An Epistemic Approach for IAQ Assessment of Air-conditioned Offices in Hong Kong

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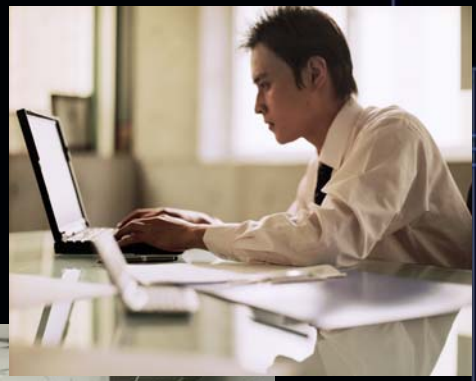
- People spend >70% time indoor
- Ensure safety and comfort of occupants in terms of IAQ



- How?

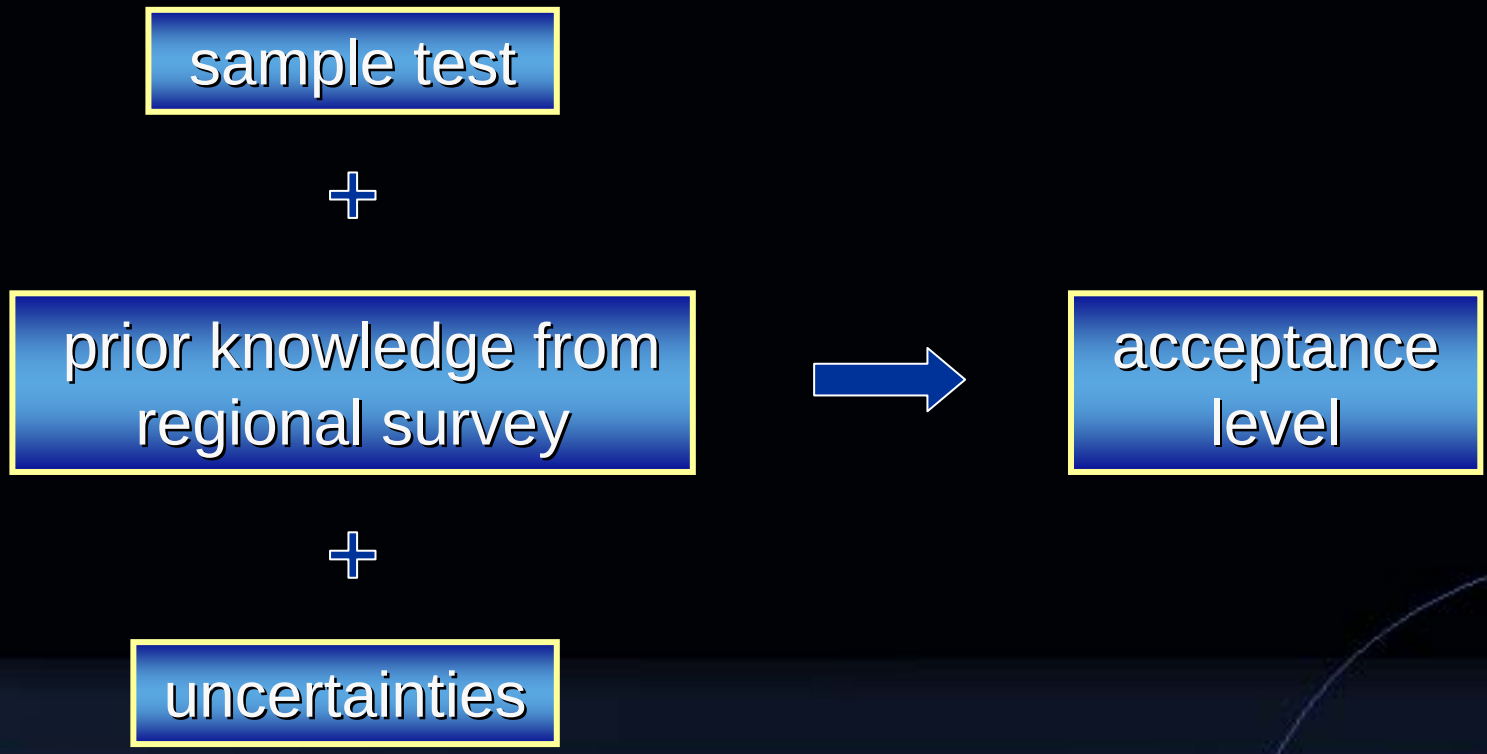
- Assessment of indoor air quality (IAQ)
  - →understanding the level of occupant exposure to various air pollutants
  - →formulating indoor environmental control strategies

