IEA-EBC Annex 78: Substituting Ventilation by Gas Phase Air Cleaning. An industry webinar

Introduction to IEA-EBC Annex 78 and the concept of substituting Ventilation by Gas Phase Air Cleaning

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Energy in Buildings and Communities Programme

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

ANNEX MEMBERS

- Czech
- China
- Denmark
- Japan
- Singapore
- Sweden
- USA
- Turkey

Planned deliverables

A. A method for predicting the energy performance of gas phase air cleaning technologies and the possible reduction of energy use for ventilation.

B. A validated procedure for supplementing (partly substituting) required ventilation rates with gas phase air cleaning.

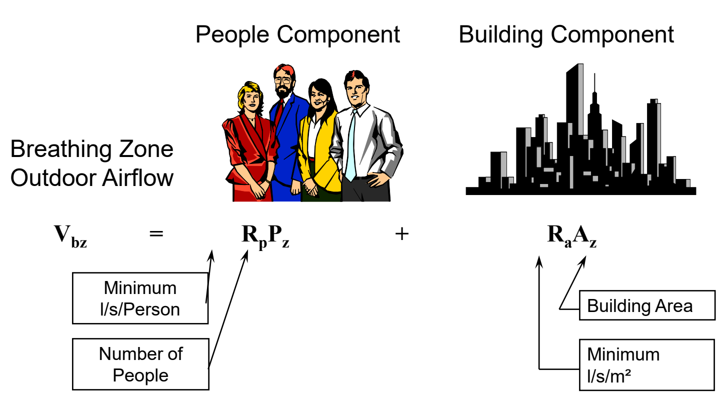
C. A test method for air cleaning technologies that besides chemical measurements include perceived air quality as a measure of performance.

D. A report on the long-term performance of gas phase air cleaning.

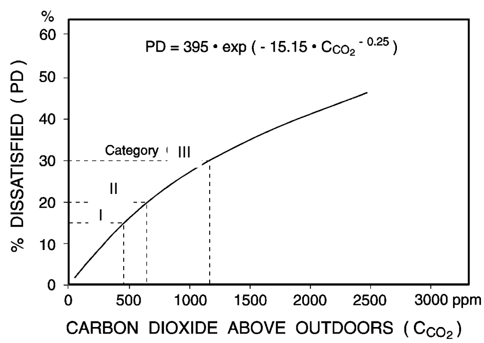
E. Models for predicting the performance of gas phase air cleaning

F. A report on Gas Phase Air Cleaning Technologies

Concept for calculation of design ventilation rate ISO CEN ASHRAE



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)**
  - **CADR = $\varepsilon_{PAQ} \cdot Q_{AP} \cdot (3,6/V)$**
  - where:
  - ε_{clean} or $\varepsilon_{PAQ.}$ 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.

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

- 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

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

  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.

- **Higher Air Quality Category**

CONCEPT OF SUPPLEMENTING VENTILATION BY GAS PHASE AIR CLEANING.

V entilation
I nformation
P aper
n° 42
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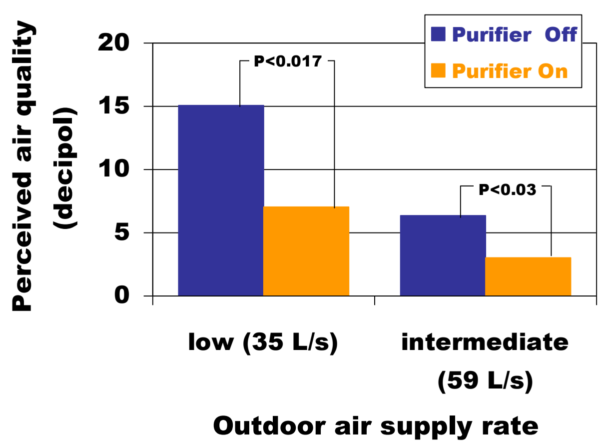
International Energy Agency's
Energy in Buildings and Communities
Programme

Air Infiltration and Ventilation Centre

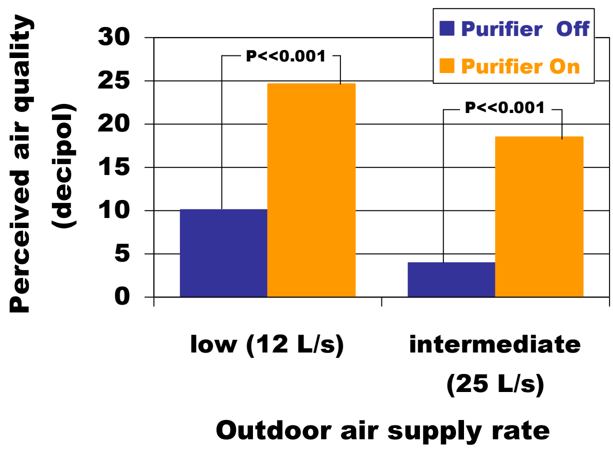
The Concept for Substituting Ventilation by Gas Phase Air Cleaning

Bjarne W. Olesen, DTU, Denmark
Chandra Sekhar, National University of Singapore, Singapore
Pawel Wargocki, DTU, Denmark

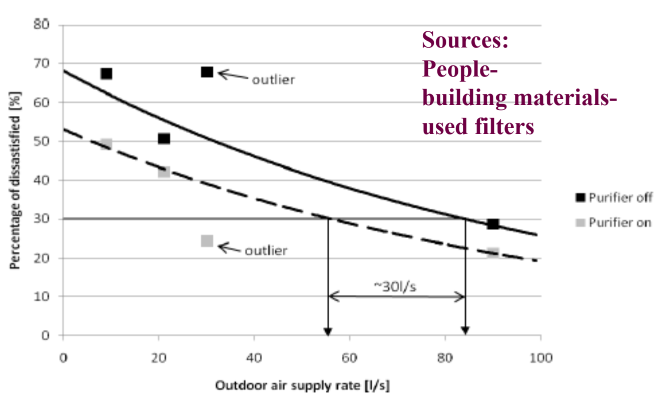
Results: Building materials, PCs, filters



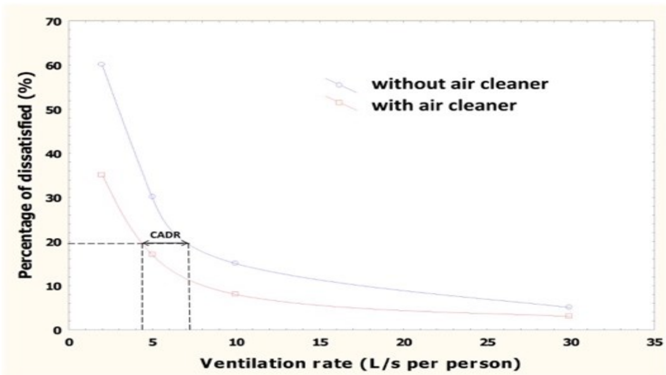
Results: Human bioeffluents



Effect of air cleaning on perceived Air Quality



Clean Air Delivery rate per person



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.

Questions?
Please put your questions in the chat.

Bjarne W. Olesen
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Energy in Buildings and Communities Programme

1

Sources of gaseous pollutants

- Sources of **inorganic gases** include gas stoves, tobacco smoke, and vehicles.
- Sources of **organic gases** include tobacco smoke, building materials, furnishings, animal metabolic processes, etc.
- **Radon** can also be found in indoor air.

2

Requirements

- Regardless of the type of technology, **three requirements** must be fulfilled.
  - High filtration efficiency must be provided for a broad range of chemical substances.
  - Low airflow resistance (small pressure drop) is required.
  - The release or generation of harmful substances must be **prevented**.

Different technologies for removing gaseous pollutants.

- There are **six principal types of gas-phase air cleaners**.
  - Adsorbent media air filters, such as activated carbon (AC)
  - Chemisorbent media air filters
  - Photocatalytic oxidation (PCO)
  - Plasma
  - O_3 generators
  - Plants

Filtration – Gaseous Materials
Adsorbent Media

- The adsorption process can be divided into two main groups:
  - Physical adsorption (e.g. the adsorption of AC for gas).
  - Chemical adsorption (e.g. activated alumina or AC impregnated with potassium or sodium permanganate, which reacts with formaldehyde and several other compounds).

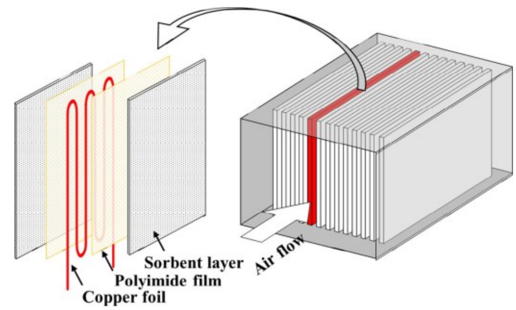
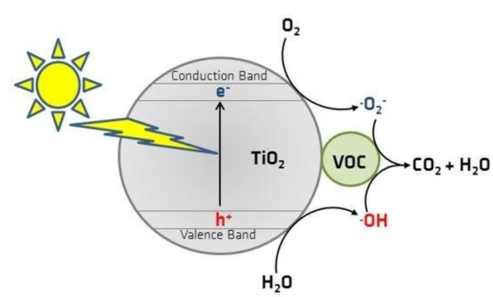


Illustration of the surface temperature adjustable laminated plate structure (left) and the air purifier module comprising multiple parallel plates (right). (Chen et al., 2019).

Filtration – Gaseous Materials
Photocatalytic Oxidation (PCO)

- The PCO process is where, upon adsorption of a photon, a semiconductor acts as a catalyst in producing reactive radicals, primarily hydroxyl radicals, which can oxidise organic compounds and mineralise them.
- Common photocatalysts in PCO are titanium dioxide (TiO2), zinc oxide (ZnO), tungsten trioxide, zinc sulphide, and cadmium sulphide.

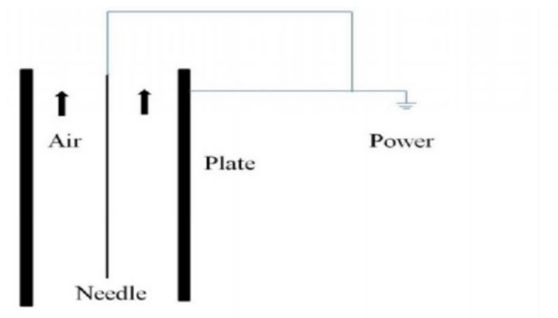


Schematic representation of photocatalytic oxidation of a volatile organic compound (VOC) (Mull et al., 2017).

Filtration – Gaseous Materials

Air Ion Generators

- Air ions are electrically charged molecules or atoms in the atmosphere.
- An air ion is formed when a gaseous molecule or atom receives sufficiently high energy to eject an electron.
- Negative air ion (NAI) generators gain electrons, whereas positive air ion generators lose electrons.
- Several types of negative air ion generators are based on corona discharges, thermionic electron emission, photoexcitation, and the Lenard effect for creating NAIs.



Schematic view of the corona discharge ioniser technology (Rahimi, 2013).

Filtration – Gaseous Materials

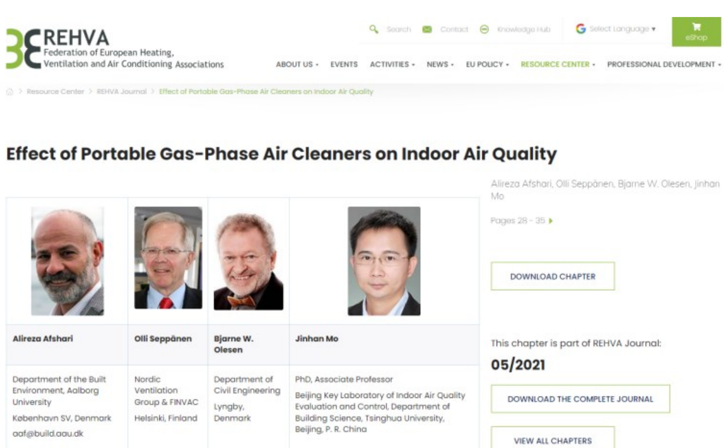
Ozone Generators

- An O_3 generator is a device that produces O_3 by adding energy to oxygen molecules (O_2), which causes the oxygen atoms to separate and temporarily recombine with other oxygen molecules.
- The process can be accomplished in the following methods: corona discharge and UV radiation.

Visualisation of how a corona discharge ozone generator operates (Ozone solutions. 2021).

