WHAT WE KNOW AND WHAT WE SHOULD KNOW ABOUT VENTILATION

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SOME FREQUENT QUESTIONS REGARDING VENTILATION

- How much ventilation is needed indoors?
- Which modality is affected by ventilation?
- Which modality should be used to set ventilation requirements?
- Can we reduce ventilation in buildings?
- What is an absolute minimum rate?
- Can we use epidemiological data for setting ventilation?
- Can ventilation be used as an IAQ metric?
- Is natural ventilation better than mechanical one?

COMMON BELIEFS REGARDING VENTILATION

- More ventilation always improves indoor air quality
- Lack of ventilation or low ventilation rates means poor air quality
- It is simple to measure ventilation
- Ventilation can be used to predict human responses (performance-based metric)
- Mechanical systems work better than passive (natural) systems

PERCEIVED AIR QUALITY AND VENTILATION

No. 1031

VENTILATION REQUIREMENTS

By C. P. YAGLOU,* E. C. RILEY ** (*MEMBERS*), AND D. I. COGGINS ** (*NON-MEMBER*), BOSTON, MASS.

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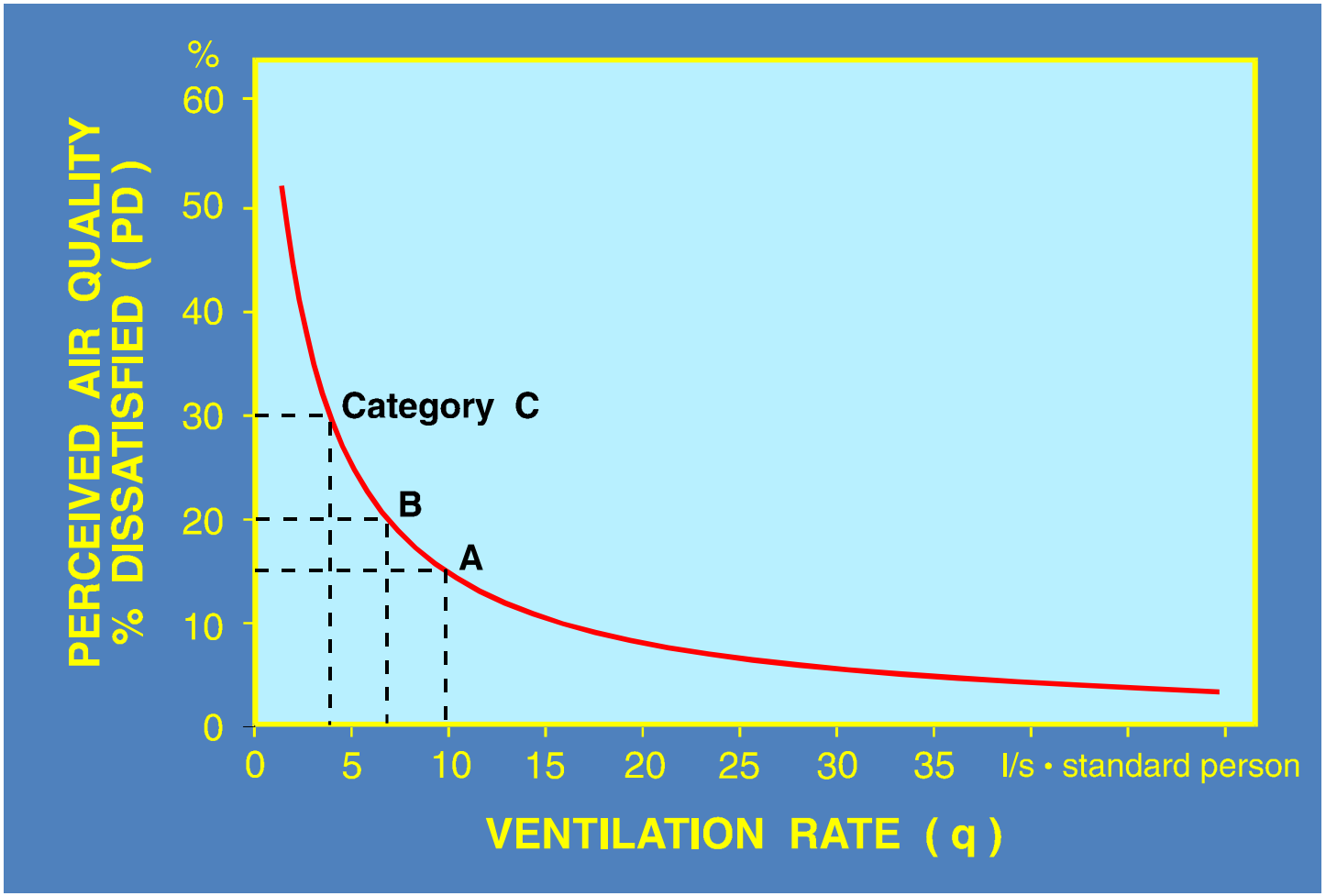
IN a previous paper [1] Lehmberg and his co-workers outlined a technic for studying ventilation requirements from the standpoint of body odors. Their work was purely fundamental, dealing largely with the development and evaluation of a suitable scale for judging intensity of body odors, and application of this scale to a laboratory experiment for studying the factors affecting odor intensity in a confined space.

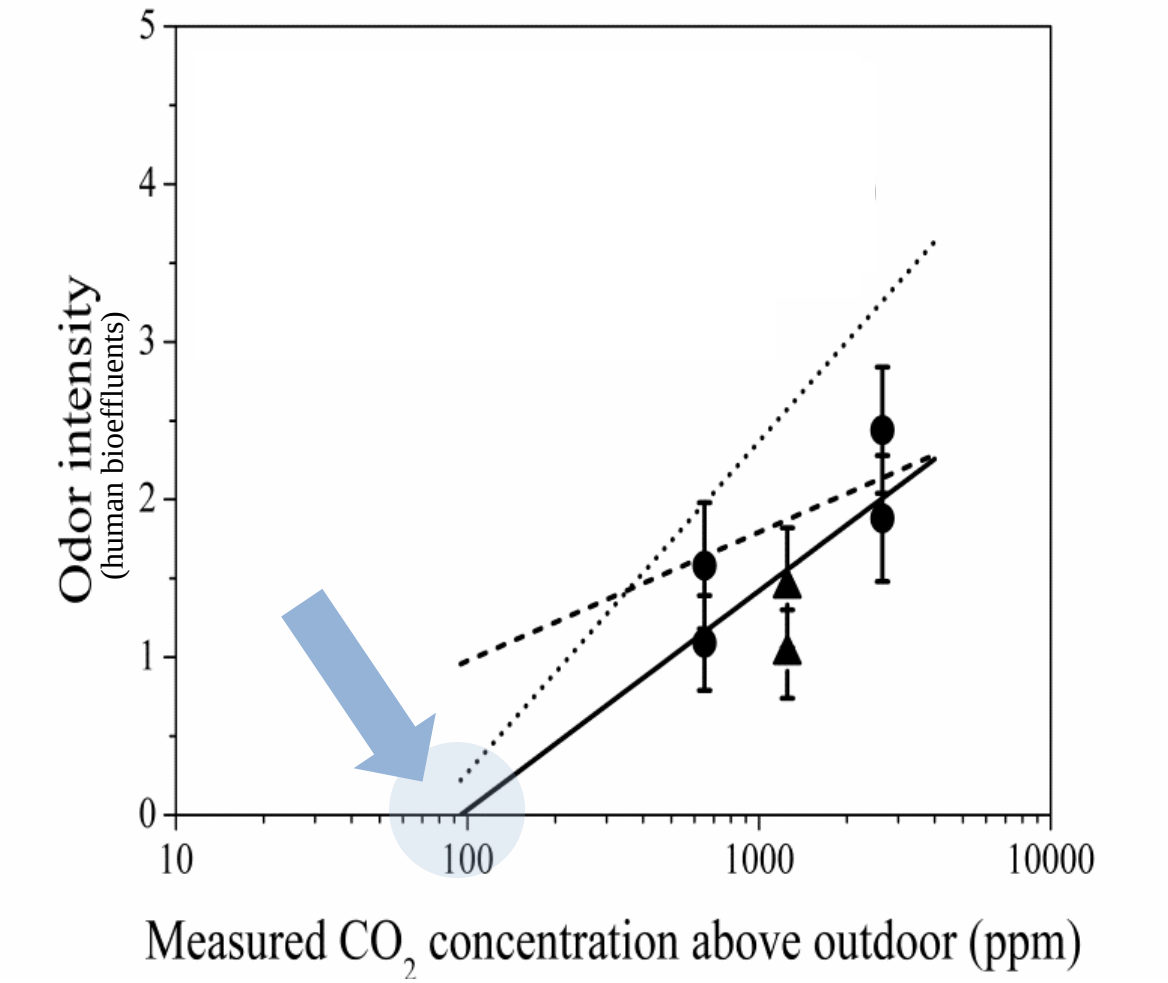
The work to be described here is an elaboration of Lehmberg's preliminary experiments. The object was to study the general problem of ventilation odors under normal conditions, comparable to those in schoolrooms, offices, homes and the like with the possibility of establishing ventilation requirements for various groups of individuals, including grade school children and adults, under representative winter and summer conditions. Three methods of odor control were