- Test concentration $\Phi_\theta \leq$ set limit Φ^* → acceptable
- Test concentration $\Phi_\theta >$ set limit Φ^* → unacceptable

- Long-term and comprehensive measurement?
- ……cost, time

- → by some sampling scheme
- ……measurement errors?
  - To what level we should believe in the assessment
  - How to interpret test results for acceptance

Epistemic approach



Epistemic IAQ Assessment

space is unacceptable

Tested unacceptable given an 'unacceptable' environment

probability of having an 'unacceptable' environment $P(A \mid B) = \frac{P(A)P(B \mid A)}{P(B)}$

Tested unacceptable

Event A: Space is unacceptable

Event B: Tested unacceptable

Epistemic IAQ Assessment

("Prior" knowledge)
space is unacceptable

(Uncertainties of sampling scheme)
Tested unacceptable given an 'unacceptable' environment

probability of having an 'unacceptable' environment

$$P(A \mid B) = \frac{P(A)P(B \mid A)}{P(B)}$$

Tested unacceptable

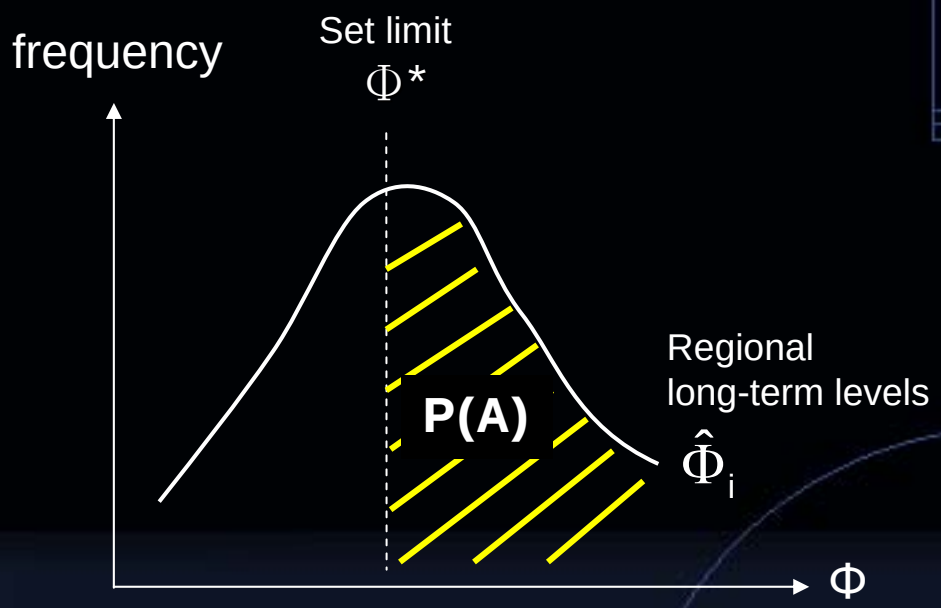
Event A: Space is unacceptable

Event B: Tested unacceptable