Filtration – Gaseous Materials
Plant

- Several articles have described air-cleaning plants used by NASA .
- Wolverton et al. (1989) found that indoor plants can scrub the air of cancer-causing VOCs, such as formaldehyde and benzene.
- Orwell et al. (2004) found that soil microorganisms in potted plants also play a part in cleaning indoor air.
- Kim et al. (2010) examined 86 species of houseplants from five general classes for their ability to remove formaldehyde.



https://www.rehva.eu/rehva-journal/chapter/effect-of-portable-gas-phase-air-cleaners-on-indoor-air-quality

Summary of the technologies

	Advantage	Disadvantage	Application
Adsorbent	• Gaseous pollutants adsorb on porous granular media or condense in pores of media. • Many types of sorbents with activated carbon most commonly used. • Widely available technology • Can remove broad range of gaseous pollutants with moderate to high efficiency	• Pollutants can be released from sorbent into indoor air • Low effectiveness for low molecular weight pollutants including formaldehyde • Must periodically replace sorbent • Sorbent lifetime for indoor air applications not well understood • Large amount of sorbent needed for long lifetime • High sorbent cost • Often high airflow resistance increasing fan energy use	• Installed in heating, ventilating and air conditioning systems or in stand-alone portable air cleaners
Chemisorbent	• Gaseous pollutants adsorb on and chemically react with porous granular media • Widely available technology • Can remove broad range of gaseous pollutants with moderate to high efficiency	• High chemisorbent cost • Often high airflow resistance increasing fan energy use	• Installed in heating, ventilating and air conditioning systems or in stand-alone portable air cleaners
Photocatalytic Oxidation	• Gaseous pollutants adsorb on a surface coated with a photocatalyst that is irradiated with a light source, usually a source of ultraviolet light; some adsorbed pollutants decompose • Can remove a range of gaseous pollutants • Usually lower airflow resistance than sorbents and chemisorbents, thus, lower fan energy use • Can destroy some bioaerosols • Many systems have low pollutant removal efficiency	• Lamp energy use • Cost of periodically replacing lamps • Photocatalysts become inactive, with unknown photocatalyst life • Incomplete breakdown of some pollutants can result in formation of new pollutants potentially harmful to health	• Installed in heating, ventilating and air conditioning systems or in stand-alone portable air cleaners
Air Ion Generator	• Radicals (small reactive molecules) created by electric discharge can oxidize and decompose volatile organic compounds and nitrogen oxides • Quiet and energy efficient • May improve particle removal performance of some particle air cleaners	• Very limited data available on pollutant removal performance in buildings • Can produce ozone, see comments on ozone air cleaners	• Usual application is a standalone portable air cleaner
Ozone Generator	• Ozone generated and released into indoor air can react with and breakdown some airborne volatile organic compounds • Quiet and energy efficient	• Releases ozone into indoor air and ozone is a harmful pollutant • Generally ineffective in significantly reducing airborne volatile organic compounds unless ozone concentrations are very high • Reactions of ozone with airborne volatile organic compounds can lead to production of formaldehyde and ultrafine particles that pose health risks	• Usual application is a standalone portable air cleaner
Plant	• Plants in buildings can remove some volatile organic compounds	• Not proven to significantly reduce indoor pollutant levels with practical number of plants	• Plants placed throughout building or in attached greenhouse

Effect of Portable Air Cleaners on Indoor Air Quality:

Particle Removal from Indoor Air

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The purpose of this literature review was to examine the studies, published in the last decades that analysed possibilities, applications and limitations of using portable air cleaners in order to improve indoor air quality. The article discusses the strengths and weaknesses of different air cleaning technologies by considering factors such as air quality improvement, filtering performance and energy aspect.

Keywords: particle, removal, indoor air, air cleaner, ventilation

13:44

3E

Testing Portable Air Cleaning Units –Test Methods and Standards: A Critical Review

Alireza Afshari

Jinhan Mo

Enze Tian

Olli Seppänen

Thank you for your attention

IEA EBC Annex 78 & AIVC Webinar

Substituting Ventilation by Gas Phase Air Cleaning
7th November 2022 [15:00-16:45 CET] - 15:20-15:30

"Existing standards for testing gas phase air cleaners"

P. Tronville
Politecnico di Torino, Turin, Italy

Politecnico di Torino
Department of Energy "G.Ferraris"

AEROSOL TECHNOLOGY LAB

Gas-phase air-cleaning performance metrics

Why are we interested in a standardized test method for such equipment?

1. Removal efficiency of gaseous pollutants: 1 minus penetration, i.e., the ratio of downstream to upstream pollutant concentration; for supplementing ventilation, typically, the pollutants are VOCs
2. Airflow resistance through the gas-phase air cleaning system; it is linked not obviously to fan energy use or airflow reduction
3. Service life of device or media: time elapsed between installation and replacement or maintenance
4. Total cost of gas-phase air cleaning per unit delivery of VOC-free air (no standard currently available for this purpose)

EN ISO standards for building applications

- EN 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)" (confirmed in 2018)
- EN 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" (confirmed in 2019)
- EN ISO 10121-3:2022 "Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 3: Classification system for GPACDs applied to treatment of outdoor air"

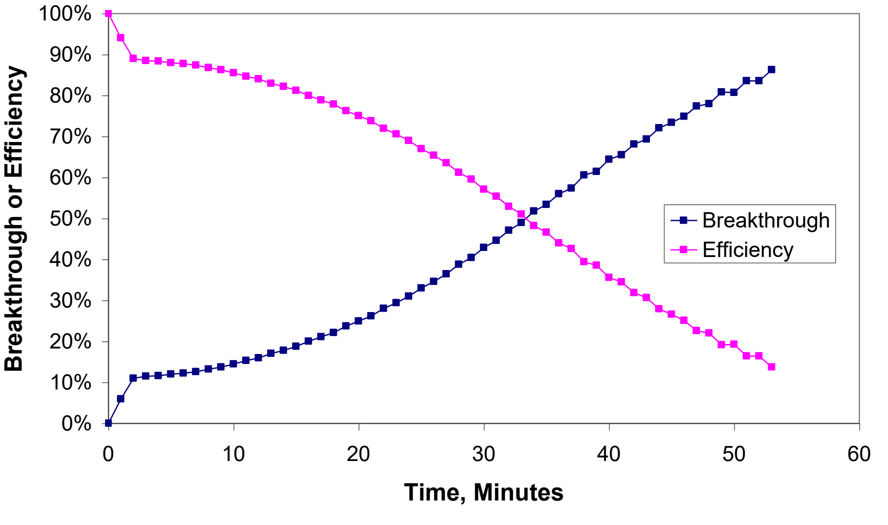
ASHRAE standards for building applications

- 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)
- ASHRAE Standard 145.4P - Proposed Standard authorized June 2022 to be developed by SSPC 145 "Method of Test for Assessing the Gas-Phase Performance of Air Cleaning Devices and Systems in a Duct-Chamber Apparatus"

Particulate vs. gas removal equipment assessment

- Particulate filter with fibrous media
  - Pressure drop gradually increases
  - Filter efficiency may increase or decrease
  - Filter is visibly working
  - Standards and test procedures to rate filters well established and being improved (new aging procedure needed for general ventilation applications)
- Gas-phase air cleaner
  - Pressure drop remains the same
  - Filter efficiency decreases
  - Usually, the filter is not visibly working
  - Standards and test procedures to rate filters are still being developed and are not commonly used

Dynamic breakthrough/Efficiency curve



Performance vs. features

Features

- Amount of sorbent media
- Residence time (airflow rate)

Performance

- Dynamic breakthrough or efficiency
- Capacity
- Life
  - Minimum efficiency (vs. 100% Breakthrough)
  - Maximum concentration
  - Pressure drop (ensure proper pre-filtration)

Traditional gas-phase air-cleaning technologies

- Traditional gas-phase removal equipment based on an adsorption process, e.g., activated carbon or permanganate alumina pellets
- Adsorption technologies have long been used in a wide range of applications, so the performances and the efficiencies under various conditions are well understood
- Some current standards have limitations in their scope, which make them not suitable for emerging gas-phase electronic air-cleaning technologies

Emerging gas-phase electronic air-cleaning technologies

- Newer technologies are used in electronic air cleaners, such as UV, UV with photocatalysts (UV-PCO), plasmas, plasma with catalysts, etc.
- These may generate oxidizing agents like radicals and ozone that remove the gases and vapors through the oxidation process; upon complete oxidation, VOCs can be converted into carbon dioxide and water
- They can generate intermediates such as carbon monoxide, formaldehyde, acetaldehyde, and acetic acid in cases of incomplete oxidation, as well as generate pollutants like ozone and nitrogen oxides inherently depending on the system

Work in progress

- ISO/TC142/WG8 is drafting ISO/PWI 23743 “Testing of gas-phase air cleaners for improving perceived indoor air quality”
- It could be based on FDIS/ISO 16000-44 “Indoor air - Part 44: Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners”
- Other experts are working on room air cleaners: IEC SC59N, JWG 2 Reduction of Chemical Gases
  - Sub Working Group 2.1 on Reduction of Ozone

Thanks for your attention!

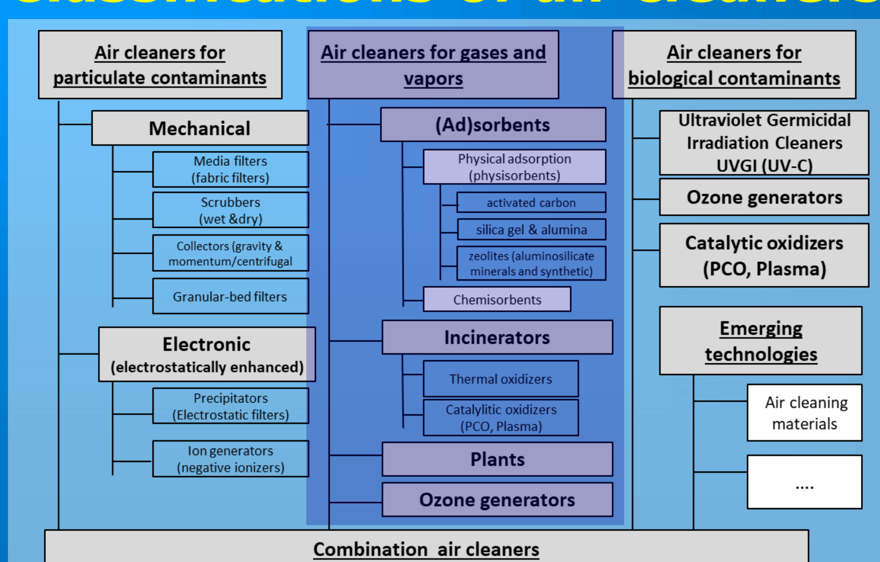
Methods to evaluate gas phase air-cleaning technologies: Perceived Air Quality

Pawel Wargocki

International Centre for Indoor Environment and Energ
Department of Environmental and Resource Engineering
Technical University of Denmark

1

Classifications of air cleaners



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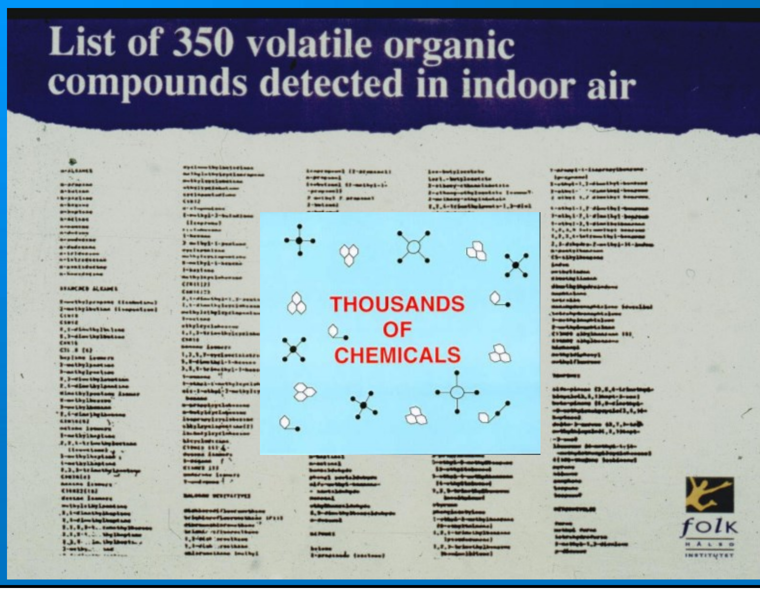
Organic Chemicals in Indoor Air



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Chemical measurements

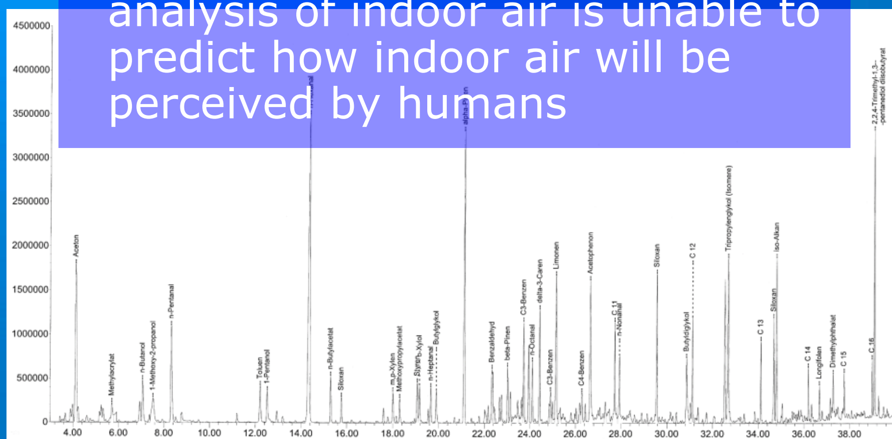
Gas Chromatography/Mass Spectrometry (GC/MS)

Proton-Transfer-Reaction Mass Spectrometry (PTR-MS)

4

Chemical analysis of indoor air

- Detailed compound-by-compound analysis of indoor air is unable to predict how indoor air will be perceived by humans



