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EVERY CLASSROOM



IAN BUTLER

BUSINESS PARTNERSHIP MANAGER AT EUROVENT CERTIFICATION

moderator

TODAY'S AGENDA



UK Health
Security
Agency

13:05-13:45h

Sani Dimitroulopoulou, Duncan Grassie, Kaja Milczewska

UKHSA

'UKHSA literature review: impacts and benefits of indoor environmental quality (IEQ) in educational buildings'



13:45-14:05h

Catherine Noakes

Professor at the University of Leeds

'Understanding the effectiveness of air cleaners in schools'



14:05-14:25h

Henry Burridge

Senior Lecturer at Imperial College London

'SAMHE air quality monitoring in more than 600 schools across the UK, including on ventilation rates and indoor pollution levels'



14:25-14:45h

Pawel Wargocki

Professor at Technical University of Denmark

'What we know and should know about classroom air quality, ventilation, and thermal environment in relation to learning and monitoring'



14:45-15:05h

Corinne Mandin

Environmental Health Researcher

'Indoor air quality in French schools: 15 years of research to improve knowledge'



15:25-15:45h

Adam Taylor

Chairman of the BESA group on IAQ

'Teachers' attitude to IAQ, and installation and maintenance concerns'



15:45-16:05h

Emma Gibbons, Peter Walsh

CIBSE

'Filters in classrooms and intrusion of externally polluted air'



16:05-16:25h

Ali Alexandre Nour Eddine

Senior Technical Manager at Eurovent Certification

'Performance-based approach simulation to predict IAQ and energy performance of ventilation systems'



16:25-17:15h

Moderated by: Simon Jones

Founder of Air Quality Matters

Panel discussion and audience Q&A

17:15-19:00h **Networking evening**

SANI DIMITROULOPOULOU, DUNCAN GRASSIE, KAJA MILCZEWSKA

UKHSA

*'UKHSA literature review: impacts and
benefits of indoor environmental
quality (IEQ) in educational buildings'*



UK Health
Security
Agency



UK Health
Security
Agency

UKHSA work on IEQ in schools

Prof. Sani Dimitroulopoulou

Principal Environmental Public Health Scientist - Indoor Environments,
Air Quality and Public Health, Environmental Hazards and Emergencies Dept, UK Health Security Agency
Visiting Professor, IEDE, The Bartlett School, University College London
Chair, UK Indoor Environments Group (UKIEG)
Fellow of ISIAQ Academy (International Society of Indoor Air Quality and Climate)

UKHSA: Who we are

UK Health Security Agency (UKHSA) prevents, prepares for and responds to infectious diseases and environmental, radiological and chemical hazards, to keep all our communities safe, save lives and protect livelihoods.

We provide scientific and operational leadership, working with local, national and international partners to protect the public's health and build the nation's health security capability.

UKHSA is an executive agency, sponsored by the Department of Health and Social Care.

Strategic priority 4: Protect health from threats in the environment

Exposure to environmental hazards, including chemicals, radiation, adverse weather and natural disasters results in significant ill-health and loss of life, as well as impacts on the economy and wider society. There were estimated to be almost 3,000 excess deaths during heatwaves in England in 2022¹³. Meanwhile, air pollution contributes to up to 43,000 deaths in the UK each year and causes a range of long-term conditions, with many deprived communities disproportionately affected¹⁴.

We will provide scientific expertise, advice and guidance to policy makers to protect health from these threats. We will increase public and cross-government understanding of evidence-based interventions to protect health from hazards such as heat waves and flooding. We will monitor the impact of climate change on environmental hazards.

- **a more developed evidence base on the health impacts of outdoor and indoor air quality**, with a greater understanding of the health impacts on different groups and communities, and effective health interventions to address these, working closely with the Office for Health Improvement and Disparities (OHID)

team of highly-specialist experts in fields such as toxicology, radiation protection and environmental monitoring, and strengthen knowledge and expertise across UKHSA to support the wider system

- **clear public health leadership across chemical, radiological and nuclear risks** and input to policy development. This includes UKHSA's contribution to the National Security Risk Assessment, and our direct input to cross-government responses where there is a health security element, domestically and internationally
- **delivery of the Adverse Weather and Health Plan** including updating adverse weather guidance, developing a supporting evidence document, implementing a new alert system for adverse weather events and providing specialist support and advice to partners and the public
- **a more developed evidence base on the health impacts of outdoor and indoor air quality**, with a greater understanding of the health impacts on different groups and communities, and effective health interventions to address these, working closely with the Office for Health Improvement and Disparities (OHID)

<https://www.gov.uk/government/publications/ukhsa-strategic-plan-2023-to-2026>

Programme Outcomes: Core ambitions of the programme

Increasing the evidence base

Develop the evidence base on air quality, including on sources of pollution, levels of exposure and how this contributes to health outcomes.

Improving awareness and understanding

Improve the understanding of the holistic view of the effect of indoor and outdoor air pollutants; improve how advice and information on indoor and outdoor air pollution can be communicated.

Influencing and supporting stakeholders

Advise and influence decision-makers; Support the implementation, sharing information and learning at various scales.

Programme Key Elements: Where we will focus our effort

Identify the evidence gaps and contribute to filling them.

Develop the evidence on the link between sources of indoor and outdoor pollutants, exposure, and health outcomes.

Understanding of future opportunities and threats and their association with air pollution and health e.g. climate change, new technologies, low-emission vehicles etc.

Quantify the impacts of indoor and outdoor air pollutants on health and wellbeing, considering the wider environmental and social determinants of health.

How we can most effectively target our actions towards the most vulnerable population groups, including more deprived communities, people with pre-existing respiratory and cardiovascular conditions and young and older people.

Develop tools, resources, training for the public, local authorities, health, and medical professionals.

Review the effectiveness of interventions and actions used by the public and decision makers to assess effectiveness.

Work with local authorities including directors of public health to equip and enable them to lead and inform local decision-making to improve air quality more effectively.

Strengthen our response to air quality incidents and emergencies.

