MŰEGYETEM 1782

Comfort in Buildings

Indoor Air Quality

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IDES-EDU

INTELLIGENT ENERGY EUROPE

PROF / TRAC

Open Training and Qualification Platform on NZEB construction and renovation

ENERGY

PEOPLE

COMFORT

BUILDING

Indoor environmental factors

- **Thermal comfort or indoor climate**
  - Temperature, humidity, air velocity
- **Indoor air quality**
  - odours, indoor air pollution, fresh air supply,…
- **Visual or lighting quality**
  - View, illuminance, luminance ratios, reflection,…
- **Acoustical quality**
  - Outside and indoor noise and vibrations

Indoor Air Quality (IAQ)

Indoor Environmental Quality (IEQ)

Raumluftqualität

Fanger (Technical University of Denmark)

Fitzner (Technische Universität Berlin)

Seppänen (Helsinki University of Technology)

Max von Pettenkofer (1818-1901)

INDOOR AIR QUALITY

IAQ = „…an indicator of the types and amounts of pollutants in the air that might cause discomfort or risk of adverse effects on human or animal health, or damage to vegetation.“ (ISIAQ)

Acceptable IAQ = “air in which there are no harmful concentrations of contaminants as determined by cognizant authorities and with which 80% or more the exposed occupants do not express dissatisfaction“ (ASHRAE)

Rehva GB14

IAQ assessment

- Measurements
- Calculation
- Subjective votes

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Perceived indoor air quality

percentage of dissatisfied

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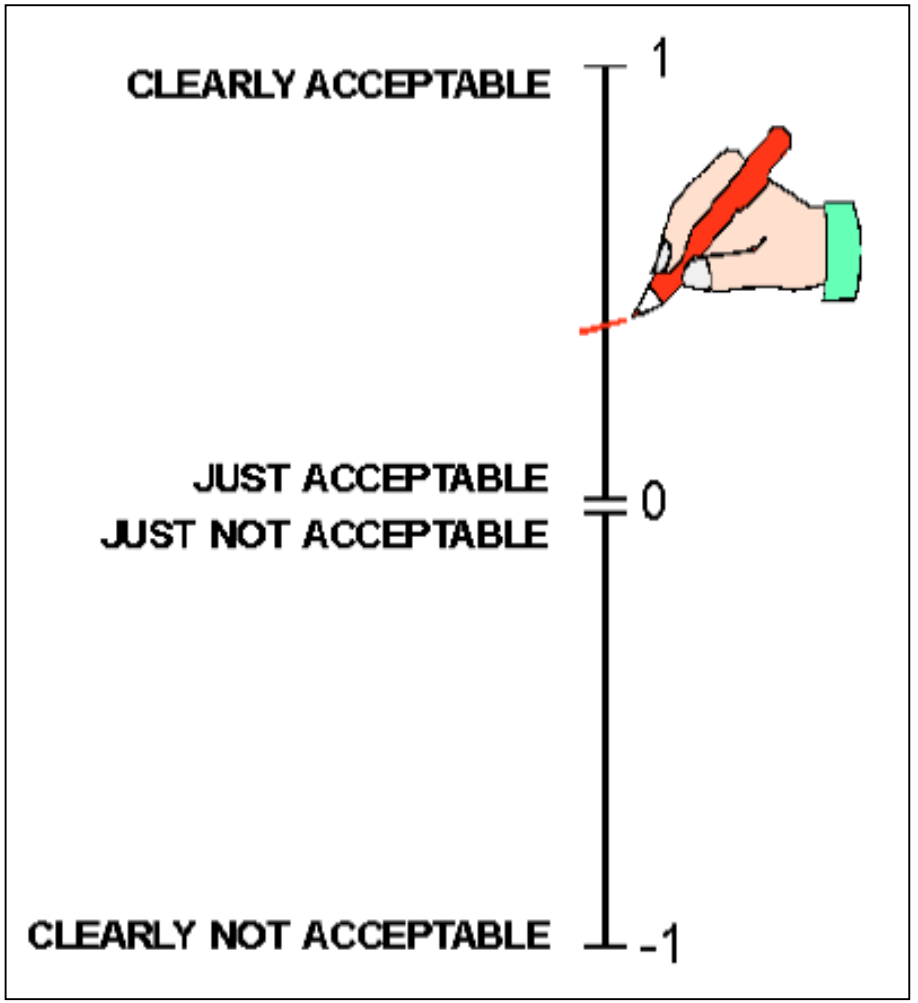
Perceived indoor air quality

- Panels of subject judging
- Individual judgement
- Immediately upon exposure
- 15 s, unadapted vote
- Continuous acceptability scale



Rehva GB14

Fanger: Indoor air quality handbook

Perceived indoor air quality

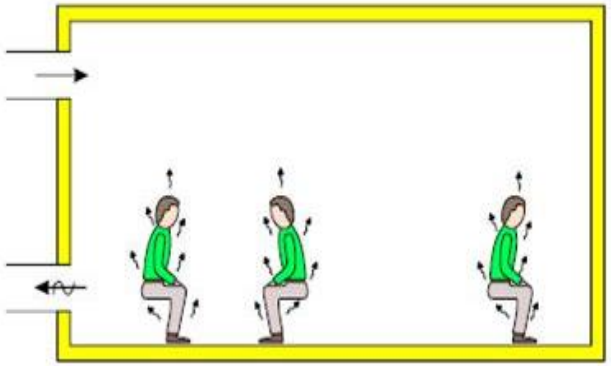
- Classification into IAQ categories:
- EN CR 1752:1998 … A, B, C
- EN 15251: 2007 … I, II, III, IV

Categ.	Categ.	Explanation
I	A	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons
II	B	Normal level of expectations
III	C	An acceptable moderate level of expectations
IV		Values outside the criteria for the above categories

Strenght of pollution souces

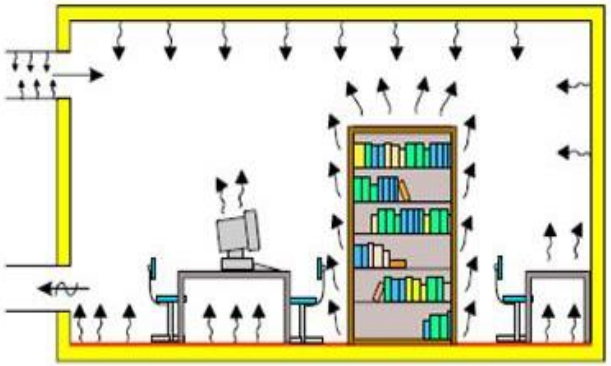
Gc - Strenght of pollution souces: **Olf unit**

1 olf = sensory pollution a standard person,
average adult working in a office ,
in thermal comfort,
0,7 bath/day

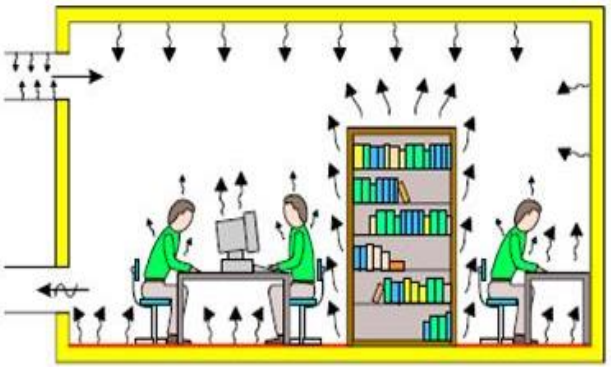


3 standard persons (olf)

