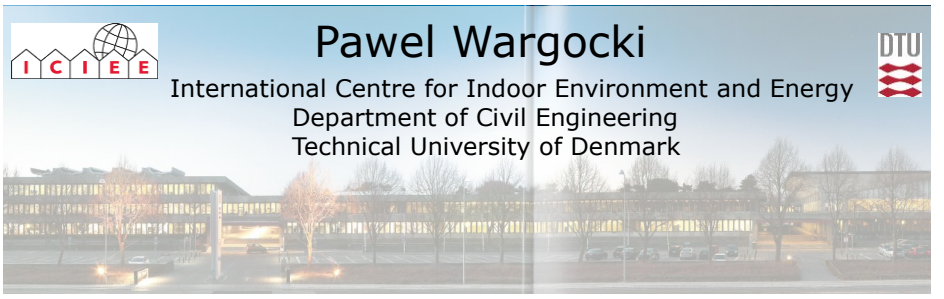
Why Can(‘t) Perceived Air Quality Indices Tell You About Indoor Air Quality?



Reflections on the history of indoor air science

- In the early years of indoor air science, odor was important, as well as interactions between odor and irritation. With PO Fanger’s keynote at the Berlin conference (1987), when he stated, rightly, that chemical analyses had not been able to find the causes of sick building syndrome, and that the human sense of odor was a better instrument, he introduced the olf as a unit to measure source strength, using the human nose as the measurement instrument. Sadly, that in a way, killed the earlier odor science (William Cain, and his group in San Diego, has continued in this field). With Fanger’s early death in 2006, the olf has also “died,” leaving us with almost no odor research.

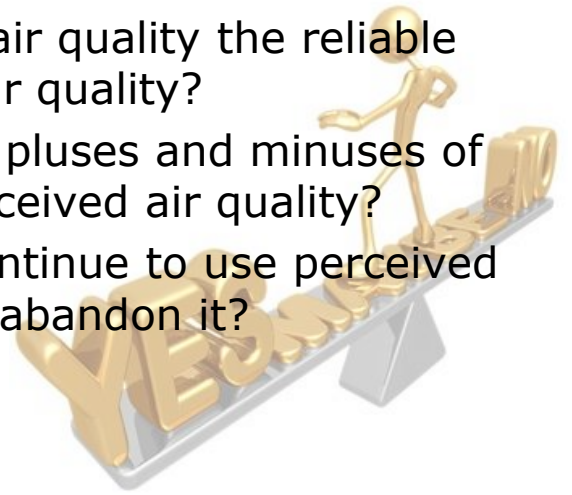
Source: Sundell (2017)

Introduction/background

- Perceived air quality is an important determinant of indoor air quality and has frequently and repeatedly been used in research and measurements dealing with the quality of air indoors
- Perceived air quality has been used to define ventilation rates prescribed in the majority of present standards (eg. EN15251 (16798-2), 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

Objectives

- Is perceived air quality the reliable measure of air quality?
- What are the pluses and minuses of using the perceived air quality?
- Should we continue to use perceived air quality or abandon it?