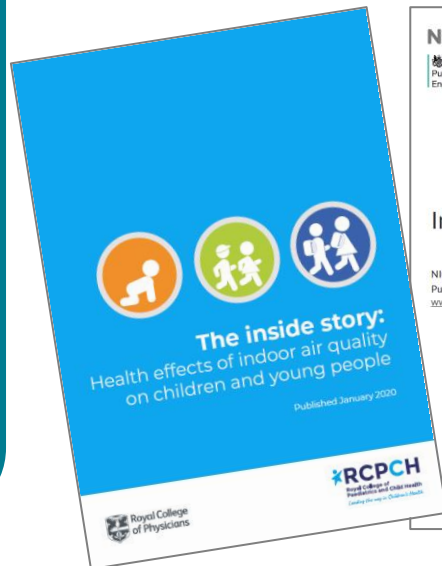
Strengthen our Global Health activities to protect health against air pollution in the UK and globally.

Support the development of the Air Pollution Control plan to implement the government Clean Air Strategy and current commitments in the

Indoor air – Health effects

Exposure to indoor air pollutants, chemicals and biological contamination is associated with

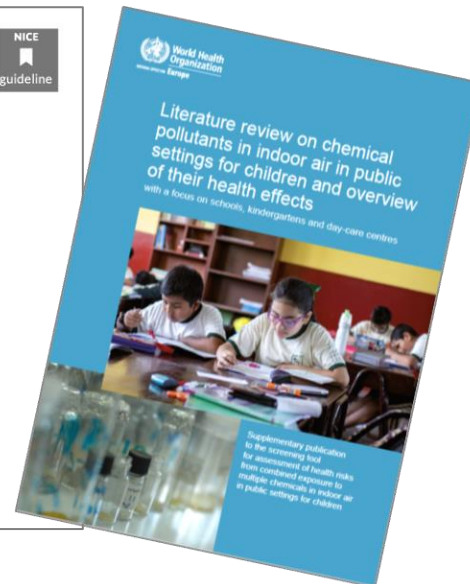
- respiratory system
- nervous system
- cardiovascular system
- carcinogenicity
- respiratory irritation



RCPCH (2020)



NICE (2020)



WHO (2021)



Birth and infancy

- Respiratory problems – wheeze, rhinitis, atopic asthma, respiratory infections
- Low birthweight and pre-term birth



Pre-school

- Respiratory problems – wheeze, allergies, asthma, risk of respiratory diseases and pneumonia
- Eczema and atopic dermatitis
- Greater hyperactivity, impulsivity and inattention



School age

- Respiratory problems – wheeze, rhinitis, asthma, throat irritation, nasal congestion, dry cough
- Eczema, dermatitis, conjunctivitis, skin and eye irritation
- Reduced cognitive performance, difficulty sleeping

RCPCH (2020) https://www.rcpch.ac.uk/sites/default/files/2020-01/the-inside-story-report_january-2020.pdf

Department for Education - Building Bulletin 101

Guidance on ventilation, thermal comfort and indoor air quality in schools (2018)

6.1 Indoor and outdoor air quality guidelines and UK air quality standards

- *For the first time in the UK policy, BB101 recommends:*
 - WHO (2010) guidelines for selected indoor air pollutants
 - WHO (2009) guidelines for dampness and mould.
- Distinguish between indoor and ambient air:
 - UK National Air Quality Objectives (DETR, 2007) for ambient air pollutants.
- Refer to HSE EH40: Pollutant levels in *Science, Design and Technology and Art* should always be kept below the levels given in EH40.

Approved Document F, 2021 edition - for use in England

B ONLINE VERSION

Table B1 Indoor air pollutants guidance values⁽¹⁾⁽²⁾

Pollutant	Exposure limit	Exposure time
Carbon monoxide (CO)	100mg/m ³	15-minute average
	30mg/m ³	1-hour average
	10mg/m ³	8-hour average
Nitrogen dioxide (NO ₂)	200µg/m ³	1-hour average
	40µg/m ³	1-year average
Formaldehyde (CH ₂ O)	100µg/m ³	30-minute average
	10µg/m ³	1-year average
TVOC ⁽³⁾	300µg/m ³	8-hour average

NOTES:

1. No safe levels can be recommended for benzene or trichloroethylene so they have not been considered in the definition of ventilation rates in dwellings. The best strategy for reducing their concentration indoors may be to control them at source.
2. Even if the designer and builder choose to reduce volatile organic compound (VOC) levels in dwellings by controlling them at source, the ventilation requirements must still be met.
3. The total volatile organic compound (TVOC) metric is representative of all airborne indoor air VOC concentrations and should not be used as a direct indicator of health. The simplified metric is used as an indicator for the purpose of ventilation control strategies. As an alternative to the TVOC limit, individual VOC limits may be used where justified in accordance with the guidance in paragraph B5.

B5 As an alternative to using TVOC, the individual VOCs may be applied where their use is supported by robust independent evidence. Public Health England's *Indoor Air Quality Guidelines for Selected Volatile Organic Compounds (VOCs) in the UK* should be used. Testing against these metrics is likely to be more complex than testing against TVOC.

B6 Control of bio-effluents (body odours) for people who have been exposed to the environment for a period of time will be achieved by an air supply rate of 4 litres per second per person (**BS EN 16798-1**).

Assumptions used in applying performance criteria for dwellings in Section 1

General

B7 Where the guidance for **less airtight dwellings** is followed, dwellings are assumed to have an infiltration rate of 0.15 air changes per hour.

B8 Where the guidance for **highly airtight dwellings** is followed, dwellings are assumed to have an infiltration rate of 0 air changes per hour.

B9 Ventilation effectiveness is assumed to be 1.0 – that is, it is assumed that supply air is fully mixed with room air.

CIBSE's Guide A *Environmental Design* provides further information on ventilation effectiveness.

