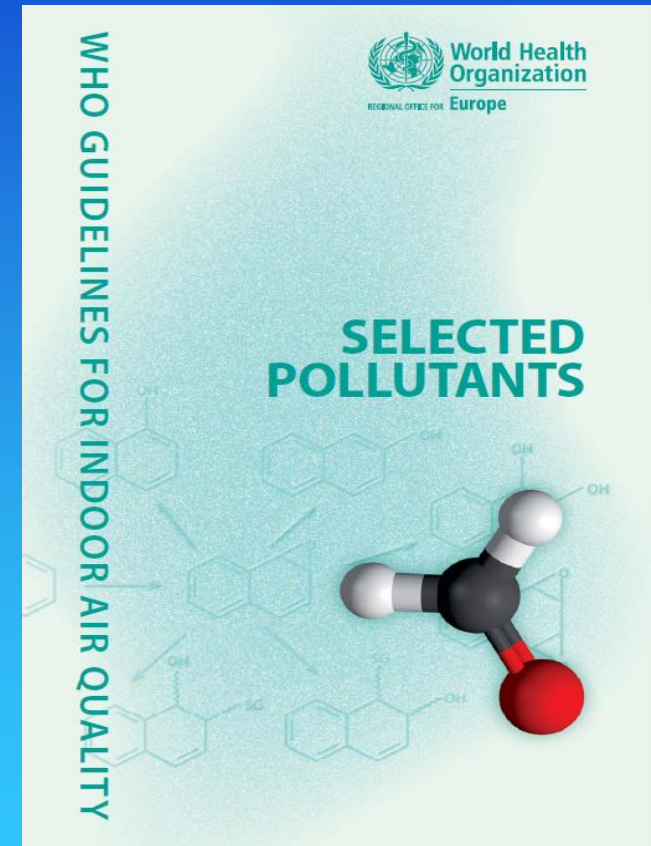
↑ = Større positiv effekt. ↓ = Negativ effekt.

Wolkoff et al. *JOEM* 54 (2012) 621-631.

☐ = Stabiliserende effekt på PTF. ☐ = Ingen effekt på PTF. ☐ = Destabiliserende effekt på PTF.

# Indoor Air Quality Guidelines WHO 2010

Pollutant	mg/m <sup>3</sup>	Criteria
<u>Benzene</u>	0.001	Life time risk = $6 \times 10^{-6}$
Carbon monoxide	100 35 10 7	15 min 1 hour 8 hours 24 hours
<u>Formaldehyde</u>	0.1	All 30 min periods, 24 hours
Naphthalene	0.01	Yearly average
<u>Nitrogen dioxide</u>	0.200 0.040	1 hour Yearly
PAH (BaP)	0.000001	Life time risk: $8,7 \times 10^{-5}$ for BaP
Radon	Per Bq	Life time risk: $0,6 \times 10^{-5}$ (non-smoker) Life time risk: $15 \times 10^{-5}$ (smoker)
Trichloro ethylene	0.0023	Life time risk = $10^{-6}$
Tetrachloro ethylene	0.25	Yearly exposure



# German Committee on Indoor Guide Values



The Committee on Indoor Guidelines sets Indoor air guidelines on 2 levels.

The Committee on Indoor Guidelines assesses indoor air pollutants and derives guide and reference values for indoor air.

<http://www.umweltbundesamt.de/en/topics/health/commissions-working-groups/german-committee-on-indoor-guide-values>

	$\mu\text{g}/\text{m}^3$	
	I	II
Limonen	1000	10000
$\alpha$ -pinen	200	2000

**Children faktor = 2**



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

# URBAN AIR, INDOOR ENVIRONMENT AND HUMAN EXPOSURE

Environment and Quality of Life

Report No 29

## **Harmonisation framework for health based evaluation of indoor emissions from construction products in the European Union using the EU-LCI concept**

Construction  
product directive  
89/106

December 2013



2013

JOINT RESEARCH CENTRE  
Institute for Health and Consumer Protection  
Chemical Assessment and Testing Unit

EUR 26168 EN



NATIONAL RESEARCH CENTRE  
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# LCI value - definition

- "Lowest concentration of interest"
- EU-LCI 'derived' value: The EU-LCI value of a compound derived de novo using the EU-LCI protocol