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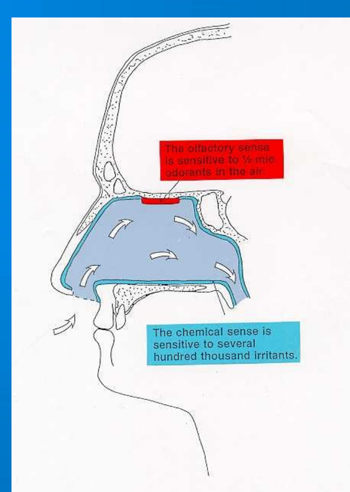
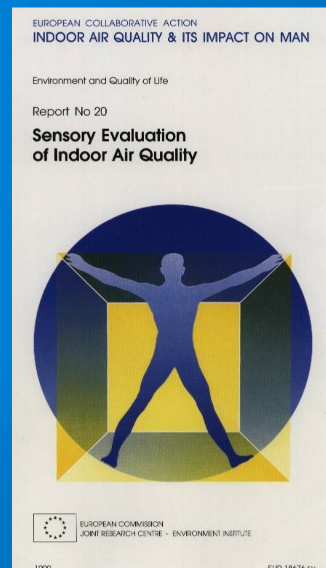
Using man as a meter

- The air quality as rated by humans in subjective evaluations (Glossary of the Indoor Air Sciences, 2006)
- Quality: the extent to which human requirements are met



Sensory evaluations of air quality

- Sensory evaluations of air quality have been used routinely in indoor air research for the past 25 years.
- Perceived air quality has been used to define ventilation rates prescribed in the majority of present standards (eg. 16798, ASHRAE 62.1)
- Perceived air quality has been used to examine emissions from building materials, it is included as a part of testing in few labelling schemes for building and furniture materials (Finnish M1 Label; Danish Indoor Climate Label, and German AgBB Scheme) and the standard describing sensory testing in connection with emission testing (ISO 16000-30)
- Perceived air quality has been used extensively in the past in field studies as a measure of air quality in rooms and buildings (eg. Wargocki et al., 2004)
- Can be considered as an exposure metric



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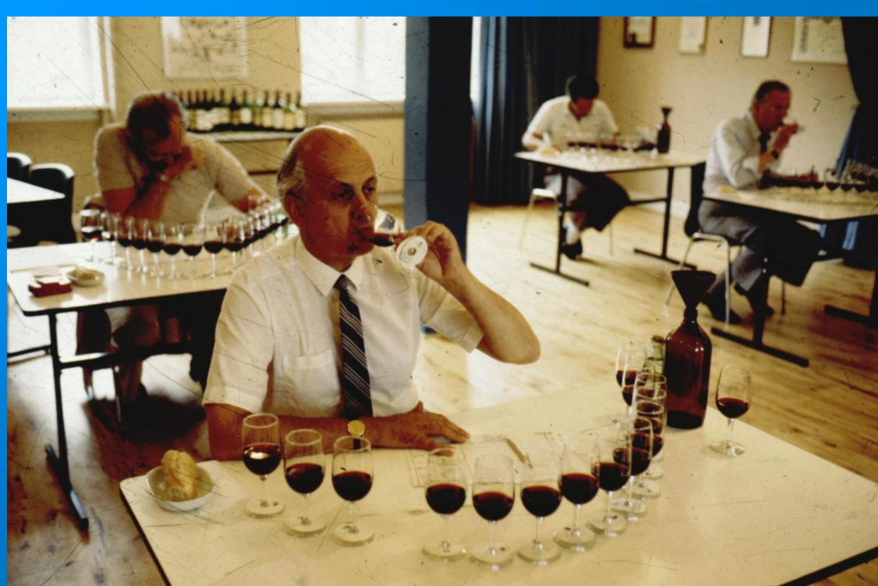

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Measurements of perceived air quality

- Subjective evaluations of air quality include ratings of intensity of odour, freshness (stuffiness), acceptability (dissatisfaction)
- Acceptable air quality: air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority of the people exposed do not express dissatisfaction
- Sensory panels of human subjects
  - Untrained panel
  - Trained panel
- Immediate response (“First impression”)
- Impartial assessment

9

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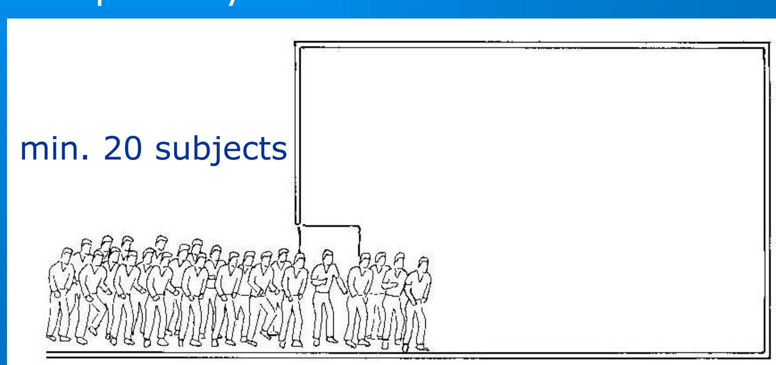
Untrained panel

“… a panel of at least 20 untrained observers (…) who render a judgement of acceptability…”



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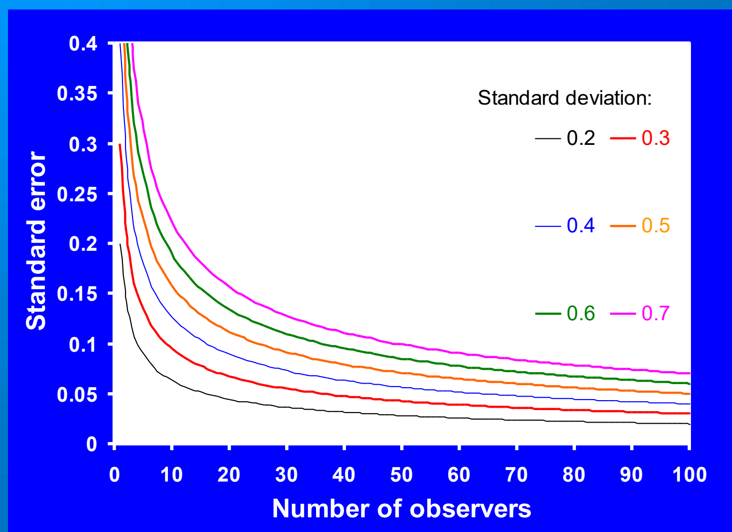
Panel size



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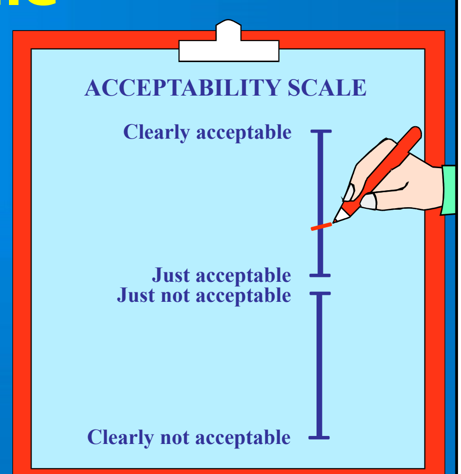
Continuous acceptability scale

How do you assess the air quality?

Pay attention to the dichotomy between acceptable and not acceptable.



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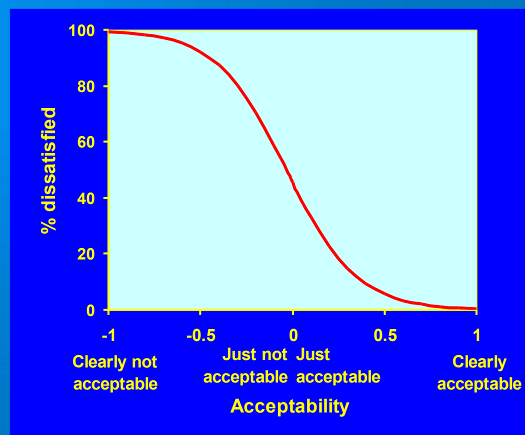
Measuring metric

Acceptability

↓

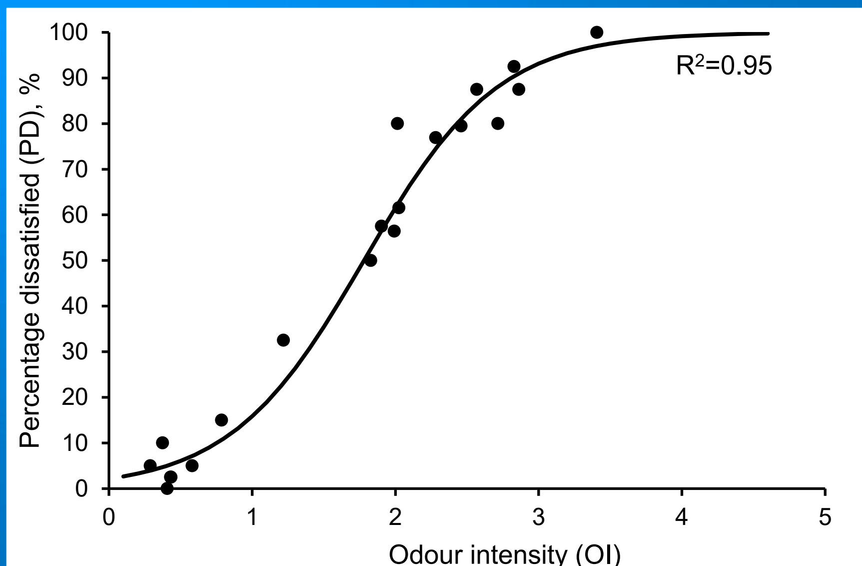
% dissatisfied



Odour intensity: category scale (Yaglou et al. 1936)

- No odour
- Slight odour
- Moderate odour
- Strong odour
- Very strong odour
- Overpowering odour

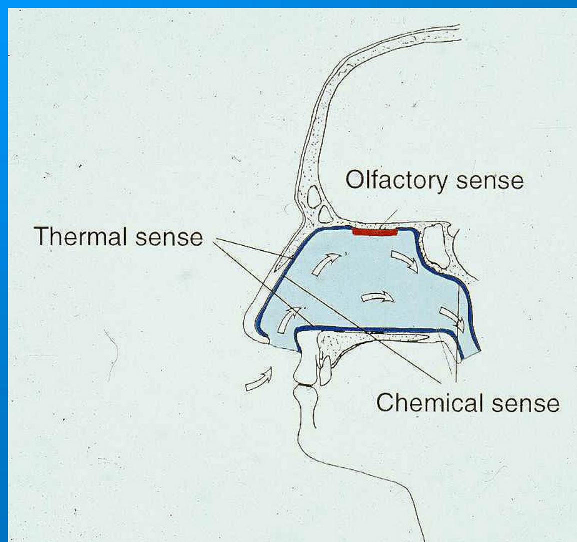
Odour intensity vs % dissatisfied



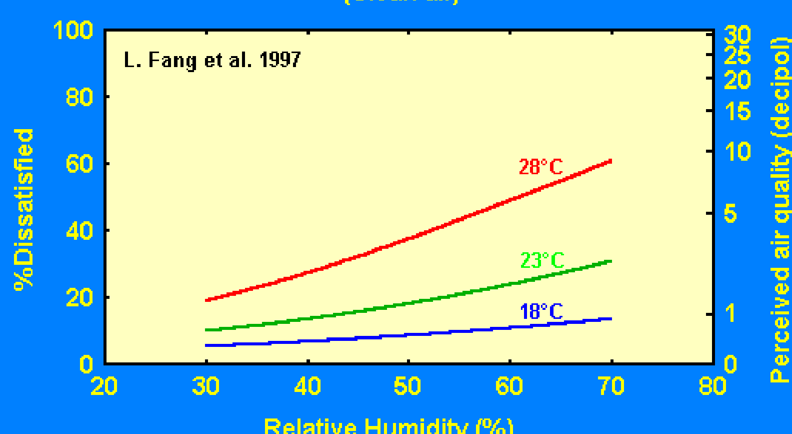
Main factors influencing sensory measurements

- Temperature and relative humidity
- Adaptation – sensory fatigue

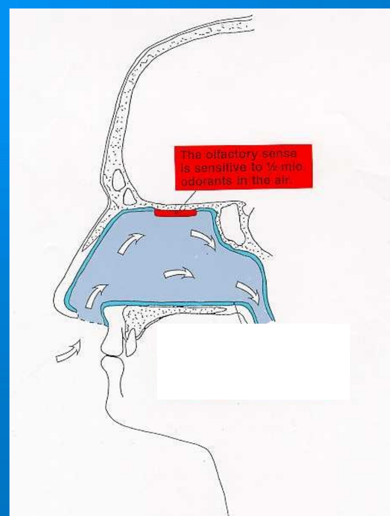
Impact of temperature and humidity on sensory measurements