PERCEIVED AIR QUALITY IMPROVES WITH VENTILATION



Source: EN16798-1 (draft)

ODOR INTENSITY IMPROVES WITH VENTILATION



Source: Zhang et al. (in the Press)

HEALTH AND VENTILATION

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What does the scientific literature tell us about the ventilation–health relationship in public and residential buildings?

Paolo Carrer [a, *], Pawel Wargocki [b], Annaclara Fanetti [a], Wolfgang Bischof [c], Eduardo De Oliveira Fernandes [d], Thomas Hartmann [e], Stylianos Kephalopoulos [f], Susanna Palkonen [g], Olli Seppänen [h]

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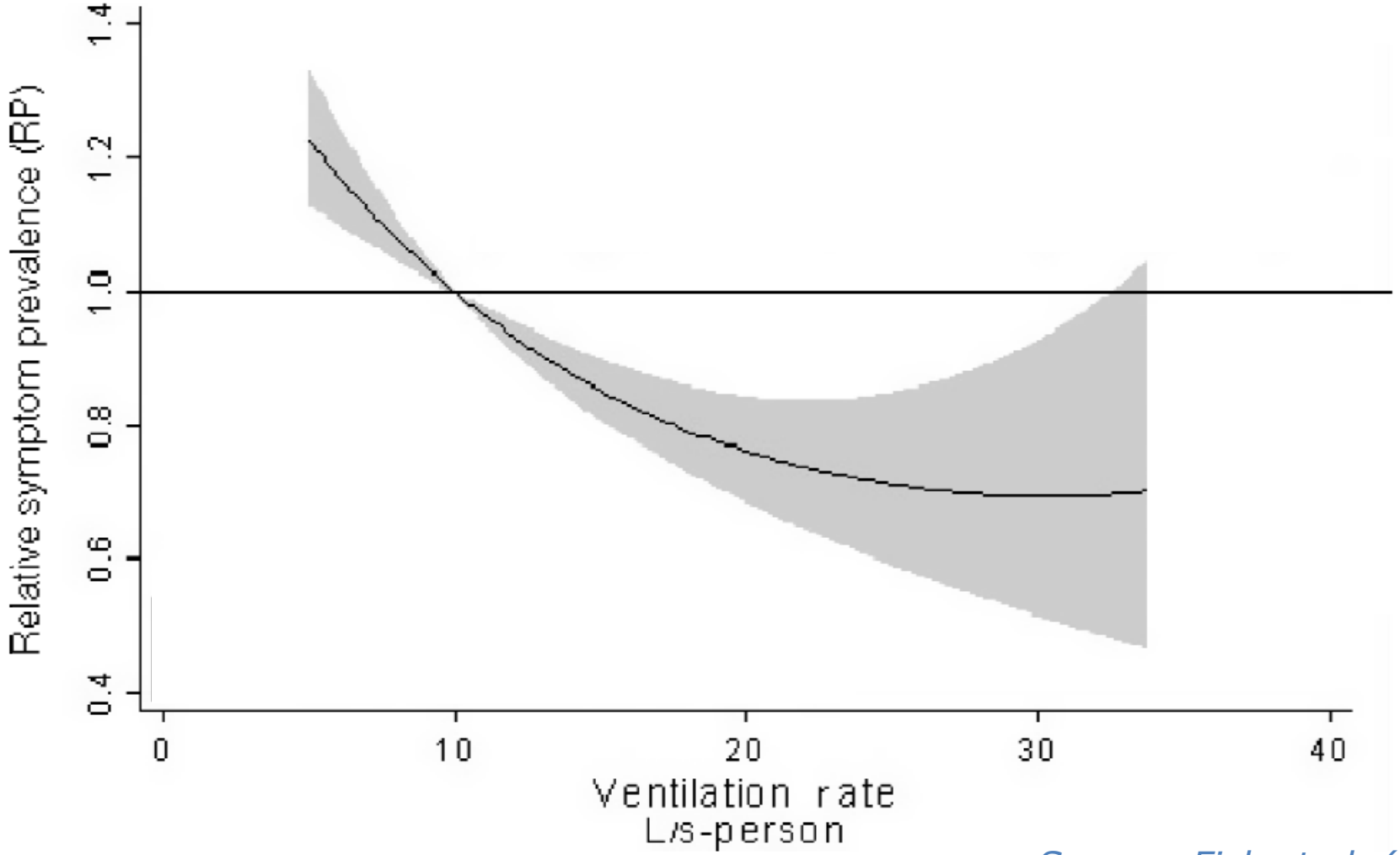
ABSTRACT

Objective of this paper is to examine whether the available epidemiological evidence provides information on the link between outdoor air ventilation rates and health, and whether it can be used for regulatory purposes when setting ventilation requirements for non-industrial built environments.