+



4 equivalent standard persons (olf)



7 equivalent standard persons (olf)

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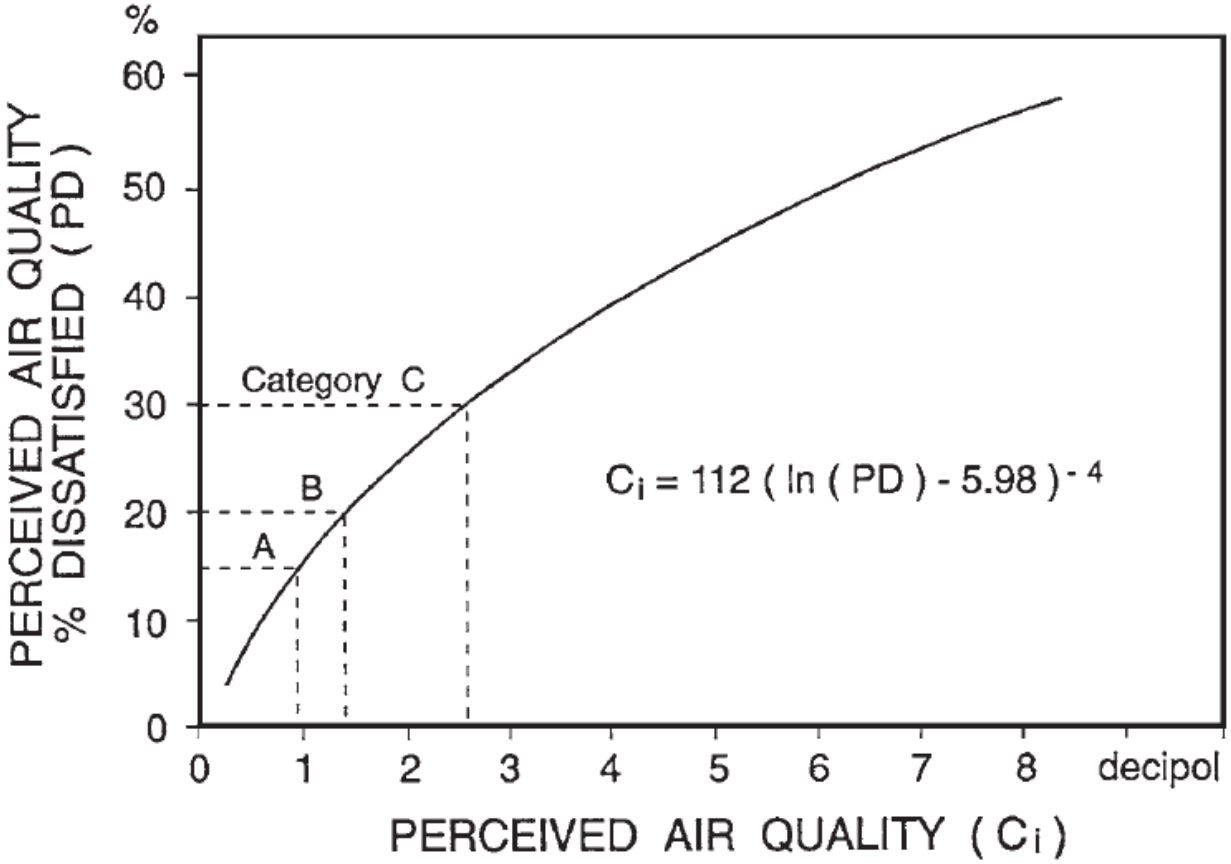
Perceived indoor air quality

- **Pol unit** - perceived air quality in a space with a sensory load of 1 olf ventilated by 1 L/s

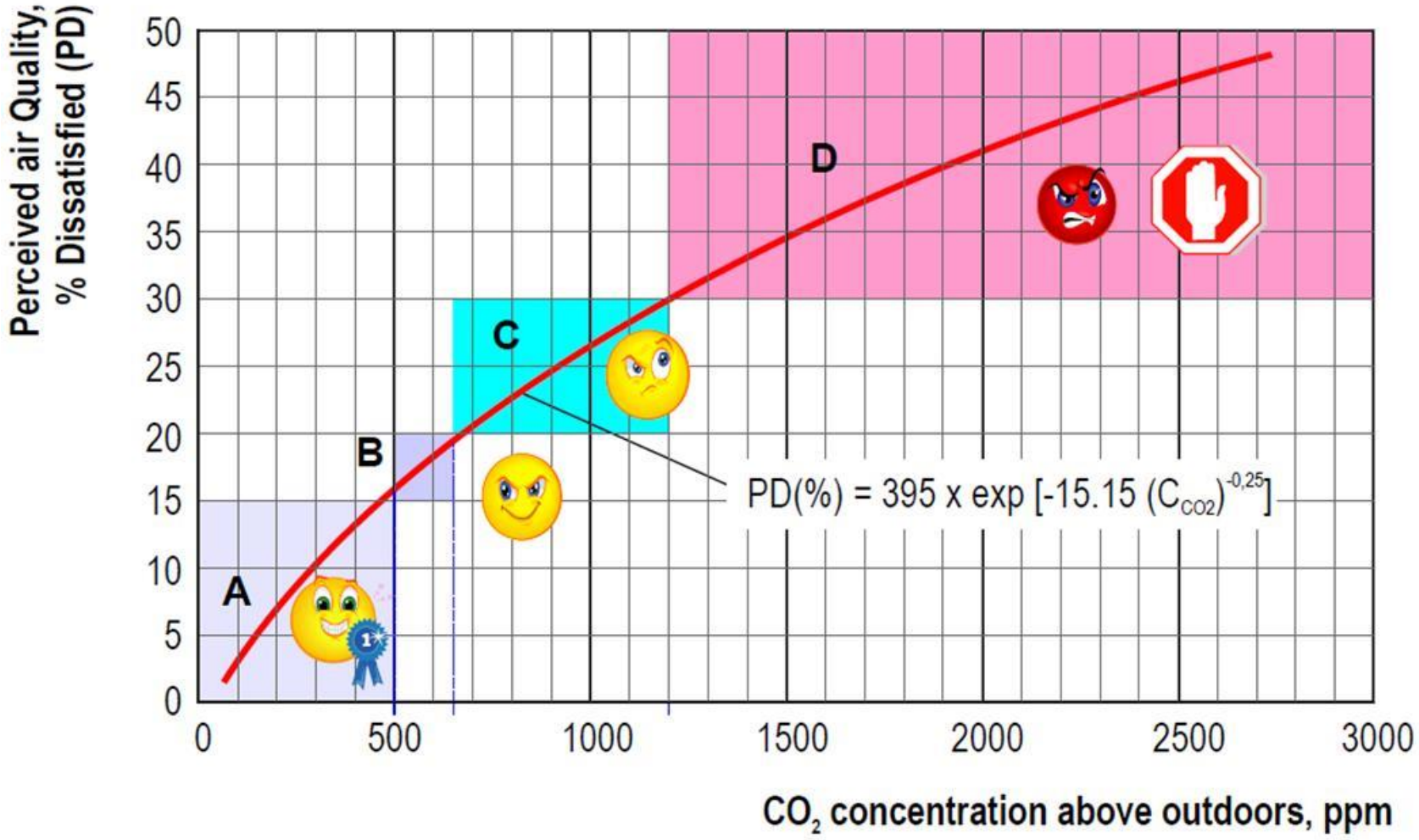
$$1\ \text{pol} = 1\ \frac{\text{olf}}{\text{L/s}}$$

