AIVC WORKSHOP

DEFINITION AND ASSESSMENT OF INDOOR AIR QUALITY CLASSES: MEASURING UNCERTAINTIES AND DISTURBING FACTORS

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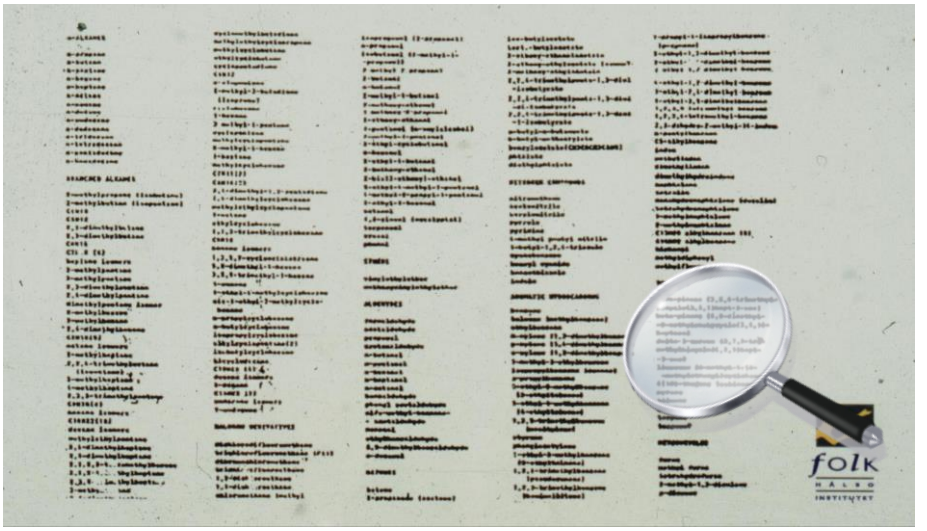
INDOOR AIR QUALITY DEFINITION

- The extent to which objective indoor air quality guidelines are met.
- The subjective rating of acceptability of an indoor atmospheric environment; the air quality as rated by humans in subjective evaluations (perceived air quality).

Source: Glossary of the Indoor Air Sciences

INDOOR AIR QUALITY = THOUSANDS OF AIR CONT.

(in small concentrations and various combinations)



INDOOR AIR QUALITY AFFECTS

- Sensory comfort: odour intensity and hedonics, air freshness, satisfaction=>perceived air quality (% dissatisfied)
- Health: acute and chronic effects
- Performance: cognitive performance, work performance, learning

OBJECTIVES

- To identify measuring uncertainties and disturbing factors resulting in inaccurate classification of indoor air quality
- To approximate the size of measuring uncertainties and the consequences for the estimated level of indoor air quality
- Objective measurements and subjective ratings will be considered to match with the specifications of EN 15251
- Effects of indoor air quality on sensory comfort (%dissatisfied with air quality) will be considered as they are the main design criteria in EN 15251 and other relevant standards

NOT INCLUDED IN THE PRESENTATION

- Experimental design and analysis
- Detailed theory of measurements
- Recommendations regarding measuring equipment
- Error theory
- Examples of measurements in the laboratory and practice

EN15251, CATEGORIES OF INDOOR ENVIRONMENT/AIR QUALITY

Category	Explanation
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons
II	Normal level of expectation and should be used for new buildings and renovations
III	An acceptable, moderate level of expectation and may be used for existing buildings
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year

EN15251 AIR QUALITY REQUIREMENTS

Category	Expected Percentage Dissatisfied	Airflow per person l/s/pers
I	15	1O
II	20	7
III	30	4
IV	> 30	< 4

Subjective measurements

Category	Corresponding CO2 above outdoors in PPM for energy calculations
I	350
II	500
III	800
IV	< 800