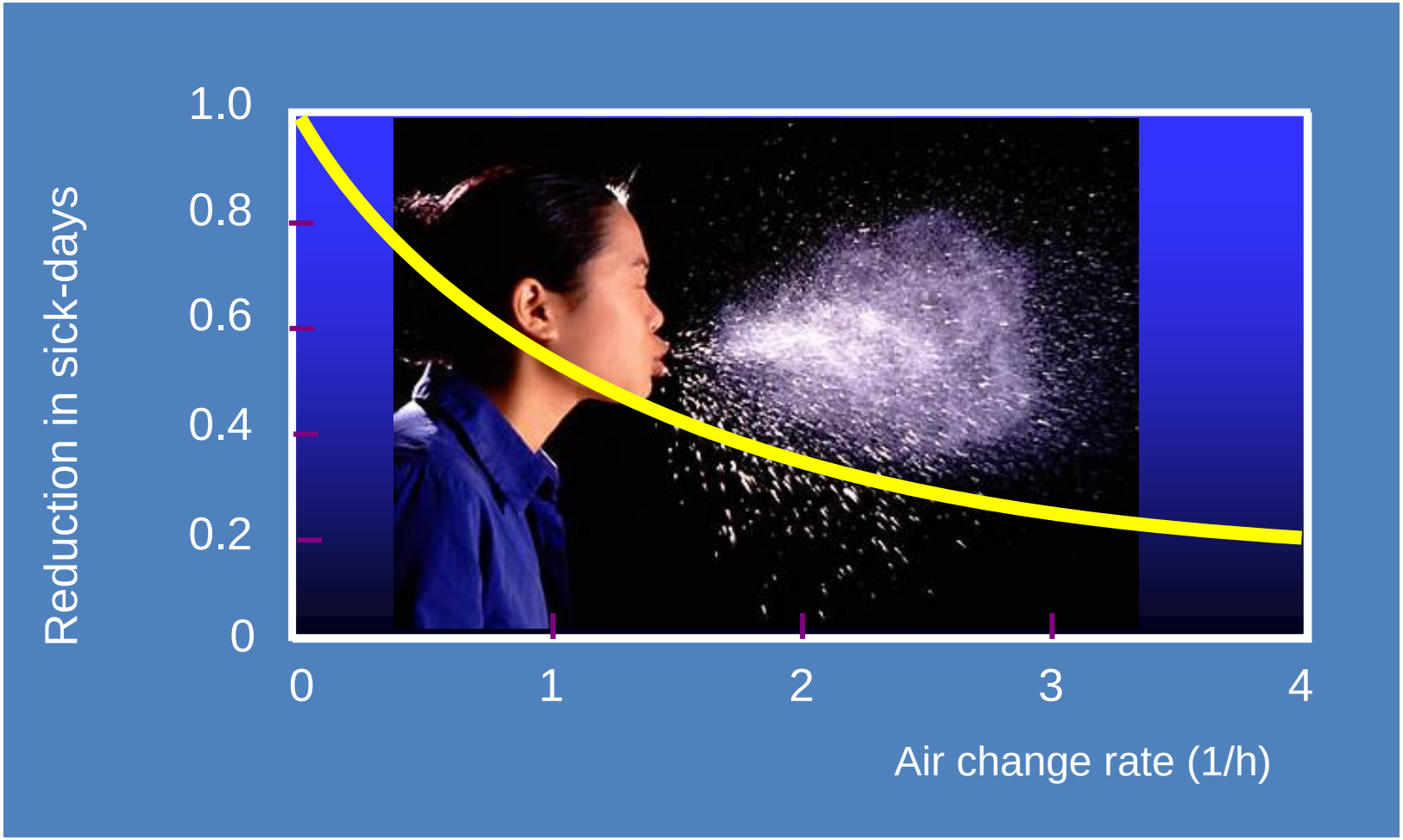
Effects on health were seen for a wide range of outdoor ventilation rates from 6 to 7 L/s per person, which were the lowest ventilation rates at which no effects on any health outcomes were observed in field studies, up to 25–40 L/s per person, which were in some studies the lowest outdoor ventilation rates at which no effects on health outcomes were seen. These data show that, in general, higher ventilation rates in many cases will reduce health outcomes, and that there are the minimum rates, at

NON-SPECIFIC SELF-REPORTED ACUTE HEALTH SYMPTOMS (SBS) IMPROVE WITH VENTILATION



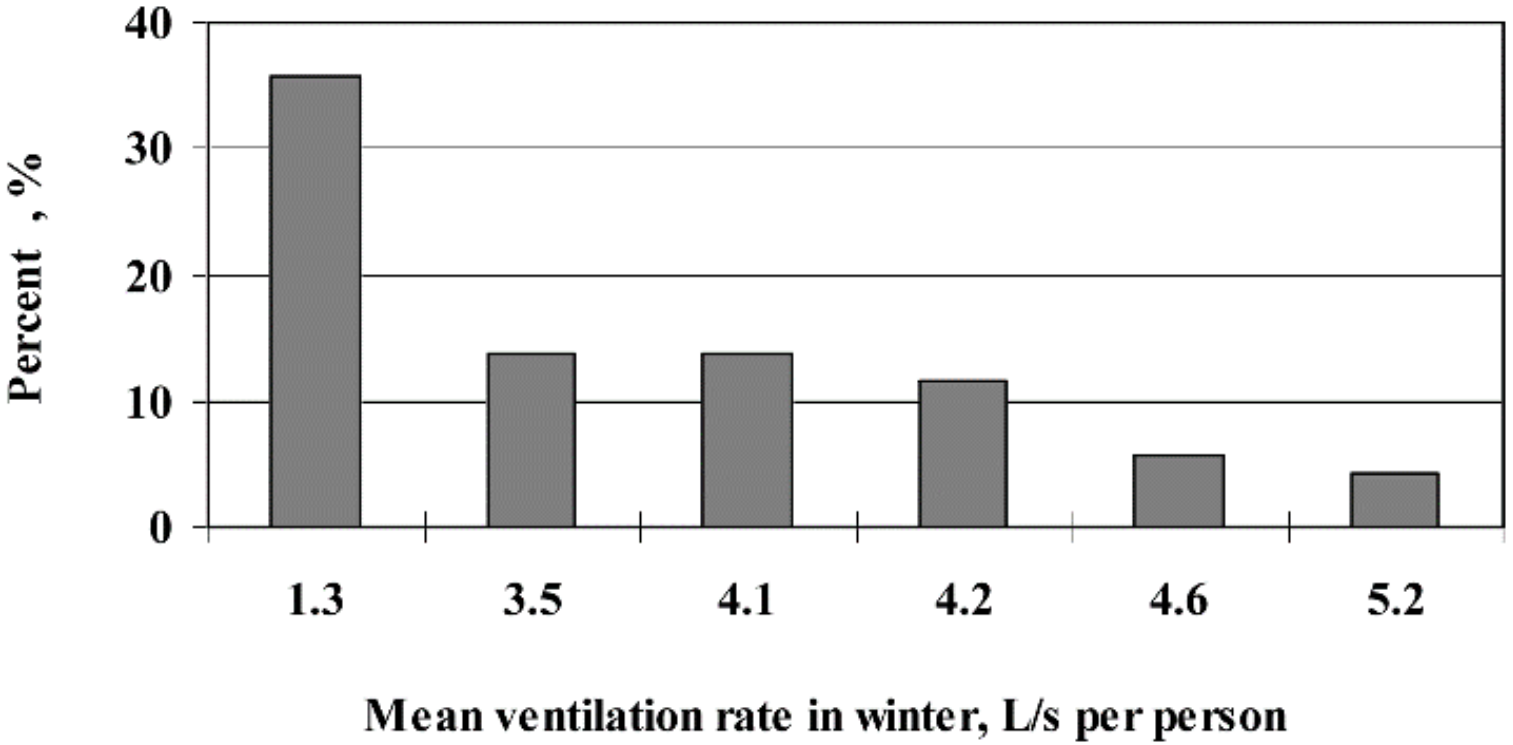
Source: Fisk et al. (2009)

