International Centre for
Indoor Environment and Energy

Do European standards for indoor air quality take into account outdoor air quality?

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ICIEE

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Global impact on people

Hans Christian Andersen: The Princess on the Pea

In developing regions 5000 persons die per day due to poor IAQ

Achieving Excellence in Indoor Environmental Quality

- **Physical factors**
  - Thermal Comfort
  - Air quality (ventilation)
  - Noise-Acoustic
  - Illumination
- **Personal factors**
  - Activity
  - Clothing
  - Adaptation
  - Expectation
  - Exposure time

STANDARDS IAQ

- **ASHRAE 62.1 and 62.2 -2013**
  - Ventilation and indoor air quality
- **EN15251**
  - Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustic
- **EN 13779**
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

International Standards
Indoor Environmental Quality

- prEN 16789-1 (revision EN15251) and ISO DIS 17772
  - Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- DTR 16789-2 and ISO TR 17772:
  - Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.

Categories

Cate-gory	Explanation
I	High level of expectation and also recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility.
II	Normal level of expectation
III	An acceptable, moderate level of expectation
IV	Low level of expectation. This category should only be accepted for a limited part of the year

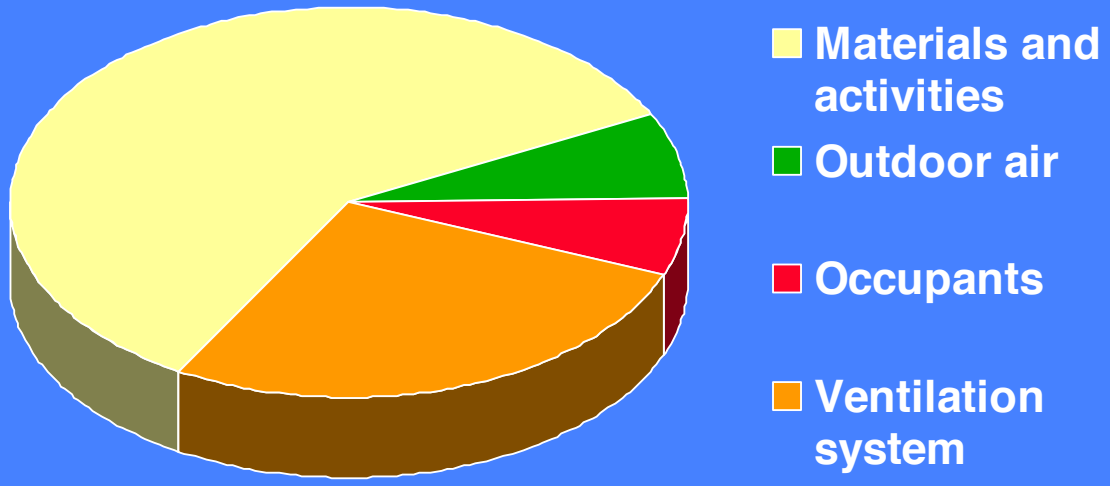
CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

- COMFORT (Perceived Air Quality)
- HEALTH
- PRODUCTIVITY
- ENERGY

Human Bioeffluents

European Audit Project to Optimise Indoor Air Quality and Energy consumption in Office Buildings

Sensory pollution load- perceived air quality

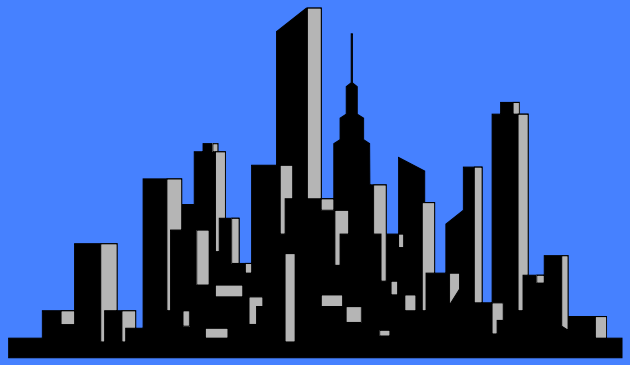


Tobacco Smoke

Concept for calculation of design ventilation rate

People Component

Building Component



Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_s S_d + R_a A_z$$

- V_{bz}: Breathing Zone Outdoor Airflow
- $R_p P_z$: People Component
  - R_p: Minimum l/s/Person
  - P_z: Number of People
- $R_s S_d$: ~~Ventilation per Smoker~~ × ~~Number of Smokers~~
- $R_a A_z$: Building Component
  - A_z: Building Area
  - R_a: Minimum l/s/m²

Total ventilation rate

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

$$q_{supply} = q_{tot} / \varepsilon_v$$

- Where
- ε_v = the ventilation effectiveness (EN13779)
- q_{supply} = ventilation rate supplied by the ventilation system
- q_{tot}= total ventilation rate for the breathing zone, l/s
- n = design value for the number of the persons in the room,
- q_p = ventilation rate for occupancy per person, l/s, pers
- A_R= room floor area, m^2
- q_B = ventilation rate for emissions from building, l/s,m^2

HEALTH CRITERIA FOR VENTILATION

Minimum 4 l/s/person

Basic required ventilation rates for diluting emissions (bio effluents) from people for different categories

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s.pers)
I	15	10
II	20	7
III	30	4
IV	40	2,5*

*The total ventilation rate must never be lower than 4 l/s per person

ASHRAE Standard 62.1 : Adapted persons 2,5 l/s person (Cat. II)

Design ventilation rates for diluting emissions from buildings

Category	Very low polluting building l/(s m^2)	Low polluting building l/(s m^2)	Non low-polluting building l/(s m^2)
I	0,5	1,0	2,0
II	0,35	0,7	1,4
III	0,2	0,4	0,8
IV	0,15	0,3	0,6
Minimum total ventilation rate for health	4 l/s person	4 l/s person	4 l/s person

Example on how to define low and very low polluting buildings

SOURCE	Low emitting products for low polluted buildings	Very low emitting products for very low polluted buildings
Total VOCs TVOC (as in CEN/TS 16516)	< 1.000 $\mu g/m^3$	< 300 $\mu g/m^3$
Formaldehyde	< 100 $\mu g/m^3$	< 30 $\mu g/m^3$
Any C1A or C1B classified carcinogenic VOC	< 5 $\mu g/m^3$	< 5 $\mu g/m^3$
R value (as in CEN/TS16516)	< 1.0	< 1.0

Example of design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (un-adapted person)

Cate-gory	Low-polluting building l/(s*m^2)	Airflow per non-adapted person l/(s*person)	Total design ventilation air flow rate for the room		
			l/s	l/(s*person)	l/(s* m^2)
I	1,0	10	20	20	2
II	0,7	7	14	14	1,4
III	0,4	4	8	8	0,8
IV	0,3	2,5	5,5	5,5	0,55

Specific Pollutans

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \qquad \text{Eq (2)}$$

where:

Q_h	**is the ventilation rate required for dilution, in litre per second;**
G_h	**is the pollution load of a pollutant, in micrograms per second;**
$C_{h,i}$	**is the guideline value of a pollutant, see Annex B6 , in micrograms per m^3;**
$C_{h,o}$	**is the supply concentration of pollutants at the air intake, in micrograms per m^3;**
ε_v	**is the ventilation effectiveness**

NOTE. $C_{h,i}$ and $C_{h,o}$ may also be expressed as ppm (vol/vol). In this case the pollution load G_h has to be expressed as l/s.