40 Approved Document F Volume 1, 2021 edition Building Regulations 2010 ONLINE VERSION

B ONLINE VERSION

Table B1 Indoor air pollutants guidance values⁽¹⁾⁽²⁾

Pollutant	Exposure limit	Exposure time	Guidance
Carbon monoxide (CO)	100mg/m ³	15-minute average	WHO, 2010
	30mg/m ³	1-hour average	WHO, 2010
	35mg/m ³	8-hour average	HSE, 2020
	(occupational exposure)		
Nitrogen dioxide (NO ₂)	200µg/m ³	1-hour average	WHO, 2010
	40µg/m ³	1-year average	WHO, 2010
Formaldehyde (CH ₂ O)	100µg/m ³	30-minute average	WHO, 2010
	10µg/m ³	1-year average	PHE, 2019
TVOC ⁽³⁾	300µg/m ³	8-hour average	ECA, 1992/WHO, 2010
Ozone	100µg/m ³		DETR, 1994

NOTES:

1. No safe levels can be recommended for benzene or trichloroethylene so they have not been considered in the definition of ventilation rates in buildings. The best strategy for reducing their concentration indoors may be to control them at source.
2. Even if the designer and builder choose to reduce volatile organic compound (VOC) levels in buildings by controlling them at source, the ventilation requirements must still be met.
3. The total volatile organic compound (TVOC) metric is representative of all airborne indoor air VOC concentrations and should not be used as a direct indicator of health. The simplified metric is used as an indicator for the purposes of ventilation control strategies. As an alternative to the TVOC limit, individual VOC limits may be used where justified in accordance with the guidance in paragraph B3.

B3 As an alternative to using TVOC, the individual VOCs may be applied where their use is supported by robust independent evidence. Public Health England's *Indoor Air Quality Guidelines for Selected Volatile Organic Compounds (VOCs) in the UK* should be used. Testing against these metrics is likely to be more complex than testing against TVOC.

Where the Health and Safety Executive gives guidance for specific situations, that guidance should be followed in preference to the guidance given here.

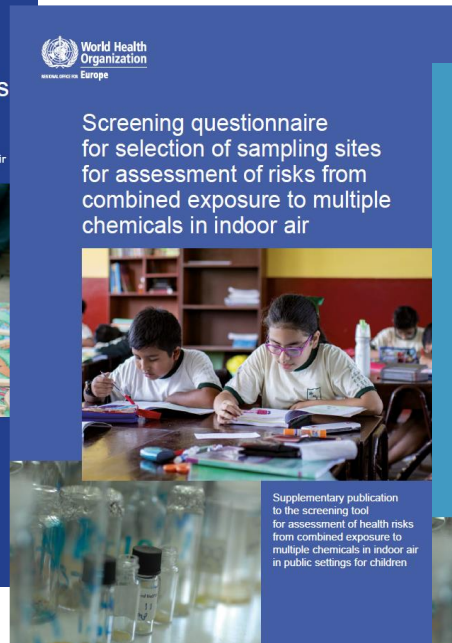
28 Approved Document F Volume 2, 2021 edition Building Regulations 2010 ONLINE VERSION

WHO – assessment of combined exposure of children in schools



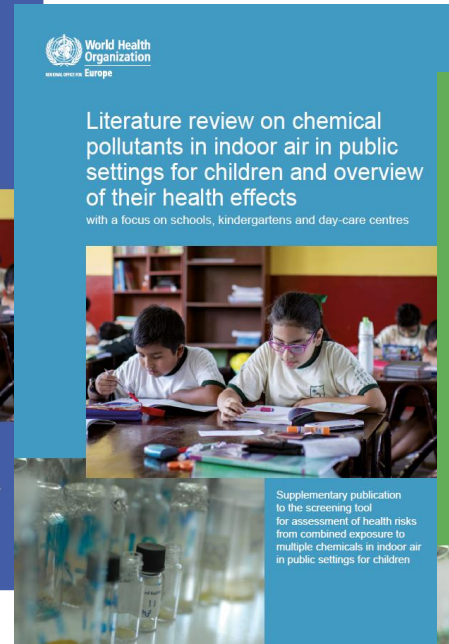
WHO (2020)

<https://apps.who.int/iris/bitstream/handle/10665/334389/9789289055239-eng.pdf>



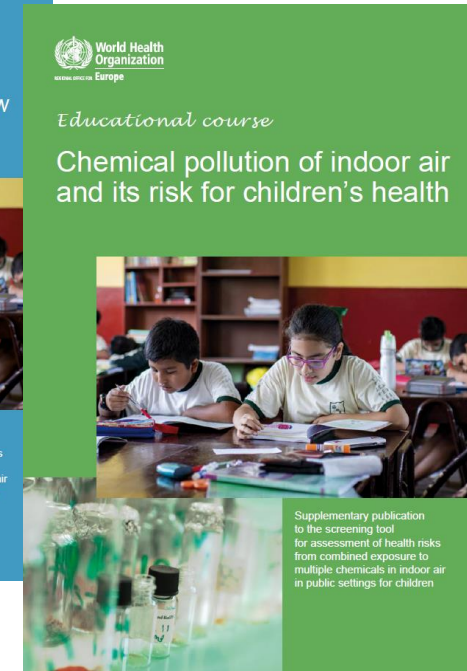
WHO (2021)

<https://apps.who.int/iris/handle/10665/341466>



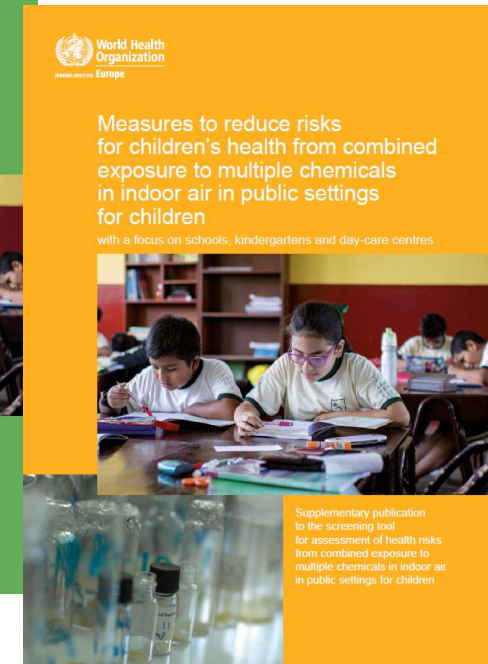
WHO (2021)