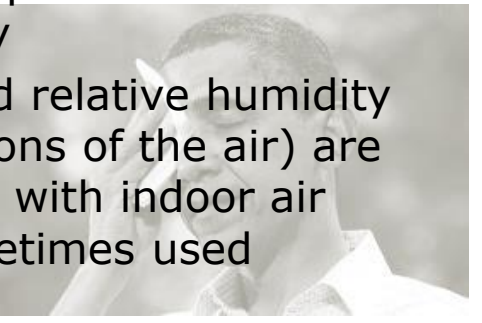


Indoor air quality definitions

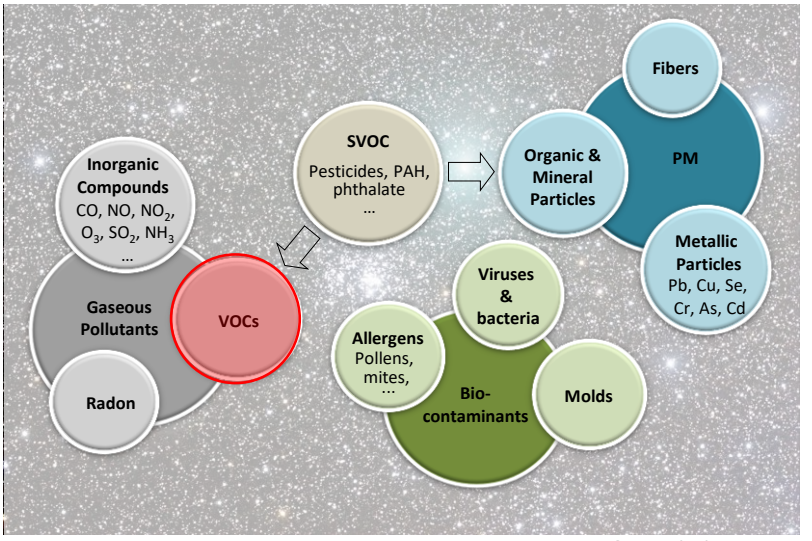
- EPA and Wikipedia: Indoor Air Quality (IAQ) refers to the air quality **within and around buildings and structures**, especially as it relates to the **health and comfort of building occupants**.
- WHO: The quality of air inside homes, offices, schools, day care centers, public buildings, health care facilities or other private and public buildings where people spend a large part of their life is an essential determinant of **healthy life and people's well-being**.
- OECD: Indoor air pollution refers to **chemical, biological and physical contamination** of indoor air. It may result in **adverse health effects**.
- Glossary (ISIAQ): Air quality: 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.

Collorary 1: Temperature and Relative Humidity

- Neither definition of indoor air quality includes the temperature and relative humidity
- Temperature and relative humidity (thermal conditions of the air) are often associated with indoor air quality and sometimes used exchangeably



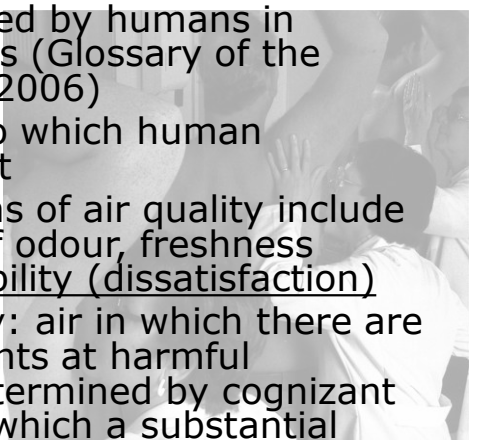
Collorary 2: The Universe of Indoor Air Pollutants



Courtesy of Marc Abadie, IEQ ANNEX 68

Definition of Perceived Air Quality

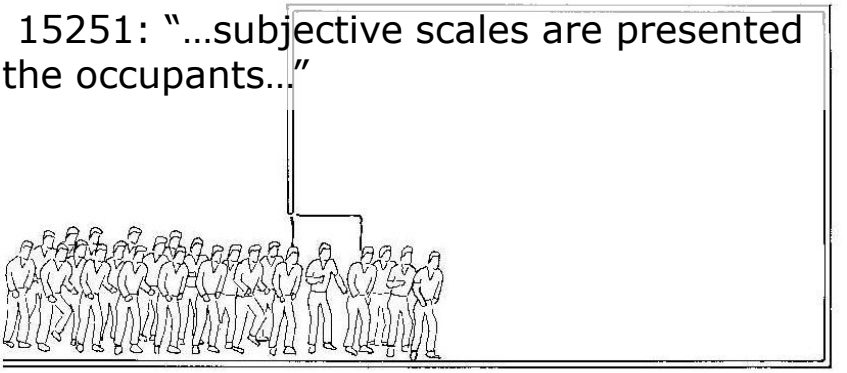
- The air quality as rated by humans in subjective evaluations (Glossary of the Indoor Air Sciences, 2006)
- Quality: the extent to which human requirements are met
- Subjective evaluations of air quality include ratings of intensity of odour, freshness (stuffiness), acceptability (dissatisfaction)
- 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 (80%) exposed do not express dissatisfaction (ASHRAE 62.1)