Impact of temperature and humidity on perceived air quality



Impact of adaptation: sensory fatigue



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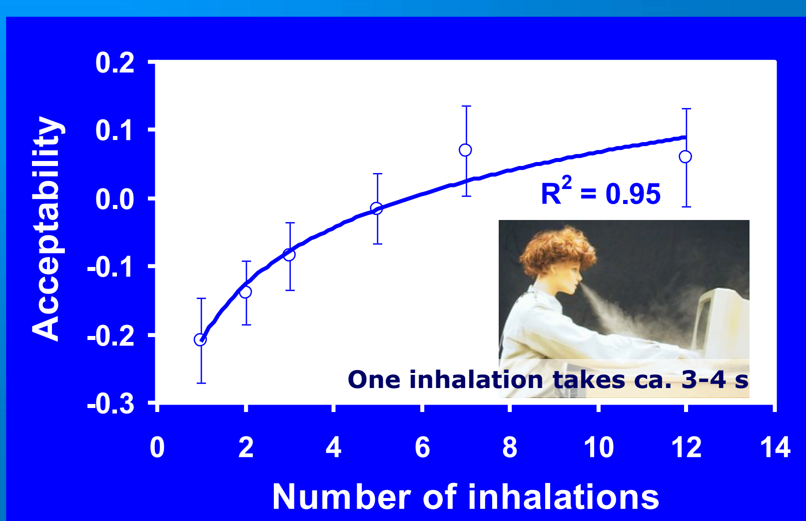
Sensory fatigue



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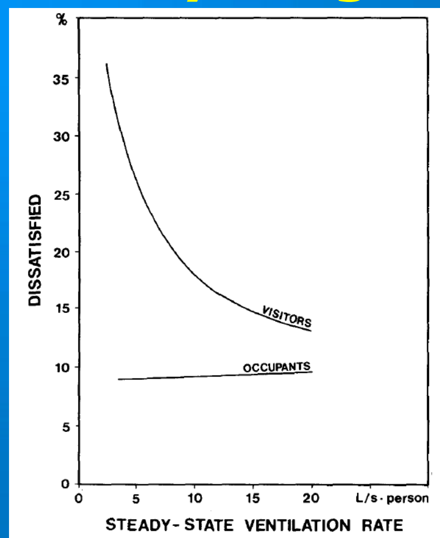
Sensory fatigue



Source: Berg-Munch et al. (1986)

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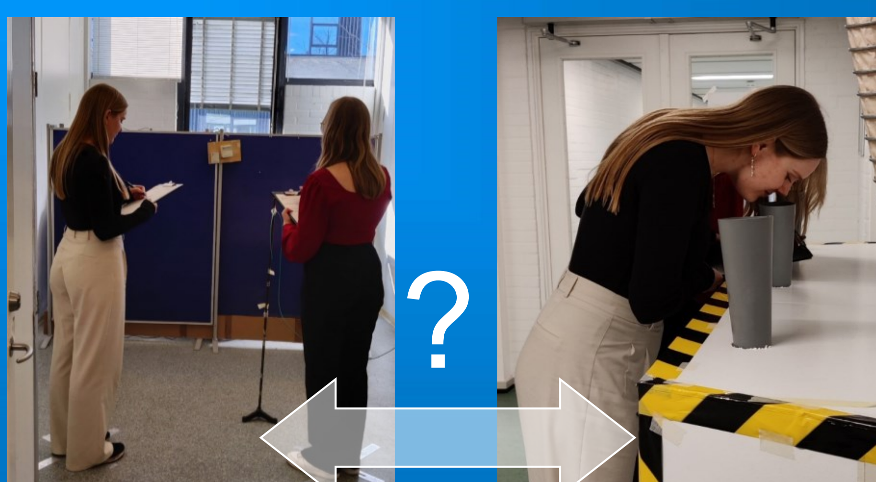
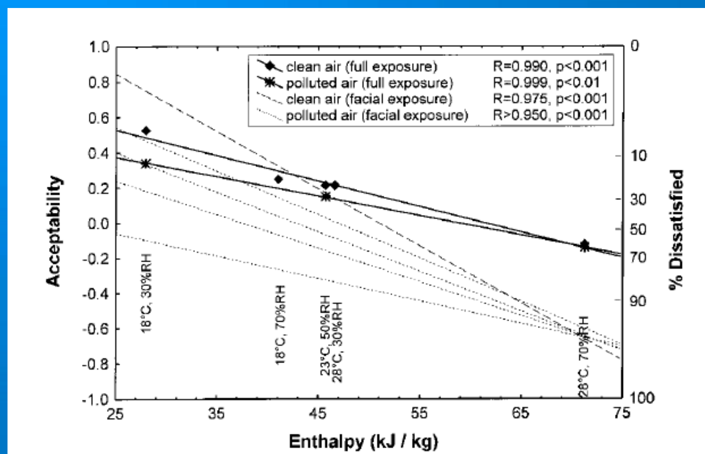
Methodological aspects



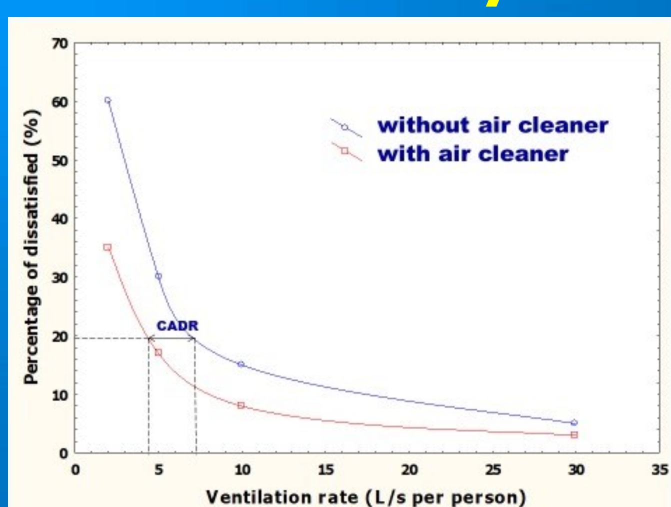
22

Face vs. whole body exposure



International Centre for Indoor
Environment and Energy

Applications
Clean air delivery rate



IEA Annex 78
Supplementing Ventilation with Gas-phase Air Cleaning

International Centre for Indoor Environment and Energy

Designed ventilation rate can be reduced by CADR

People Component

Building Component

Breathing Zone Outdoor Airflow

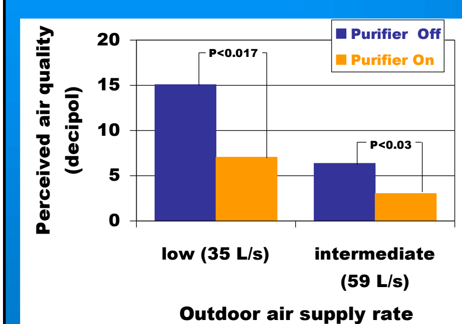
$$V_{bz} = R_p P_z + R_a A_z$$

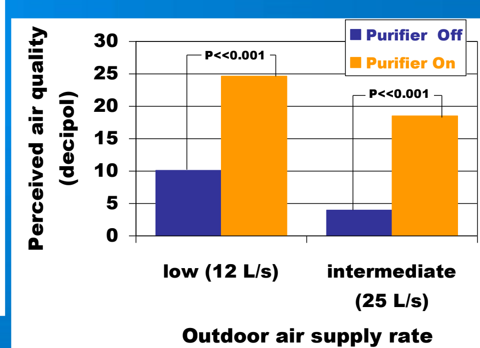
- R_p: Minimum l/s/Person
- P_z: Number of People
- A_z: Building Area
- R_a: Minimum l/s/m²

IEA Annex 78
Supplementing Ventilation with Gas-phase Air Cleaning

International Centre for Indoor Environment and Energy

Applications detection of by-products





Thank you (pawar@dtu.dk)

DTU

Test of air cleaners for evaluating the method of perceived air quality assessment

Lei Fang and Pawel Wargocki

International Centre for Indoor Environment and Energy, Technical University of Denmark

1

1

Stage 1: selection of air cleaners for testing

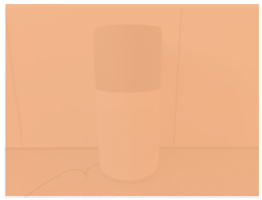
2

Test conditions

Ventilation rate: 7.5 L/s (0.54 1/h)

Air Cleaners (AC)

AC1



AC2

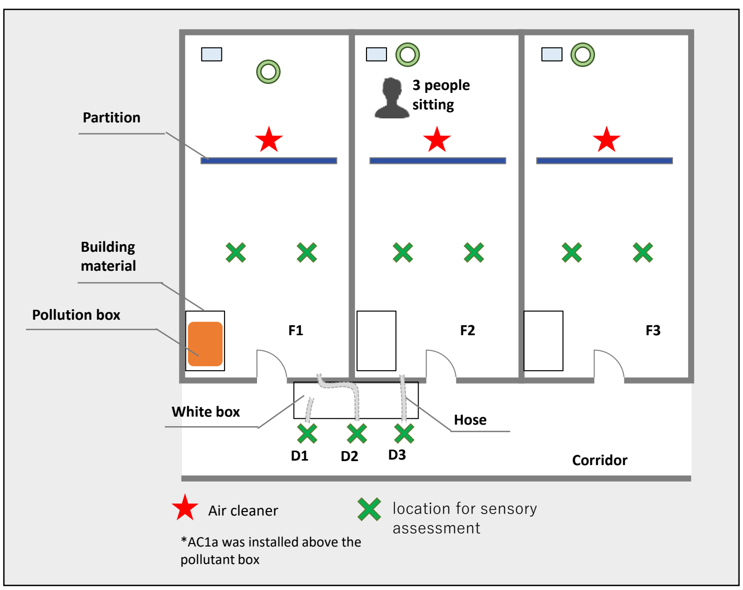
AC3

Pollution source

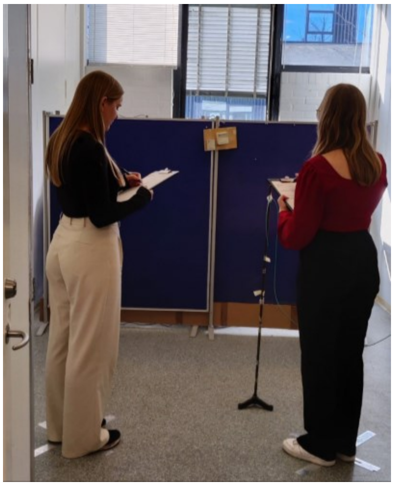
Building material

Human bioeffluents

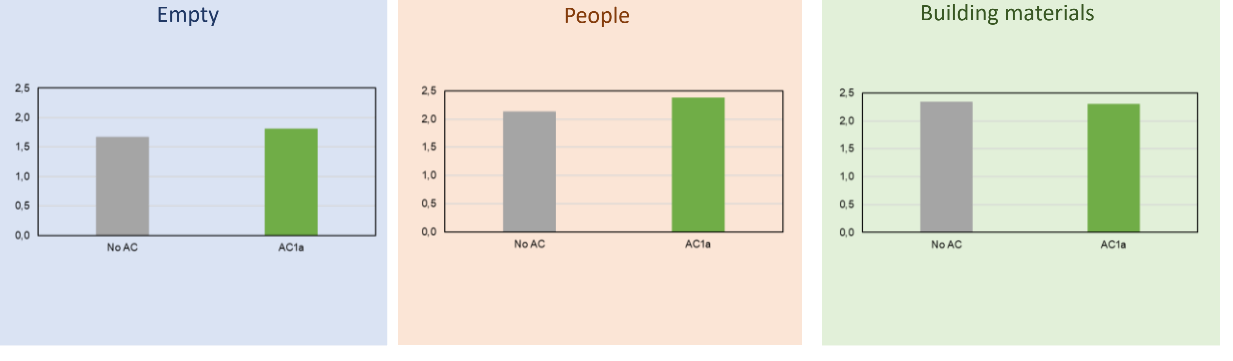
Setup



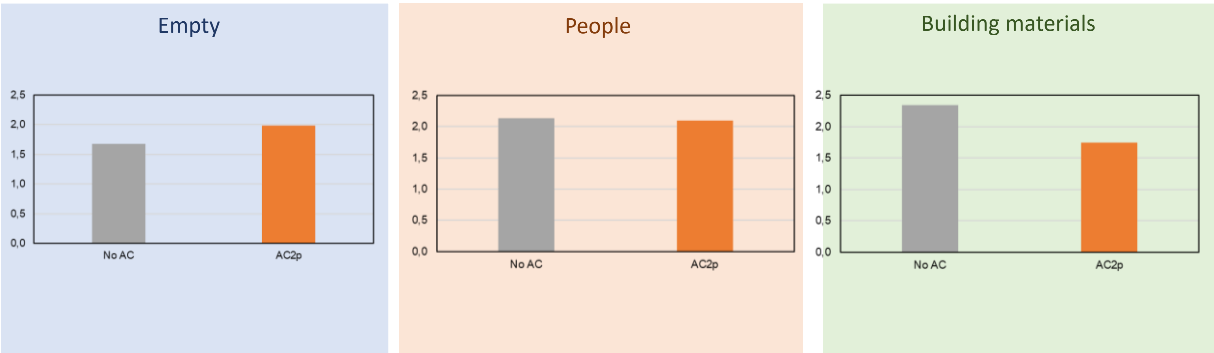
Whole body vs Facial exposure



Assessment of odor intensity (AC1)