Objective **measurements**

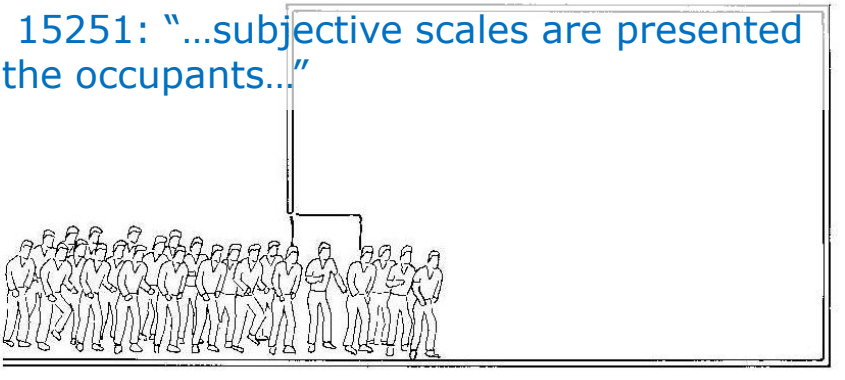
EN15251
CATEGORIES OF EMISSIONS FROM BUILDING

Category	Very-low polluting building	Low-polluting building	Non-low polluting building
I	✓	✓	✓
II	✓	✓	✓
III	✓	✓	✓
IV	✓	✓	✓

SUBJECTIVE MEASUREMENTS OF INDOOR AIR QUALITY

ASHRAE 62-2013: "… a group of untrained subjects (…) who render a judgement of acceptability…"

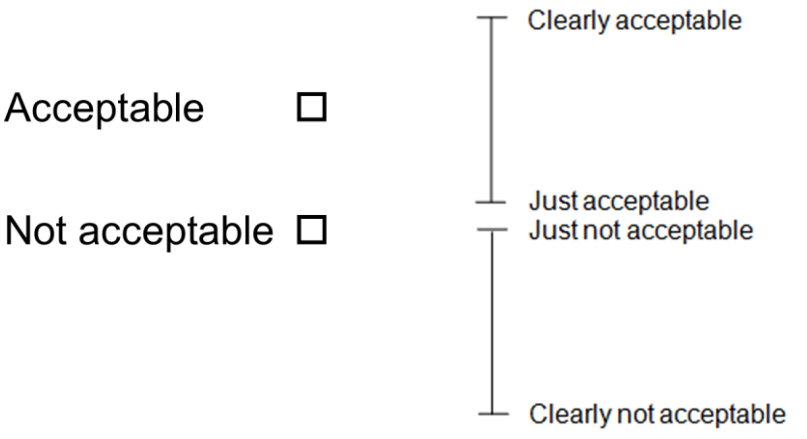
EN 15251: "…subjective scales are presented to the occupants…"



SOME FACTORS DISTURBING PRECISION OF SUBJECTIVE MEASUREMENTS OF AIR QUALITY

- Type of measuring scale
- Group size (panel) and variation
- Transformation curves
- Endpoints of sensory comfort
- Temperature and relative humidity
- Length of exposure

TYPE OF SCALE CONTINUOUS OR DICHOTOMOUS ACCEPTABILITY SCALE



DICHOTOMOUS SCALE VARIANCE AND PANEL SIZE

Acceptable ☐

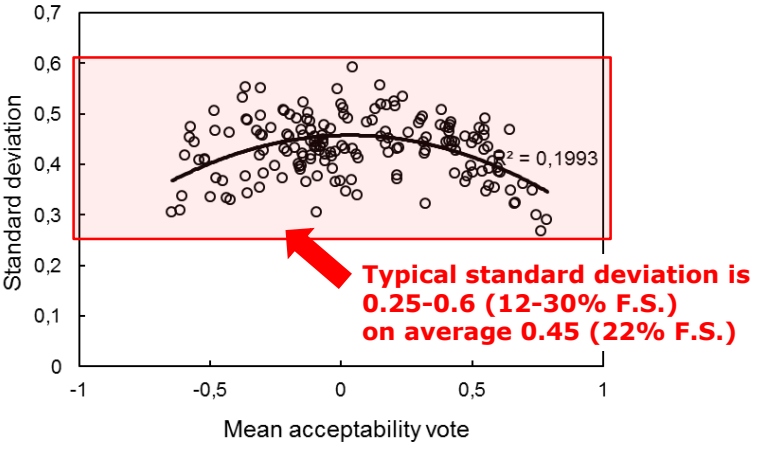
Not acceptable ☐

- Relative standard error (RSE*) ca. 20% for 20 panelists
- RSE ca. 10% for ca. 65 panelists
- RSE ca. 1% for ca. 6,000 panelists