$$1\ \text{decipol} = 1\ \text{dp} = 0.1\ \text{pol}$$



Fanger: Indoor air quality handbook

Perceived indoor air quality and the concentration of CO_2



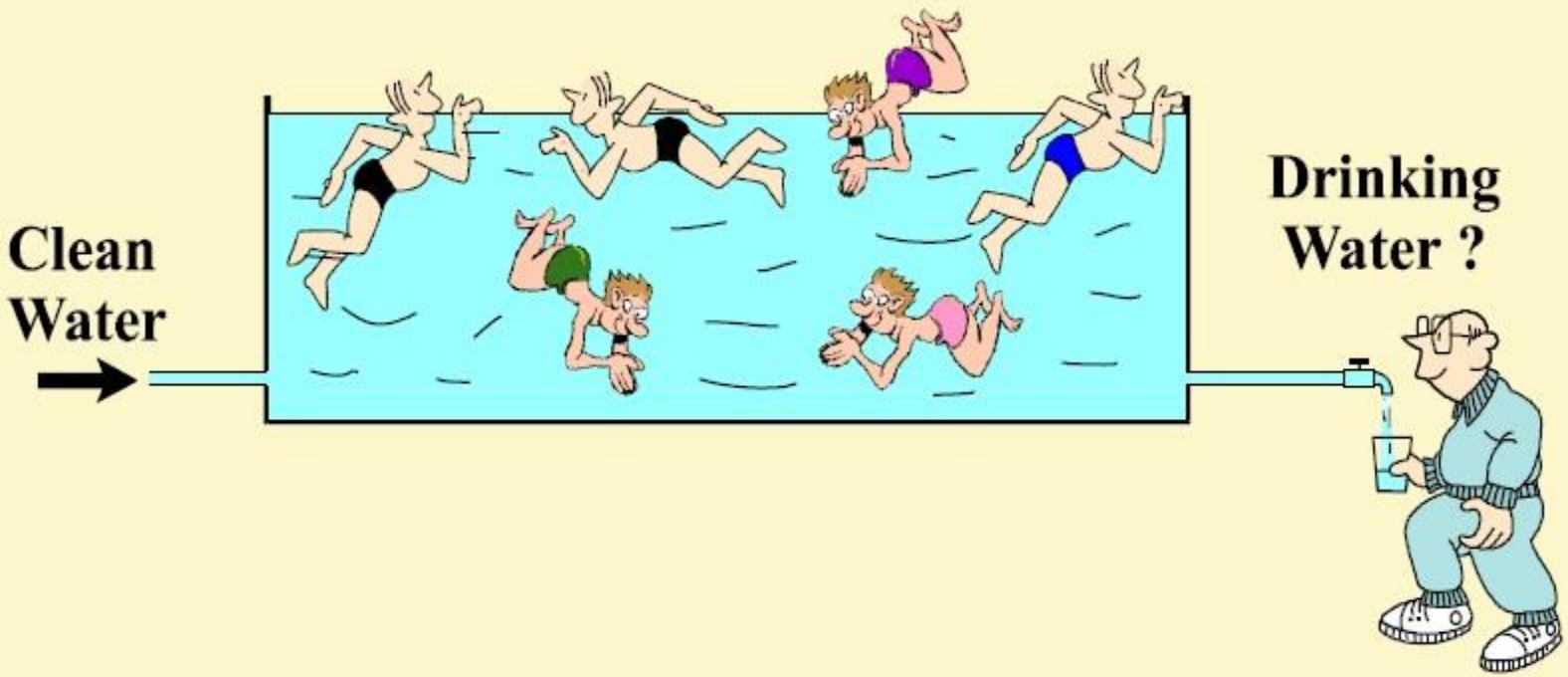
The Age-of-air

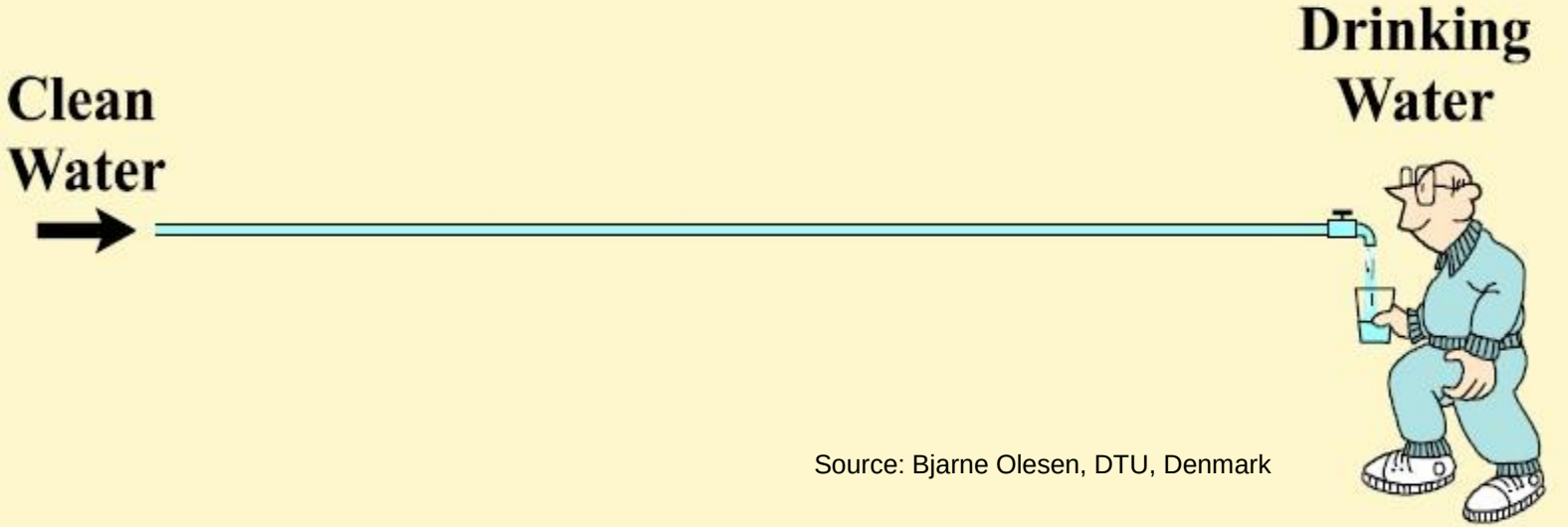
www.innova.dk

- Age-of-air in a room
- Local-mean-age-of-air
- Room-average age-of-air

Ventilation today ...