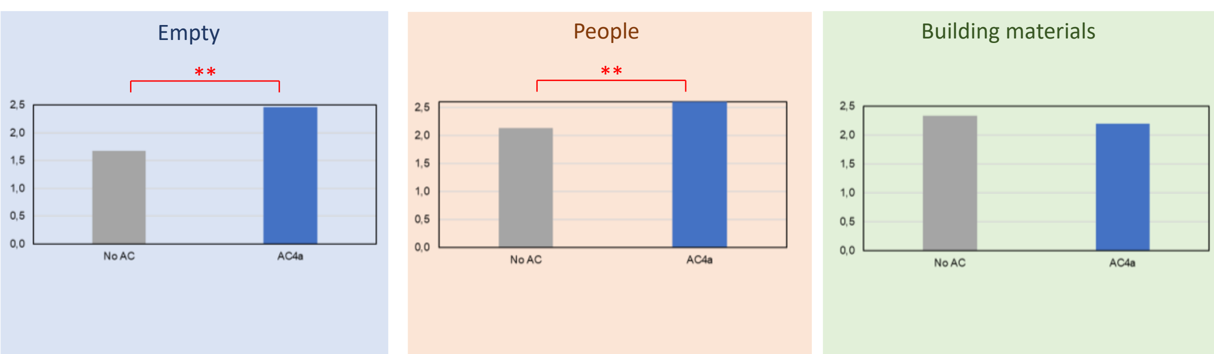


Assessment of odor intensity (AC2)



7

Assessment of odor intensity (AC3)



8

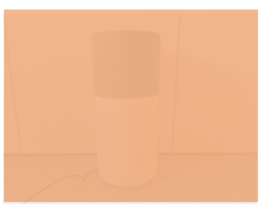
Stage 2: test of air cleaners

Test conditions

Ventilation rate [L/s]	7.5 / 12.0 / 21.0 / 30.0
[1/h]	0.5 / 0.9 / 1.5 / 2.2

Air Cleaners (AC)


AC1


AC2

AC4

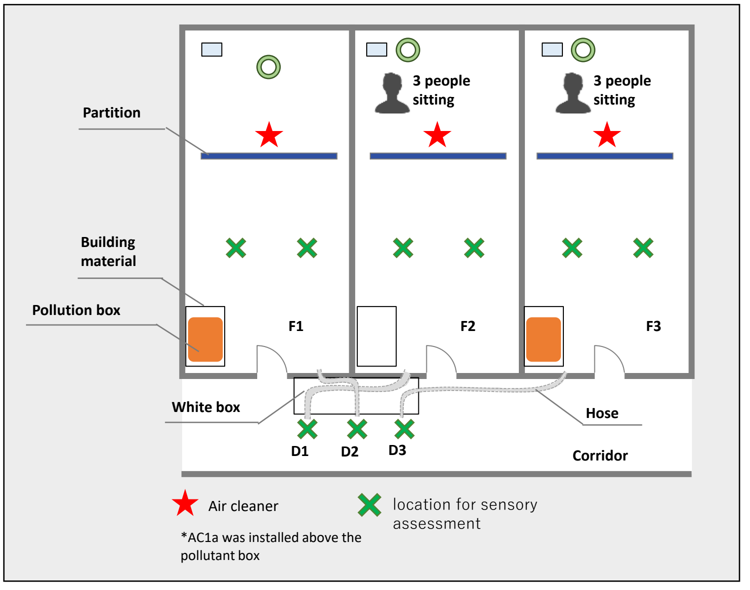
Pollution


Building material


Human bioeffluents


Both

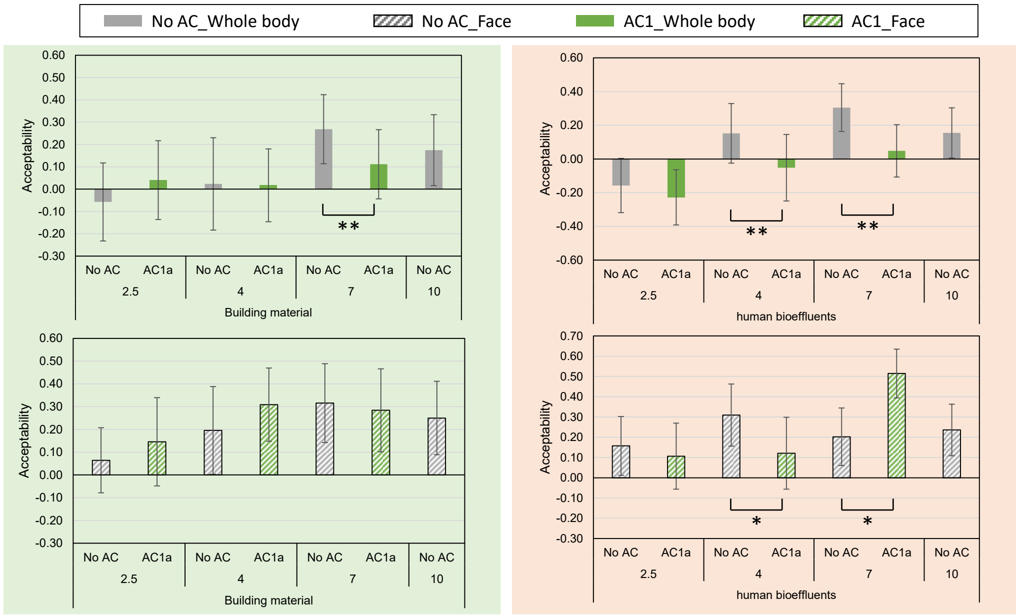
Setup



Results of AC1

■ Results : AC1 Bar means range of 95% Confidence Interval Wilcoxons signed rank test(**p<.01, *p<.05)

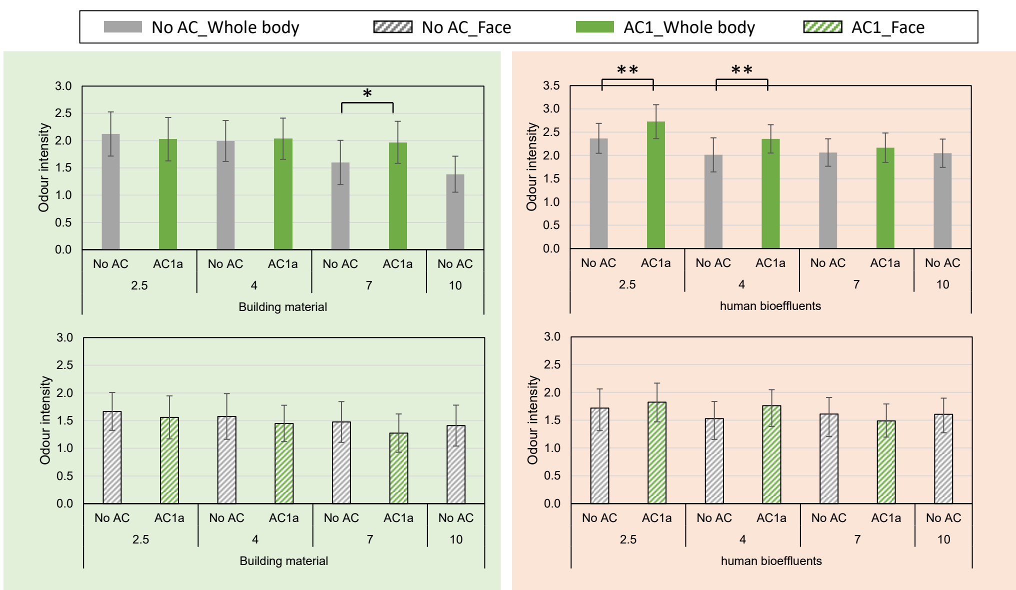
Acceptability



13

■ Results : AC1 Bar means range of 95% Confidence Interval Wilcoxons signed rank test(**p<.01, *p<.05)

Odour intensity

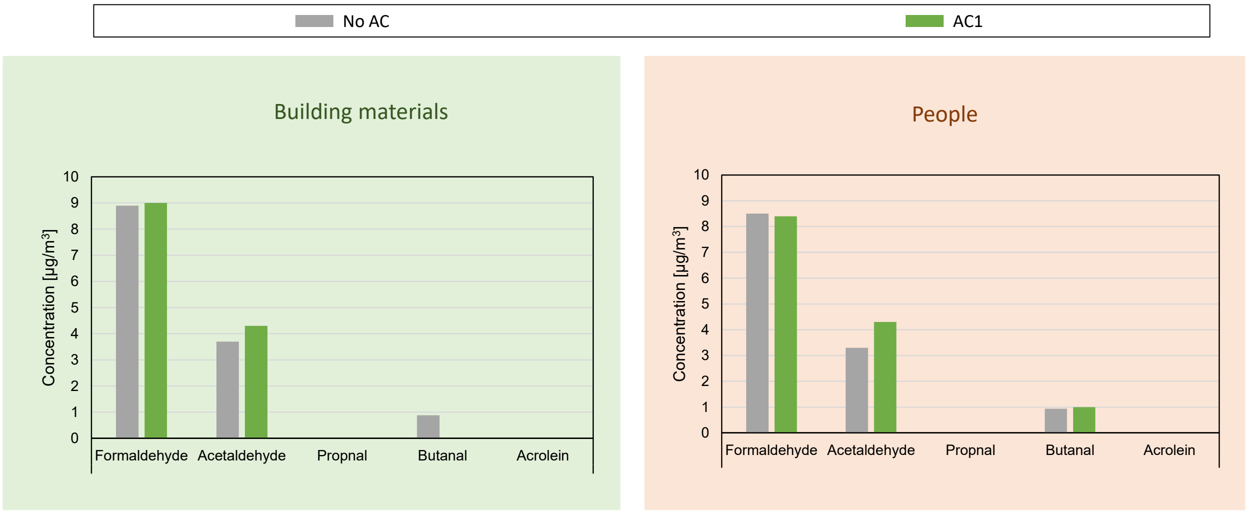


14

Results : AC1

Chemical compounds - Aldehydes

Ventilation rate: 7.5 L/s

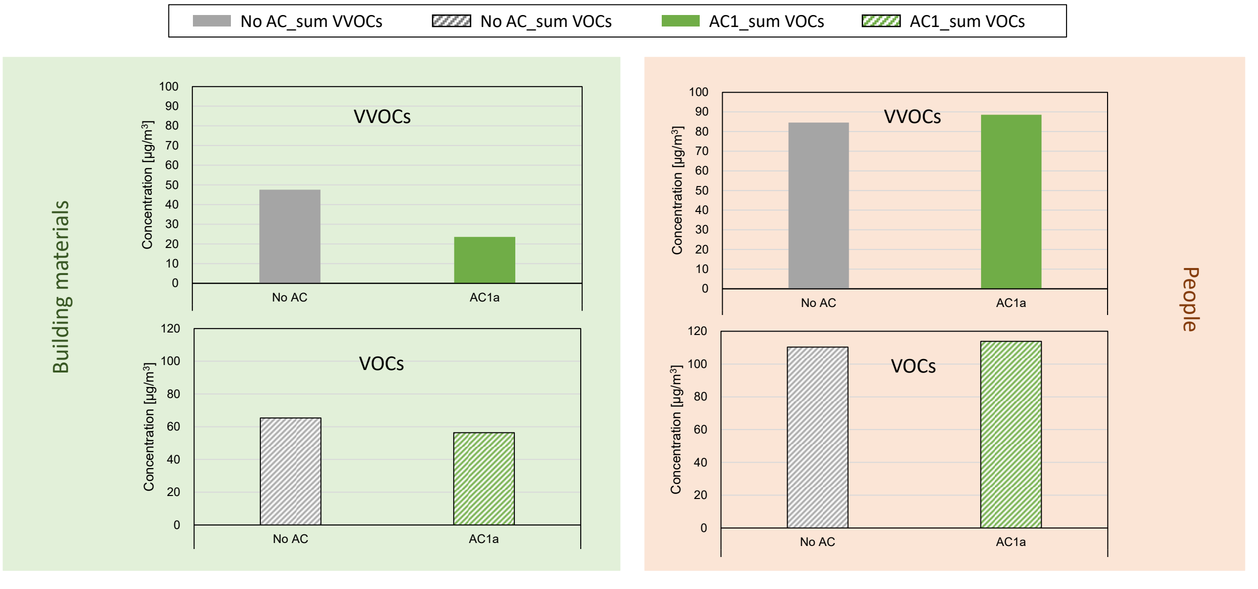


15

Results : AC1

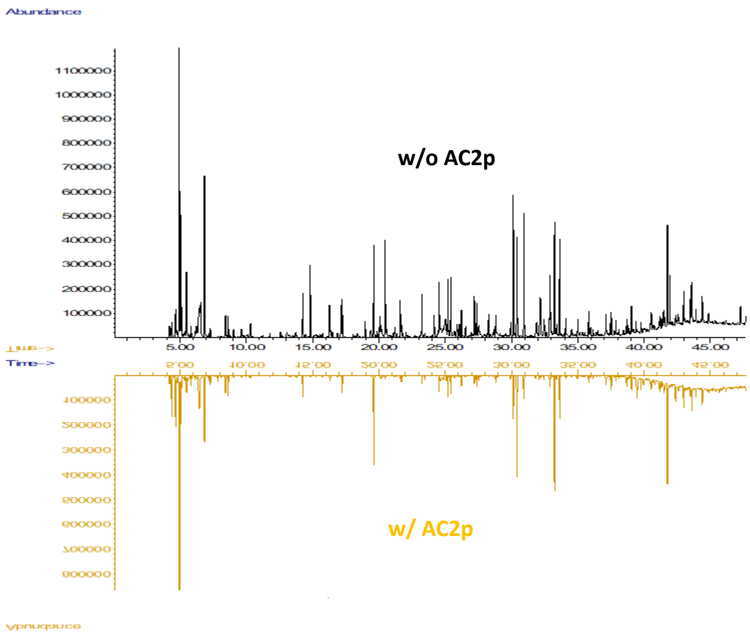
Chemical compounds – VVOCs, VOCs – total sum