SHORT-TERM SICK-LEAVE AND VENTILATION



Source: Wargocki and Seppanen (2006)

INFECTIOUS DISEASE TRANSMISSION: COMMON COLD



Source: Sun et al. (2011)

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10 Questions

Ten questions concerning thermal and indoor air quality effects on the performance of office work and schoolwork

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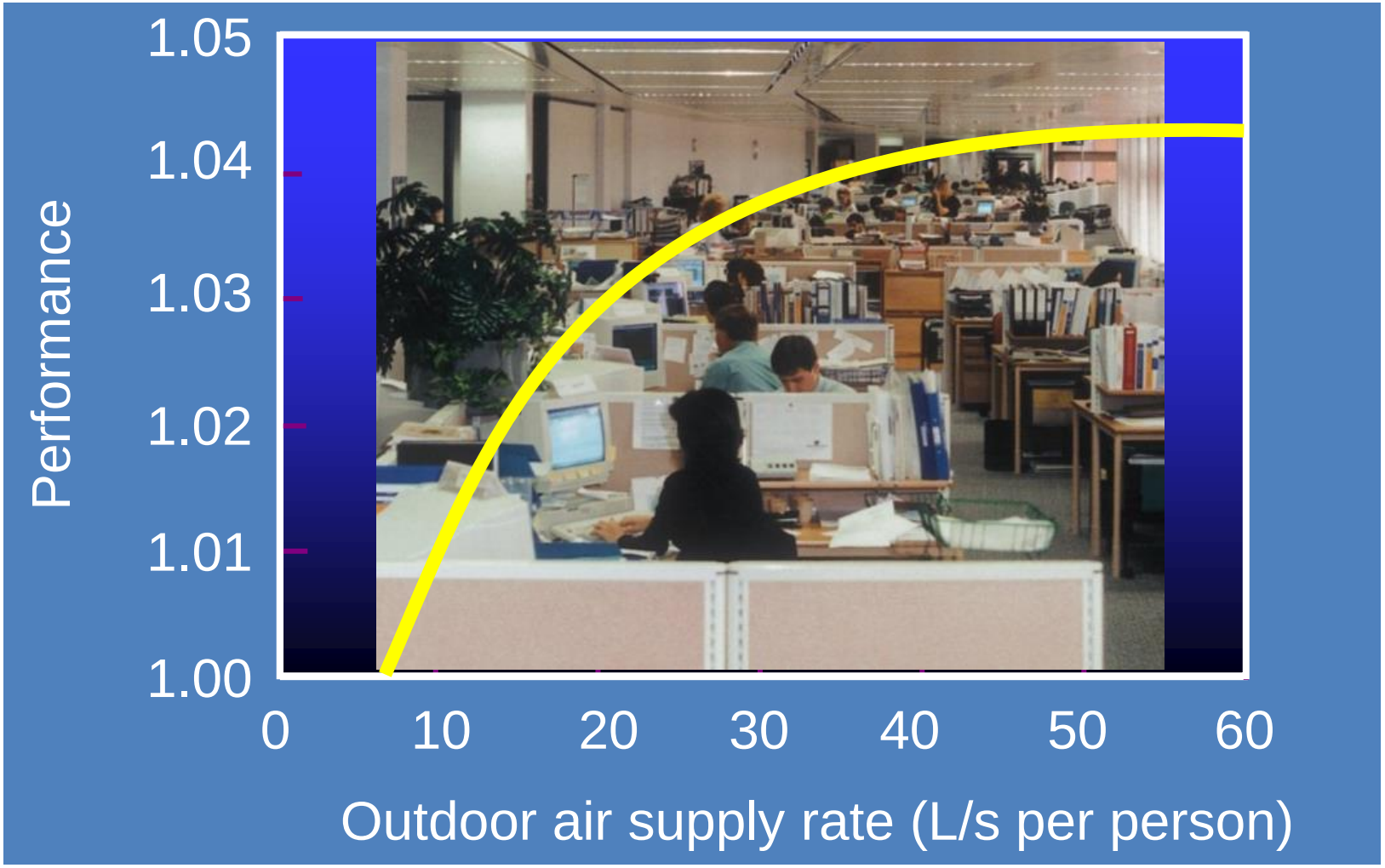
ABSTRACT

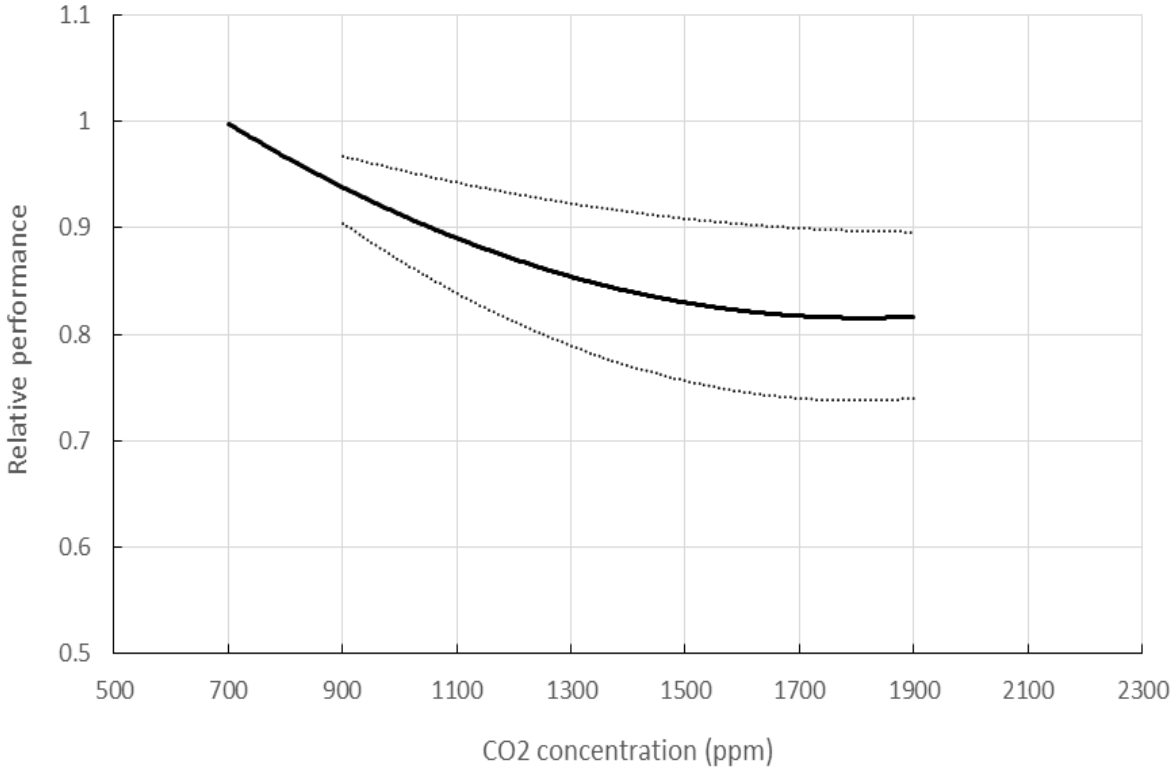
Energy conservation in buildings as a way to reduce the emission of greenhouse gases is forcing an urgent re-examination of how closely thermal and air quality conditions should be controlled in buildings. Allowing conditions to drift outside the optimum range would conserve very large amounts of energy and would in most cases have only marginal effects on health or subjective comfort. The question that then arises is whether occupant performance would be negatively affected and if so, by how much. This information is required for cost-benefit analyses. The answers in this paper are based on laboratory and field experiments that have been carried out since the massive increase in energy costs that took place in the 1970s. Although only a few of the mechanisms by which indoor environmental effects occur have been identified, it is already clear that any economies achieved by energy conservation will be greatly exceeded by the costs incurred due to decreased performance. Reducing emissions by allowing indoor environmental conditions to deteriorate would thus be so expensive that it would justify greatly increased investment in more efficient use of energy in buildings in which conditions are not allowed to deteriorate. Labour costs in buildings exceed energy costs by two orders of magnitude, and as even the thermal and air quality conditions that the majority of building occupants currently accept can be shown to reduce performance by 5–10% for adults and by 15–30% for children, we cannot afford to allow them to deteriorate still further.