Measurements of Perceived Air Quality: Untrained subjects

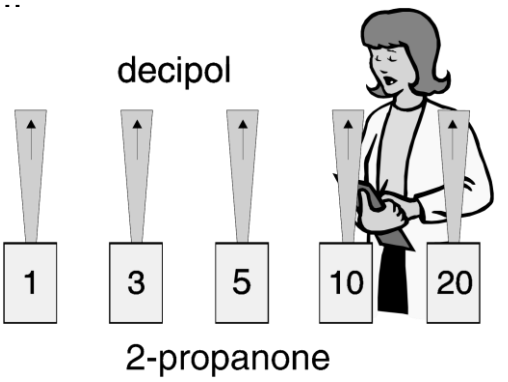
ASHRAE 62.1: "… a group of untrained subjects (…) who render a judgement of acceptability…"

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



Measurements of Perceived Air Quality: Trained subjects

"… a panel of 10-15 subjects trained to assess the perceived air quality directly in decipol…"



Advantages of using PAQ

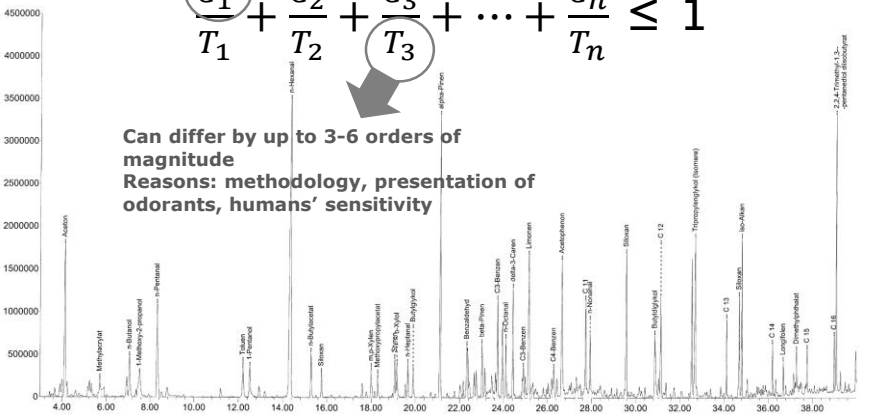
- Integration of exposure and response into one metric
- Capturing the result of interaction and combined effects between different pollutants
- Sensitive, at least as much as chemical analyses
- Cannot be replaced by sesor array (”electronic nose”)
- Providing instant information about air quality as it is perceived by humans at group level (average) and at individual level (preference)
- First indicator (warning) of a potential problem
- Very intuitive and communicative

Combined exposure and response

Depends on analytical precision

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

Can differ by up to 3-6 orders of magnitude
Reasons: methodology, presentation of odorants, humans’ sensitivity



Source: Devos et al. (1990)

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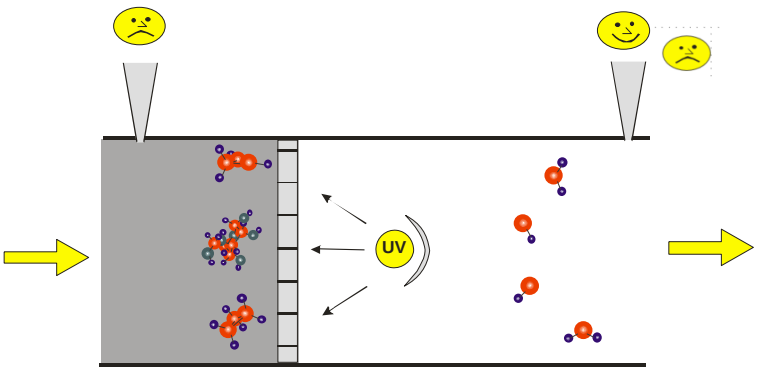
Detection of unwanted pollutants