<https://iris.who.int/handle/10665/341467>



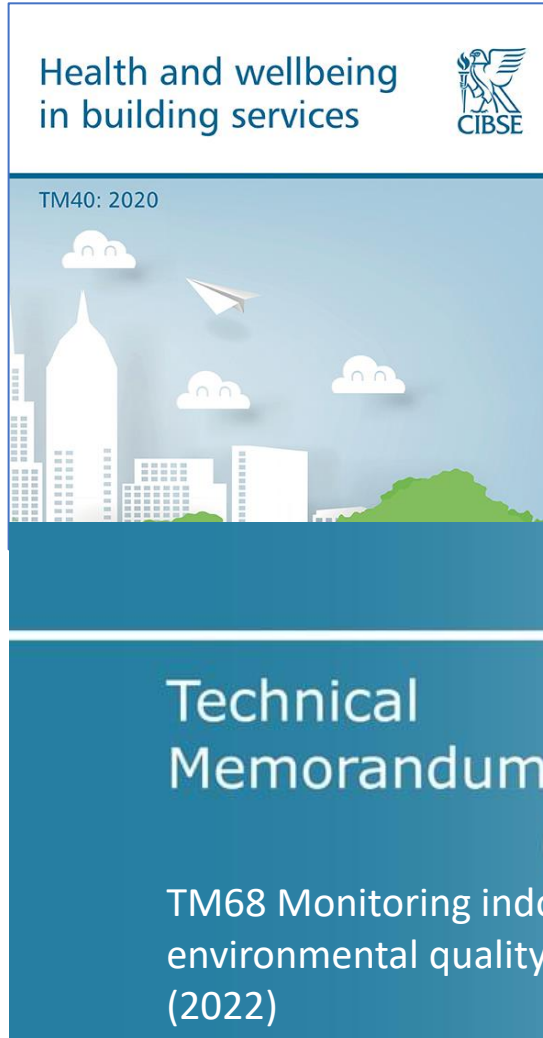
WHO (2021)

<https://iris.who.int/bitstream/handle/10665/341984/9789289055628-eng.pdf>



WHO (2022)

<https://www.who.int/europe/publications/i/item/9789289057974>



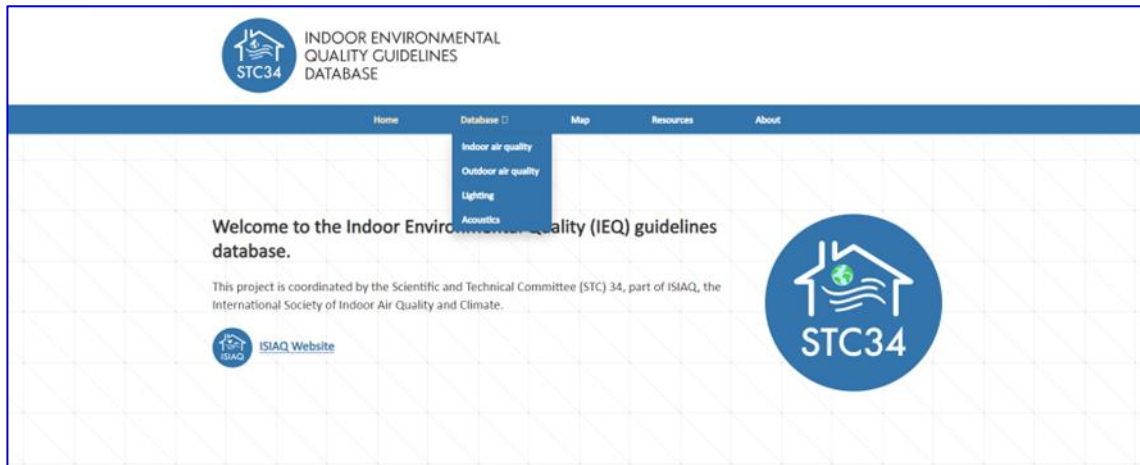
CIBSE Knowledge Generation Panel



Revision of TM57, including:

- revised chapter on overheating
- new chapter on IAQ

ISIAQ – International Society of IAQ and Climate - Indoor Environmental Quality open database



<https://ieqguidelines.org/>

An ISIAQ Scientific and Technical Committee (STC34) was officially launched in September 2020.

Since then, the committee has created an open IEQ guideline database, held regular online meetings, and organized workshops at ISIAQ conferences.

Toyinbo O, et al., on behalf of the STC 34 / ISIAQ, 2022. Open database for international and national indoor environmental quality guidelines. Editorial; Indoor Air. 2022;32:e13028. <https://doi.org/10.1111/ina.13028>

Dimitroulopoulou S, et al., 2023. Indoor Air Quality Guidelines from across the world: An appraisal considering energy saving, health, productivity and comfort. Environment International, 178, 108127 <https://doi.org/10.1016/j.envint.2023.108127>

UKHSA research on air quality around schools

Environmental Research 196 (2021) 110817



Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres



Review article

Air quality around schools: Part I - A comprehensive literature review across high-income countries

Stephanie Osborne, Onyekachi Uche, Christina Mitsakou, Karen Exley, Sani Dimitroulopoulou *

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Environmental Research 197 (2021) 111038



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Air quality around schools: Part II - Mapping PM_{2.5} concentrations and inequality analysis

Stephanie Osborne, Onyekachi Uche, Christina Mitsakou, Karen Exley, Sani Dimitroulopoulou *

Air Quality & Public Health Group, Environmental Hazards and Emergencies Department, Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Harwell Science and Innovation Campus, Chilton, Oxon, OX11 0RQ, UK



Interventions to mitigate exposure:

- Clean air zones around schools
- Green infrastructure
- School site selection
- Active travel to and from school
- Playtime outside of rush hours
- Follow a holistic approach, tackling emissions and mitigating exposures

The analysis highlighted that:

- large number of children (in approximately one third of schools - 7,801) in England are experiencing poor air quality outside their school;
- this happens disproportionately for children from low-income families and ethnic minority backgrounds.