VENTILATION AND PERFORMANCE OF OFFICE WORK



Source: Wargocki and Seppanen (2006)

ABILITIES AND PERFORMANCE OF SCHOOL TASKS IMPROVE WITH VENTILATION (<K6 PUPILS)



Source: Wargocki & Salazar (work in progress)

SLEEP AND VENTILATION

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The effects of bedroom air quality on sleep and next-day performance

Abstract The effects of bedroom air quality on sleep and next-day performance were examined in two field-intervention experiments in single-occupancy student dormitory rooms. The occupants, half of them women, could adjust an electric heater to maintain thermal comfort but they experienced two bedroom ventilation conditions, each maintained for 1 week, in balanced order. In the initial pilot experiment ($N = 14$), bedroom ventilation was changed by opening a window (the resulting average CO_2 level was 2585 or 660 ppm). In the second experiment ($N = 16$), an inaudible fan in the air intake vent was either disabled or operated whenever CO_2 levels exceeded 900 ppm (the resulting average CO_2 level was 2395 or 835 ppm). Bedroom air temperatures varied over a wide range but did not differ between ventilation conditions. Sleep was assessed from movement data recorded on wristwatch-type actigraphs and subjects reported their perceptions and their well-being each morning using online questionnaires. Two tests of next-day mental performance were applied. Objectively measured sleep quality and the perceived freshness of bedroom air improved significantly when the CO_2 level was lower, as did next-day reported sleepiness and ability to concentrate and the subjects' performance of a test of logical thinking.

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Key words: Air quality; Ventilation; Windows; Sleep; Sleep quality; Performance.

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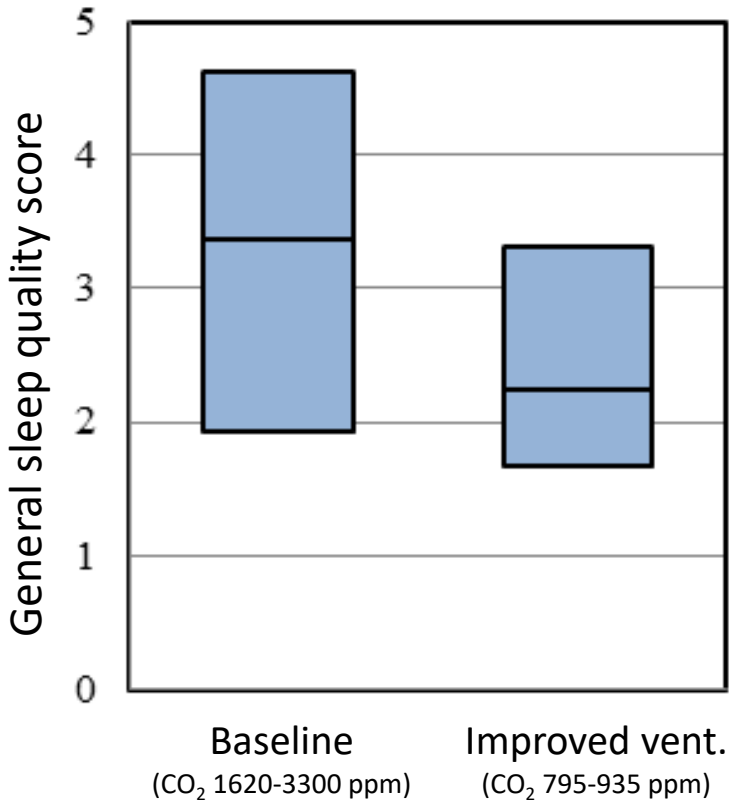
SLEEP QUALITY AND NEXT DAY PERFORMANCE IMPROVES WITH VENTILATION

- Both sleep quality and next-day performance can be negatively affected when the outdoor air supply rate to the bedroom is reduced
- A small current of fresh air to the breathing zone seems to improve sleep quality



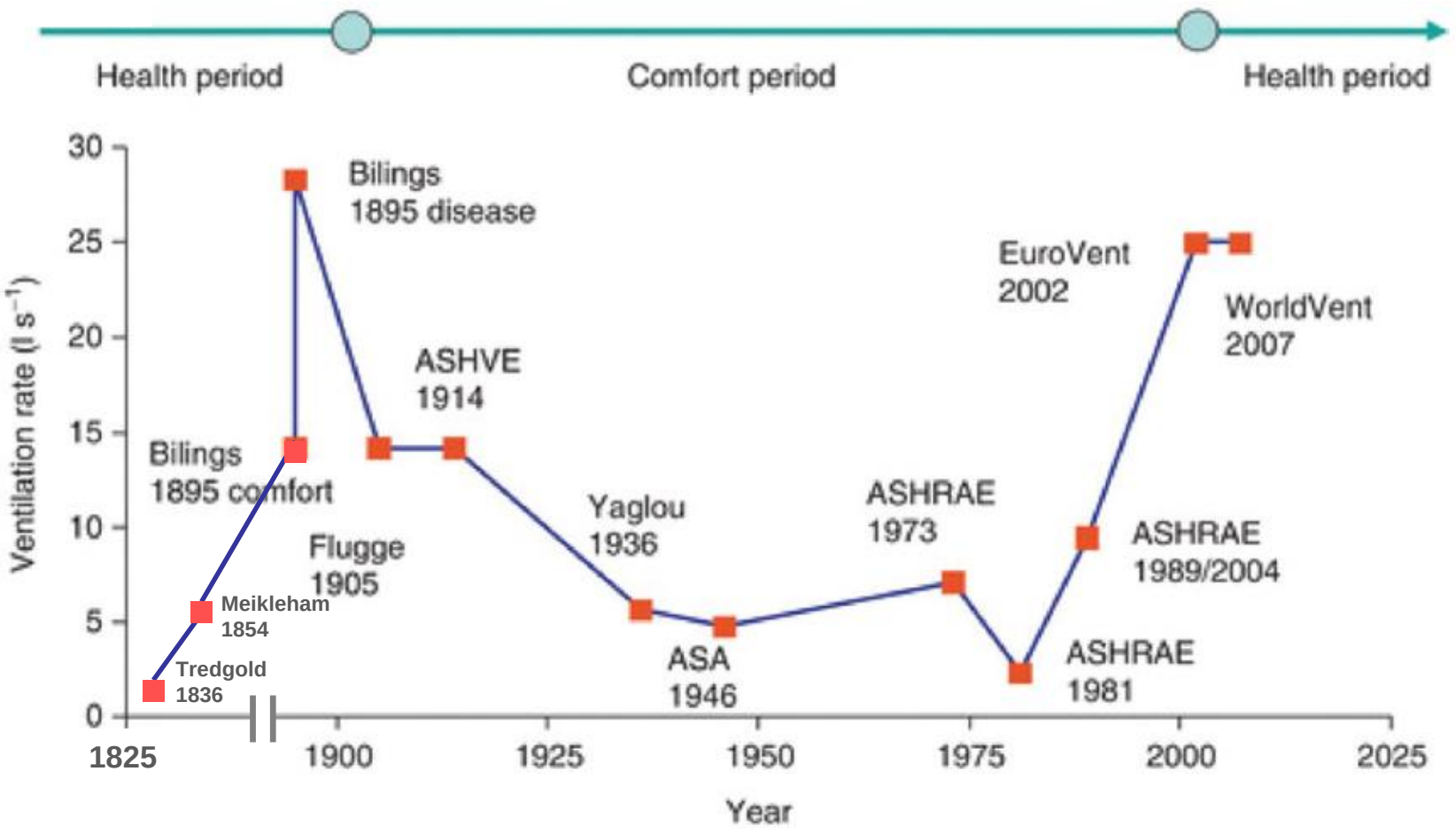
Source: Zhou et al. (2014); Strøm-Tejsen et al. (2016)