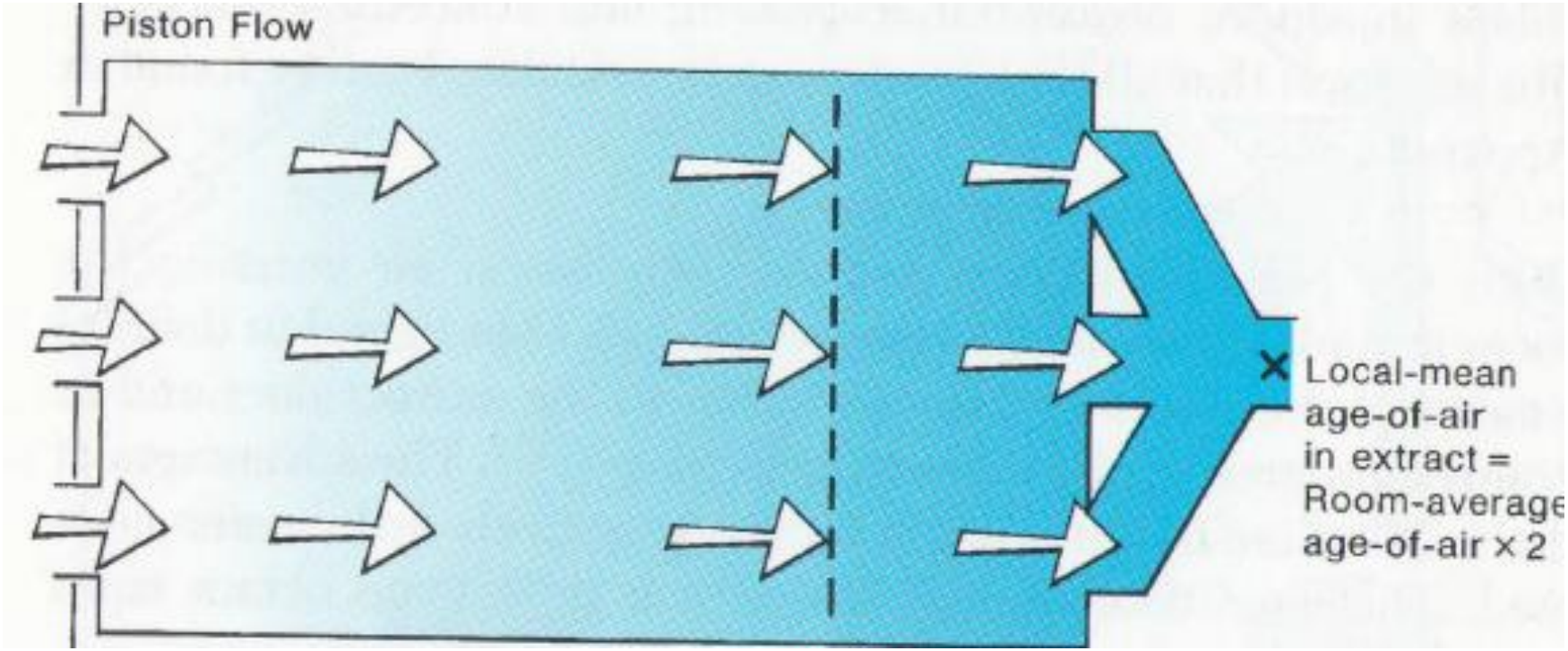
Source: Bjarne Olesen, DTU, Denmark





Source: Bjarne Olesen, DTU, Denmark

Age-of-air And Air-exchange Efficiency



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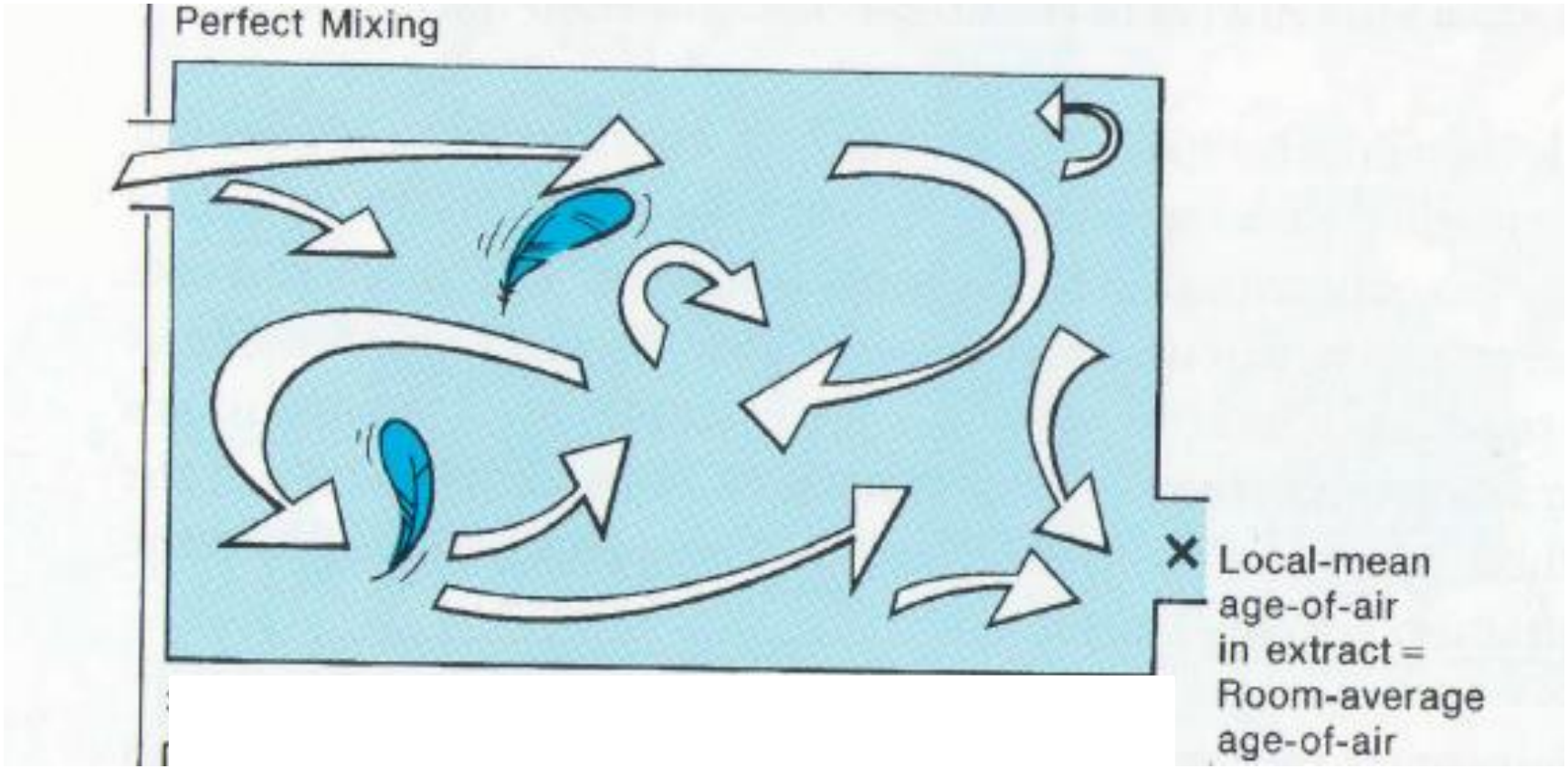
Age-of-air And Air-exchange Efficiency