New funded research

Funding opportunity

Realising the health co-benefits of the transition to net zero

Opportunity status:	Closed
Funders:	UK Research and Innovation, Arts and Humanities Research Council (AHRC) , Biotechnology and Biological Sciences Research Council (BBSRC) , Economic and Social Research Council (ESRC) , Engineering and Physical Sciences Research Council (EPSRC) , Medical Research Council (MRC) , Natural Environment Research Council (NERC) , Science and Technology Facilities Council (STFC)
Co-funders:	National Institute for Health and Care Research (NIHR)
Funding type:	Grant
Total fund:	£30,000,000
Maximum award:	£6,000,000
Publication date:	12 September 2023
Opening date:	12 September 2023 9:00am UK time
Closing date:	14 November 2023 4:00pm UK time

Last updated: 13 October 2023 - [see all updates](#)

Apply for funding to lead a transdisciplinary research hub towards realising the health co-benefits of the UK transition to net zero

Timeline

- 12 September 2023 9:00am
Opening date
- 5 October 2023 3:00pm
Webinar
- 14 November 2023 4:00pm
Mandatory expression of interest deadline closing date
- 12 and 13 December 2023
Workshop event
- To be confirmed
Full application deadline
- April or May 2024
Panel meeting
- June 2024
Decisions communicated

<https://www.ukri.org/opportunity/realising-the-health-co-benefits-of-the-transition-to-net-zero/>

5 Challenge areas:

.....

Indoor environments in a net zero world

The Child And Adolescent Health Impacts Of Learning Indoor Environments Under Net Zero : The Chili Hub

Government + Industry + Academia:
We produce our best
when we ALL work together

Thank you

Sani.Dimitroulopoulou@ukhsa.gov.uk



UK Health
Security
Agency



Impact of indoor environmental quality in educational buildings on health, wellbeing, and performance

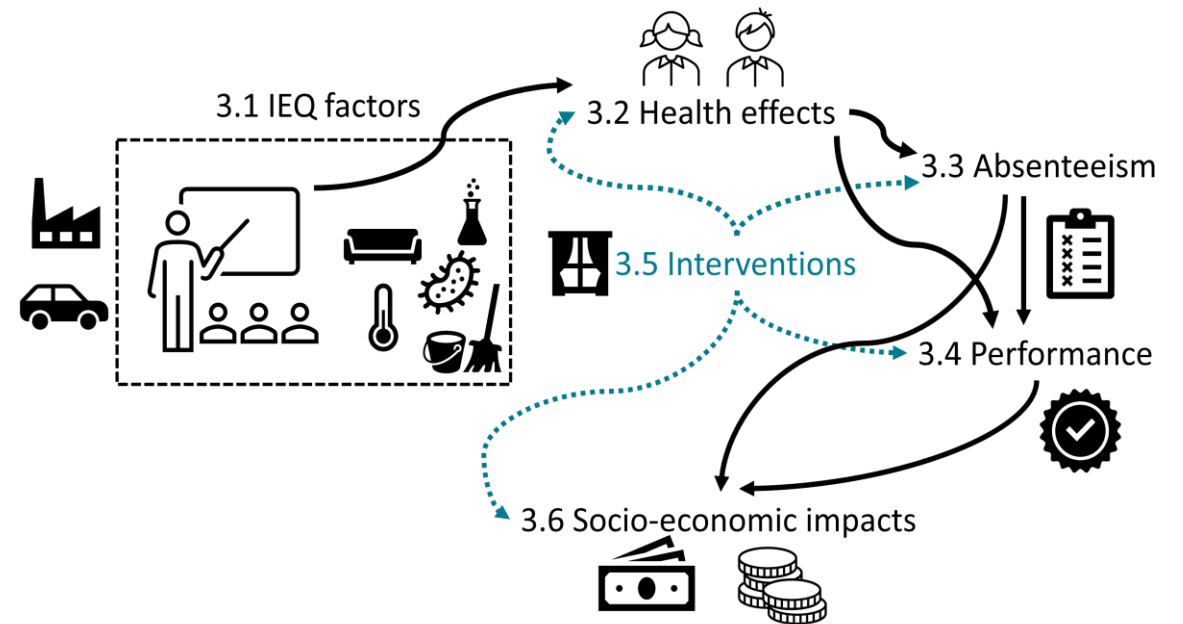
Duncan Grassie, Kaja Milczewska, Sani Dimitroulopoulou

Air Quality and Public Health,
Radiation, Chemicals, Climate and Environmental Hazards Directorate
UK Health Security Agency

IAQmatters Conference, London, 22 January 2025

Background

- 30% of a child's waking hours spent in educational buildings – a key setting for environmental exposures.
- Exposure to air quality, thermal, audio and visual aspects of indoor environmental quality (IEQ) can impact young people's health and wellbeing
- Links also to absenteeism and academic performance
- Interventions required to improve IEQ and energy efficiency to reach net-zero carbon and GHG emission targets.



Scope of the study



- To identify impact of IEQ on health, wellbeing, absenteeism and performance in educational settings
- Focus on IAQ, ventilation, thermal comfort, noise (related to ventilation)
 - Indoor sources of pollutants
 - Infiltration of traffic-related air pollution (TRAP)
 - Hygrothermal conditions
- To identify interventions for controlling IEQ
- To quantify monetary gains (or losses) associated with interventions

Key literature reviews	Topic
Toyinbo et al. 2023	Ventilation and health
Sadrizadeh et al. 2022	Academic outcomes
Gartland et al. 2022	TRAP
Osborne et al. 2021	Outdoor pollution exposure
Vakalis et al. 2019	Green schools
Fisk et al. 2017	Ventilation and student performance
Salthammer et al. 2016	Indoor and outdoor, climate change
Wargocki et al. 2013	Temperature & IAQ vs performance
Annesi-Maesano et al. 2013	Health effects
Mendell and Heath, 2005	Student performance

Methodology of scoping literature review

	Included	Excluded
Type of building	Educational building, Classroom, Exam hall, School, Nursery, University	Residential settings Recreational facilities
Type of occupants	Students, Pupils, Toddlers, Children	Occupational exposure studies, staff.
Environmental conditions	Indoor environmental quality (IEQ), Indoor air quality (IAQ) / pollution, Thermal comfort, Ventilation, Heating, Cooling, Carbon dioxide (CO ₂), Particulate matter (PM), Nitrogen dioxide (NO ₂), Temperature, Relative humidity, Allergens, Volatile organic compounds (VOCs), Radon, Noise from ventilation system, External noise	
Health impacts	Respiratory disease (Asthma, Allergies, Transmission of airborne disease, COVID-19, Influenza), Irritation, Neurological/ dizziness/ fatigue	
Attainment	Absences, Exams, Standardised scoring tests	
Impact of climate change policy	Retrofit/retrofitting, Energy efficiency, Net zero	