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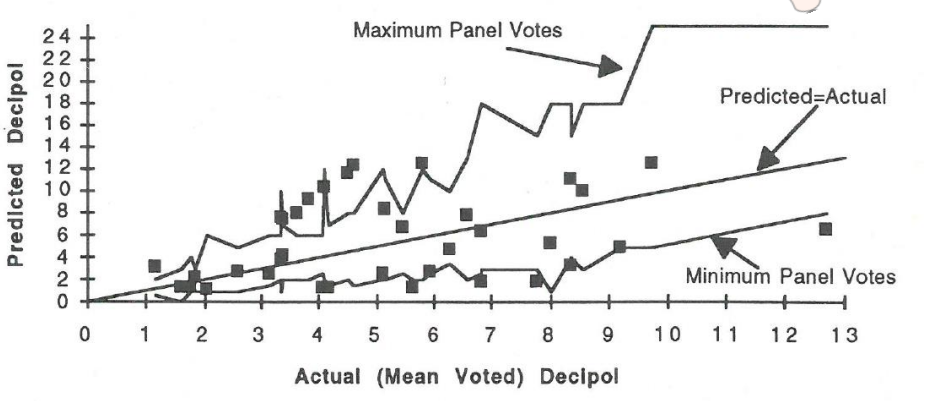
One of the first “electronic nose” for PAQ



Source: Wegner et al. (1993)

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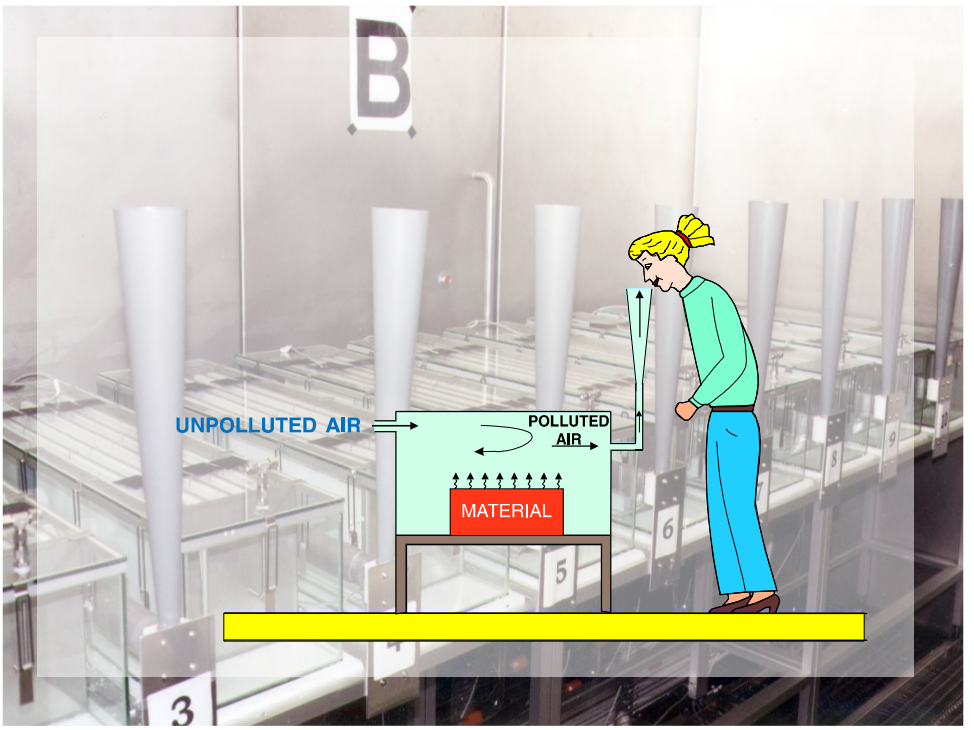

