EBC Webinar
Reducing the Performance Gap between
Design Intent and Real Operation

IEA-EBC Annex 78:
Supplementing Ventilation with Gas-phase Air Cleaning

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Energy in Buildings and Communities Programme

Outline/Agenda

EBC-IEA ANNEX 78: Operating Agents

- Dr. Bjarne W. Olesen, Technical University of Denmark.
- Dr. Pawel Wargocki, Technical University of Denmark.

- PREPARATION PHASE 01-07-2018 TO 30-06-2019
- WORKING PHASE 01-07-2019 TO 30-06-2023
- REPORTING PHASE 01-07-2023 TO 30-06-2024

ANNEX STRUCTURE

- Subtask A: Energy benefits using gas phase air cleaning
  - Subtask leader: Alireza Afshari, Denmark
  - Co-leader: *Sasan Sadrizadeh* , Sweden
- Subtask B: How to partly substitute ventilation by air cleaning
  - Subtask leader: Pawel Wargocki, Denmark
  - Co-leader: Shin-Ichi Tanabe , Japan
- Subtask C: Selection and testing standards for air cleaners
  - Subtask leader: Paolo Tronville, Italy
  - Co-leader: Jinhan Mo, China
- Subtask D: Performance modelling and long-term field validation of gas phase air cleaning technologies
  - Subtask leader: Karel Kabele, Czech
  - Co-leader: Jensen Chang , USA

Concept for calculation of design ventilation rate ISO CEN ASHRAE

People Component

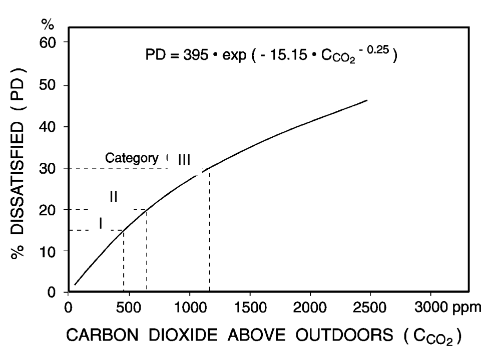
Building Component

Breathing Zone Outdoor Airflow

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

- R_p: Minimum l/s/Person
- P_z: Number of People
- A_z: Building Area
- R_a: Minimum l/s/m²

CO_2 as reference



$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon v}$$

where

- Q_h is the ventilation rate required for dilution, in m^3 per second;
- G_h is the generation rate of the substance, in micrograms per second;
- $C_{h,i}$ is the guideline value of the substance, in micrograms per m^3;
- $C_{h,o}$ is the concentration of the substance of the supply air, in micrograms per m^3;
- ε_v is the ventilation effectiveness.

CONCEPT OF SUPPLEMENTING VENTILATION BY GAS PHASE AIR CLEANING.

- **Clean Air Delivery Rate (CADR)**
  - $\mathbf{CADR = \varepsilon_{PAQ} \cdot Q_{AP} \cdot (3{,}6/V)}$
  - where:
  - ε_{clean} or ε_{PAQ}. is the air cleaning efficiency
  - Q_{AP}· is the air flow through the air cleaner, l/s;
  - V is the volume of the room, m^3.

- **Air Cleaning Efficiency**
  - $\mathbf{\varepsilon_{clean} = 100(C_U - C_D)/C_D}$

  where:

  - ε_{clean} is the air cleaning efficiency
  - C_U is the gas concentration before air cleaner
  - C_D is the gas concentration after air cleaner.

$$\varepsilon_{PAQ} = Q_o / Q_{AP} \cdot (PAQ / PAQ_{AP} - 1) \cdot 100$$

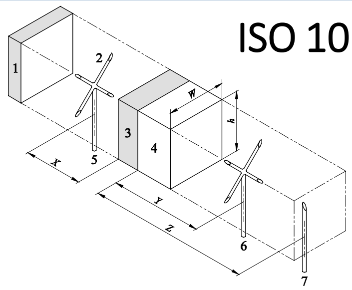
- where:
- ε_{PAQ} is the air cleaning efficiency for perceived air quality;
- Q_o is the ventilation rate without air cleaner, l/s;
- Q_{AP} is the ventilation rate with air cleaner, l/s;
- PAQ is the perceived air quality without the air cleaner, decipol;
- PAQ_{AP} is the perceived air quality without the air cleaner, decipol