Prior knowledge of office IAQ

$$P(A) = 1 - \int_{-\infty}^{\Phi^*} \hat{\Phi}_i \, d\Phi_i$$

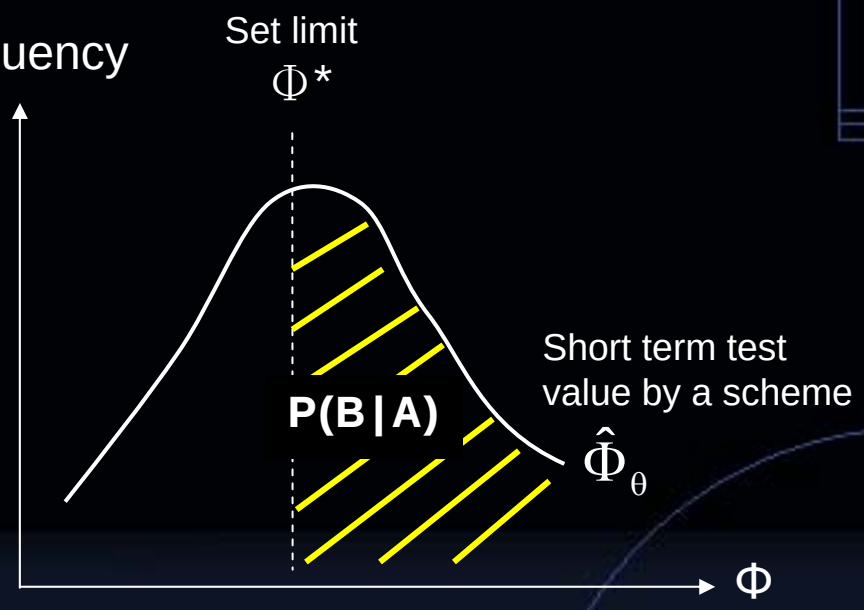
Regional levels of similar offices would be used to formulate “prior” knowledge of failure



Uncertainties of sampling schemes

$$P(B \mid A) = 1 - \int_{-\infty}^{\Phi^*} \hat{\Phi}_\theta \, d\Phi_\theta$$

Probable short term tested levels by a scheme



Example for demonstration

- CO_2
- relationships between indoor CO_2 concentration and IAQ:
- the health effects of elevated CO_2 concentrations,
- the impact on occupant perceptions of the environment,
- the relationship with other contaminants,
- outdoor air ventilation rate

Field measurements (1)

- Application of the epistemic approach to CO_2 level assessment
- A district survey was carried out in 330 offices
- Samples were randomly selected and covered all major commercial regions of office development in Hong Kong
- For determining the prior failure rates of workplace IAQ in this region
- CO_2 levels were measured in the occupied zones during office hours