Compound	TOLUENE		Factsheet
Parameter	Note	Comments	Value / descriptor
<b>EU-LCI Value and Status</b>			
EU-LCI value	1	Mass/volume [ $\mu\text{g}/\text{m}^3$ ]	2900
EU-LCI status	2	Interim / Confirmed	Interim
EU-LCI year of issue	3	Year when the EU-LCI value has been issued	29 August 2012
<b>General Information</b>			
CLP-INDEX-Nr.	4	INDEX	R2B
EC-Nr.	5	EINECS – ELINCS - NLP	203-625-9
CAS-Nr.	6	Chemical Abstracts Service number	108-88-3
Harmonised CLP classification	7	Human health risk related classification	Flam. Liq. 2 Asp. Tox. 1 Skin. Irrit. 2 STOT SE 3 Rep. 2 STOT RE 2
Molar mass	8	[g/mol]	92.14
<b>Key Data / Database</b>			
Key study, Author(s), Year	9	Critical study with lowest relevant effect level	Zavalic et al., 1998
Read across compound	10	Where applicable	
Species	11	Rat,... human	Human
Route/type of study	12	Inhalation, oral feed,...	Inhalation, occupational
Study length	13	Days, subchronic, chronic	17 years
Exposure duration	14	Hrs/day, days/week	
Critical endpoint	15	Effect(s), site of	Neurological effects (colour vision impairment)
Point of departure (POD)	16	LOAEC*L, NOAEC*L, NOEC*L, Benchmark dose,....	LOAEC
POD Value	17	[mg/m <sup>3</sup> ] or [ppm]	123 mg/m <sup>3</sup>
<b>Assessment Factors (AF)</b>			
Adjustment for exposure duration	19	Study exposure hrs/day, days/week	4.2
AF Study Length	20	sa $\rightarrow$ sc $\rightarrow$ c (R8-5)	
Route-to-route extrapolation factor	21		
AF Dose-response	22 a	Reliability of dose-response, LOAEL $\rightarrow$ NOAEL	2
	22 b	Severity of effect (R 8-6d)	
Interspecies differences	23 a	Allometric Metabolic rate (R8-3)	

	23 b	Kinetic + dynamic	
<u>Intraspecies differences</u>	24	Kinetic + dynamic Worker - General population	5
AF (sensitive population)	25	Children or other sensitive groups	
Other adjustment factors Quality of whole database	26	Completeness and consistency Reliability of alternative data (R8-6 d,e)	
<b>Result</b>			
Summary of assessment factors	27	Total Assessment Factor (TAF)	42
POD/TAF	28	Calculated value ( $\mu\text{g}/\text{m}^3$ and ppb)	.....2928.57 $\mu\text{g}/\text{m}^3$ ..... 772.58 ppb
Molar adjustment factor	29	Used in read-across	
Rounded value	30	$[\mu\text{g}/\text{m}^3]$	2900
<b>Additional Comments</b>	31		
<b>Rationale Section</b>	32		

### Rationale for critical effects

Neurological effects have been demonstrated in rodents and in humans exposed by the respiratory route during chronic exposure. Toluene like many other organic solvents can impair colour vision, even at concentrations below 50 ppm. Reprotoxic and developmental effects have also been shown, particularly in animals. However, the neurological effects were reported at lower concentrations than those for effects on fertility or development.

WHO, RIVM, ATSDR, US-EPA, ANSES, German IAQ, Austria IAQ, based their values on human studies showing neurologic effects (could be neurobehavioural, vision impairment, ...).





VERSION: 07 January 2013		Trimethyl- benzenes	Xylenes	Butoxyethanol	Acetaldehyde	Styrene	p-Dichlorobenzene	Toluene	Ethyl- benzene	n-Butanal	ε-Caprolactam	α-Pinene
		Compounds assessed with priority (1)								Additionally assessed compounds (2)		
STANDARDISED SUMMARY FACTSHEET'S PARAMETERS	STANDARDISED SUMMARY FACTSHEET LINE											
ASSESSMENT FACTORS												
Interspecies: kinetic+dynamic	23b	2.5					2.5		3.6			
Intraspecies: kinetic+dynamic / Worker - General Population	24	10	5	10	10	5	10	5	10	10	5	10
AF Sensitive population	25											
Other assessment factors: quality of whole database	26									2		
Total Assessment Factor (TAF)	27	280	126	112	224	189	700	42	1015	224	84	112
Point of Departure (POD) Value	17	123 mg/m <sup>3</sup>	14.2 ppm	25 ppm	275 mg/m <sup>3</sup>	10 ppm	20 ppm	123 mg/m <sup>3</sup>	200 ppm	50 ppm	24 mg/m <sup>3</sup>	50 ppm
EU-LCI Value [µg/m <sup>3</sup> ]	1 & 30	450	500	1100	1200	250	150	2900	850	650	300	2500