Ventilation rate: 7.5 L/s



16

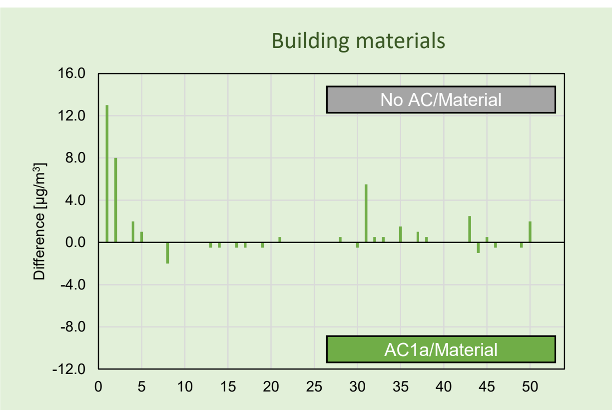
Gas chromatograms

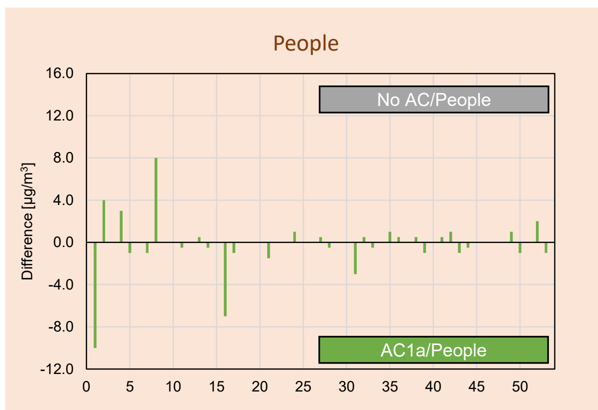


Results : AC1

Chemical compounds – each chemicals

Ventilation rate: 7.5 L/s





1	Ethanol	11	n-Butanol	21	n-Hexanal	31	Glycerol	41	Acetophenone	51	Nonanoic acid
2	Acetone	12	2-Pentanone	22	n-Butyl acetate	32	Hexanoic acid	42	C11 (Undecane)	52	Dodecamethylcyclohexasiloxane (D6)
3	n-Pentane	13	Propanoic acid	23	Hexamethylcyclotrisiloxane (D3)	33	Phenol	43	n-Nonanal	53	Texanol
4	Isoprene	14	Pentanal	24	m,p-Xylene (m-Xylene)	34	Octamethylcyclotetrasiloxane (D4)	44	Decamethylcyclopentasiloxane (D5)	54	1-Dodecanol
5	3-Butene-2-one	15	C7 (Heptane)	25	iso-Pentyl acetate	35	6-Methyl-5-heptene-2-one	45	Benzoic acid		
6	2,3-Butanedione	16	1,2-Propanediol	26	Pentanoic acid	36	2,2,4,6,6-Pentamethylheptane	46	Octanoic acid		
7	2-Butanone (MEK)	17	Toluene	27	C9 (Nonane)	37	Octanal	47	Menthone		
8	Acetic acid	18	i-Butylacetate	28	n-Heptanal	38	DPGMME (mixture of isomers)	48	Menthol		
9	Ethyl acetate	19	Butanoic acid	29	alpha-Pinene	39	2-Ethyl-1-hexanol	49	Butyldiglycol		
10	Benzene	20	C8 (Octane)	30	Benzaldehyde	40	Limonene	50	n-Decanal		

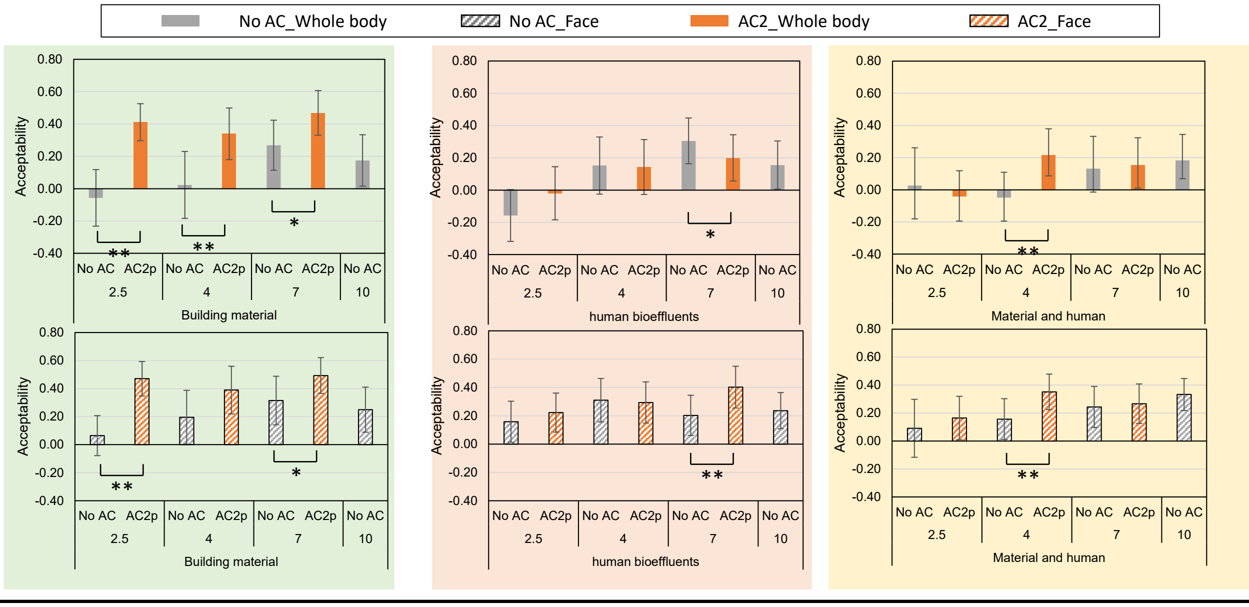
Results of AC2

■ Results : AC2

Bar means range of 95% Confidence Interval

Wilcoxons signed rank test(**p<.01, *p<.05)

Acceptability

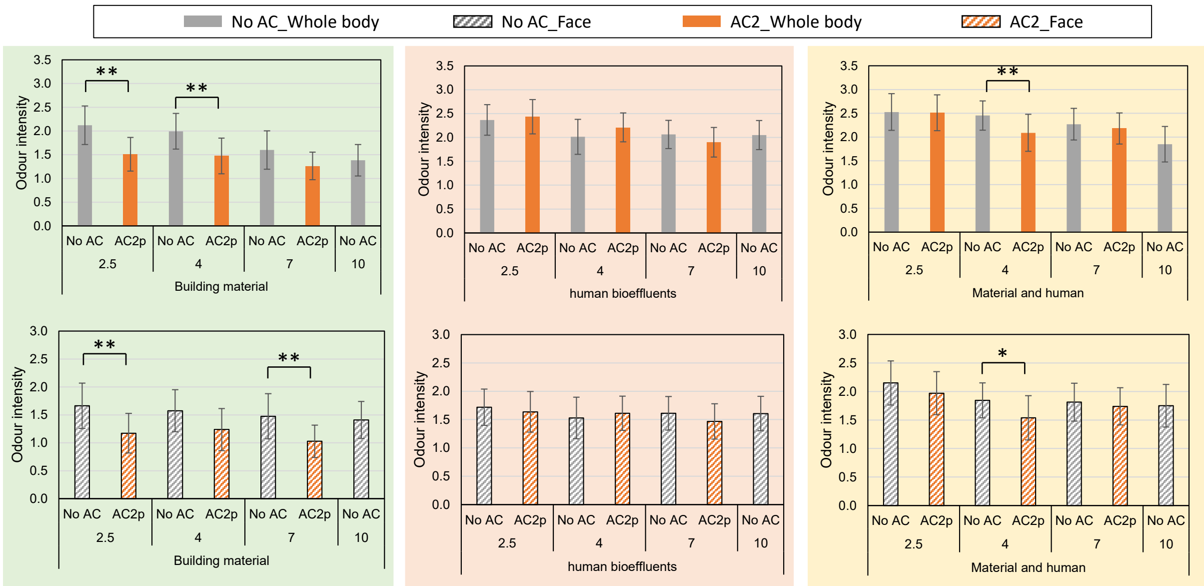


■ Results : AC2

Bar means range of 95% Confidence Interval

Wilcoxons signed rank test(**p<.01, *p<.05)

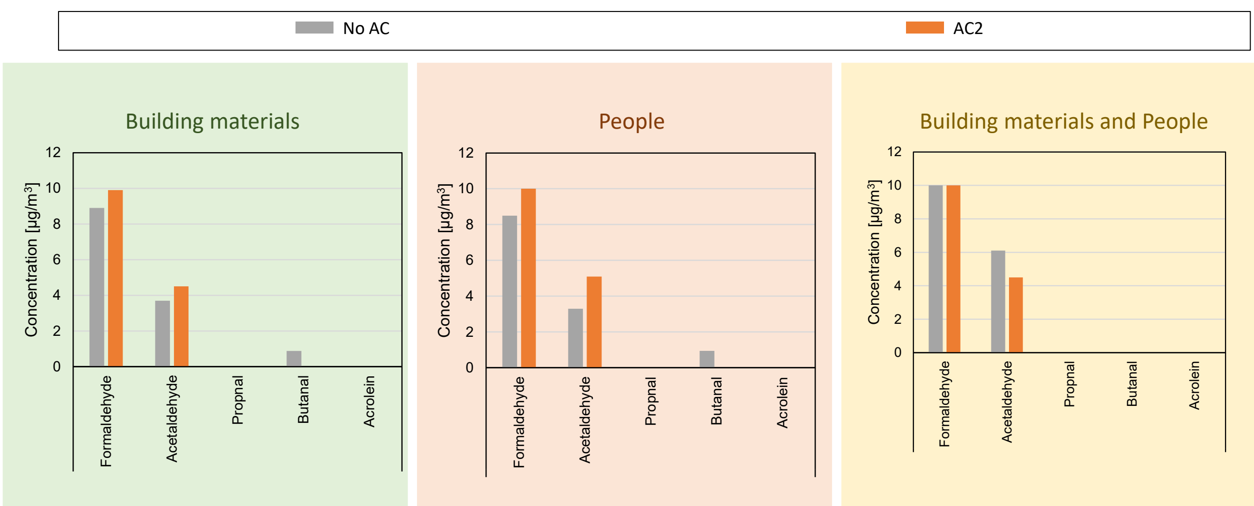
Odour intensity



■ Results : AC2

Chemical compounds - Aldehydes

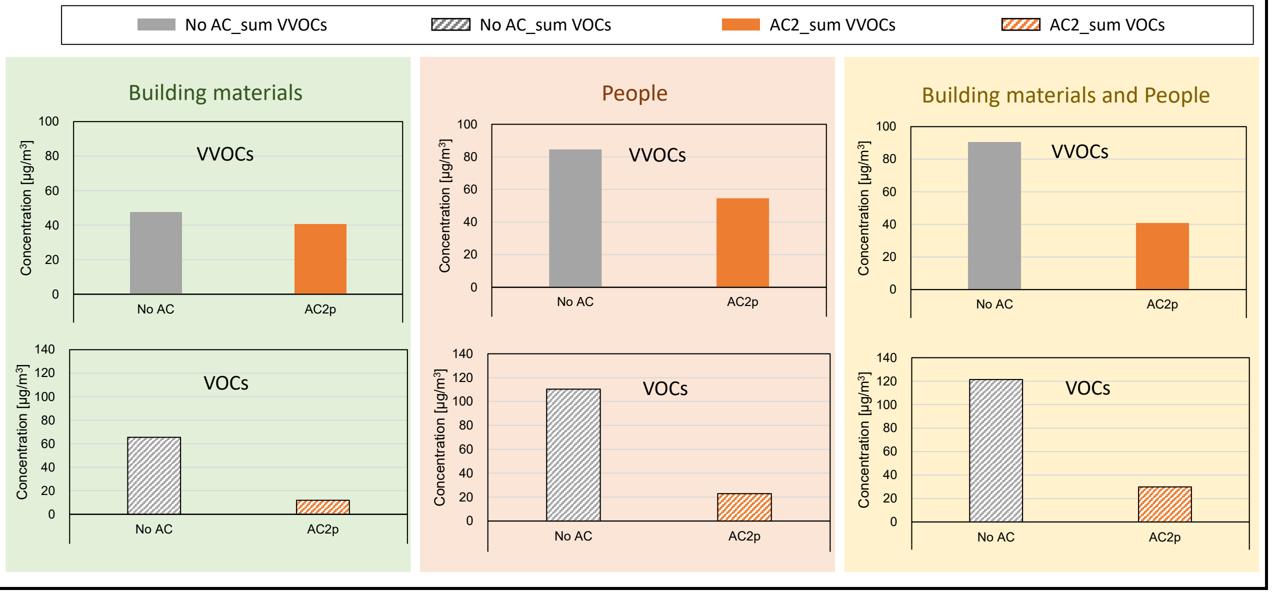
(Ventilation rate: 7.5 L/s)