- Scoping review initiated through UKHSA's Knowledge and Library Service
 - OVID Medline, Embase & Scopus databases
- Eurovent expert panel provided papers and grey literature
- Considered high-income countries only

Summary of literature review

Stage 1: Initial search by KLS

Ovid Medline, Embase, Scopus
7,600 records identified

Stage 2: Exclusion criteria applied:

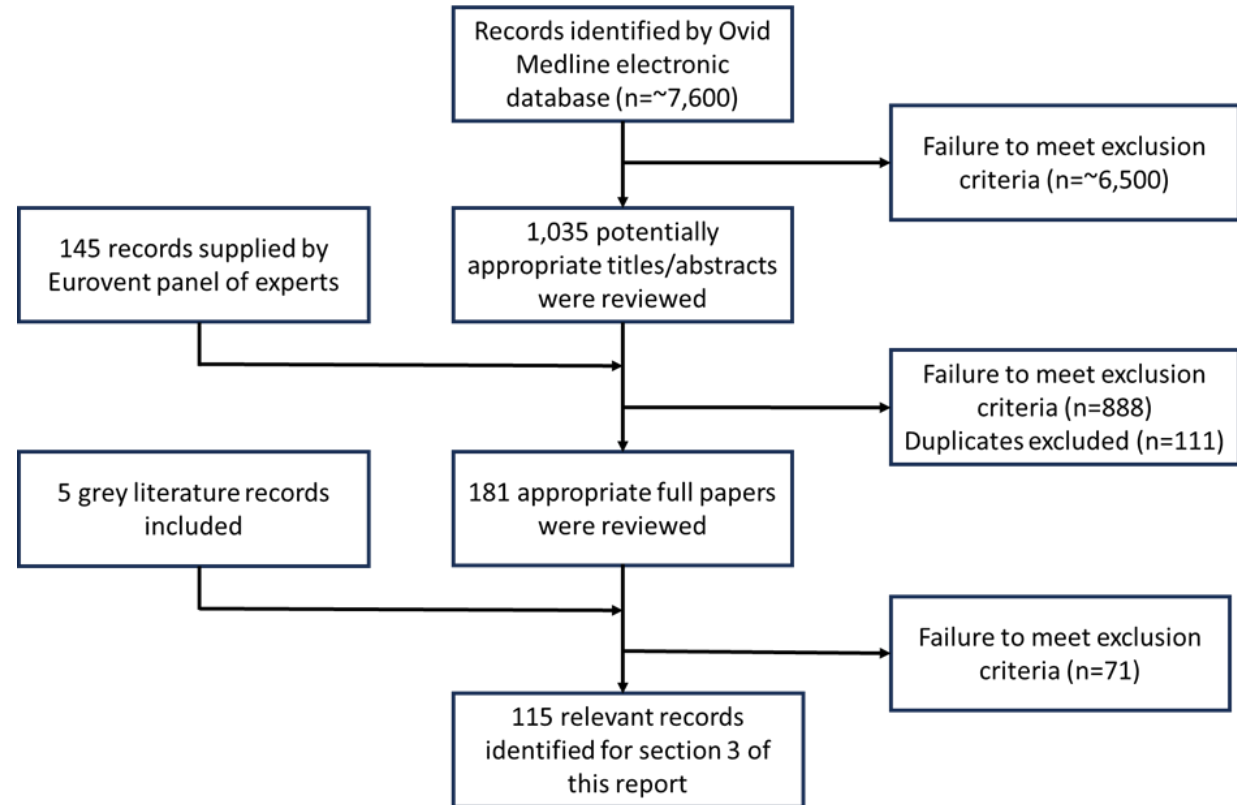
1,035 records remained
145 records added by Eurovent

Stage 3: Review on title & abstract:

181 records remained

Stage 4: Review on full text

115 relevant records identified



IEQ factors, sources and exposures

Challenge: Isolating school effects from other environments (outdoor, domestic)

- Spatial
 - Proximity to industrial sites, roads
 - Orientation, design of buildings
- Non-spatial
 - Easier to mitigate, possibly not by staff/pupils
 - Use of building, cleaning, furnishing materials
 - Heating/cooling systems
- Air pollution exposures can be dependent on, e.g.,
 - Indoor and traffic-related air pollutants
 - Damp and mould, poorly ventilated conditions



IEQ factors: Ventilation

Types:

- Natural: Dominant in US, S. Europe, pre-1980s
- Mechanical: Similar % to natural ventilation in Nordics, dominant in modern buildings

Guidelines:

- Scientific Technical Committee 34 (STC34) developed a worldwide database
- Building Bulletin 101 (Department for Education, 2018) limits daily average CO₂ concentration while occupied to 1500 ppm (natural), 1000 ppm (mech).
- During Covid, UK HSE (Health and Safety Executive) doubled minimum fresh air supply guidelines



Health effects and pollutants

Pollutant	Symptoms
NO ₂	Irritative cough, wheezing, decreased lung function
O ₃	Irritative cough, decreased lung function
PM _{2.5}	Irritative cough, airway inflammation, slower cognitive development, increased risk of asthma symptoms
PM ₁₀	Lifetime allergic rhinitis
VOCs	Irritative cough, wheezing, nasal symptoms, increased risk of asthma symptoms, allergic rhinitis, neuro-physical development (PAHs), carcinogenic (e.g., Benzene, formaldehyde),
Mould	Eye/throat irritation, headache, concentration problems, dizziness

Key publications: (a) The Inside Story (RCPCH, 2020), (b) Literature review on chemical pollutants in indoor air in public settings for children and overview of their health effects (WHO, 2020)

Individual studies on:

- a) Mechanisms, e.g., narrowing of retinal blood vessels due to fine particles, causing inflammation.
- b) Mitigations, e.g., dermatitis decreased by ventilation/baking out new school buildings.
- c) Limits: e.g. Increased symptoms from extra NO₂, O₃ exposure, even when below threshold.