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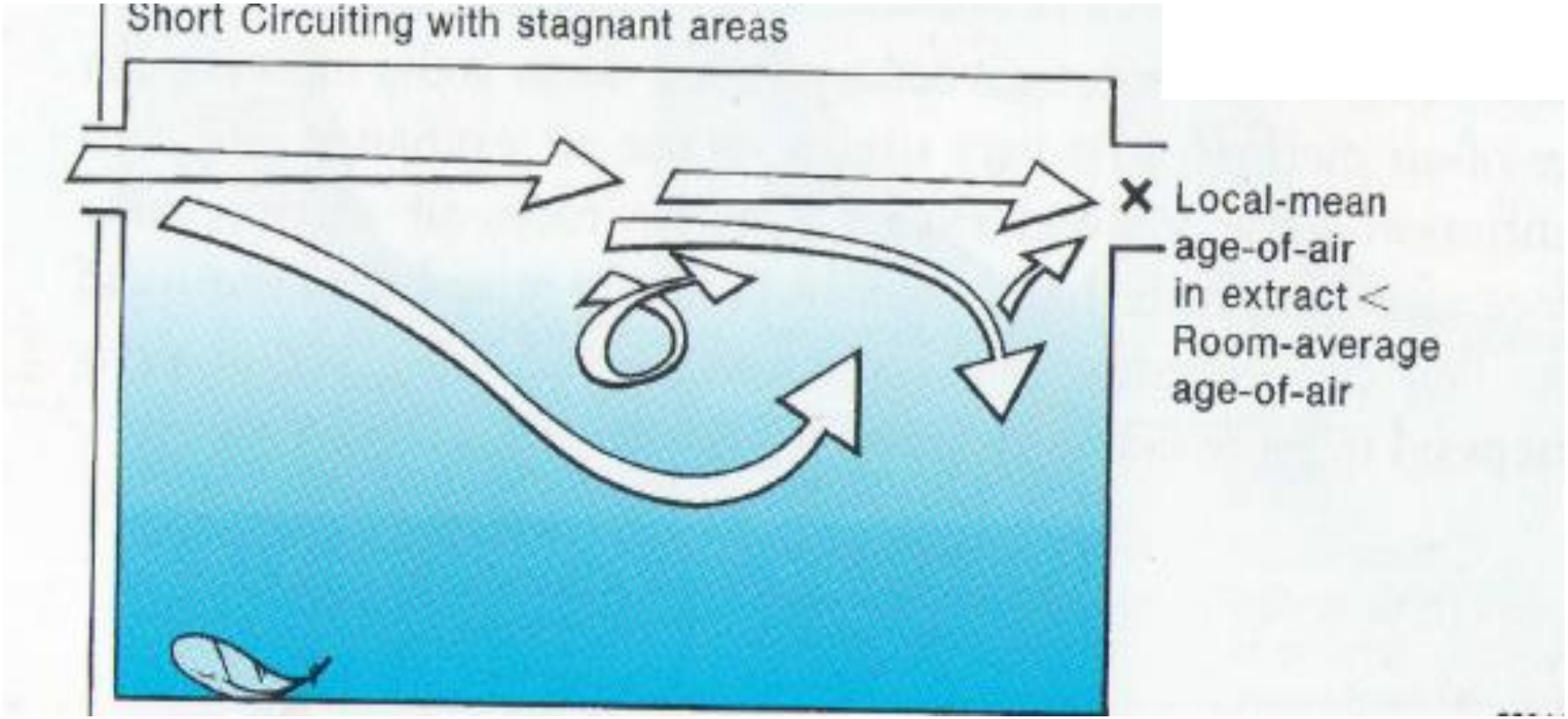
Age-of-air And Air-exchange Efficiency



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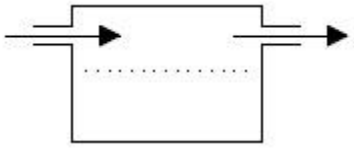
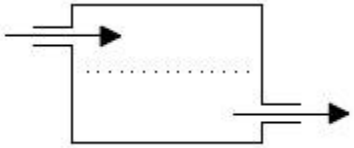
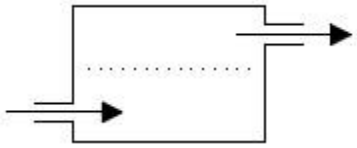
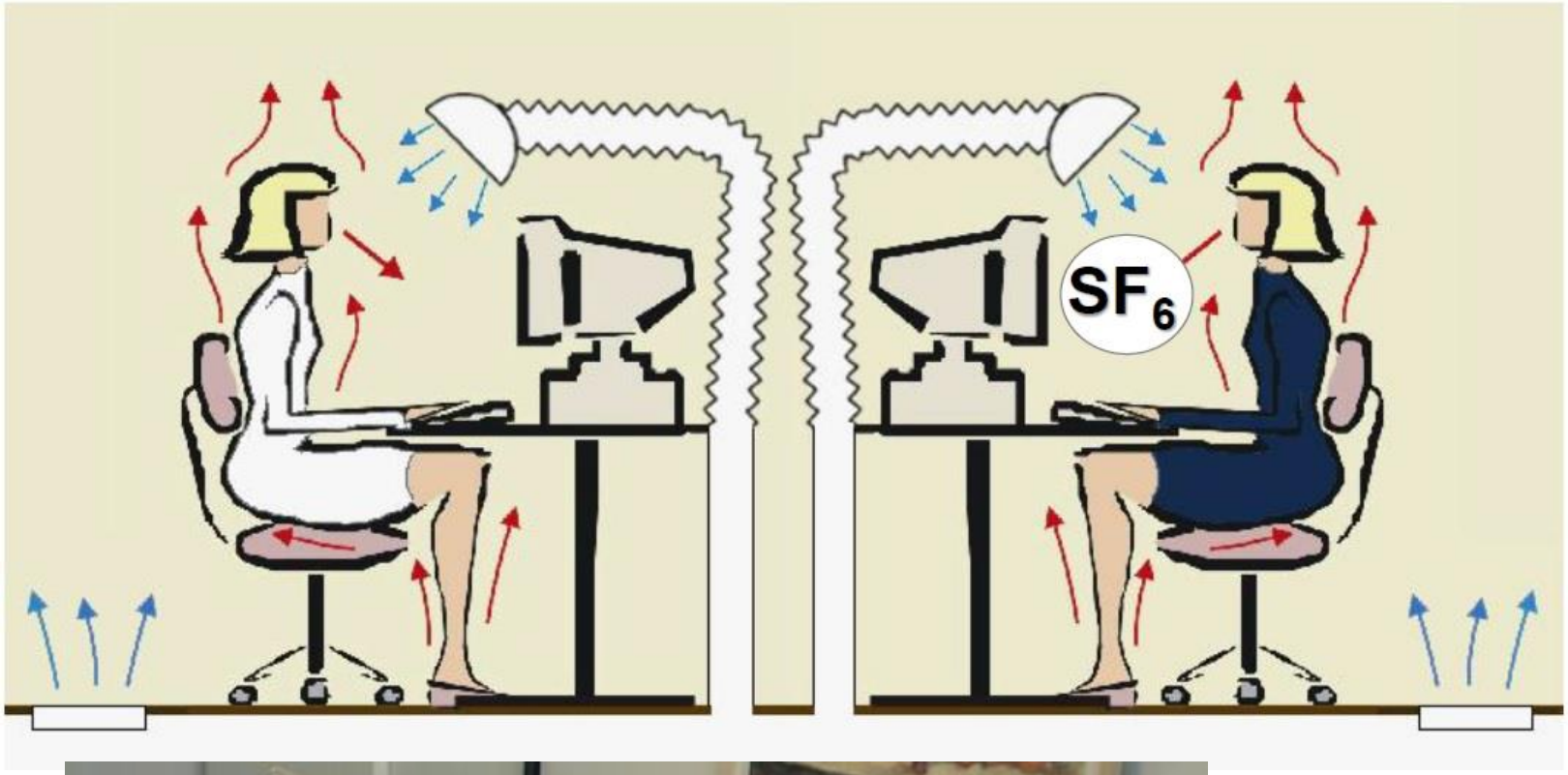
Ventilation Effectiveness