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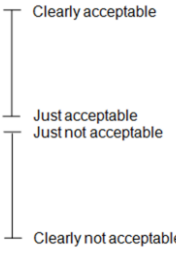
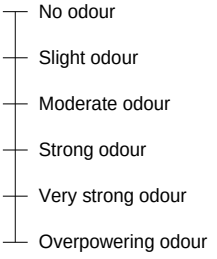
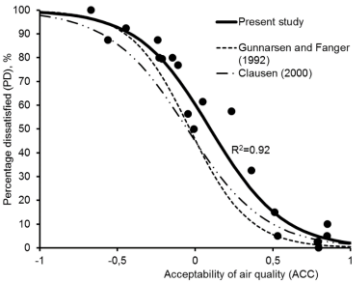
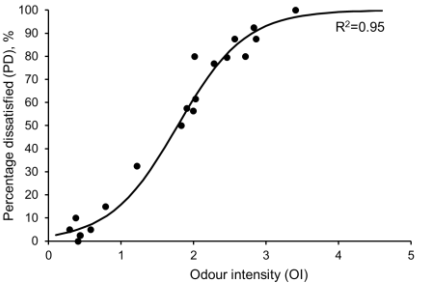








Disadvantages of using PAQ

- Difficult to measure – human subjects not repleacable by instruments; arguable reliability and repeatability
- Disturbed by other environmental factors – temperature and relative humidity
- Disturbed by sensory fatigue
- Unable to identify (detect) pollutants that do not produce sensory response (eg. Radon, CO)
- Address mainly exposures to chemical compounds neglecting other pollutants such as those having microbiological origin and particulate matter
- Address one modality that may not create protection against other impacts (not a solution to a Sick Building Syndrome mystery)
- Not unique – different combination of pollutants can produce the same response (dissatisfaction)

Factors disturbing precision of subjective ratings of air quality

- Endpoints of sensory comfort
- Type of measuring scale
- Transformation curves
- Group size (panel) and variation
- Various sensitivity of subjects

Accuracy and panel size (1)

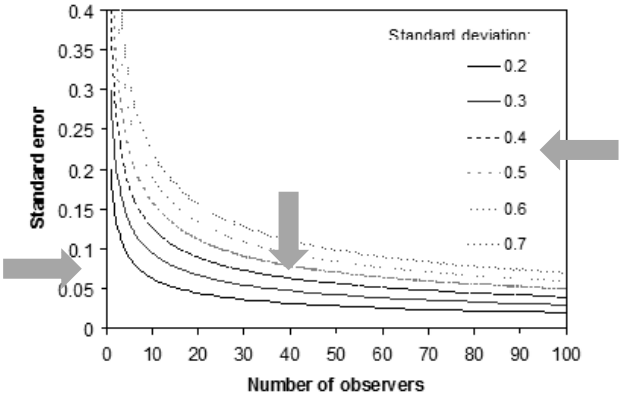
Acceptable ☐

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

Accuracy and panel size (2)



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

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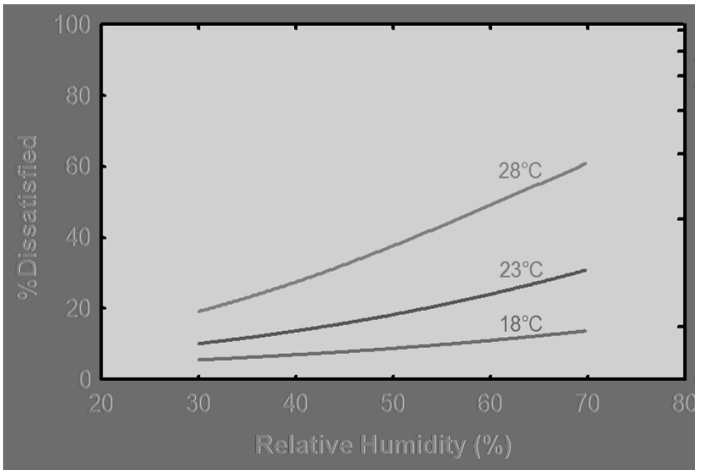
Effect of temperature and relative humidity