Results

- geometric mean μ_N = 639 ppm
- set limit Φ^* from HKEPD

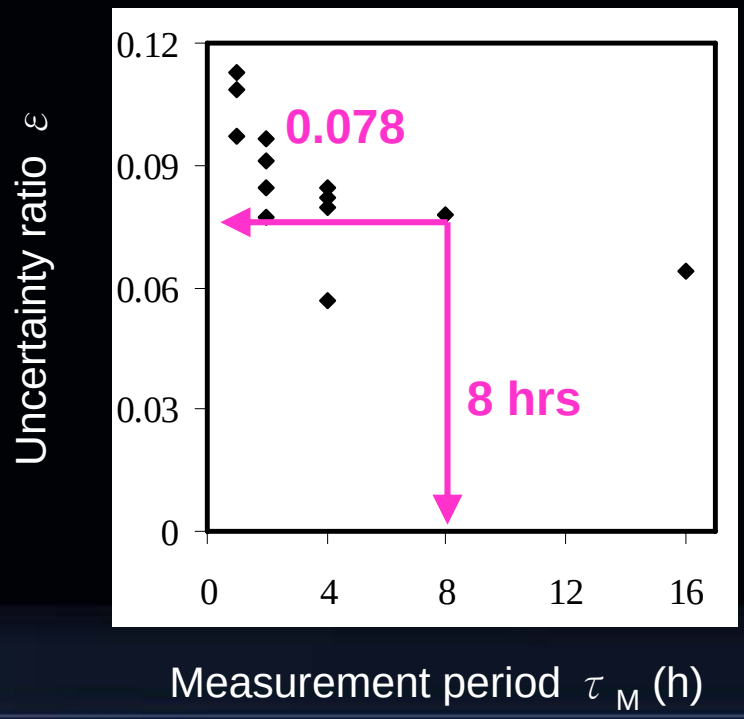
  <800 ppm → Excellent

  <1000 ppm → Good
- only a small number of offices exceeded the two criterion limits set for offices in Hong Kong,
  - $P(A)_{\Omega}^{\Phi^*=800}$ = 1 – 0.83 = 0.17 (CI_{95} = 0.13-0.20)
  - $P(A)_{\Omega}^{\Phi^*=1000}$ = 1 – 0.97 = 0.03 (CI_{95} = 0.01-0.04).

Field measurements (2)

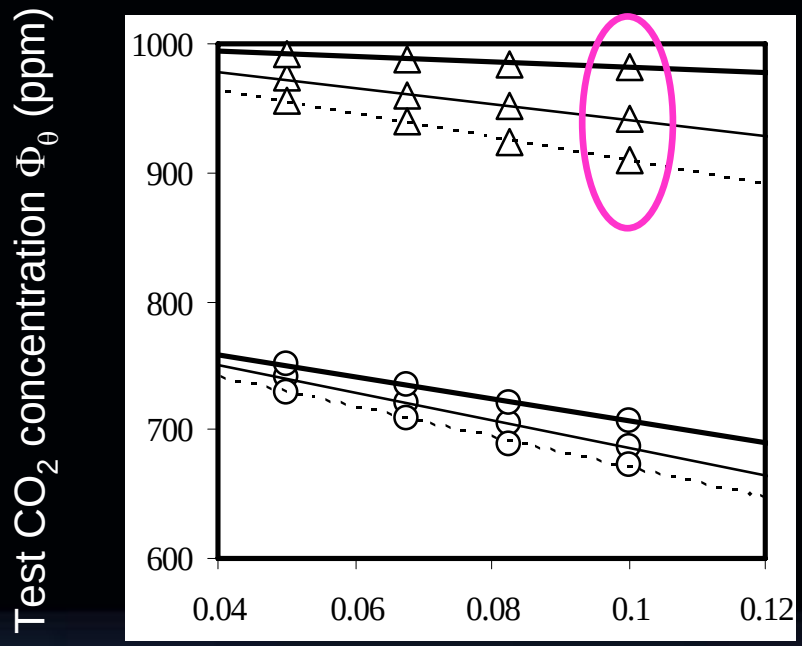
- To quantify the probable errors associated with some sampling schemes, a one-year CO_2 measurement was also conducted in an in-use office building
- open-plan offices
- an independent air handling unit (AHU) for each office floor
- supply 20% fresh air and 80% re-circulated air mix.
- CO_2 concentrations were measured at a number of comparable spatial locations on one open-plan office floor
- in the occupied period on all working days for one year