$$\varepsilon_V = \frac{C_E - C_S}{C_I - C_S}$$

Concentrations: C_E exhaust air
C_S supply air
C_I breathing zone

CEN Report CR 1752 (1998)

Mixing ventilation		Mixing ventilation		Displacement ventilation		Personalized ventilation	
							
T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T room °C	Vent. effect. -
< 0	0,9 - 1,0	< -5	0,9	<0	1,2 - 1,4	-6	1,2 - 2,2
0 - 2	0,9	-5 - 0	0,9 - 1,0	0-2	0,7 - 0,9	-3	1,3 - 2,3
2 - 5	0,8	> 0	1	>2	0,2 - 0,7	0	1,6 - 3,5
> 5	0,4 - 0,7						



Forrás: Bjarne Olesen, DTU, Denmark

Factors affecting the quality of indoor air coming from the external environment of the building

- **Natural sources** (background pollution)
- **Human activity** (industrial plants, vehicles, emissions from cooling towers)
- **Pollutants from soil**

Factors affecting the quality of indoor air coming from inside the building

- Combustion Processes
- Existing Materials
- Human activity
- People, animals and plants

Indoor Pollutants

Volatile Organic Compounds - VOCs

- contain carbon
- participate in photochemical reactions in the ambient air
- gaseous or easily escape from the liquid phase
- paint, solvent use, fuel storage, carpeting, adhesives, motor vehicles, tobacco smoke, bath and beauty products, cleaning supplies
- **Little exposure**:irritation of the throat, nose and eyes
- **Chronic exposure**: considerable damage to the liver, kidneys and nervous system

Indoor Pollutants

Formaldehyde (CH_2O)

- Very common chemical

- smoke from forest fires, car exhaust, furnaces, cigarette smoke
- photochemical oxidation of atmospheric methane

- **Indoors:** furniture, plywood, chipboard, synthetic carpets, textiles, furniture, etc.
- many uses : preservative, disinfectant and antiseptic with the brand name formalin
- **Exposure** : headaches, sore throat and fatigue, nausea, dizziness and irritation to eyes and respiratory system

Indoor Pollutants

Nitrous Oxides (No_x)

- Main oxides: NO, NO2

$$2NO + O_2 \rightarrow 2NO_2$$

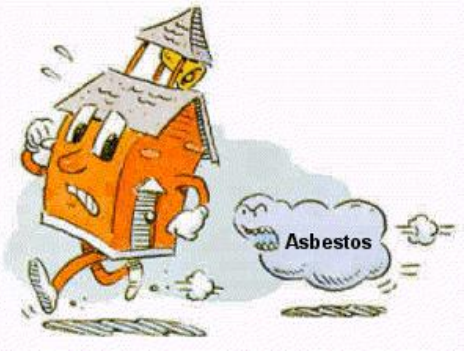
- Combustion Products
- Exposure
- Exposure to high levels of NO2
- Continued exposure to high levels of NO2

Indoor Pollutants

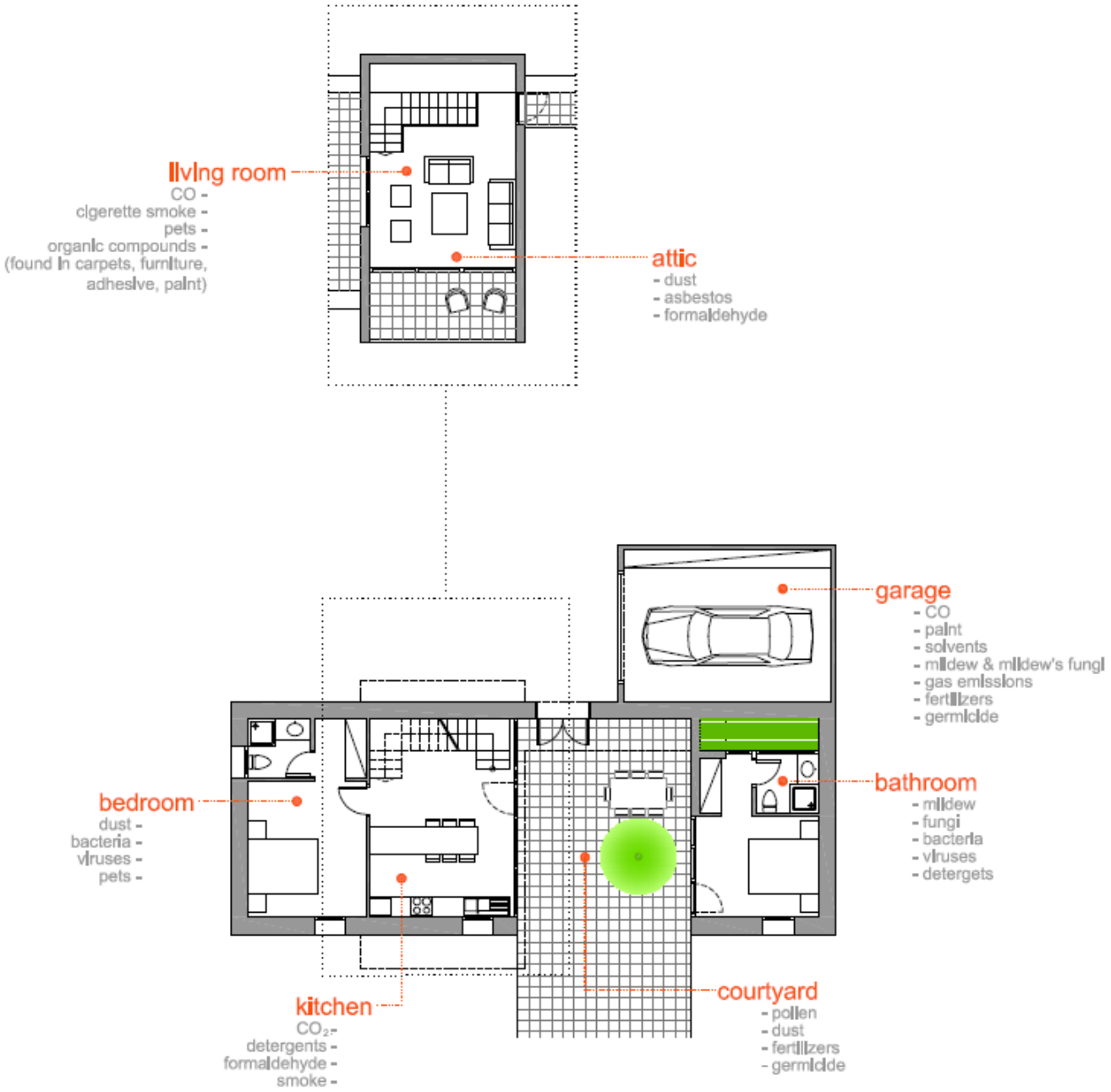
Asbestos

- Mineral fibers of crystalline structure
- Mixed with various adhesives, insulating material in tiles, ovens, stoves, etc.
- gradual aging of materials , maintenance operations