Source: Fang et al. (1998)

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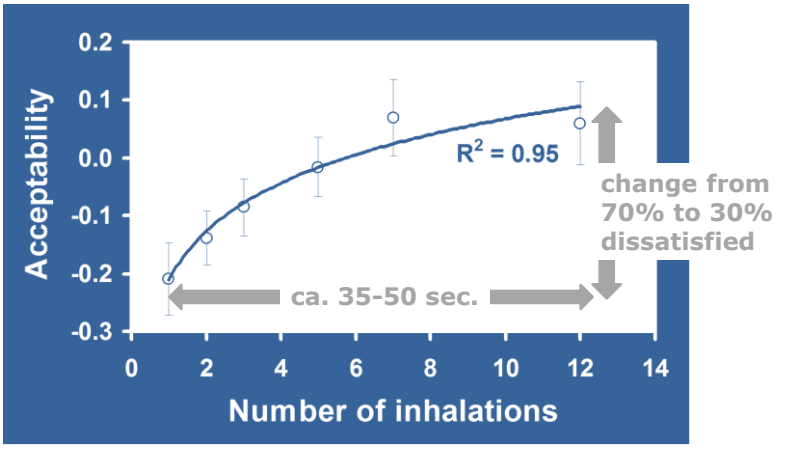
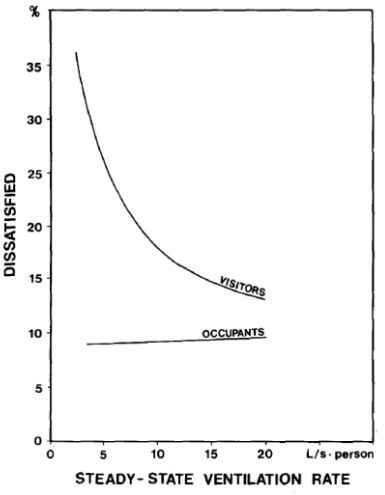
Length of exposure: adaptation



Sensory fatigue



Source: Berg-Munch et al. (1986)

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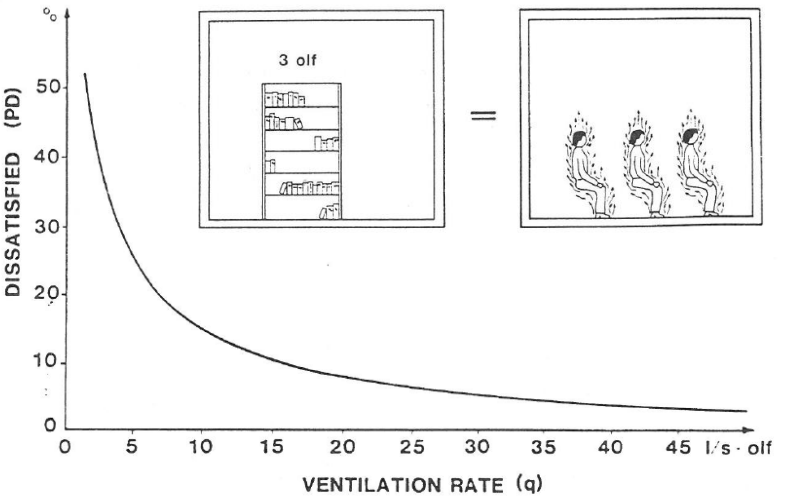
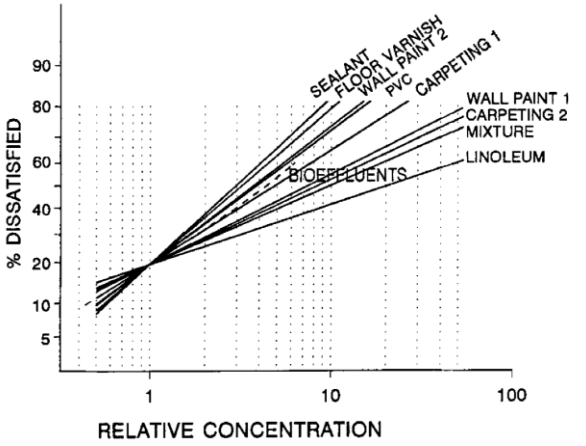
Olf and decipol approach