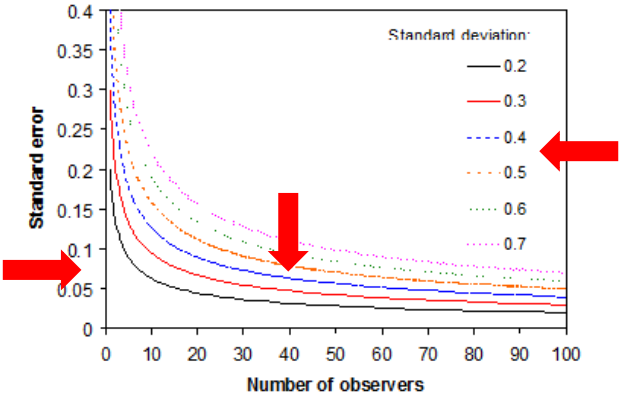
*$\mathrm{RSE} = 1/\sqrt{n} \cdot 100\%; \mathrm{RSE} \geq 20 - 25\%$ is unacceptable

=> EXAMPLE: Relative standard error is 20% when a group of 20 panelists is used to verify whether the indoor air quality level corresponding to 80% acceptability (20% dissatisfaction) is satisfied

CONTINUOUS SCALE VARIANCE



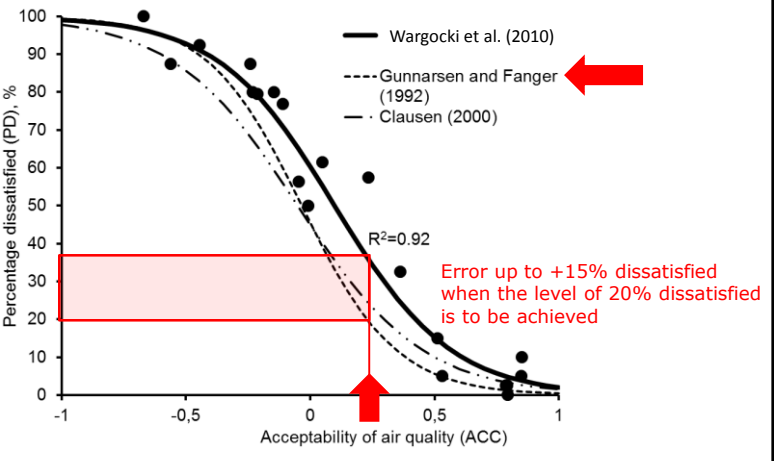
CONTINUOUS SCALE VARIANCE AND PANEL SIZE



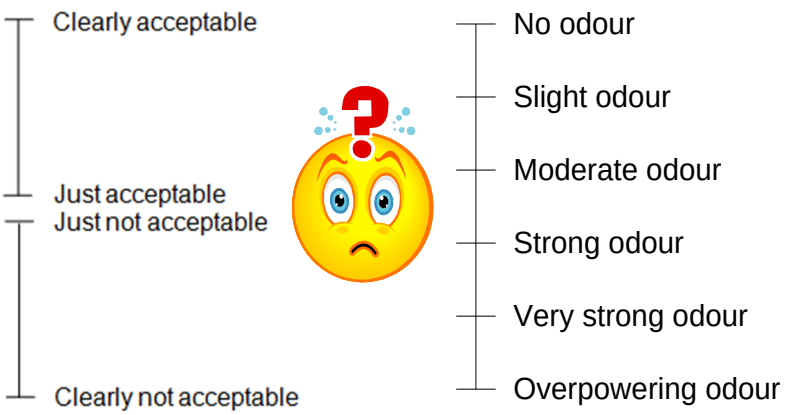
=> EXAMPLE: With a group of 40 panelists, 20% dissatisfied is estimated with SE=~0.08 (RSE=35%; >80 panelists so RSE<20%) uncertainty is 5-10% (the range is ca. 15-30% dissatisfied (note=> whole range of categories of indoor environment in EN 15251)