- cancer


living room
CO -
cigerette smoke -
pets -
organic compounds -
(found in carpets, furniture,
adhesive, paint)
attic
- dust
- asbestos
- formaldehyde
garage
- CO
- paint
- solvents
- mildew & mildew's fungi
- gas emissions
- fertilizers
- germicide
bedroom
dust -
bacteria -
viruses -
pets -
bathroom
- mildew
- fungi
- bacteria
- viruses
- detergets
kitchen
CO_2 -
detergents -
formaldehyde -
smoke -
courtyard
- pollen
- dust
- fertilizers
- germicide

Indoor Air Quality (Limits)

- Carbon monoxide (CO) : **9 ppm (8h)**
- **Carbon dioxide (CO_2):** upper limit (ASHRAE): **1001 ppm** for continuous exposure
- **Formaldehyde (CH_2O):** upper limit (WHO): **80 ppm**
- **Nitrous oxides (NO_x):** upper limit (EPA): **0.053ppm**
- **Ozone (O_3):** upper limit (EPA): **0.1 ppm**

Suspended Particular Matter

Type of Particle	Aerodynamic Diameter (µm)
Human hair	100 – 150
Skin flakes	20 – 40
Visible dust	>10
Typical pollen	15 – 25
Spores	2 – 10
Bacteria	1 – 5
Tobacco smoke	0.1 – 1
Metallic and organic gases	< 0.1 – 1
Viruses	< 0.1

Filters

• Mechanical filter efficiency:

- Pressure drop
- Quality Standards
- Installation, operation and maintenance equipment
- Airflow conditions
- Humidity

• Type / form of filter:

- Flat filters (plaques): filtering medium (porous, low density) on a flat surface
- Filters with creases: folded filter medium - higher performance
- Bag filters: bags inflate as air enters
- Removable curtain or renewable filter: dual roll

Filters

• HEPA Mechanical filters (High Efficiency Particulate Air):

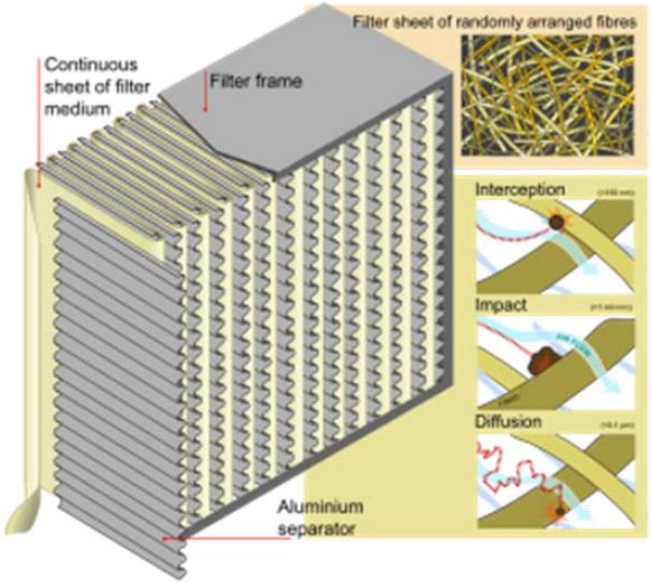
- High efficiency (99.97%) for particles> 0.3 µm
- Dry type - large surface
- Combination with prefilters

• ULPA Mechanical filters (Ultra-Low Penetration Air):

- 99,999% efficiency for removal of particles ≥ 0.12 µm

• Prefilters:

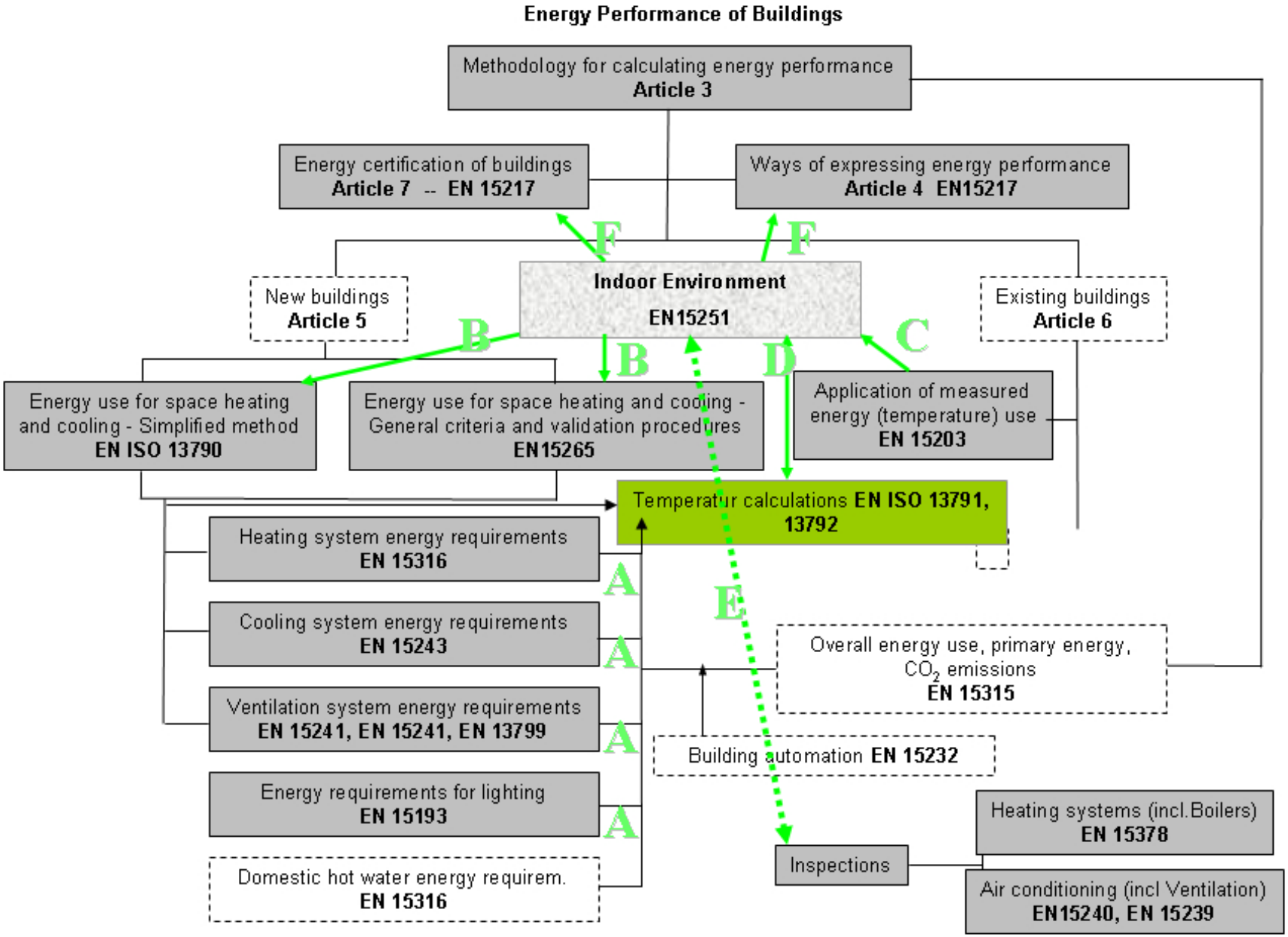
- Efficiency :70-90%
- For particles ≤ 1 µm
- Combination with HEPA and ULPA