- **Higher Air Quality Category**

Testing Gas Phase Air Cleaners Standards

- ISO 10121-2:2013 "Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 2: Gas-phase air cleaning devices (GPACD)"
- • ISO 10121-1:2014 "Test method for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 1: Gas-phase air cleaning media"
- • ANSI/ASHRAE Standard 145.2-2016 "Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Air-Cleaning Devices" (first edition in 2011)
- • ANSI/ASHRAE Standard 145.1-2015 "Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Loose Granular Media" (first edition in 2008)

TESTING OF GAS PHASE AIR CLEANERS



ISO 10121-2:2014

Air Cleaning Efficiency

$$\varepsilon_{clean} = 100(C_U - C_D)/C_D$$

where:

E_{clean} is the air cleaning efficiency

C_U is the gas concentration before air cleaner

C_D is the gas concentration after air cleaner.

Key

1 diffusor and Δp device

2 sampling points – should be of "fork" type or similar with multiple inlet points to make a compounded sample over the whole cross section

3 GPACD under test

4 GPACD section of test duct

5 upstream sampling point for T_U, RH_U, p_U and C_U at X mm before the GPACD

6 Downstream sampling point for T_D, RH_D, p_D and C_D at Y mm after the GPACD

7 Q, air flow rate sampling point at Z mm after the GPACD

W internal width of the test duct along the GPACD section, 3+4

h internal height of the test duct along the GPACD section, 3+4

Figure 1 — Normative section of test stand showing ducting, measurement parameters and sampling points

PERCEIVED AIR QUALITY

INTERNATIONAL STANDARD

ISO 16000-28

First edition 2012-03-15

Indoor air —

Part 28:
Determination of odour emissions from building products using test chambers

Air intérieur —

Partie 28: Détermination des émissions d'odeurs des produits de construction au moyen de chambres d'essai

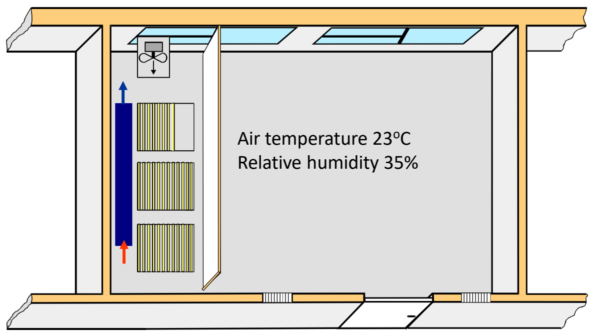
Test Panel
- Trained
- Untrained

Odour
- Acceptance
- Intensity
- Hedonic tone

Examples of diffuser and mask used for odour evaluatio

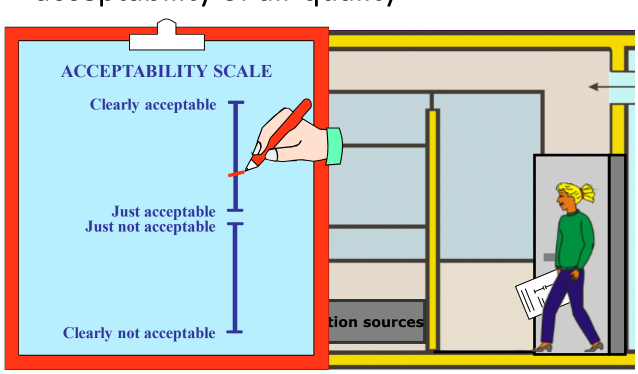
Figure C.1 — Diffuser

Experimental setup



Sensory measurements

- Panel of 50 untrained subjects assessed acceptability of air quality



PERCEIVED AIR QUALITY

$$ACC = \frac{\sum_{i=1}^{N} (ACC)_i}{N} \qquad [1]$$

where:
ACC = mean vote of acceptability of air quality;
ACC_i = acceptability vote by the observer.
N = number of observers.

The accuracy of evaluations is expressed by a standard error of the measured acceptability [2]:

$$SE = \frac{SD}{\sqrt{N}} \qquad [2]$$

where:
SE = standard error;
SD = standard deviation of mean vote of acceptability;
N = number of observers.