CURRENT VENTILATION STANDARDS ARE DILUTION STANDARDS, OUTDOOR AIR ASSUMED TO BE GOOD, COMFORT ENDPOINT

		Airflow for building emissions pollutions (l/s/m²)		
Category	Airflow per person l/s/pers.	Very low polluting building	Low polluting building	Non low polluting building
I	1O	0,5	1	2
II	7	0,35	0,7	1,4
III	4	0,2	0,4	0,8

Source: EN15251 (2007)

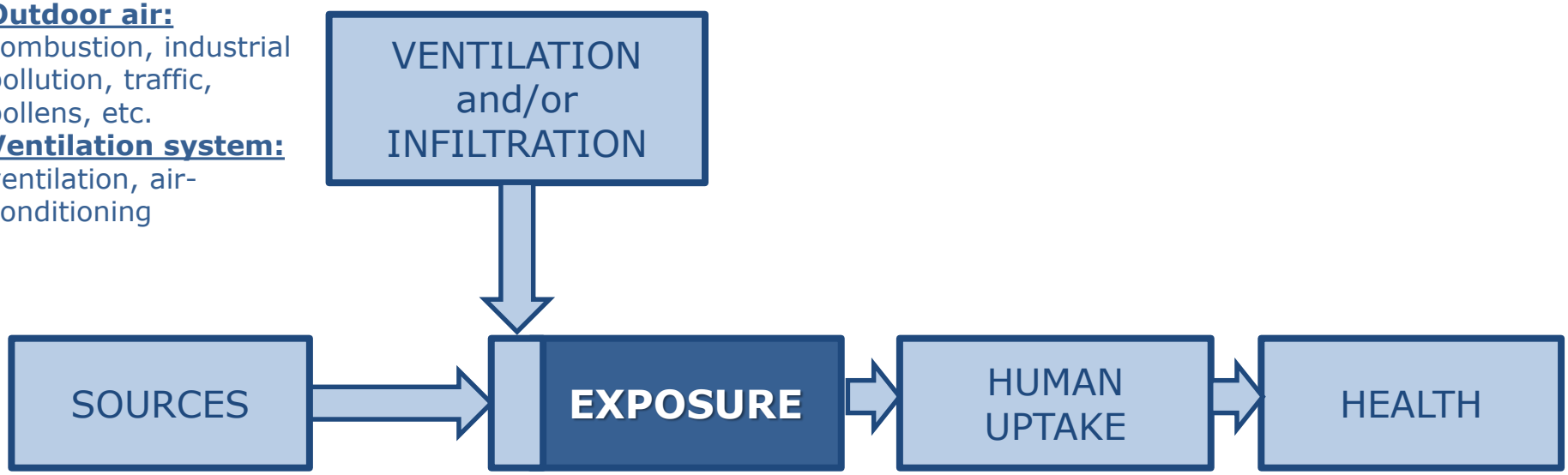
VENTILATION THROUGH HISTORY



Adapted from Li (2013)

VENTILATION IS A MEDIATING FACTOR NOT THE CAUSE

Outdoor air: combustion, industrial pollution, traffic, pollens, etc.
Ventilation system: ventilation, air-conditioning



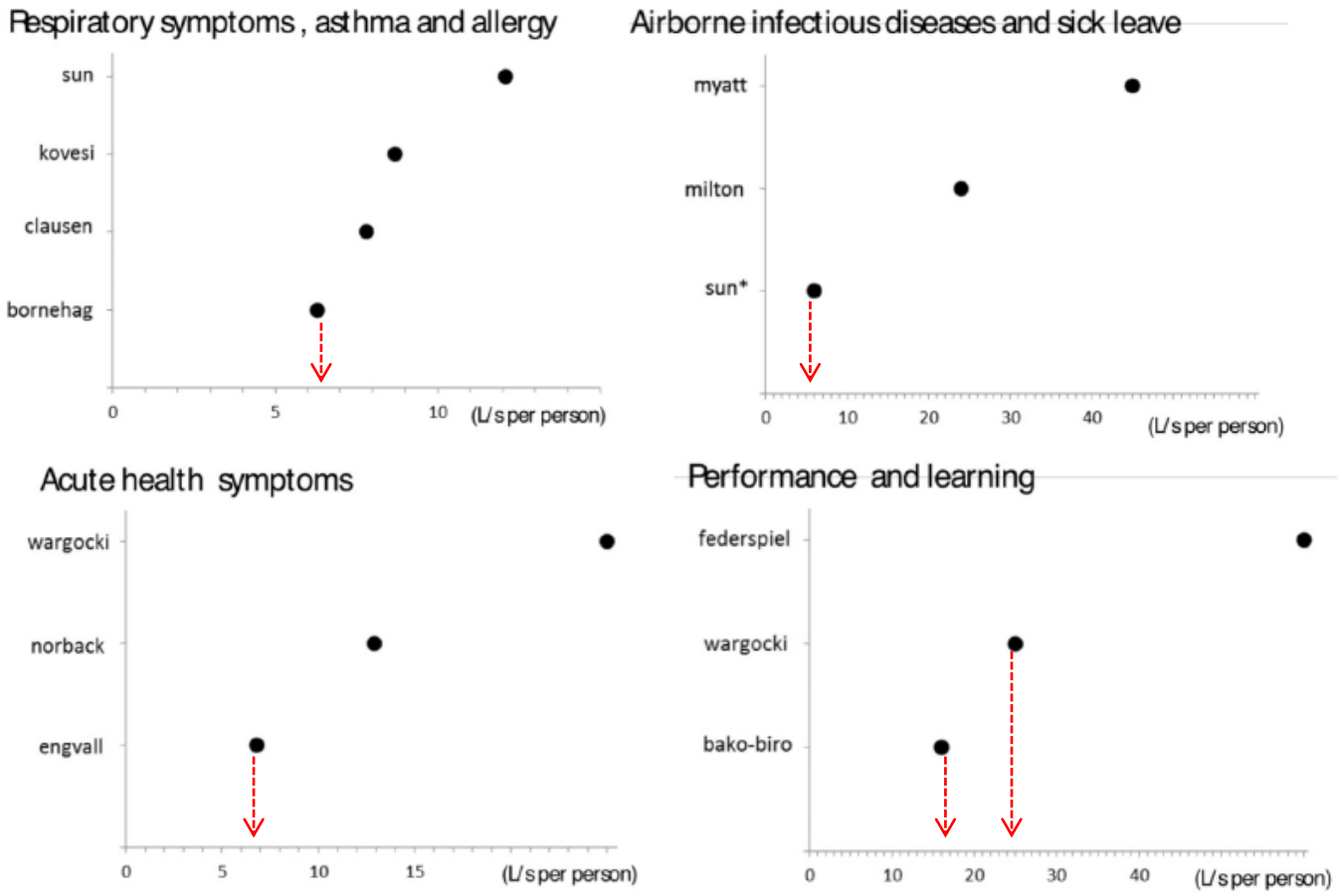
Building: building materials, furnishing, equipment, consumer products, etc.
Humans: occupants & their activities