WHO guidelines values for indoor and outdoor air pollutants

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

Filtration and air cleaning

- The influence of position of outdoor air intakes, filtration and air cleaning shall be considered. (DTR 16798-4, DTR 16798-2)
- If filtration and air cleaning is used the following points shall be considered:
  - Reducing the amount of airborne pollutants (pollens, molds, spores, particles, dust) from the outdoor air intake by circulating the air through a filter.
  - Circulating secondary air through a filter or other air cleaning technology to reduce the amount of pollutants in the air
  - Reduce the concentration of odors and gaseous contaminants by circulating the secondary air or recirculating the return air (gas phase air cleaning)

    » Note: Design guidelines on air cleaning and filtration are given in prEN 16798-3 and ISO DIS 16814. How to partially substitute outside air by air cleaning is described in DTR 16798-2

Ventilation Systems

- **prEN16798-3**
  - Energy performance of buildings - Part 3: Ventilation for nonresidential buildings — Performance requirements for ventilation, air conditioning and room-conditioning systems; (revision of EN 13779)

- **DTR 16798-4**
  - Ventilation for non-residential buildings — Performance requirements for ventilation, air conditioning and room conditioning systems (Revision EN 13779) –Technical Report

OUTDOOR AIR

- In the process of system design, consideration needs to be given to the quality of the outdoor air around the building or proposed location of the building. In the design, there are two main options for mitigating the effects of poor outdoor air on the indoor environment:
  - locate air intakes where the outdoor air is least polluted (if the outdoor air pollution is not uniform around the building)
  - apply some form of air cleaning
  - NOTE 1 See TR 13779 for further information about these options.

Table 6 — Classification of outdoor air (ODA)

Category	Description
ODA 1	Outdoor air which may be only temporarily dusty (e.g. pollen)
ODA 2	Outdoor air with high concentrations of particulate matter and/or gaseous pollutants
ODA 3	Outdoor air with very high concentrations of gaseous pollutants and/or particulate

Air Filtration

Table 27 —Minimum filtration efficiency based on particle outdoor air quality

Outdoor air quality	Supply air class			
	SUP 1	SUP 2	SUP 3	SUP 4
ODA (P) 1	88%*	80%*	80%*	80%*
ODA (P) 2	96%*	88%*	80%*	80%*
ODA (P) 3	99%*	96%*	92%*	80%*
*Combined average filtration efficiency over a single or multiple stage filtration an accordance to average filtration efficiency specified in EN 779				

Gas Filtration

Table 18 — Required application of Gas Filter as compliment to particle filtration based on gaseous outdoor air quality

Outdoor air quality				
	SUP 1	SUP 2	SUP 3	SUP 4
ODA (G)1	recommended			
ODA (G) 2	required	recommended		
ODA (G)3	required	Required	recommended	

- GF= Gas Filtration, should be considered when going from above ODA / SUP levels. Dimensioning should be done in accordance with EN ISO 10121 – 1&2.

RESIDENTIAL

Table B2.1.4-1 Criteria based on pre-defined ventilation air flow rates: Total ventilation (1), Supply air flow (2) and (3) supplemented by exhaust air flow.

Category	Total ventilation including air infiltration (1)		Supply air flow per. person (2)	Supply air flow based on perceived IAQ for adapted persons (3)		Supply air flow for bedrooms (4)	Exhaust air flow peak or boost flow for high demand l/s		
	l/s,m²	**ach**	**l/s*per**	**q_p l/s*per**	**q_B l/s,m²**	**l/s per person**	**Kit-chen (3a)**	**Bath-rooms (3b)**	**Toilets (3c)**
I	**0,49**	**0,7**	**10**	**3,5**	**0,25**	**10**	**28**	**20**	**14**
II	**0,42**	**0,6**	**7**	**2,5**	**0,15**	**8**	**20**	**15**	**10**
III	**0,35**	**0,5**	**4**	**1,5**	**0,1**	**4**	**14**	**10**	**7**
IV*	**0,23**	**0,4**				**2,5***	**10**	**6**	**4**

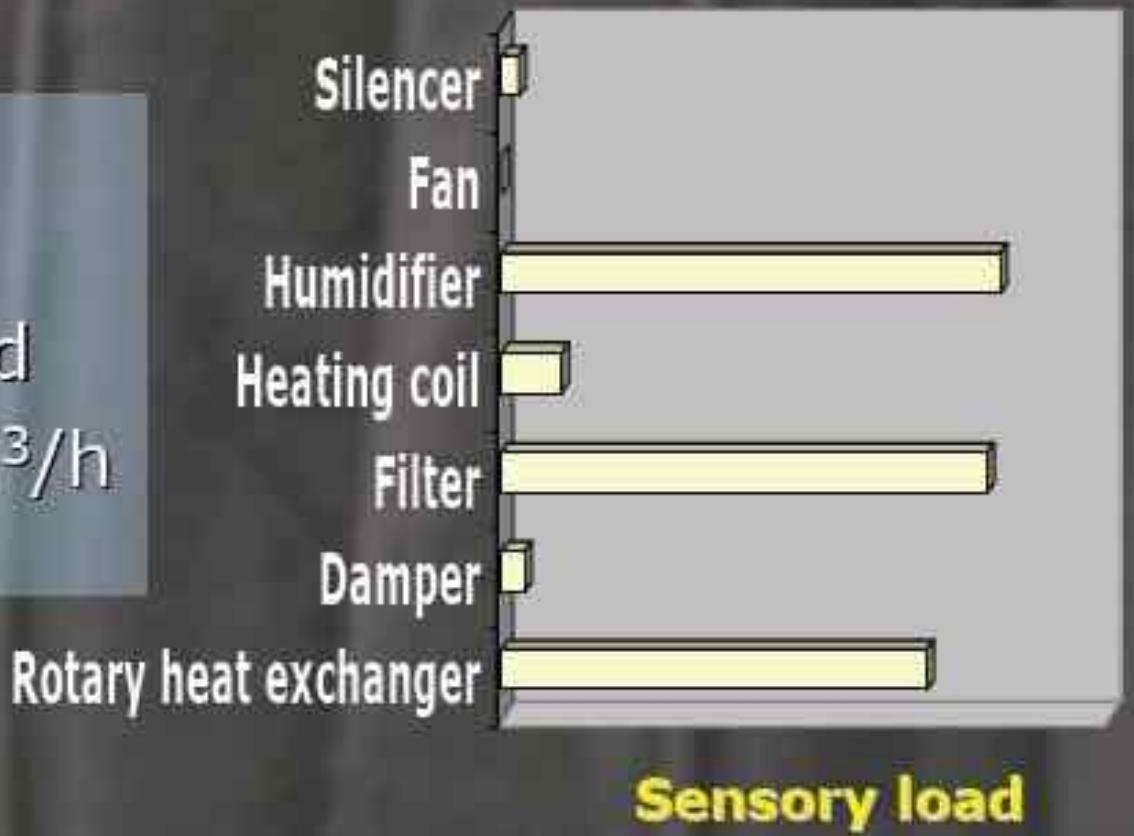
NOTES

Column 3 and 4: The ventilation air flow rates must be available when the rooms are occupied. The design can take into account that not all bedrooms are occupied at the same time, e.g. during daytime