Using mean acceptability ratings, the percentage dissatisfied with the air quality can be calculated (Gunnarsen and Fanger, 1992) [3]:

$$PD = \frac{\exp(-0.18 - 5.28 \cdot ACC)}{1 + \exp(-0.18 - 5.28 \cdot ACC)} \cdot 100 \qquad [3]$$

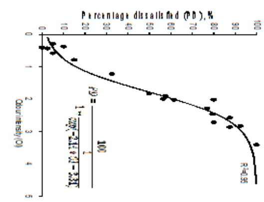
where:
PD = percentage dissatisfied with the air quality, %;
ACC = mean vote of acceptability.

Using the percentage dissatisfied, the perceived air quality expressed in decipol, as defined by Fanger (1988), can be calculated [4]:

$$PAQ = 112 \cdot [\ln(PD) - 5.98]^{-4} \qquad [4]$$

where:
PAQ = perceived air quality, decipol;
PD = percentage dissatisfied with the air quality, %.

Both the percentage dissatisfied with the air quality [3] and the perceived air quality in decipol [4] are used to set requirements regarding air quality and ventilation of spaces (e.g., ASHRAE, 2004; CEN, 1998).



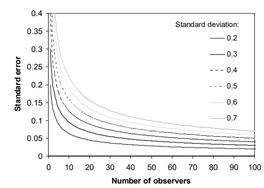
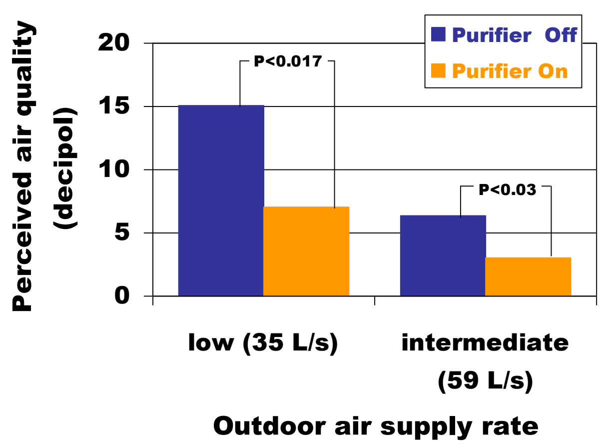
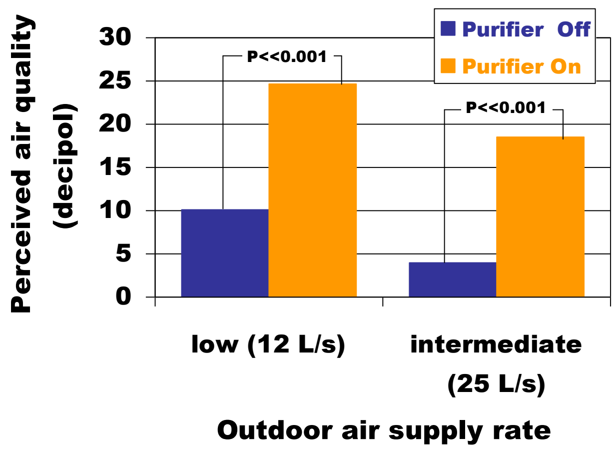


Figure 3. Standard error of the acceptability rating as a function of number of observers and standard deviation of the rating of acceptability

Results: Bldg mat, PCs, filters



Results: Human bioeffluents



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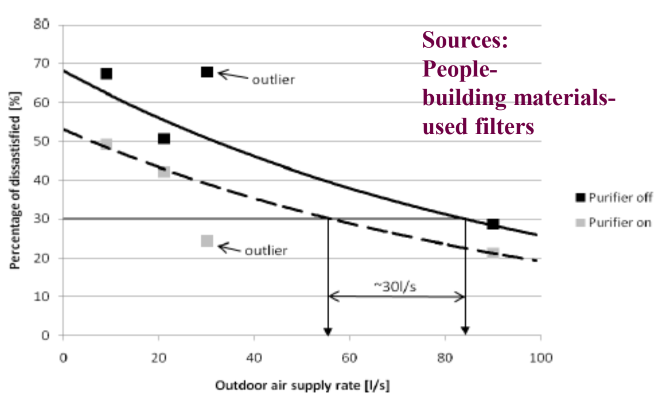
Effect of air cleaning on perceived Air Quality