IEQ – criteria for classification

- Standard EN 15251

Indoor environmental input parameters for design and assessment of energy performance of buildings – addressing indoor air quality, thermal environment, lighting and acoustics.


Energy Performance of Buildings
Methodology for calculating energy performance
Article 3
Energy certification of buildings
Article 7 -- EN 15217
Ways of expressing energy performance
Article 4 EN15217
F
F
Indoor Environment
EN15251
New buildings
Article 5
Existing buildings
Article 6
B
B
D
C
Energy use for space heating and cooling - Simplified method
EN ISO 13790
Energy use for space heating and cooling - General criteria and validation procedures
EN15265
Application of measured energy (temperature) use
EN 15203
Temperatur calculations EN ISO 13791, 13792
Heating system energy requirements
EN 15316
A
E
Cooling system energy requirements
EN 15243
A
Overall energy use, primary energy, CO_2 emissions
EN 15315
Ventilation system energy requirements
EN 15241, EN 15241, EN 13799
A
Building automation EN 15232
Energy requirements for lighting
EN 15193
A
Heating systems (incl.Boilers)
EN 15378
Inspections
Domestic hot water energy requirem.
EN 15316
Air conditioning (incl Ventilation)
EN15240, EN 15239

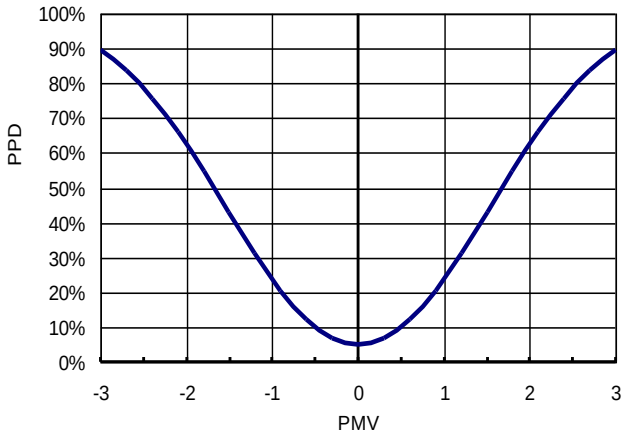
EN 15251 Comfort Categories

- **New categories**
- **Category II is assumed to be the 'norm'**

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

Thermal comfort

- EN ISO 7730 – parmeters especially for HVAC systems design
- 3 cathegories of thermal comfort according to PPD and PMV



Categories of thermal environment (EN ISO 7730)

Category of indoor thermal environment	Thermal state of the body as a whole	
	PPD	PMV
A	< 6%	– 0,2 < PMV < + 0,2
B	< 10%	– 0,5 < PMV < + 0,5
C	< 15%	– 0,7 < PMV < + 0,7

PMV - predicted mean vote, PPD - predicted percentage of dissatisfied

Indoor resultant (operative) temperature

Type of building, Space	Clothing, winter (clo)	Activity (met)	Category of indoor environment	Operative temperature, winter (°C)
Office	1,0	1,2	A	21,0 - 23,0
			B	20,0 - 24,0
			C	19,0 - 25,0
Open space office	1,0	1,2	A	21,0 - 23,0
			B	20,0 - 24,0
			C	19,0 - 25,0
Cafe, restaurant	1,0	1,2	A	21,0 - 23,0
			B	20,0 - 24,0
			C	19,0 - 25,0
Shopping center	1,0	1,6	A	17,5 - 20,5
			B	16,0 - 22,0
			C	15,0 - 23,0
Housing	1,0	1,2	A	21,0 - 23,0
			B	20,0 - 24,0
			C	19,0 - 25,0

EN 15251 - ventilation

Type of building or space	Cate-gory	Floor area m²/per-son	q_p	q_B	q_{tot}	q_B	q_{tot}	q_B	q_{tot}	Add when smoking
			l/s, m² for occupancy	l/s,m² for very low-polluted building		l/s,m² for low-polluted building		l/s,m² for non-low polluted building		l/s,m²
Single office	I	10	1,0	0,5	1,5	1,0	2,0	2,0	3,0	0,7
	II	**10**	**0,7**	**0,3**	**1,0**	**0,7**	**1,4**	**1,4**	**2,1**	**0,5**
	III	10	0,4	0,2	0,6	0,4	0,8	0,8	1,2	0,3
Land-scaped office	I	15	0,7	0,5	1,2	1,0	1,7	2,0	2,7	0,7
	II	**15**	**0,5**	**0,3**	**0,8**	**0,7**	**1,2**	**1,4**	**1,9**	**0,5**
	III	15	0,3	0,2	0,5	0,4	0,7	0,8	1,1	0,3
Conference room	I	2	5,0	0,5	5,5	1,0	6,0	2,0	7,0	5,0
	II	**2**	**3,5**	**0,3**	**3,8**	**0,7**	**4,2**	**1,4**	**4,9**	**3,6**
	III	2	2,0	0,2	2,2	0,4	2,4	0,8	2,8	2,0

Sick Building Syndrome (SBS)

- **Definition**
  - Residents of a building experience acute health problems and / or discomfort **clearly** associated with time spent on the building, while no specific illness or cause of these results can be determined
- Users of buildings complain of symptoms such as lethargy, headaches, loss of concentration, runny/stuffy nose, sore throat and eye and skin irritation
- These symptoms often disappear quickly when users leave the building

- **Factors that determine the appearance of SBS**
  - Ventilation system
  - Internal contaminants
  - External contaminants
  - Biological contaminants

Common Symptoms of SBS

- In the central nervous system:
  - Fatigue
  - Headaches
  - Dizziness, nausea
  - Memory loss
  - Sleep disturbances
  - Difficulty in concentration
  - Stress
  - Nervousness
  - Lethargy

- In the respiratory system
  - Asthma
  - Bronchitis
  - Rhinitis
  - Tightness in chest
  - Breathlessness

- In the immune system
  - Susceptibility to disease
  - Allergy problems
  - Symptoms similar to flu

- Other
  - Disturbances in the digestive system
  - Leaks
  - Cramps
  - Bloating stomach
  - Constipation
  - Eye problems (dryness / irritation / sensitivity)
  - Irritation to the skin (dryness / irritation / rashes)
  - Problems in the neck (dryness)
  - Fever
  - Aching muscles and joints

Thank you the attention!

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