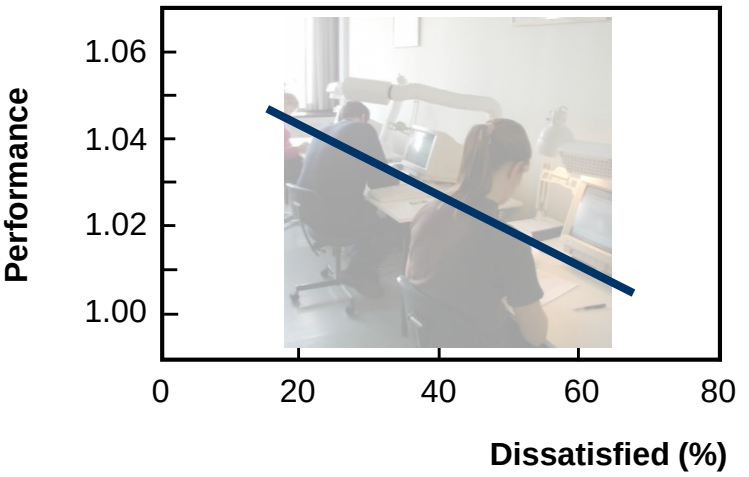
Source: Fanger (1998)

Dose-esponse relationships are different



Source: Knudsen et al. (1997)

PAQ and performance of (simulated) office work



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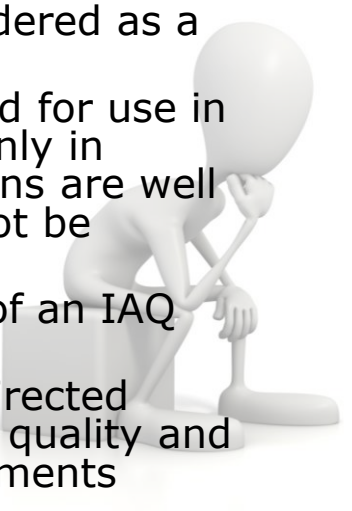
Can(‘t) PAQ tell about IAQ?

- ☑ PAQ can detect gaseous pollutants otherwise not identified by chemical analyses
- ☑ PAQ can tell about preferences

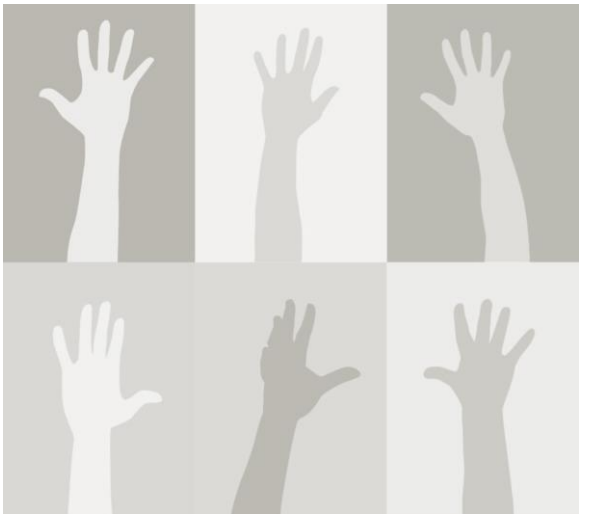
- ☒ PAQ does not provide information about pollutants not detectable by olfactory sense
- ☒ PAQ may not always provide protection against other negative effects resulting from exposures to poor indoor air quality
- ☒ PAQ is disturbed by thermal conditions and adaptation (and also by few other factors)

What next?