■ Results : AC

Chemical compounds – VVOCs, VOCs – total sum

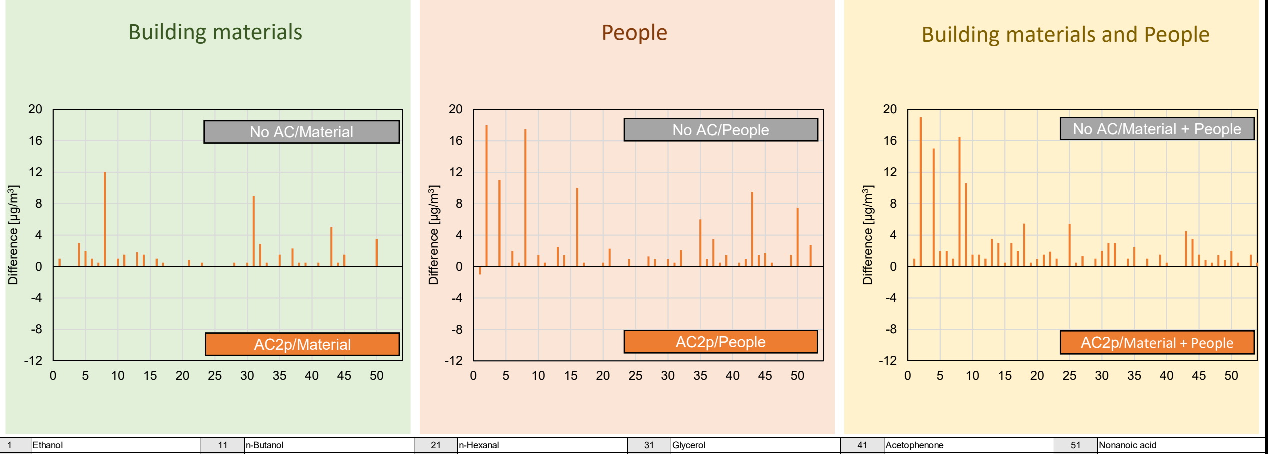
(Ventilation rate: 7.5 L/s)



■ Results : AC2

Chemical compounds – each chemicals

Ventilation rate: 7.5 L/s



1	Ethanol	11	n-Butanol	21	n-Hexanal	31	Glycerol	41	Acetophenone	51	Nonanoic acid
2	Acetone	12	2-Pentanone	22	n-Butyl acetate	32	Hexanoic acid	42	C11 (Undecane)	52	Dodecamethylcyclohexasiloxane (D6)
3	n-Pentane	13	Propanoic acid	23	Hexamethylcyclotrisiloxane (D3)	33	Phenol	43	n-Nonanal	53	Texanol
4	Isoprene	14	Pentanal	24	m,p-Xylene (m-Xylene)	34	Octamethylcyclotetrasiloxane (D4)	44	Decamethylcyclopentasiloxane (D5)	54	1-Dodecanol
5	3-Butene-2-one	15	C7 (Heptane)	25	iso-Pentyl acetate	35	6-Methyl-5-heptene-2-one	45	Benzoic acid		
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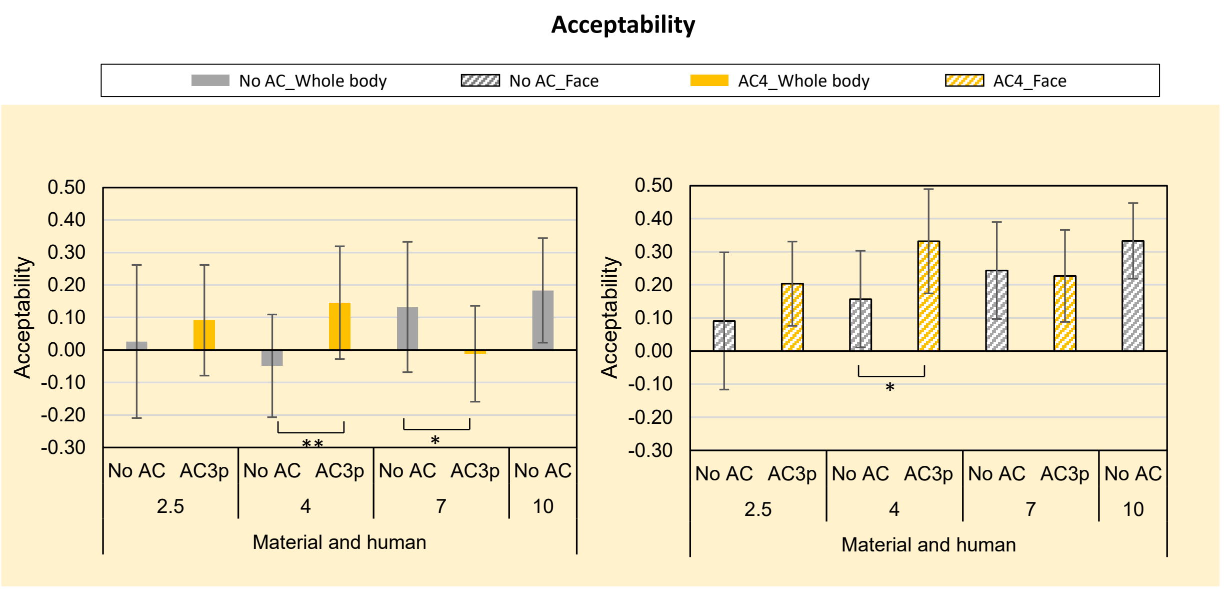
9	Ethyl acetate	19	Butanoic acid	29	alpha-Pinene	39	2-Ethyl-1-hexanol	49	Butyldiglycol		
10	Benzene	20	C8 (Octane)	30	Benzaldehyde	40	Limonene	50	n-Decanal		

Results of AC4

25

■ Results : AC4 Bar means range of 95% Confidence Interval Wilcoxons signed rank test(**p<.01, *p<.05)



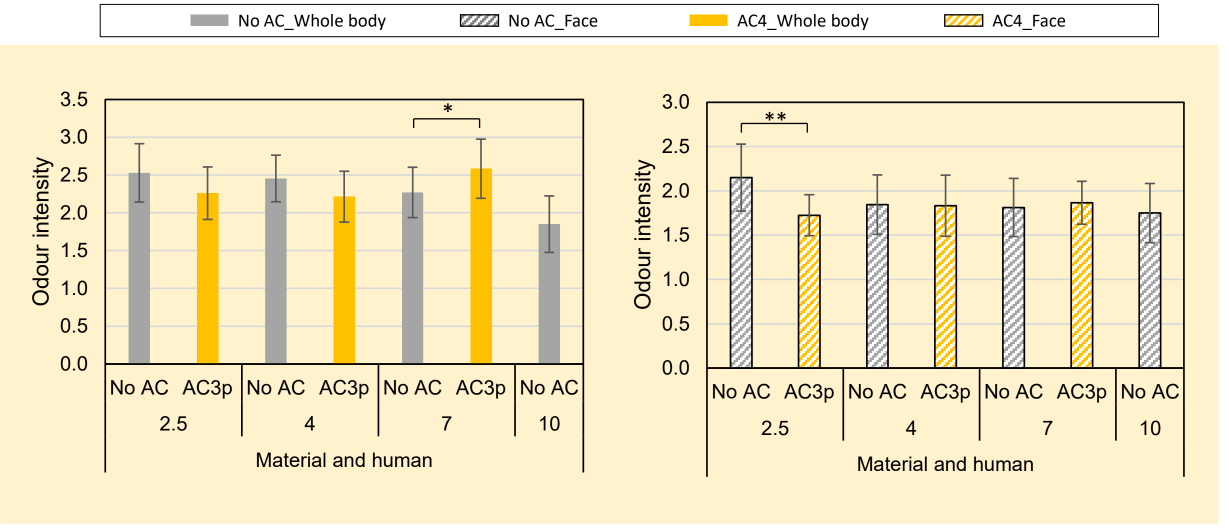
26

■ Results : AC4

Bar means range of 95% Confidence Interval

Wilcoxons signed rank test(**p<.01, *p<.05)