**Fig. 1: Flow chart for the evaluation of VVOC, VOC and SVOC emissions from building products**



Test 1  
after 3 days

To be checked:

**TVOC<sub>3</sub> ≤ 10 mg/m<sup>3</sup>?** *No* → **Reject**

*Yes* ↓

**Carcinogens<sub>3</sub> of EU cat. 1A and 1B<sup>1</sup> ≤ 0.01 mg/m<sup>3</sup>?** *No* → **Reject**

*Yes* ↓

Test 2  
after 28 days

**TVOC<sub>28</sub> ≤ 1.0 mg/m<sup>3</sup>?** *No* → **Reject**


*Yes* ↓

**Σ SVOC<sub>28</sub> ≤ 0.1 mg/m<sup>3</sup>?** *No* → **Reject**

*Yes* ↓

**Carcinogens<sub>28</sub> EU cat. 1A and 1B<sup>1</sup> ≤ 0.001 mg/m<sup>3</sup>?** *No* → **Reject**

*Yes* ↓

 Sensory testing (pilot phase)

↓

**Assessable compounds:**  
all VVOC, VOC, SVOC with LCI\*\*  
(including Carcinogens with LCI)  
**R = Σ C<sub>i</sub>/LCI<sub>i</sub> ≤ 1?** *No* → **Reject**

*Yes* ↓

**Non-assessable compounds:**  
sum of VOC with unknown LCI\*\*  
**Σ VOC<sub>28</sub> ≤ 0.1 mg/m<sup>3</sup>?** *No* → **Reject**

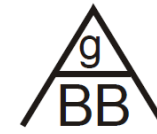
*Yes* ↓

**Product is suitable for indoor use**

Ausschuss zur gesundheitlichen  
Bewertung von Bauprodukten

Committee for Health-related  
Evaluation of Building Products

AgBB - February 2015  
Updated List of LCI values 2015 in Part 3



Ausschuss zur  
gesundheitlichen  
Bewertung von  
Bauprodukten

Committee for  
Health-related  
Evaluation of  
Building Products

*This version applies from the date it is published. The version it replaces will continue to be valid for one more year. This also applies to updated lists of LCI values. However, old and new versions must each be applied as a complete document; they may not be mingled.*

**A contribution to the Construction Products Regulation:**

**Health-related Evaluation Procedure for Volatile Organic  
Compounds Emissions (VVOC, VOC and SVOC) from  
Building Products**

For the evaluation of each compound  $i$  the ratio  $R_i$  is established as defined in equation (2).

$$R_i = C_i / LCI_i \quad (2)$$

where  $C_i$  is the chamber concentration of compound  $i$ . For  $R_i < 1$ , it is assumed that there will be no effects. If several compounds with a concentration  $> 5 \mu\text{g}/\text{m}^3$  are detected, additivity of effects is assumed and it is required that  $R$ , the sum of all  $R_i$ , shall not exceed the value 1

$$R = \text{sum of all } R_i = \text{sum of all ratios } (C_i / LCI_i) \leq 1 \quad (3)$$

Products which do not fulfil this condition are rejected.

# Unsolved issues

- Multiple sources
- Odour
- Reactive chemistry
- Quality control
- TVOC – what does it really mean?
- R-value – adding compounds with different toxicity!
- LCI value versus IAQ guideline?
- Compounds with inadequate tox data to derive a value, e.g. benzaldehyde and phenol

# ”Delegated act” (2017-2018) for byggemateriale VOC emission performance i henhold til produktstandard

4 egenskaber:

- 1) TVOC
- 2) Formaldehyd
- 3) Carcinogene stoffer
- 4) EU-LCI ratio – R-value baseret

”The delegate Act” vil danne basis for af kunne implementere VOC emissioner i produktstandarder

# Løsninger/Solutions

- **Regulering**
- **Guidelines-grænseværdier**
- **Kilde/emissions-kontrol (WHO 1989)**
- **Mærkningssystem for emissioner**
- **Ændringer i adfærd**
- **Vær bevidst om dit indeklima**

## THE END