The number of persons in bedroom depends on the size according to design criteria and building regulations

Sensory Pollution Load

- 8 systems investigated
- 2 – 16 years old
- 500 – 29000 m³/h



Source: Pejtersen et al, 1989

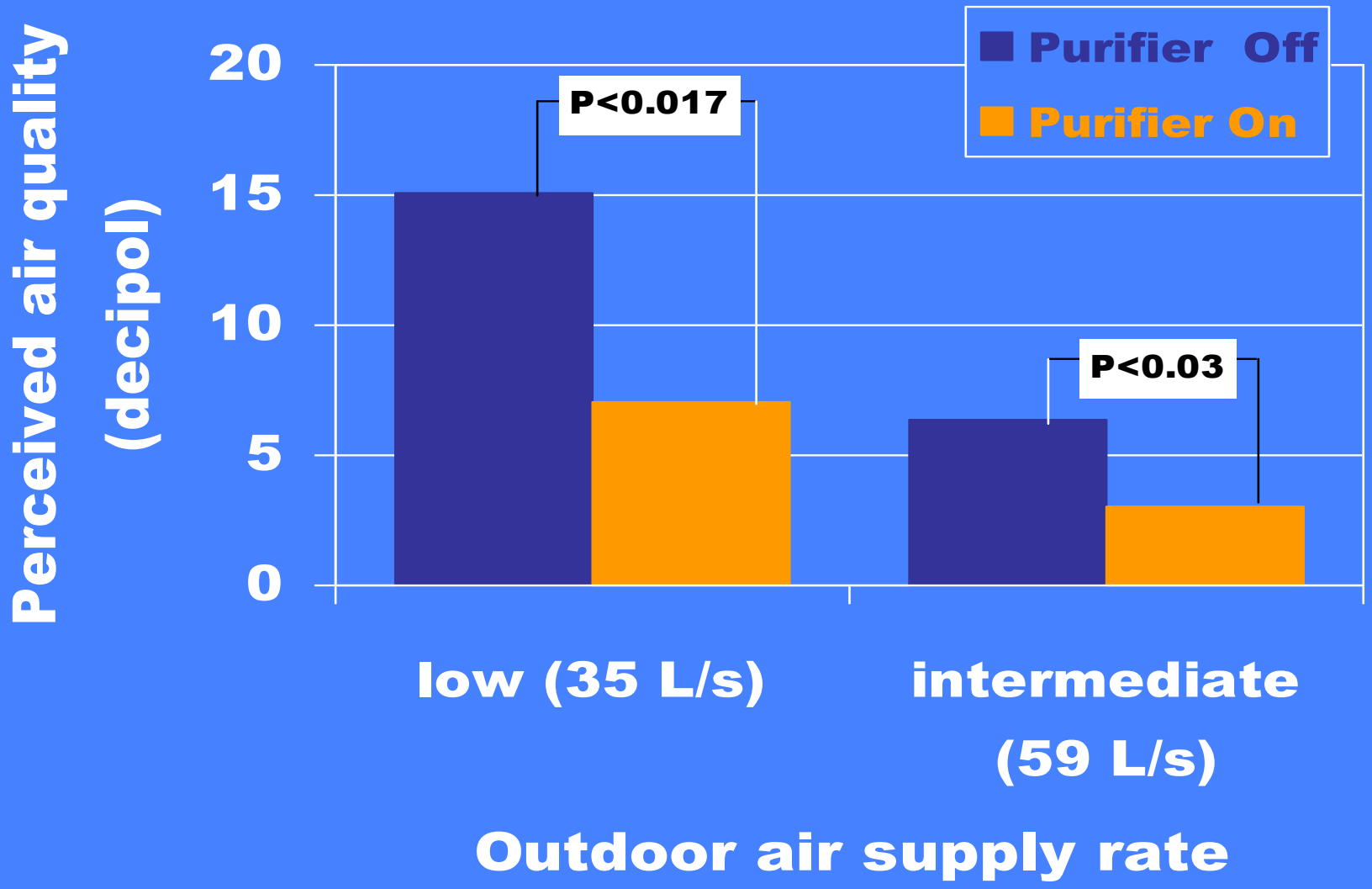
Trends regarding ventilation

- Increasing use of air cleaning
  - Filtration
  - Gas phase air cleaning
- Personalized systems for better comfort and energy savings
- Demand control ventilation
  - Occupant precense
  - CO_2 sensors
  - Artificial nose