- PAQ should not be considered as a universal IAQ metric
- PAQ should be considered for use in certain applications, mainly in laboratory when conditions are well controlled, and should not be completely abandoned
- PAQ can be an element of an IAQ metric
- Future efforts must be directed towards improvement of quality and repeatability of measurements



Thank you
Questions and comments

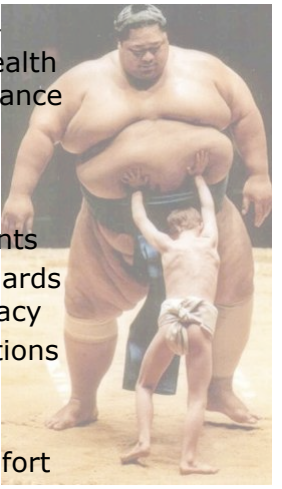


Please contact paw@byg.dtu.dk for additional comments and questions

Considerations regarding IAQ metric

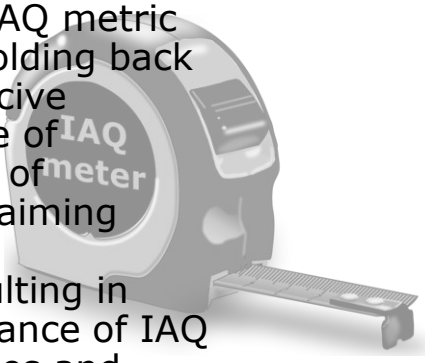
Major challenges relative to PAQ and IAQ metric

- Incomplete data on the exposures to low-levels of pollutants and their effects on health (acute and chronic), comfort and performance
- Lack of understanding on interactions between pollutants and consequences on humans
- Lack of reference values for many pollutants
- Measurement challenges especially as regards the repeatability, comparability and accuracy
- Time variance of exposure and concentrations
- Huge variation in human susceptibility/sensitivity
- IAQ is not a main attribute of human comfort



Is it necessary?

- Lack of IAQ metric or disagreement what should constitute IAQ metric is a significant barrier holding back innovation of IAQ conducive technologies, emergence of undocumented methods of measurements of IAQ claiming their high efficiency and authenticity, this all resulting in undervaluing the importance of IAQ in different credit schemes and compliance metrics related to built environment



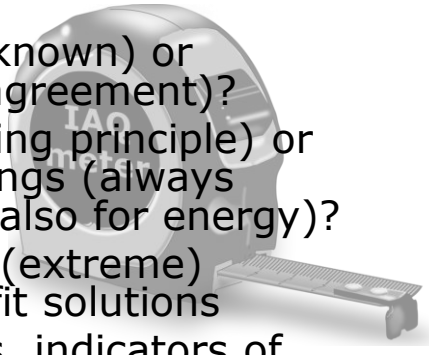
Source: Steinemann et al. (2016), in the Press

What is the premise?

- Basic human requirements: Indoor air should not compromise the basic human requirements, which include high quality of life, good health and optimal physical and mental activity
- Full spectrum of pollutants
- Use single or multiple criteria/indices

What is the purpose?

- Which human response should be addressed? (health?)
- Voluntary (uptake unknown) or mandatory (political agreement)?
- Used for design (guiding principle) or for operation of buildings (always different from design also for energy)?
- Indicators of unusual (extreme) conditions, cost benefit solutions
- Markers of conditions, indicators of assets, stamps, footprints or labels



Minimum requirement: source reduction and elimination

- Sources are ubiquitous
- Sources dominate
- Sources are diverse
- Products purchased and used by people are diverse
- Minimum standardization is needed otherwise no progress will be achieved
- This applies both for commercial and residential building sector