Source: Wargocki et al. (2004)

TRANSFORMATION CURVES ACCEPTABILITY VS % DISSATISFIED



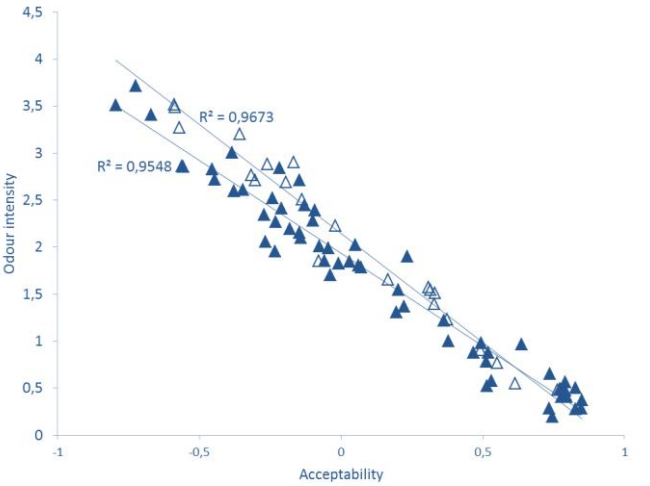
ENDPOINTS OF SENSORY COMFORT ODOR INTENSITY OR ACCEPTABILITY



ACCEPTABILITY OR ODOUR INTENSITY

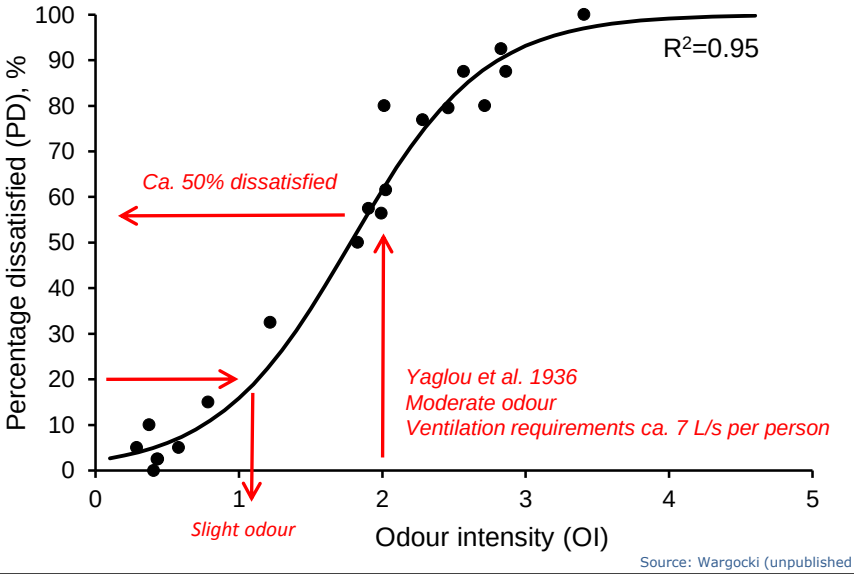
- Acceptability = Odour intensity + other sensory attributes (freshness, pleasantness), but probably also past experience and preferences
- Odour intensity = stimulation of odour sense, straightforward direct measurement

ACCEPTABILITY VS ODOUR INTENSITY



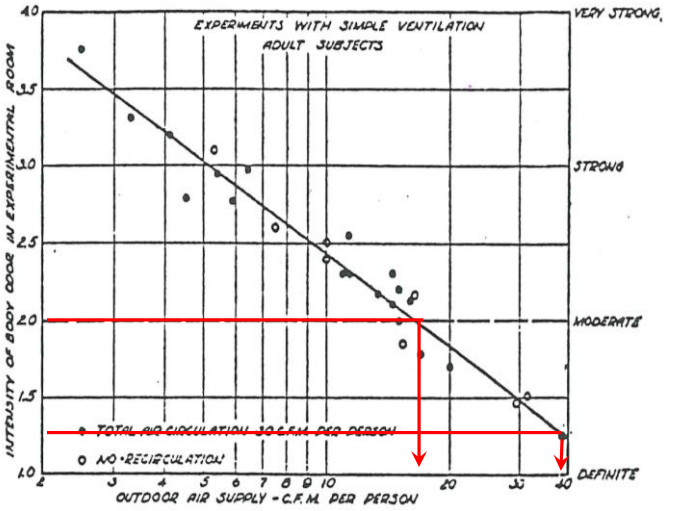
=> rating of acceptability is merely the rating of odour intensity