Absenteeism: building-related factors

- Behind effect of acoustics on cognitive performance, absenteeism is most analysed impact.
- Associations recorded with:
 - Temperature: 1.28-fold increase when 27-30 °C
 - Ventilation rate: 1.6% to 5.8% decrease of absences for 1 l/s/person increase
 - CO₂: Often used to demonstrate ventilation effectiveness.
- Mould/allergen impact often driven by confounding factors:
 - Age of building, absences caused by home rather than school environment, vermin issues



Absenteeism: Relationships with pollutants

Pollutant	Study	Details	Relationship with absenteeism
PM ₁₀	Marcon et al. (2014)	Absenteeism at school near cement factory in Italy	10 µg/m ³ increase over 5 days associated with 2.4% (CI = 1.2-3.5%) rise in absenteeism 2 days later. Driven by longer exposures rather than peak.
PM _{2.5}	Deng et al. (2021)	85 elementary classrooms, Midwest USA	3% increase in illness-related absenteeism with 1,000,000 counts/l PM _{2.5} increase (heating season)
	Deng et al. (2023)	144 classrooms, 31 schools, Midwest USA	Mean indoor PM _{2.5} is 3.6µg/m ³ , every additional 1 µg/m ³ increase associated with 7.36 increase in days with absences / year
SO ₂	Ponka (1990)	Day care, nurseries, offices, Helsinki, Finland	Correlation with day care absences only, despite significant correlation between SO ₂ and reported URIs (p<0.0001) and tonsillitis (p=0.0098). 2-day lag correlation highest (exposure to onset)
NO ₂	Ponka (1990)	Day care, nurseries, offices, Helsinki, Finland	No correlation with absences, significant correlation between NO ₂ and URIs from health centres (p=0.0225).
	Pilotto et al. (1997)	41 classrooms: 4 electric, 4 gas-heated Focus on short term hourly peak levels of NO ₂	Short, hourly NO ₂ peaks of ~80 ppb, (20 ppb ambient), caused respiratory absences, significant dose-response relationships as NO ₂ increased. During heating period, cold symptoms last >7 days (average) when highly exposed rather than 4 days.
Mould	Simons et al. (2009)	Condition & absentee data for 2751 New York schools	Where visible mould was reported, OR = 2.22 (CI = 1.34-3.68)

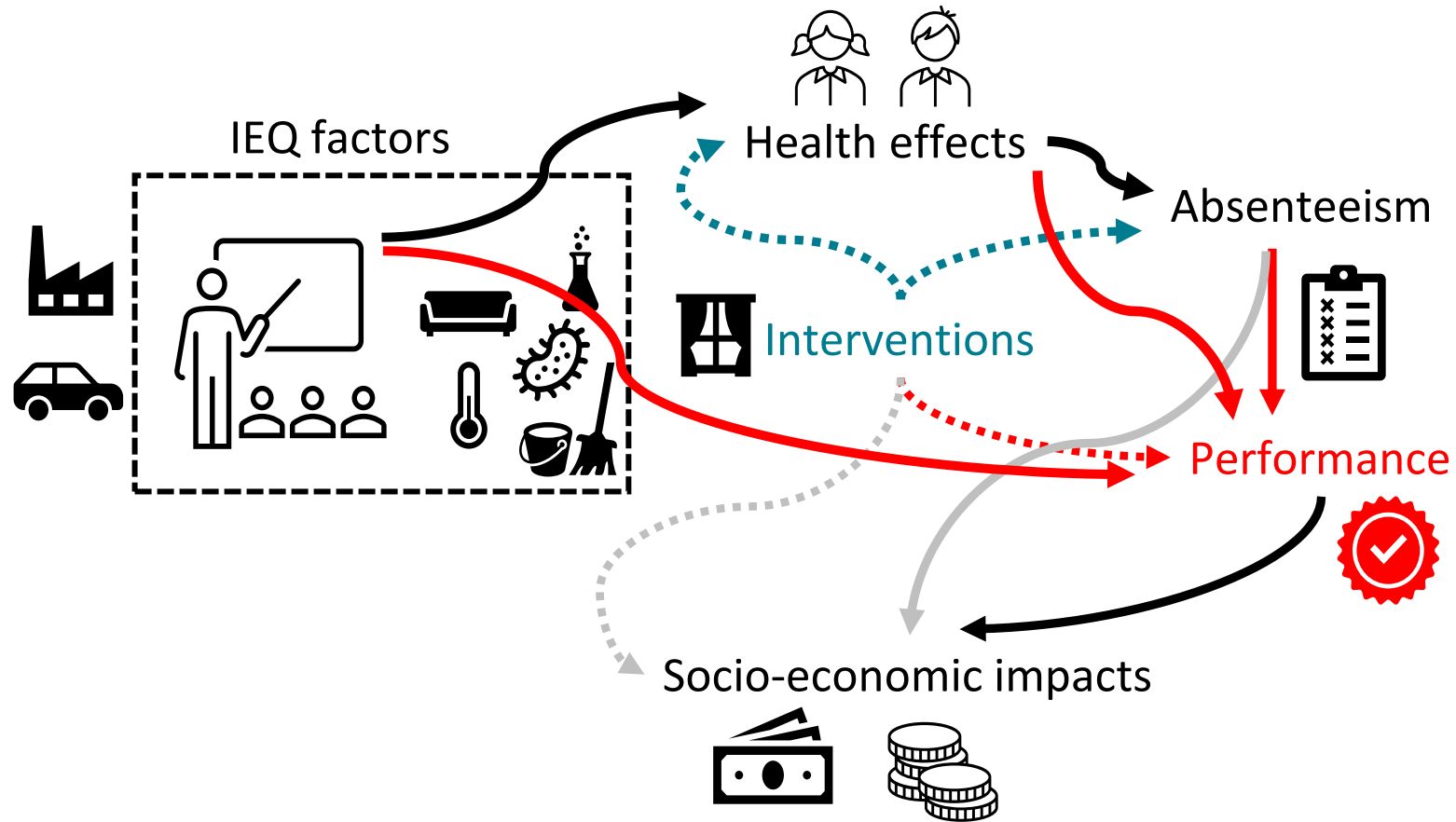
- Relationships relate to indoor concentrations of pollutants, rather than outdoor
- No significant studies relating to VOCs causing absenteeism
- Longer exposures to PM, drive absences 2 days later
- Short peaks of NO₂ may cause respiratory absences.