Ca. three scores of studies on ventilation & human outcomes

Study	Main results
Mendell (1993) [13]	Acute health (SBS) symptoms of office workers were associated with air-conditioning, carpets, more workers in a space, VDT use, and ventilation rates at or below 10 L/s per person.
Godish and Spengler (1996) [14]	Limited evidence suggests that increasing the ventilation rate up to 10 L/s per person may be effective in reducing prevalence of acute health (SBS) symptoms and occupant dissatisfaction with air quality. Because of complex relationships between ventilation rates, contaminant levels, and building-related health complaints, the use of ventilation as a mitigation measure for air quality problems should be tempered with an understanding of factors that may limit its effectiveness.
Seppänen et al. (1999) [15]	Ventilation rates below 10 L/s per person in all building types were associated with statistically significant worsening in one or more health or perceived air quality outcomes. Some studies determined that increasing ventilation rates above 10 L/s per person up to approximately 20 L/s per person, were associated with a significant decrease in the prevalence of acute-health symptoms or with a significant improvement of the perceived air quality. The risk of acute health (SBS) symptoms continued to decrease significantly with decreasing carbon dioxide concentrations below 800 ppm.
Wargocki et al. (2002) [16]	Ventilation rates below 25 L/s per person increase the risk of acute health (SBS) symptoms, increase short-term sick leave, and decrease productivity.
Mendell and Heath (2005) [101]	No sufficiently persuasive evidence to establish specific causal relationships between indoor pollutants or thermal conditions in schools and the performance of students. Suggestive (although not fully consistent) evidence links low ventilation rates in buildings to decreased performance in children and adults.
Seppänen et al. (2006) [102]	A 1–3% improvement in average performance was associated with an increase in ventilation rate by 10 L/s per person. The performance increase was statistically significant when ventilation rates increased up to 15 L/s per person (95% confidence interval, CI) and up to 17 L/s per person (90% CI). The performance increase per unit increase in ventilation was larger with ventilation rates below 20 L/s per person and almost negligible with ventilation rates over 45 L/s per person.
Li et al. (2007) [23]	There is strong and sufficient evidence substantiating the association between ventilation, air movements in buildings and the transmission/spread of infectious diseases such as measles, tuberculosis, chickenpox, influenza, smallpox and SARS. There is insufficient data to clearly define the ventilation rates that can reduce the risk of the spread of infectious diseases via the airborne route for hospitals, schools, offices, homes and isolation rooms. Overcrowding is a risk factor that may be related to the ventilation of buildings but it also increases transmission via direct contact.
Fisk (2009) [103]	As the ventilation rate is reduced from 10 to 5 L/s per person, the relative prevalence of acute health (SBS) symptoms increases by ca. 23% (12%–32%). As the ventilation rate is increased from 10 to 25 L/s per person, the relative prevalence of symptoms decreases by 29% (15%–42%).
Sundell et al. (2011) [25]	Higher ventilation rates in offices, up to about 25 L/s per person, were associated with reduced prevalence of acute health (SBS) symptoms. Ventilation rates in homes above 0.5 air changes per hour are associated with a reduced risk of allergic manifestations among children in Nordic climates.

Source: Carrer et al. (2015)