ODOUR INTENSITY VS. % DISSATISFIED



Source: Wargocki (unpublished data)

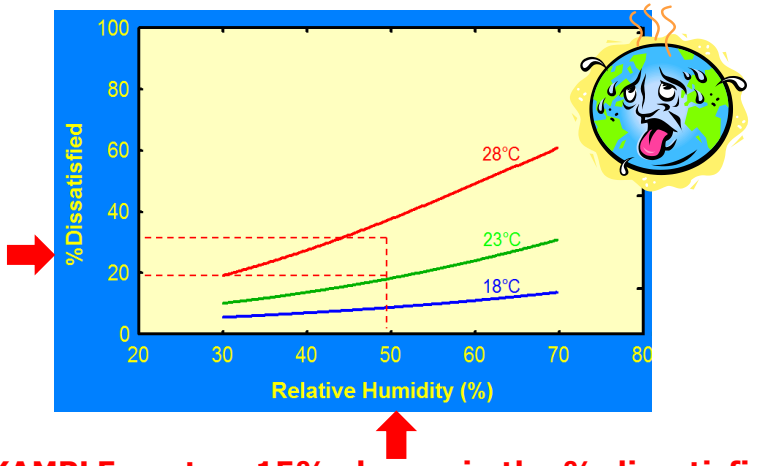
CONSEQUENCES FOR VENTILATION REQUIREMENTS



~40 cfm/p, ca. 20 L/sp

Source: Yaglou et al. (1936)

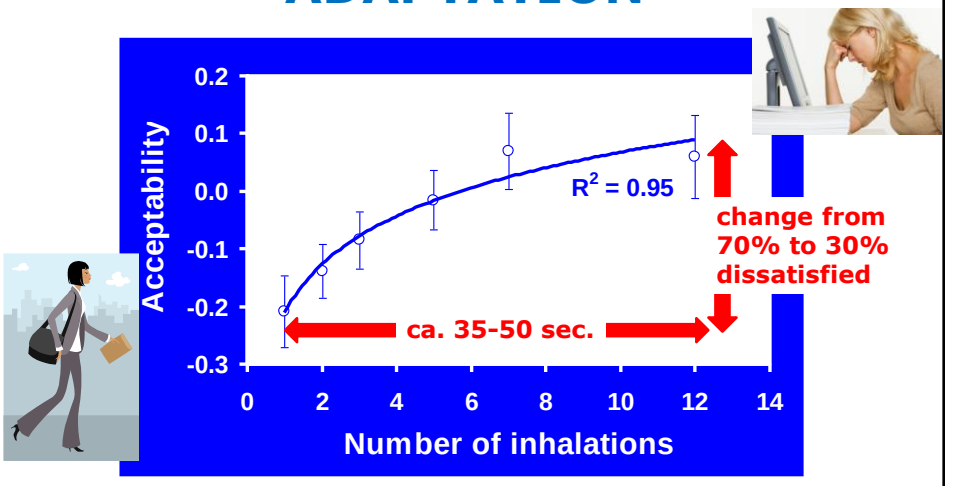
TEMPERATURE AND RELATIVE HUMIDITY, EFFECTS ON SENSORY COMFORT



=> EXAMPLE: up to a 15% change in the % dissatisfied with air quality in the range of temperatures recommended in the Category II (EN 15251)

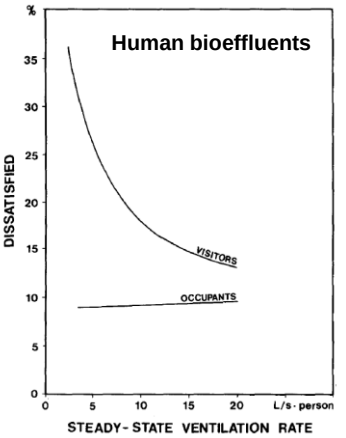
Source: Fang et al. (1997)

LENGTH OF EXPOSURE: ADAPTATION



=> for visitors an immediate assessment is essential

ADAPTED OR UNADAPTED?