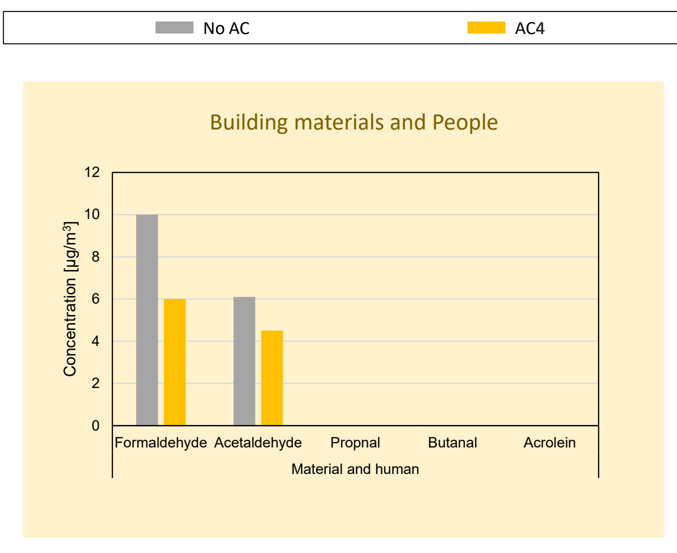
Odour intensity



■ Results : AC4

Chemical compounds - Aldehydes

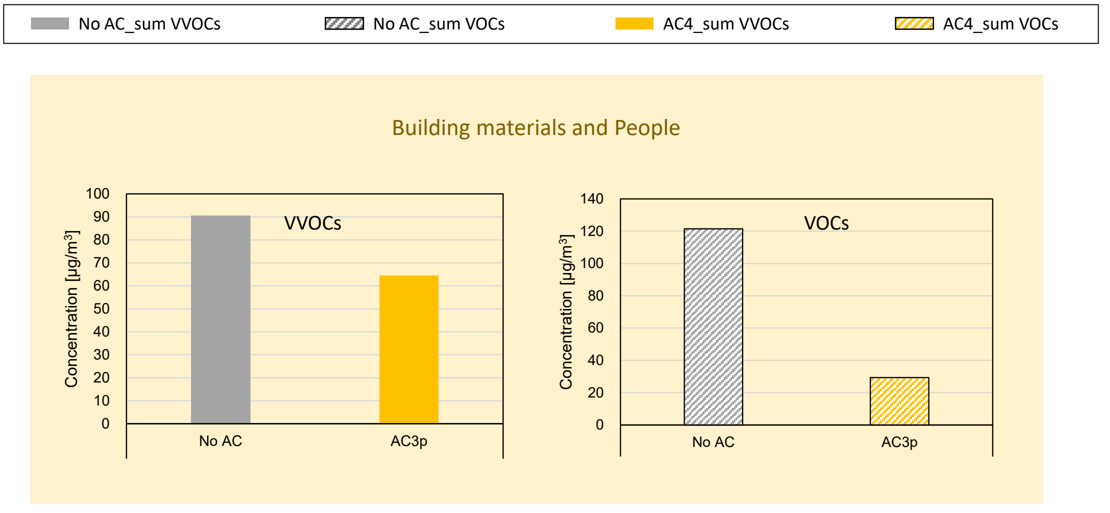
Ventilation rate: 7.5 L/s



Results : AC4

Chemical compounds – VVOCs, VOCs – total sum

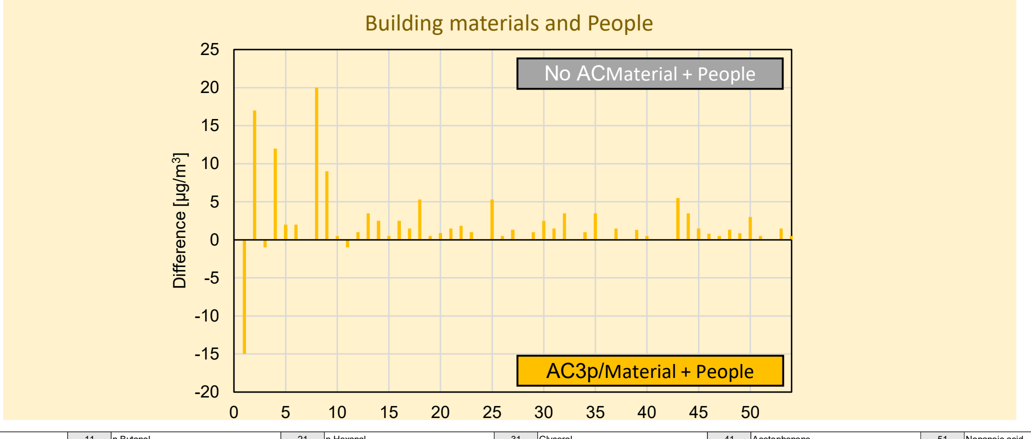
Ventilation rate: 7.5 L/s



Results : AC4

Chemical compounds – each chemicals

Ventilation rate: 7.5 L/s



1	Ethanol	11	n-Butanol	21	n-Hexanal	31	Glycerol	41	Acetophenone	51	Nonanoic acid
2	Acetone	12	2-Pentanone	22	n-Butyl acetate	32	Hexanoic acid	42	C11 (Undecane)	52	Dodecamethylcyclohexasiloxane (D6)
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5	3-Butene-2-one	15	C7 (Heptane)	25	iso-Pentyl acetate	35	6-Methyl-5-heptene-2-one	45	Benzoic acid		
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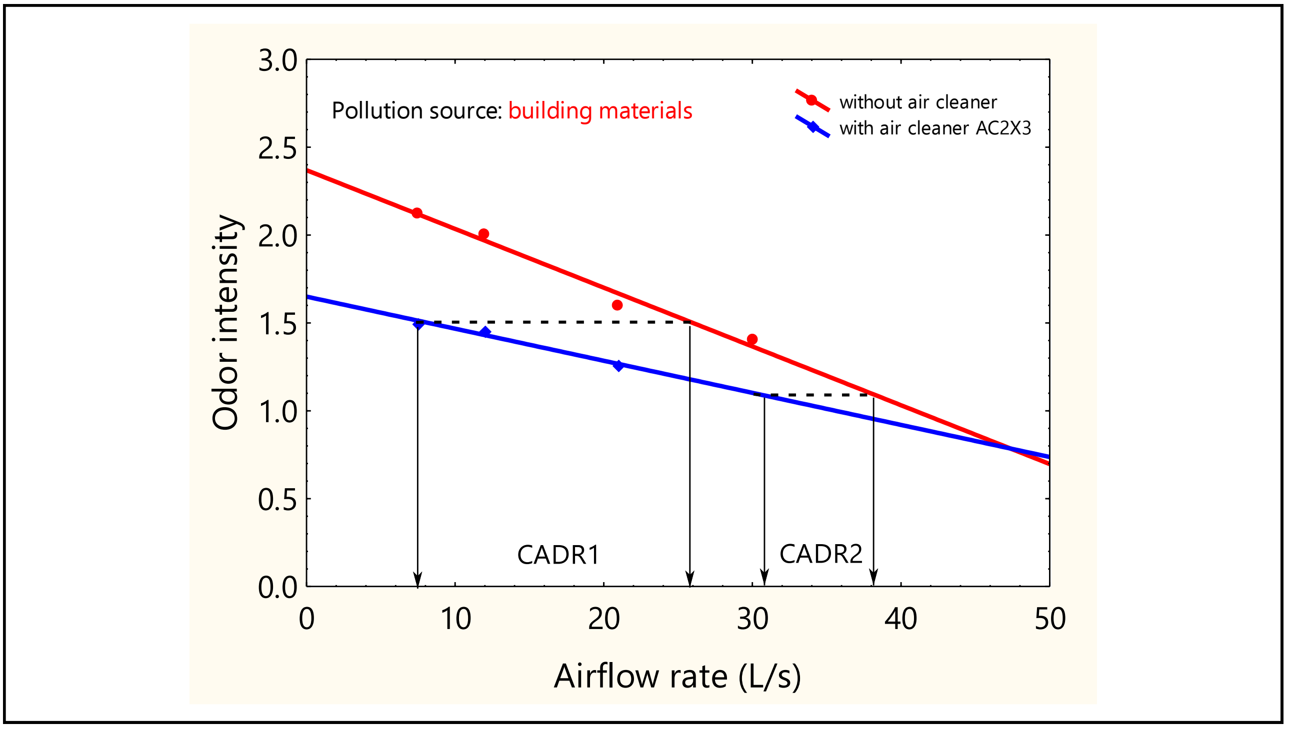
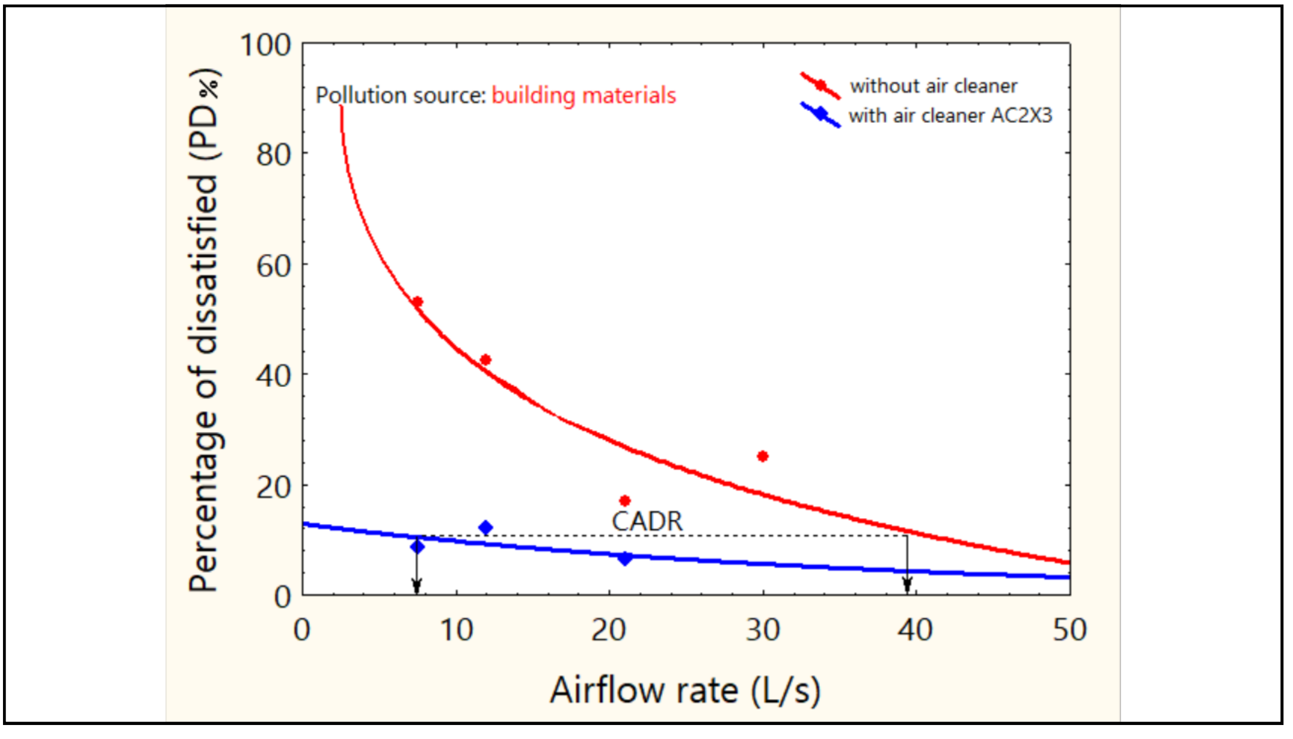
8	Acetic acid	18	i-Butylacetate	28	n-Heptanal	38	DPGMME (mixture of isomers)	48	Menthol		
9	Ethyl acetate	19	Butanoic acid	29	alpha-Pinene	39	2-Ethyl-1-hexanol	49	Butyldiglycol		
10	Benzene	20	C8 (Octane)	30	Benzaldehyde	40	Limonene	50	n-Decanal		



3.0
2.5
2.0
1.5
1.0
0.5
0.0
Odor intensity
Pollution source: building materials
without air cleaner
with air cleaner AC2X3
CADR1
CADR2
0
10
20
30
40
50
Airflow rate (L/s)

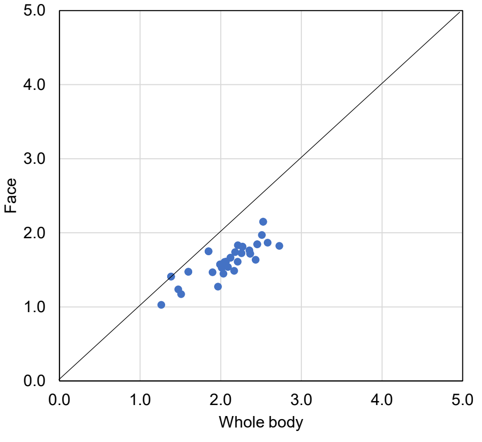
31



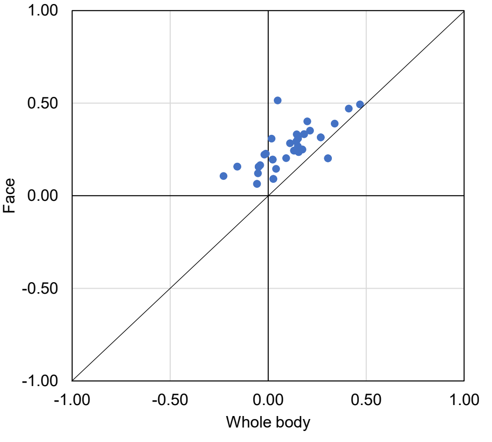
100
80
60
40
20
0
Percentage of dissatisfied (PD %)
Pollution source: building materials
without air cleaner
with air cleaner AC2X3
CADR
0
10
20
30
40
50
Airflow rate (L/s)

32

Whole body vs Face Assessments



Odour intensity



Acceptability

Conclusions

- Facial exposure assessed lower odor intensity and better air quality compared to the assessment made by whole-body full exposure
- The air cleaners with activated charcoal filters were effective on removing VOCs, reduce odor intensity and improve perceived air quality
- Human bioeffluents are difficult to be controlled as a constant source of air pollution for testing indoor air cleaners

IEA-EBC Annex 78: Substituting Ventilation by Gas Phase Air Cleaning. An industry webinar

Proposed plan for developing a new testing standard

Professor Bjarne W. Olesen Ph.D.

- International Centre for Indoor Environment and Energy, ICIEE
- Technical University of Denmark
    - bwo@byg.dtu.dk

1

ONGONIG STANDARDISATION

- ISO TC146/SC6/WG25
    - ISO DIS 16000-44:2022: Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners
- ISO TC142/WG8: Gas Phase Air Cleaning Devices and Media
    - ISO/PWI 23743 "Testing of gas phase air cleaners for improving perceived indoor air quality".

2

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

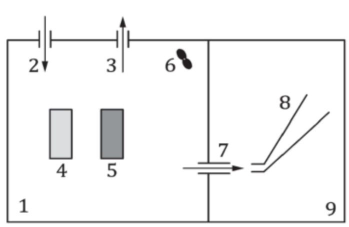
Test Panel
- Trained
- Untrained

Odour
- Acceptance
- Intensity
- Hedonic tone

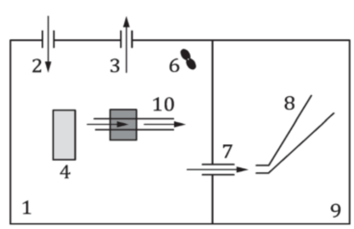
Examples of diffuser and mask used for odour evaluatio

Figure C.1 — Diffuser

ISO DIS 16000-44:2022: Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners



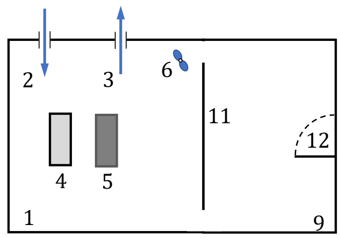
A test room for a stand alone air cleaner



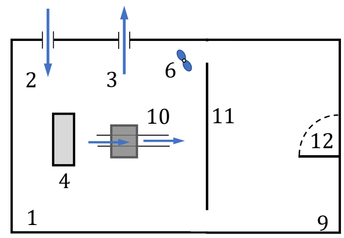
A test room for an in duct air cleaner

1 test chamber
2 clean air supply inlet
3 exhaust outlet
4 emission source
5 An air cleaner
6 mixing fan
7 tube or duct
8 sniffing device,
9 front/anterior space in which human panel enter
10 in duct air cleaner

ISO DIS 16000-44:2022: Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners



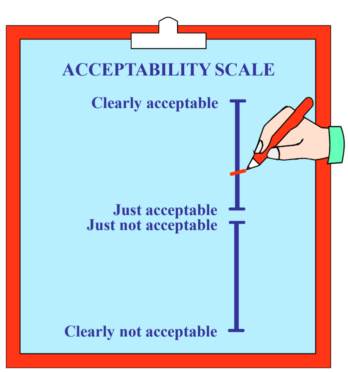
A test room for a stand alone air cleaner

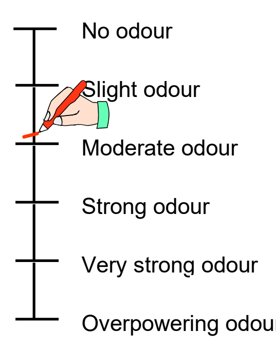


A test room for an in duct air cleaner

1 test chamber/room
2 clean air supply inlet
3 exhaust outlet
4 odour emission source
5 standalone air cleaners
6 mixing fan
7 tube or duct
8 sniffing device,
9 front/anterior space in which human panel enter
10 in duct air cleaner
11 partition
12 door for access

PERCEPTION SCALES





ISO/PWI 23743 “Testing of gas phase air cleaners for improving perceived indoor air quality”.

- An AdHoc/task force group under ISO TC142WG8 will based on the results from the testing at DTU start developing the concept for a standard.
- Activation of the PWI expected in September 2023
- The test method developped at DTU will be used at one or two other universities during 2023-24
- End report from Annex 78 on a test method to be available June, 2024

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	IEQI	370	278
		IEQII	**529**	**397**
		IEQIII	926	694
		IEQIV	**1389** (1010)	**1010** (794)
With air cleaner	10	IEQI	529	397
		IEQII	**756**	**567**
		IEQIII	**1323** (1029)	**992** (817)
		IEQIV	**1984** (1100)	**1443** (911)

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

Questions?
Please put your questions in the chat.

Bjarne W. Olesen
bwol@dtu.dk

DTU

ICIEE

AIVC

EBC
Energy in Buildings and Communities Programme