RESULTS: MINIMUM VENTILATION RATE FOR NO EFFECT

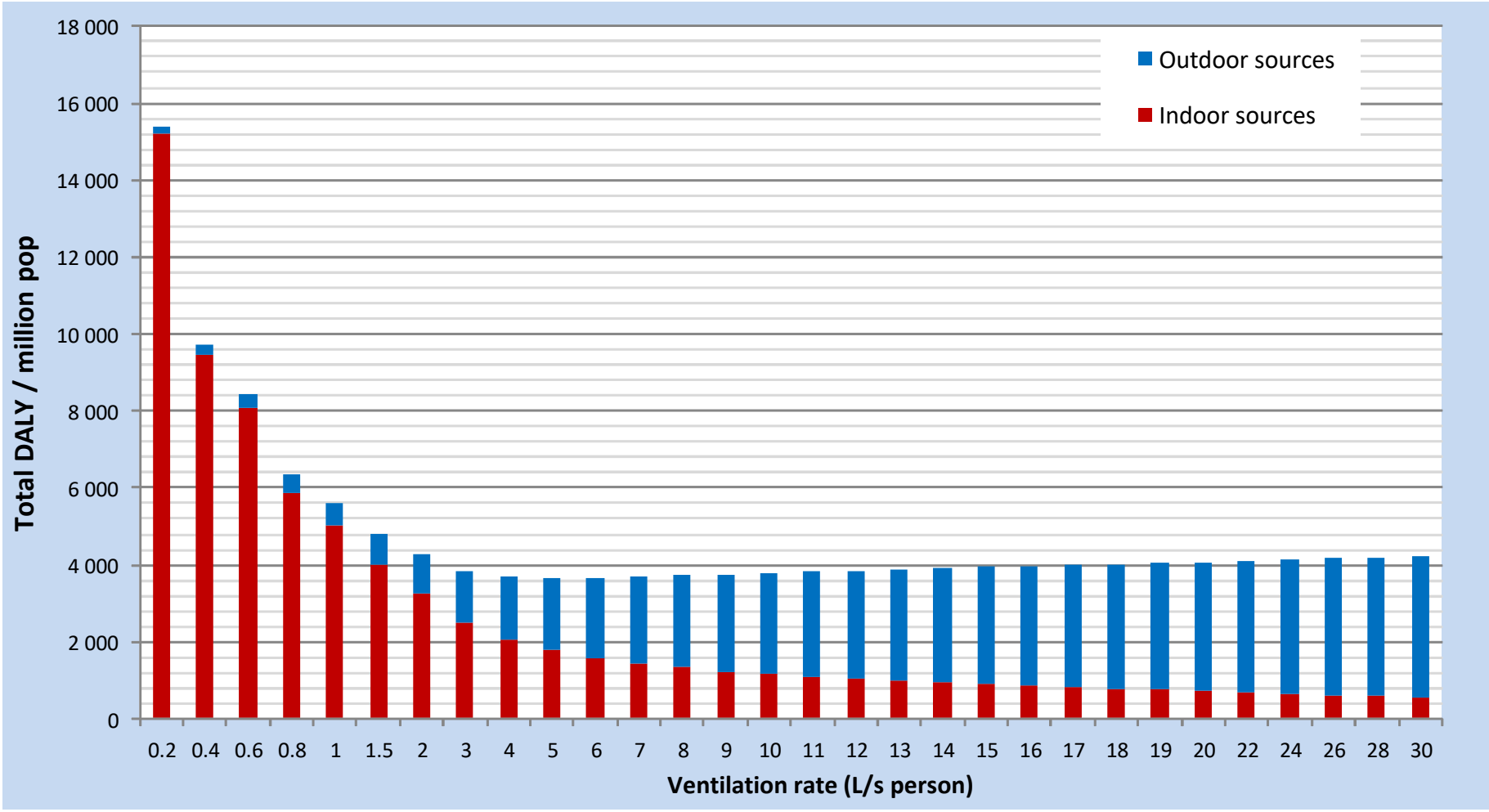


For health, the minimum no-effect rate ca. 6-7 L/sp
For schoolwork and office work, the minimum no effect rate 16-24 L/sp

LIMITATIONS OF THE AVAILABLE DATA

- Incomparable or difficult to compare
- Improper characterization of buildings and exposures
- Lack of data on indoor pollution sources including maintenance of ventilation systems
- Assumption of clean (unpolluted) outdoor air
- Weak characterization of health outcomes (mainly self-estimated acute symptoms, no chronic outcomes)
- Weak (poor) characterization of ventilation, and crude ventilation measurements
- Poor or no characterization of exposed population and its sensibility
- Weak experimental designs

BURDEN OF DISEASE AS A RESULT OF JUST INCREASED VENTILATION (W/NO SOURCE CONTROL)



Source: Asikainen et al. (2016)

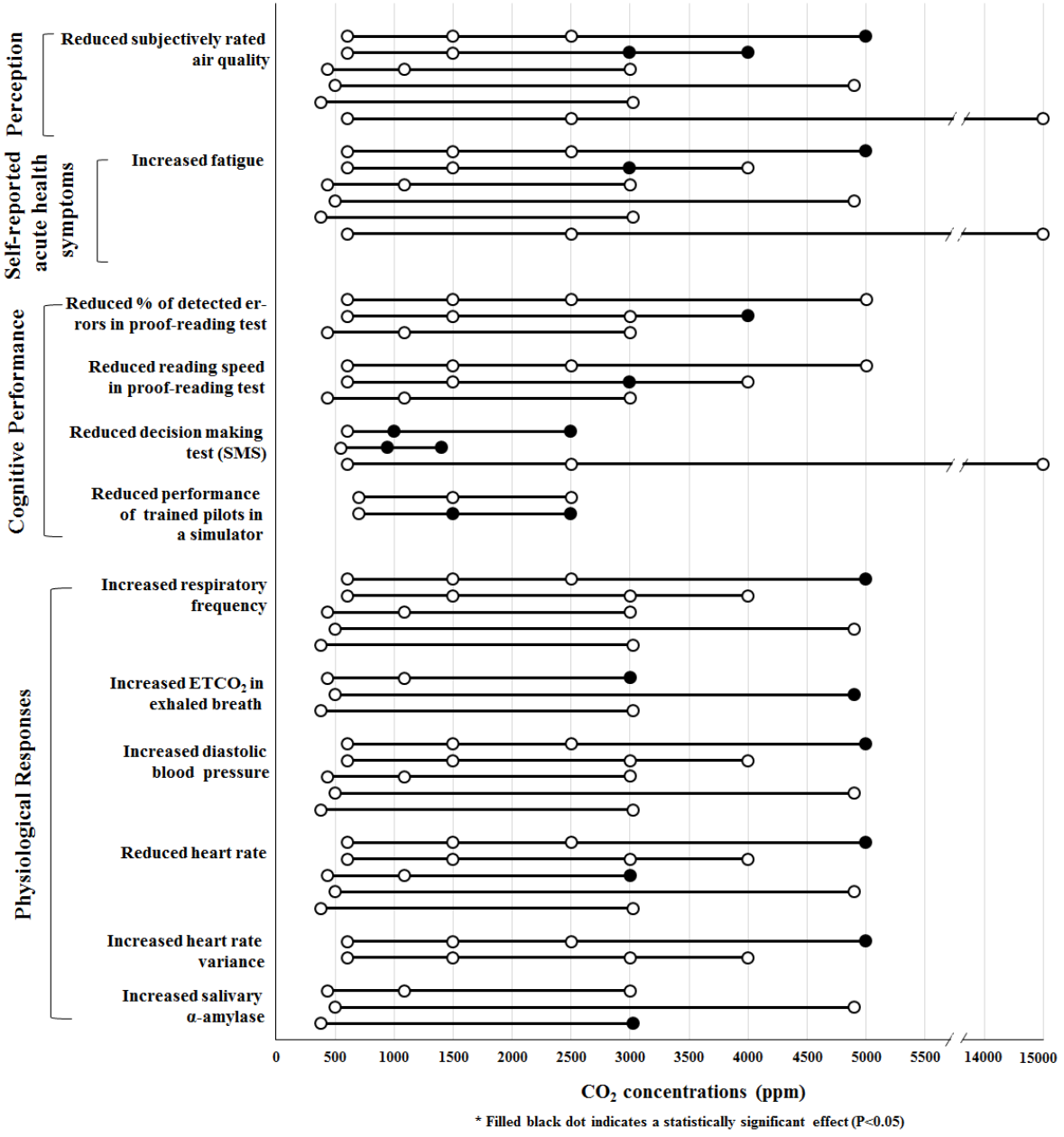
THE BASE VENTILATION RATE REQUIREMENT

- It is a basic requirement that must always be satisfied when people are present indoors.
- The base ventilation rate is the rate intended to dilute and exhaust occupant bioeffluents.
- HealthVent proposed 4 L/s per person acknowledging limited data but the rate may be different

TENTATIVE DOSE-RESPONSE RELATIONSHIP EXPOSURE FOR BIOEFFLUENTS

450 ppm CO_2:	detection of bioeffluents
1,100 ppm $CO_{2:}$	no observed effect level (except the effect on $ETCO_2$ and perceived air quality and odor)
1,800 ppm CO_2:	lowest observed effect level (effect on decision making performance)
>3000 ppm CO_2:	range of adverse (negative) effects as regards self-estimated acute health symptoms, cognitive performance and physiological reactions

Summary of effects of CO_2 on humans



COMMON BELIEFS REGARDING VENTILATION

- More ventilation always improves indoor air quality (YES/NO)
- Lack of ventilation or low ventilation rates means poor air quality (YES/NO)
- It is simple to measure ventilation (YES/NO)
- Ventilation can be used to predict human responses (performance-based metric) (YES/NO)
- Outdoor air and the systems are clean and free of pollution
- The air is fully mized within indoor volumes

QUESTIONS……

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