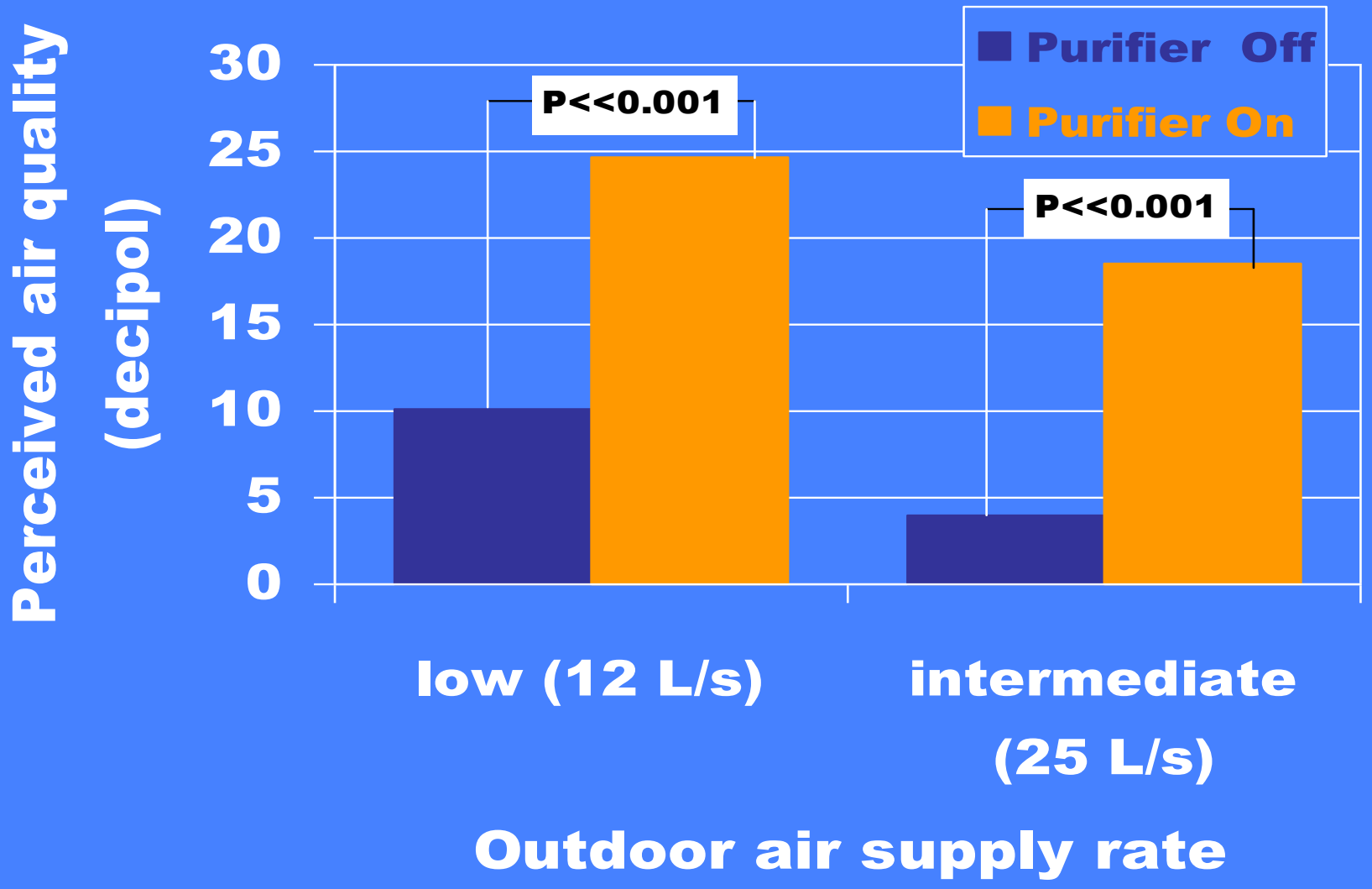
Gas phase air purification technologies

- Photo-catalytic oxidation (PCO)
- Ozone oxidation
- Thermal catalytic oxidation (TCO)
- Plasma oxidation
- Botanic filtration
- Sorption filtration