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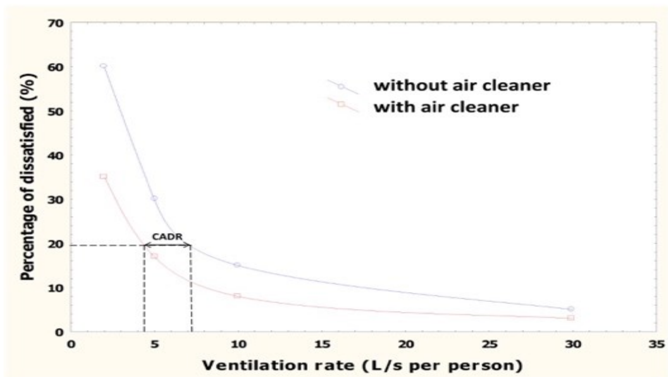
Clean Air Delivery rate per person



Issues

- International Standards for Ventilation (Indoor Air Quality) like EN16798-1, ISO17772-1 and ASHRAE 62.1 are mainly based on criteria for the Perceived Air Quality (PAQ), sometimes expressed as levels of CO_2 as a tracer for emission from occupants.
- If air cleaning is used, an equivalent level of air quality will be reached at higher CO_2 concentrations.
- It is also assumed that when ventilation is used for PAQ, the required ventilation will also dilute other substances like Radon, VOCs.
- The decreased ventilation rate when using gas phase air cleaning may not be sufficient.

ΔCO_2 levels considering a 30 % reduced ventilation rate due to air cleaners

Space type ***Single office***	*Occupancy [m^2 per person]*	*Category*	*Derived from qtot*	
			Very low-polluting building	*Low-polluting building*
			Indoor CO_2 level above outdoor level ΔCO_2 *[ppm]*	
Without air cleaner	10	IEQ_I	370	278
		IEQ_{II}	**529**	**397**
		IEQ_{III}	926	694
		IEQ_{IV}	**1389** (1010)	**1010** (794)
With air cleaner	10	IEQ_I	529	397
		IEQ_{II}	**756**	**567**
		IEQ_{III}	**1323** (1029)	**992** (817)
		IEQ_{IV}	**1984** (1100)	**1443** (911)

Issues

- Today, gas phase air cleaners are tested based on a chemical measurement, which do not account for the influence on PAQ and human bio effluents as a source of pollution.
- Studies have shown that some gas phase air cleaning technologies will not work when humans are the source, and the evaluation is done by PAQ.
- There is a need for new test standards
- Testing with PAQ requires a measurement of subjective reactions
- Testing with human bio effluents as a source requires the use of humans as a source

Testing Issues

- If only a test with chemical measurements is done, should it be allowed to reduce the building component?
- How to standardise the building source?
- How to standardise the human bio effluent source?
- What if human source is Chinese persons and testing panel is Danish persons?
- It is a relative measurement, which makes some of the issues less important

ENERGY USE-INDOOR ENVIRONMENT

- Reduced Energy Use
  - Heating/Cooling of Supply Air
  - Reduced energy for humidification and/or De-humidification
  - Fan Energy
  - Energy Use of Air Cleaner
  - Heat Recovery or not
- Noise level
  - Reduced air flow in AHU
  - Noise from air cleaner
- Draught level
  - Reduced air flow in occupied space
  - Draught from portable air cleaner

Conclusion

- A concept for substituting part of the required ventilation with gas phase air cleaning technology has been presented
- There is a need for new testing standards that considers perceived air quality and human emissions as a source.
- The energy impact of using gas phase air cleaning must be studied further. By reducing the ventilation rate energy use can be reduced for:
  - pre-heating or pre-cooling of outside supply air
  - humidifying or de-humidifying
  - fan energy for air transport
- Energy use may be increased due to:
  - Additional fan energy for stand-alone air cleaners
  - Additional fan energy due to increased pressure drop over the device
  - Reduced potential for cooling by outside air
- It must be verified that the reduced ventilation rate is still high enough to dilute individual contaminants.
- Adjusted CO_2 criteria must be used to express the indoor air quality and to use for demand-controlled ventilation.

Questions?

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