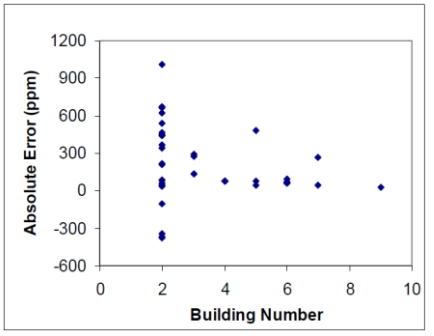
=> the ratings of occupants may not provide credible information re. actual % of dissatisfied with air quality

Source: Berg-Munch et al. (1986)

SOME FACTORS DISTURBING PRECISION OF OBJECTIVE MEASUREMENTS OF AIR QUALITY

- Uncertainty of measurements of CO_2 concentration
- Position of measurements
- Uncertainty of odor thresholds and the precision of chemical measurements
- Precision of estimation of strength of pollution sources

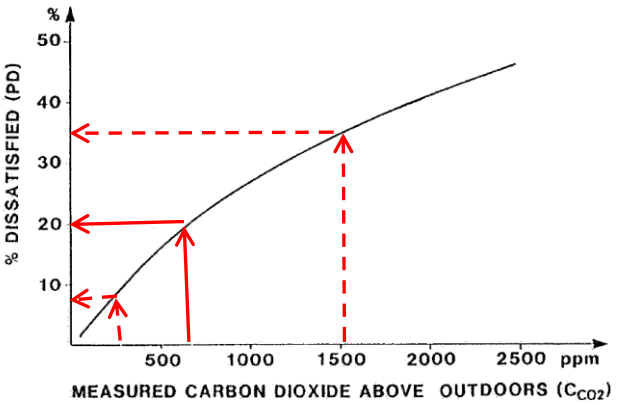
ACCURACY OF TYPICAL CO_2 SENSORS DEPLOYED IN BUILDINGS



- 44 sensors in 9 buildings in California
- Some with zero calibration
- Single point calibration with 470 ppm or less
- Range of error: 378-1013 ppm
- Reasons for poor performance not examined (could be due to technical limitations, poor maintenance and lack of calibration)

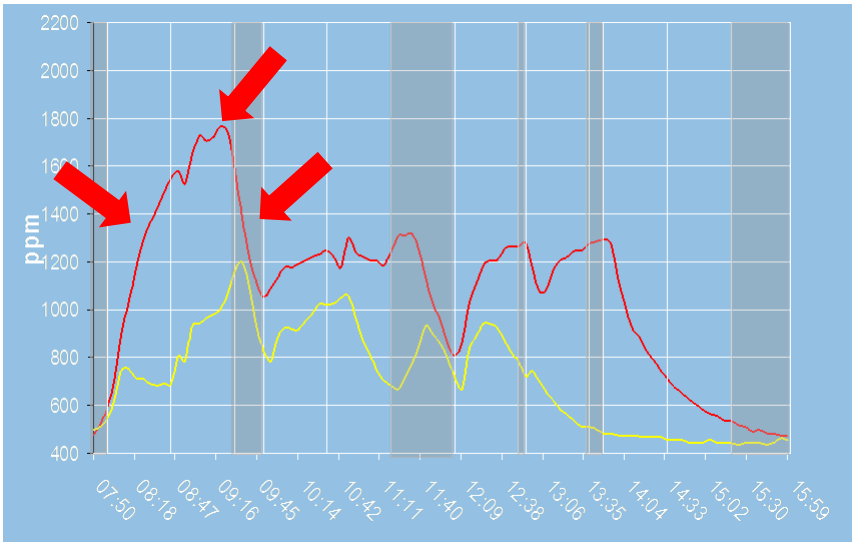
Source: Fisk (2007)