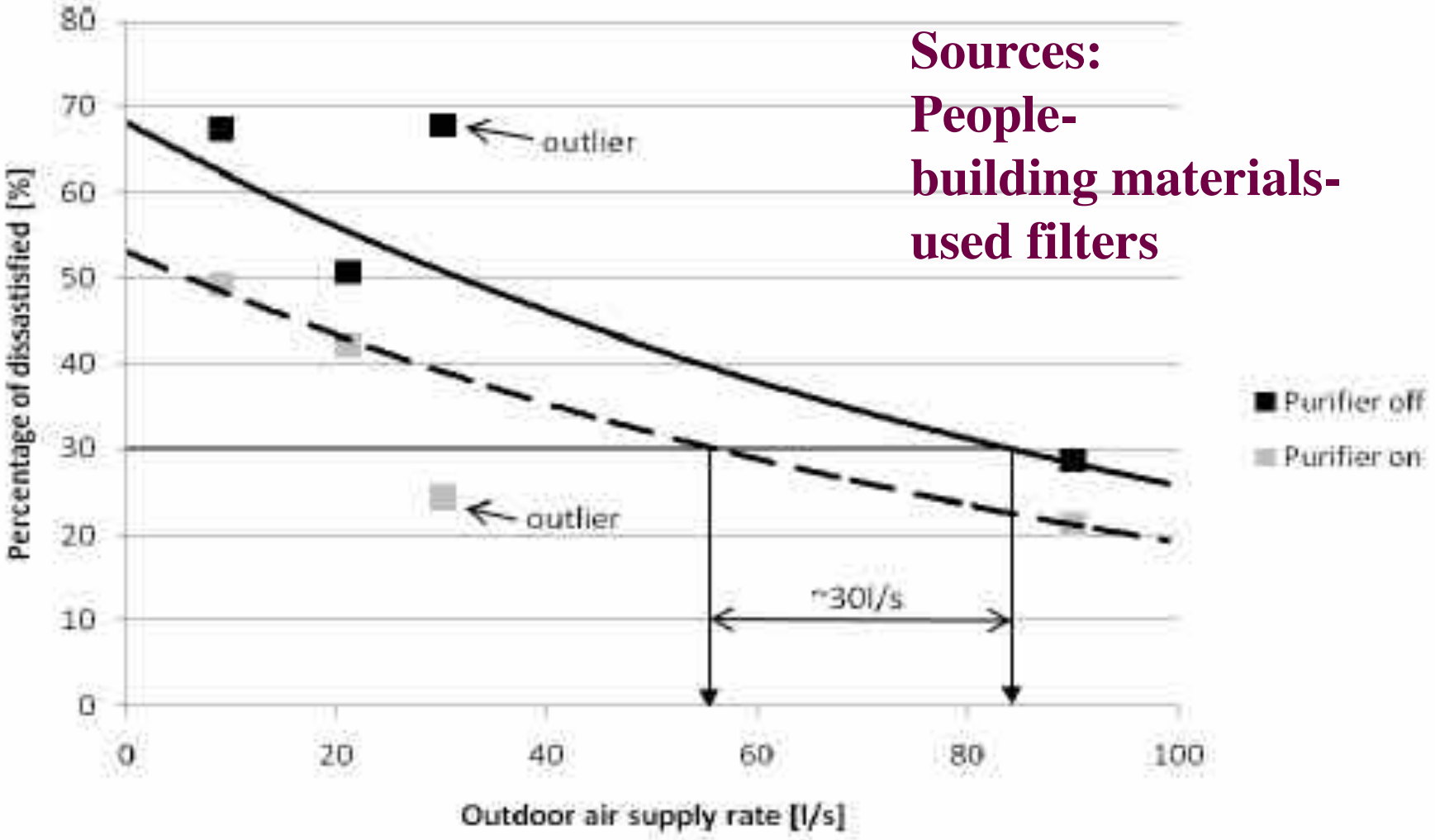
Results: Bldg mat, PCs, filters



Results: Human bio effluents



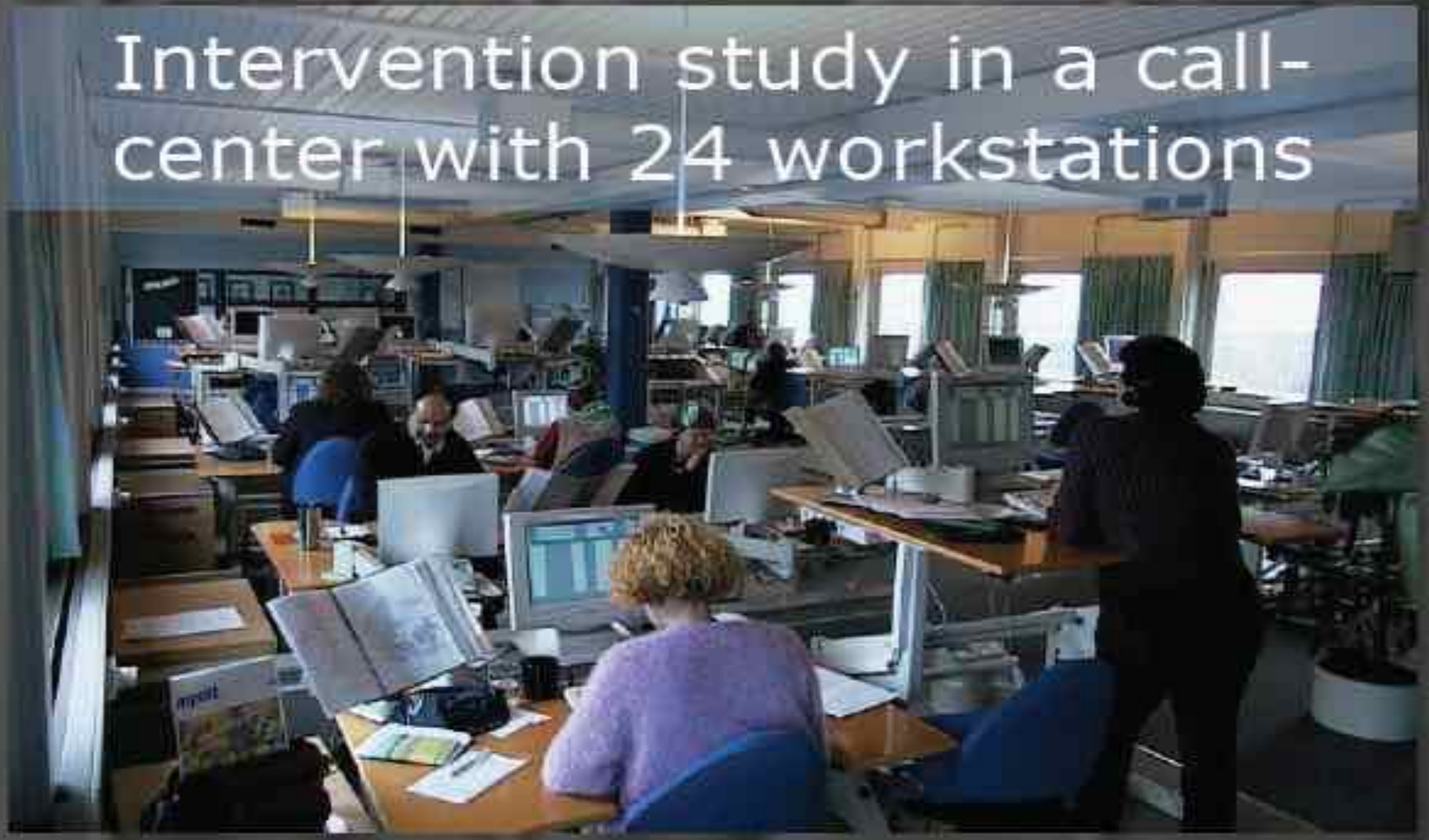
Effect of air cleaning on perceived Air Quality



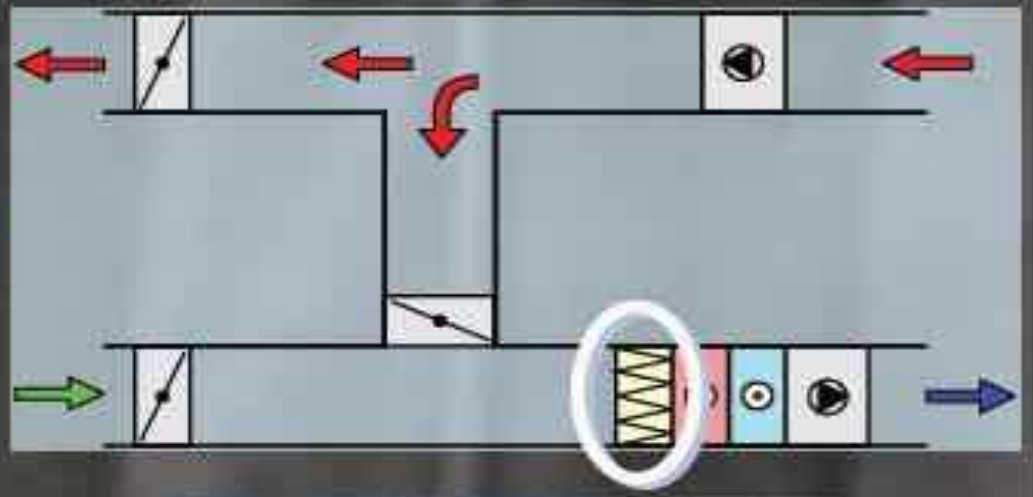
Sources:
People-
building materials-
used filters