Uncertainties of some sampling schemes over a measurement period

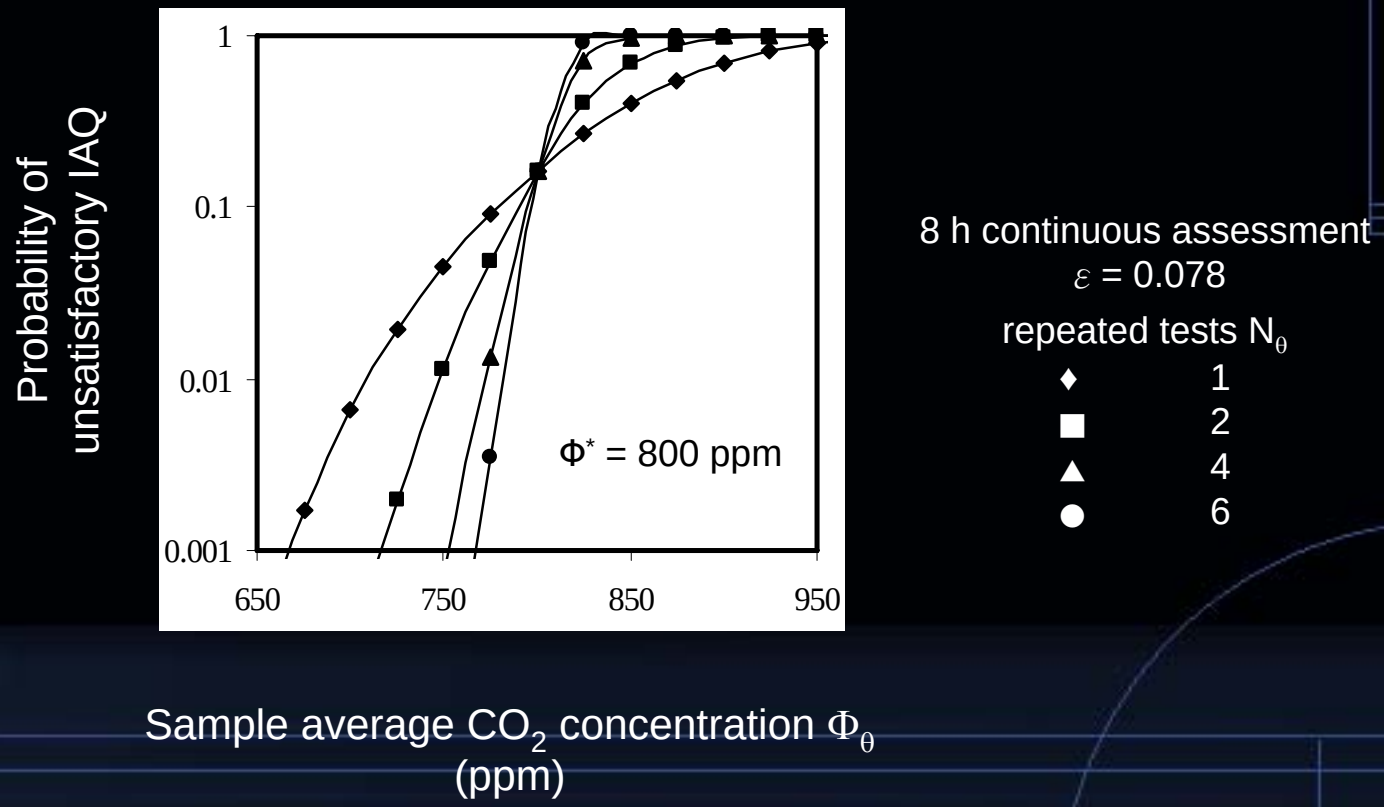


$\varepsilon = \sigma_\theta / \mu_\theta$

Maximum test values Φ_θ for satisfactory IAQ at indoor CO_2 level Φ^*



Probability of unsatisfactory IAQ against test CO_2 concentration Φ_θ for an office in Hong Kong



Conclusion

- Long-term measurement could be the best channel to identify indoor air pollution mitigation needs, but it usually requires considerable measurement efforts to attain accurate results.
- Preliminary IAQ assessment for offices in Hong Kong was thus proposed.
- To avoid overreliance on the assessment results, measurement uncertainty must be considered as well.
- This study proposed that regional survey results of IAQ could be treated as a prior understanding in an epistemic approach to assessing the acceptance of an indoor environment in the region.

Conclusion

- CO_2, a common pollutant found in air-conditioned offices, was used as an example to demonstrate the application of the epistemic IAQ assessment method.
- The prior failure rates of offices were determined from a large scale regional survey of 330 air-conditioned offices in Hong Kong.
- Taking the sampling uncertainty into account, the acceptance of office IAQ was evaluated based on a test CO_2 level against an action CO_2 level.
- With an ‘agreed’ range of acceptable assessment uncertainties, different parties involved in IAQ monitoring can make better decisions to devise the appropriate and cost-effective sampling strategies for IAQ control and improvement.

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