CO_2 AND % DISSATISFIED



=> EXAMPLE: inaccuracy of predicting % dissatisfied is about 15%

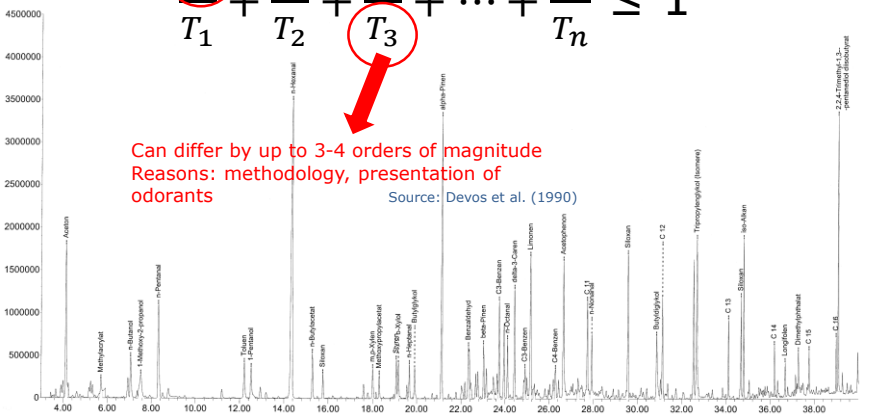
DYNAMIC CHANGE OF CO_2



AIR QUALITY BASED ON (ODOUR) THRESHOLD LIMITS

Depends on analytical precision

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \cdots + \frac{C_n}{T_n} \leq 1$$



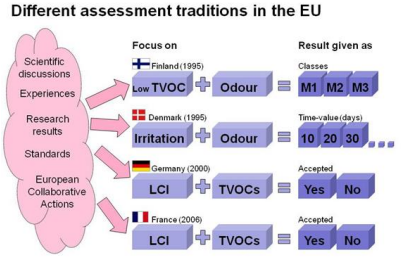
BASIC VENTILATION FOR DILUTING EMISSIONS FROM BUILDING, CAT. II

8 studies in existing buildings	**olf/m²floor**	**L/sm²**
97 office buildings & assembly halls (previous ETS)	0.23±0.06	1.7±0.5
6 office buildings (no ETS)	0.11±0.09	0.8±0.6
10 kindergartens	0.06±0.04	0.4±0.3
6 schools	0.06±0.06	0.4±0.6
1 department store	0.15	1.1
3 office buildings (no ETS)	<0.05	<0.37
EN15251		
Non-low-polluting building	0.2	1.4
Low-polluting building	0.1	0.7
Very low polluting building	0.05	0.35

Source: Wargocki et al. 2004

DEFINITION OF EMISSION CLASSES

- Non-low-polluting building (w/ETS?)
- Low-polluting building (w/o ETS?)
- Very low polluting building (meet national/intl criteria)

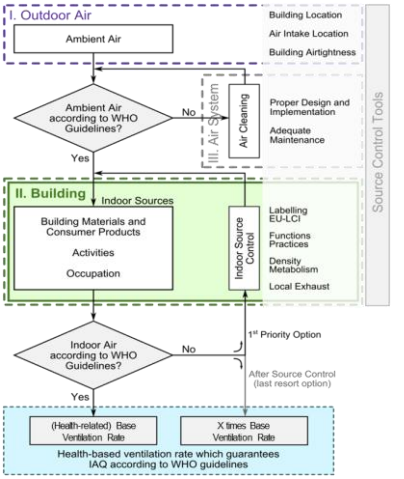


CONCLUSIONS

- Many factors can influence assessments of indoor air quality resulting in imprecise estimation of the indoor air quality levels expressed by the percentages dissatisfied with air quality.
- At relatively high air quality, when the percentages of dissatisfied are <30%, the uncertainty of estimates can be as large as the entire range of the % dissatisfied with air quality defined by the Standard EN15251 for different categories of indoor air quality.
- Using % dissatisfied to set the indoor air quality requirements can be regarded as somewhat challenging because of the difficulties to perform accurate measurements and to ensure compliance.
- There is a need for reexamination of current approach in order to minimize uncertainties related to estimates of % dissatisfied with air quality