Field study

Intervention study in a call-center with 24 workstations



Changing filter



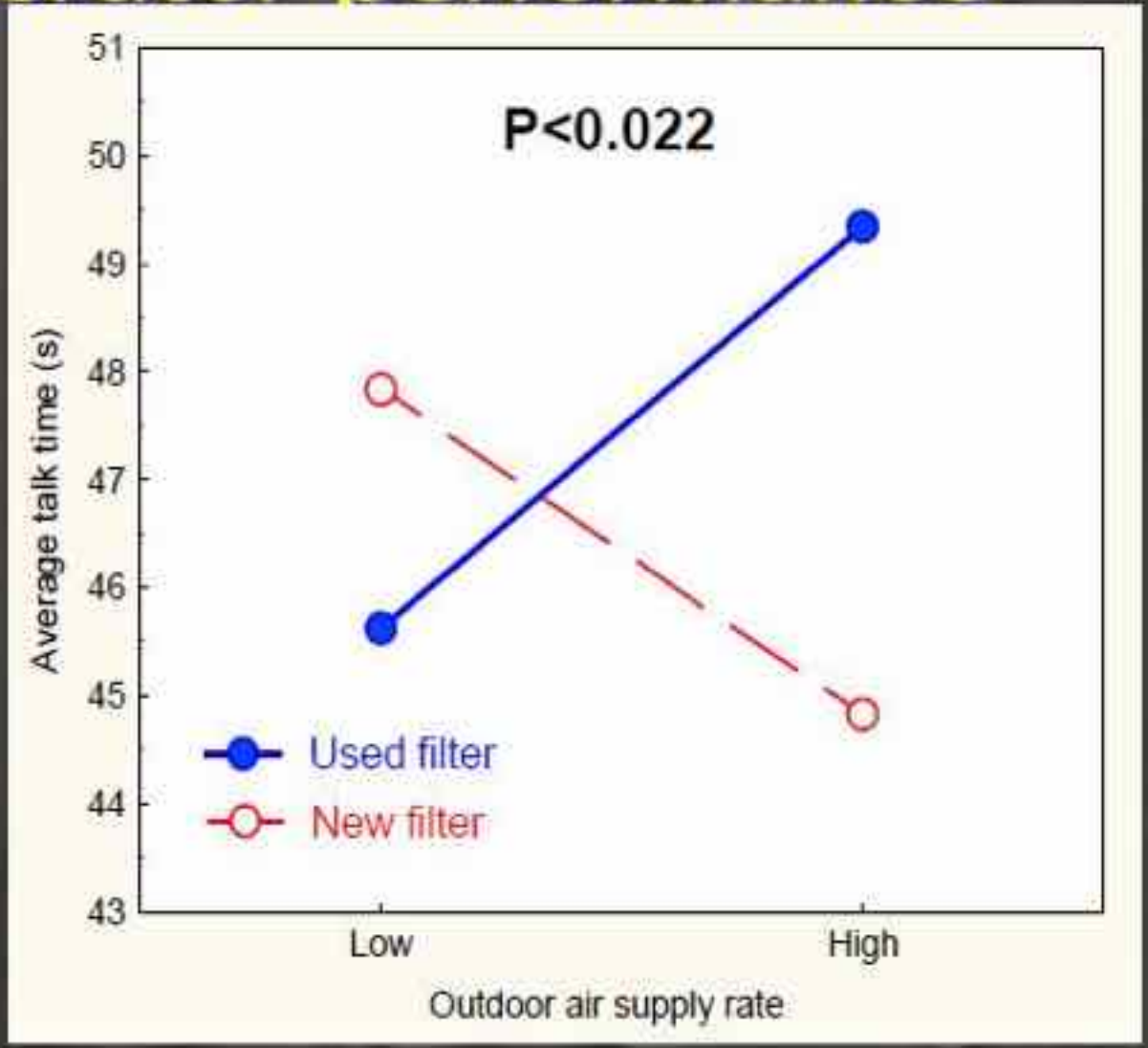
Synthetic-fibre coarse filter class G3

Measurements of performance

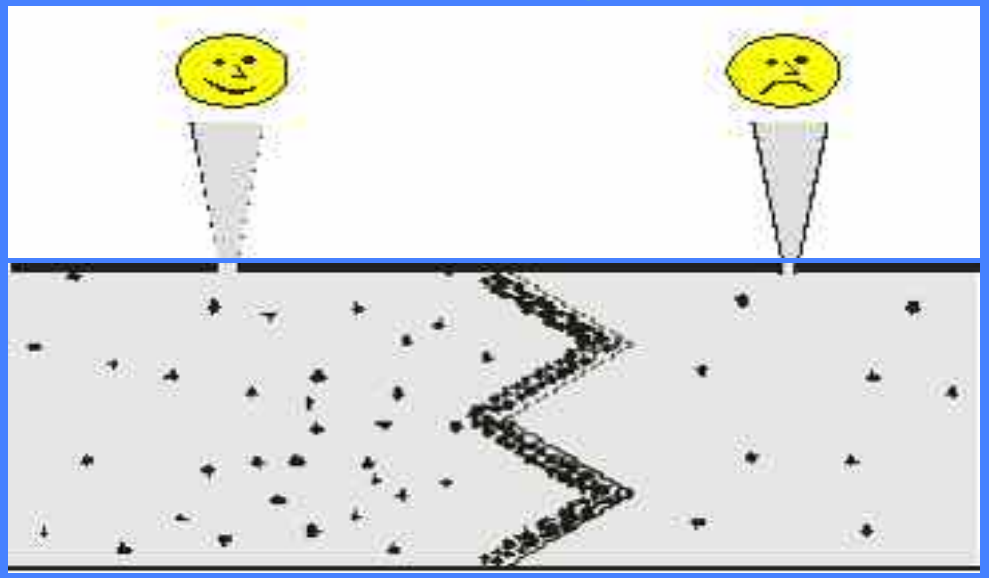
- Number of calls
- Talk-time
- Length of pauses

Automatically and continuously registered for every 30-minute for each operator during the whole experimental period

Operator performance

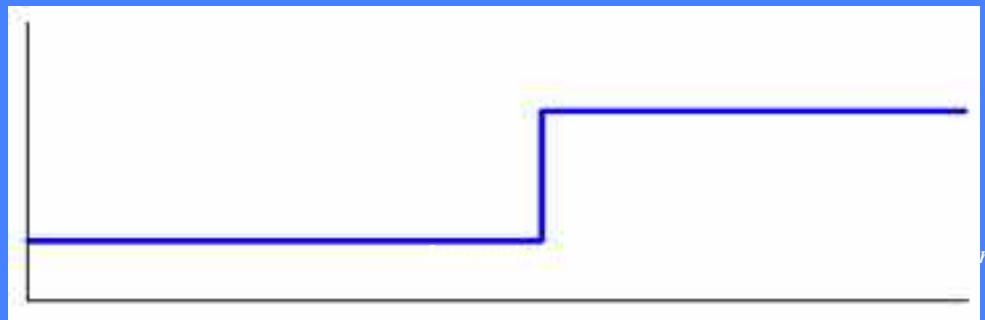


Why do filters pollute ?

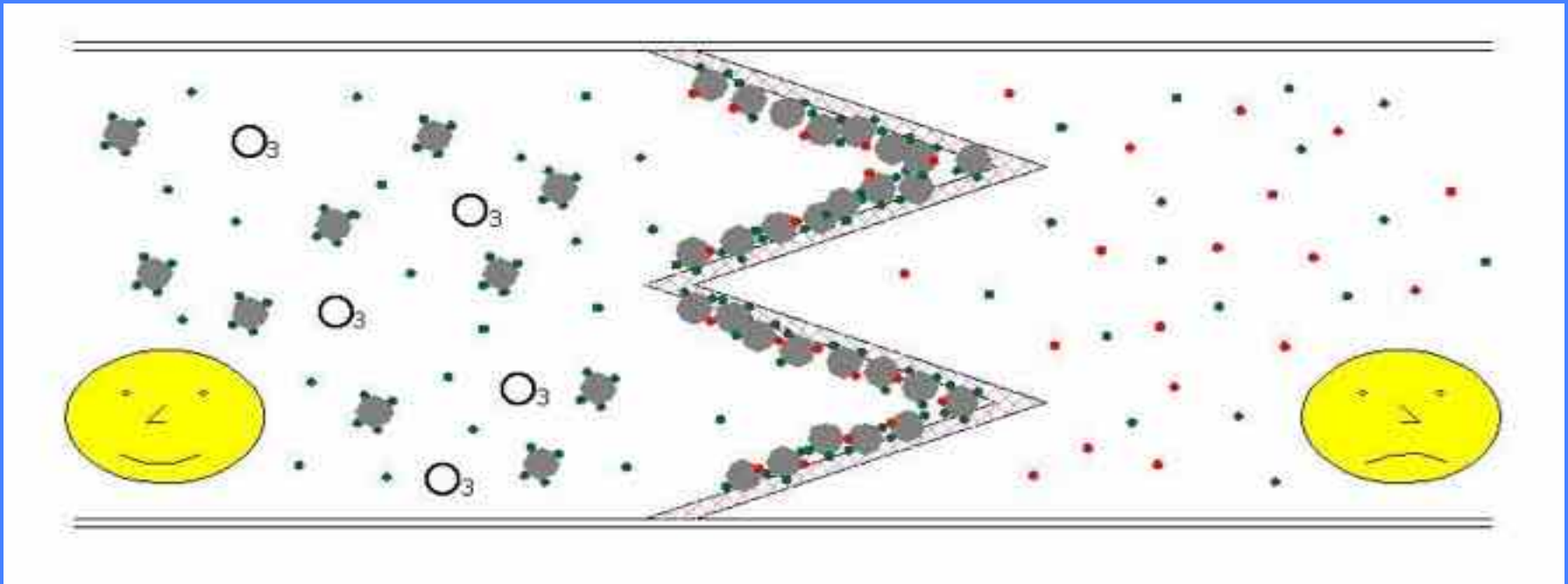


Particle concentration

Percentage Dissatisfied



Hypotheses



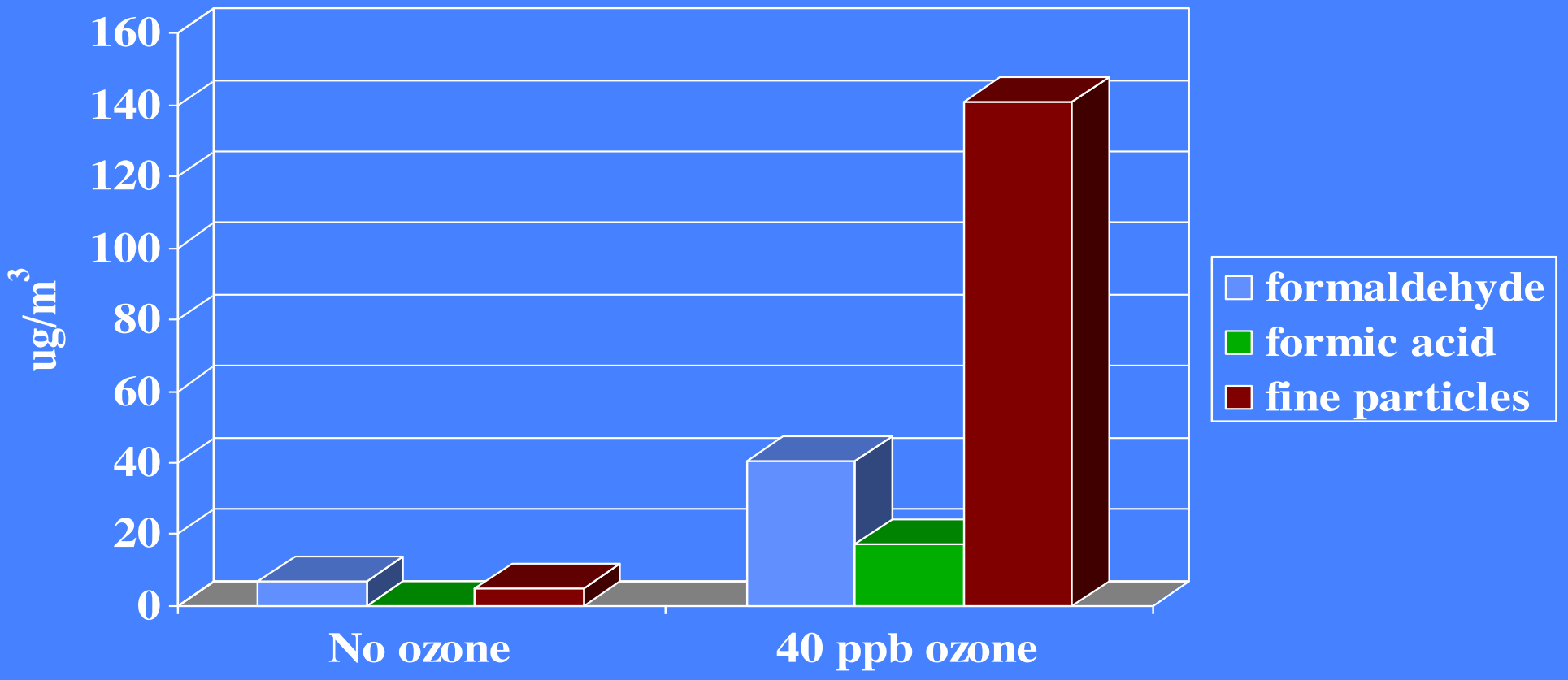
SVOCs sorbed on particles

Oxidized SVOCs

SVOCs in gas phase

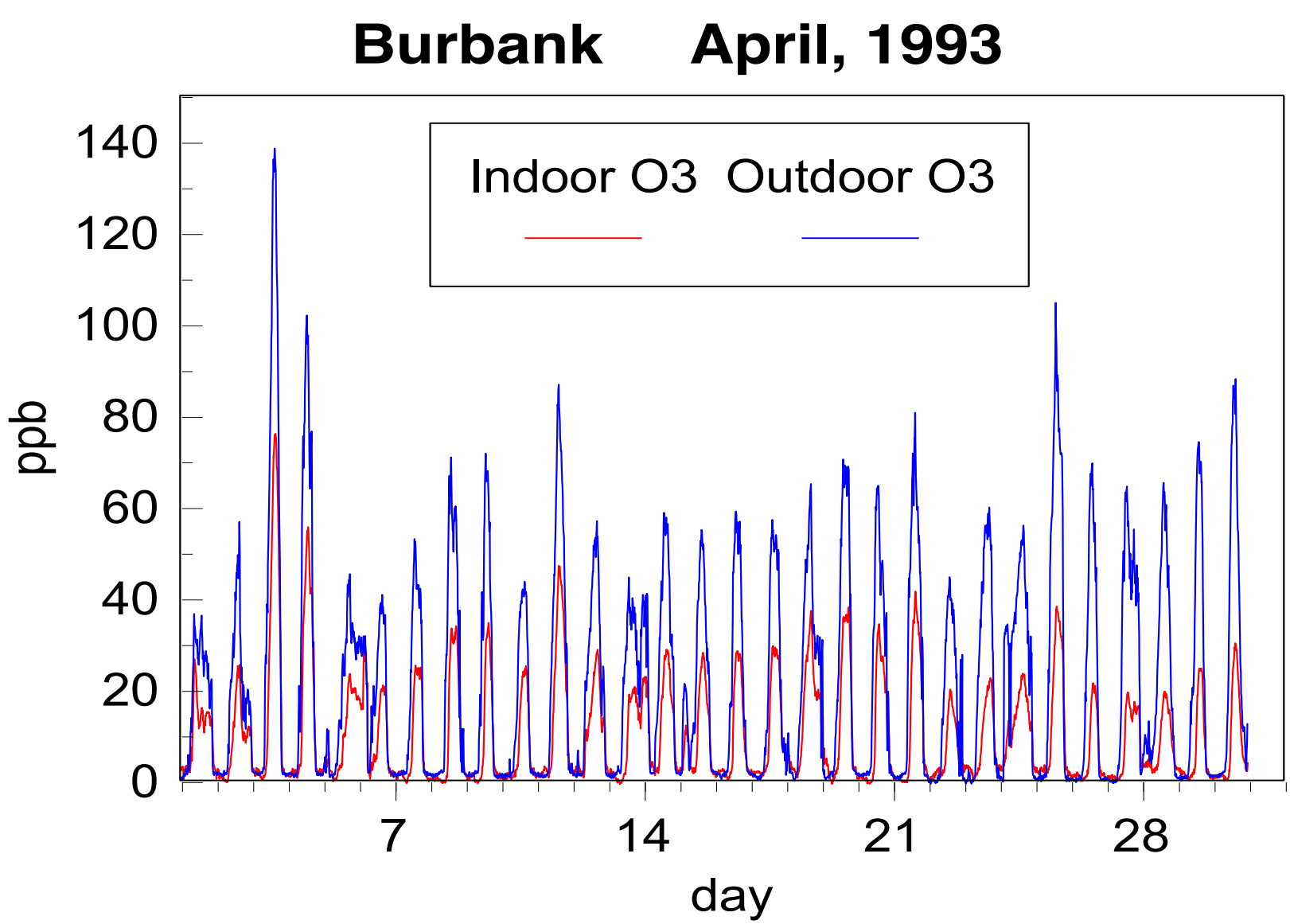
Unreacted SVOCs

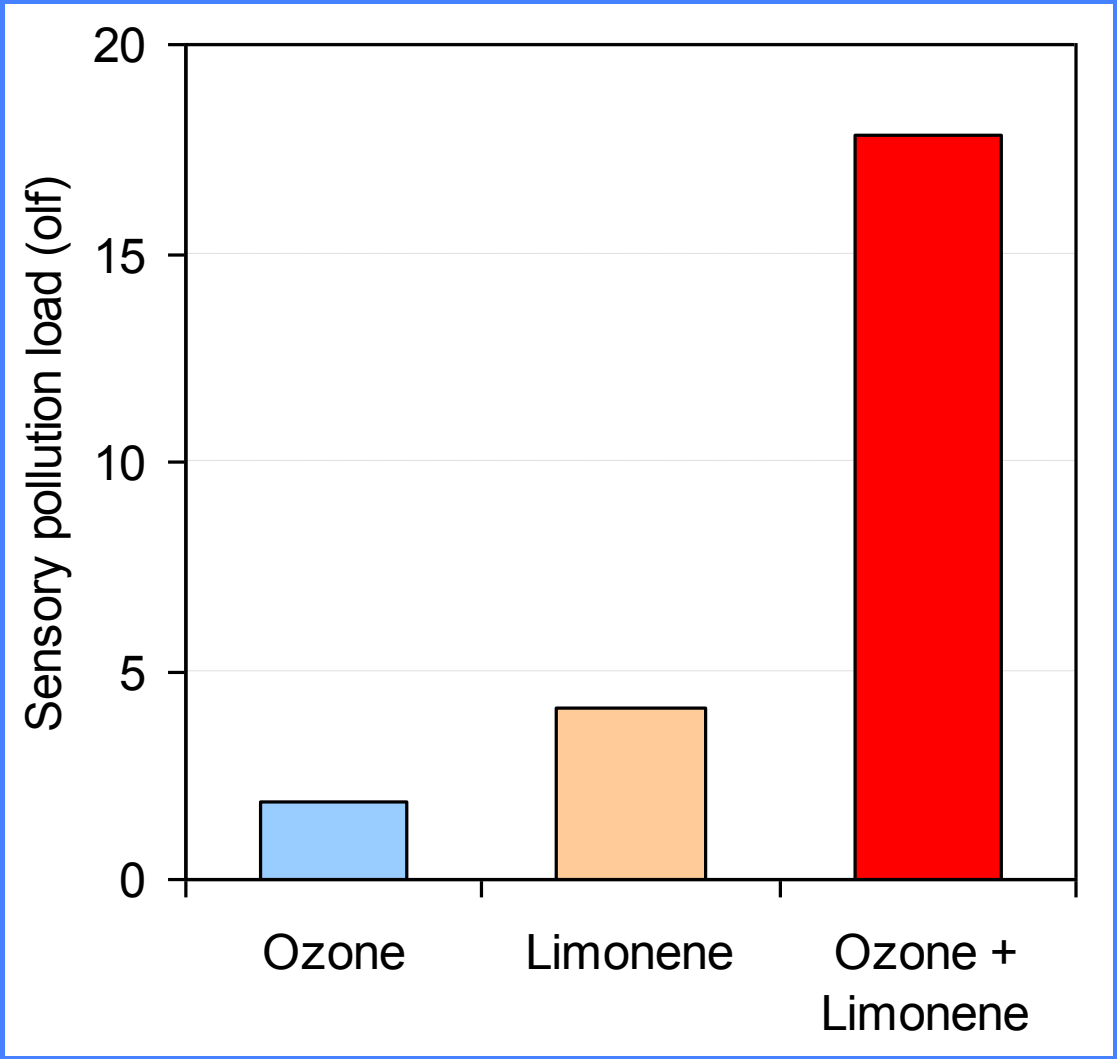
Mixture of 23 VOCs (including d-limonene and α-pinene)



Indoor Chemistry

- **Indoor chemistry can influence the kind and concentration of organic chemicals in indoor air**


Burbank April, 1993
Indoor O3
Outdoor O3
ppb
140
120
100
80
60
40
20
0
7
14
21
28
day



The sensory pollution load in an office where either ozone (15 ppb) or limonene (83 ppb) were present separately or both ozone and limonene (15 ppb+83 ppb respectively) were mixed in the office air (Tamás et al., 2005); the increased sensory pollution load is due to the presence of reaction products in the office air.

THANK YOU