POSSIBLE WAY FORWARD HEALTH-BASED VENTILATION, ECA REPORT 30

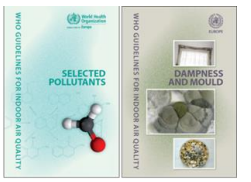
- Use health endpoints (acute and chronic)
- Define exposure levels (WHO Air Quality Guidelines for ambient and indoor air)
- Use source control as primary strategy to achieve indoor air quality (labeling, local exhaust, air filtration and cleaning, air tightness)
- Use ventilation as a secondary/supplementary method designed based on flow per person and health criteria
- Disconnect from systems used to control thermal environment



USE e.g. WHO AIR QUALITY GUIDELINES AS A ~~MINIMUM~~ BASIC REQUIREMENT

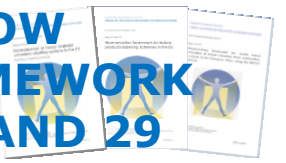
Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Benzene	No safe level can be determined	-
Carbon monoxide	15 min. mean: 100 mg/m^3 1h mean: 35 mg/m^3 8h mean: 10 mg/m^3 24h mean: 7 mg/m^3	-
Formaldehyde	30 min. mean: 100 µg/m^3	-
Naphthalene	Annual mean: 10 µg/m^3	-
Nitrogen dioxide	1h mean: 200 µg/m^3 Annual mean: 40 mg/m^3	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m^3	
Sulfure dioxide	-	10 min. mean: 500 µg/m^3 24h mean: 20 mg/m^3
Ozone	-	8h mean:100 µg/m^3
Particulate Matter PM 2,5	-	24h mean: 25 µg/m^3 Annual mean: 10 µg/m^3
Particulate Matter PM 10	-	24h mean: 50 µg/m^3 Annual mean: 20 µg/m^3

WHO, 2006 WHO, 2000



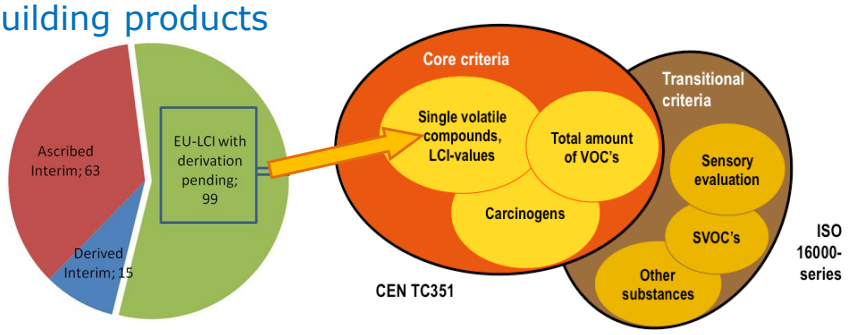
WHO, 2010 WHO, 2009

ADAPT AND FOLLOW HARMONIZATION FRAMEWORK ECA REPORTS 24, 27 AND 29



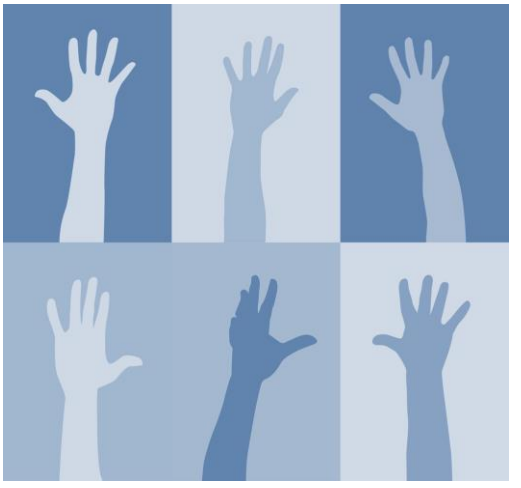
- EU-LCI: Harmonization of the health based evaluation of **chemical emissions** from building products

- Harmonization framework for indoor **products labeling schemes** in EU



Courtesy of Stylianos Kephalopoulos, JRC, Ispra, Italy

QUESTIONS?



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