Absenteeism: Incorporating within analysis



- Definition of “Absenteeism” is a key consideration:
 - Illness-related?
 - Non-illness related found to have a stronger link to performance
 - High absenteeism may be a symptom of deprivation rather than of poor IEQ
- Quantifying relationships from studies, either:
 - Consider an individual aspect of poor IEQ (e.g. particulate matter), or
 - IEQ is quantified from a number of factors using a numerical index

Academic performance



Academic performance: Methods of measuring

- Long-term attainment (e.g., exam results, standardised test scores, GPA)
 - School- or district-wide
 - Standard school subjects
 - Measuring long term impact of interventions
- Controlled tests of executive function
 - Short-term impact of interventions
 - Numerical or language-based tests
 - Concentration, cognitive flexibility, working memory, attention, episodic memory, visual processing speed, reaction time, non-verbal reasoning, and coordination

Academic performance

IAQ:

- **PM:** working memory, attention, and other cognitive outcomes
- **Reduction of PM and NO₂** associated with improved speed on some tasks (not error rate).
- Lower cognitive development in children attending schools in **highly polluted areas (NO₂, EC and UFP)**

Temperature:

- **High temperatures** negatively affect alertness & working memory;
- **Low temperatures** negatively affect executive ability, mental workload, alertness, mental fatigue
- Performance of psychological tests expected to increase by 20% with classroom temperatures lowered from 30°C to 20°C
- Optimal $T \leq 22^{\circ}$ **

Ventilation:

- 2x outdoor air supply rate could improve task completion speed by 8 to 14%
- Significant association between VR and maths scores.
- **Higher national test scores** for pupils in schools with **mechanical ventilation** than those with only natural ventilation.
- Increasing from 2 to 7.5 l/s per person could improve performance in national tests by 5%, and attendance by 1.5%
- Increased ventilation improves short-term IAQ – effects on neurologic symptoms and decision-making.

Secondary effects:

- Absenteeism: decreased number of teaching hours does not always lead to lower attainment.
- Illness- vs non-illness-related

Interventions

- source control: minimising both indoor and outdoor sources
- providing adequate, controlled, and well-maintained ventilation
- using air purifiers;
- employing energy efficient systems for HVAC



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Daily Mail / Georgie Gillard



Peter Dazeley / Getty Images / The Guardian



Wikipedia

Interventions – source control

- Minimisation of indoor pollutant emissions sources
 - Aldehydes
 - VOCs (e.g., aromatic or chlorinated hydrocarbons, esters, terpenes, PAH)
 - SVOCs (e.g., PAHs)
 - inorganic compounds
- **Continuous sources:**
 - Furniture, floor/wall/ceiling coverings, curtains, varnishes and paint, plastics, formaldehyde resins and glues
- **Intermittent sources:**
 - Class activities (e.g., labs, art class), printers, computers, blackboards, cleaning products, pesticides
- Using smaller quantities of emission sources
- Replacing with certified “green” substitutes or low-emission and solvent-free products
- Temperature and RH (40 – 55%) control
 - Renovation: elimination of microbes and fungi in damp buildings
- Density of occupants – CO₂ and bioeffluents

Methods for sampling and analysis of chemical pollutants in indoor air



Supplementary publication to the screening tool for assessment of health risks from combined exposure to multiple chemicals in indoor air in public settings for children

Measures to reduce risks for children's health from combined exposure to multiple chemicals in indoor air in public settings for children

with a focus on schools, kindergartens and day-care centres



Supplementary publication to the screening tool for assessment of health risks from combined exposure to multiple chemicals in indoor air in public settings for children

Source control in schools

(based on WHO (2020; 2022))

Table 2. Source control of pollutant emissions from indoor sources (based on WHO, 2022)

Potential indoor sources	Pollutants	Source control / mitigation measures
Furniture and wooden products (for example, pressed board, plywood, particle board, fibreboard furniture, flooring, panelling, doors)	formaldehyde, acetaldehyde, benzene, α -pinene	Choose certified, eco-labelled materials with low VOC emissions for floor/wall/ceiling coverings and furniture
Flooring materials (e.g., PVC flooring with adhesive, carpet backings)	formaldehyde, acetaldehyde, benzene, ethylbenzene, xylenes, styrene, toluene	- Implement renovations and refurbishments in the first month of the summer holiday - Use woven or knotted textile carpets instead of synthetic ones
Wall paints, solvent-based (water-resistant)	benzene, xylenes, styrene, toluene	Implement renovations and refurbishments in the first month of the summer holiday - Use water-based paints
DIY products (for example, solvents, paints, wallpapers, glues, adhesives, varnishes, lacquers)	formaldehyde, acetaldehyde, benzene, ethylbenzene, trimethylbenzene, xylenes, styrene, toluene, tetrachloroethylene trichloroethylene, n-butyl-acetate, naphthalene, benzo(a)pyrene	- Implement renovations and refurbishments in the first month of the summer holiday - Use smaller quantities of or green alternatives to paints, solvents, adhesives and science laboratory chemicals - Increase ventilation, e.g., open windows when working with chemicals
Painted or varnished coatings	benzene, ethylbenzene, xylenes, toluene, dichlorobenzene, n-butyl-acetate	Choose certified, eco-labelled materials Limit the use of chemical products
Paint and varnish removers	α -pinene,	Choose certified, eco-labelled materials
stain removers, wood cleaners	tetrachloroethylene, trichloroethylene	Limit the use of chemical products
Electronic equipment (e.g., photocopy machines)	formaldehyde, acetaldehyde	Place photocopiers and printers in separately ventilated rooms
Plastics	trimethylbenzene, styrene	
New books, magazines, newspapers	formaldehyde, toluene	Locate in dedicated rooms /library, well ventilated
Cleaning products and disinfectants	formaldehyde, trimethylbenzene, toluene, limonene, α -pinene, trichloroethylene naphthalene	Use fragrance-free cleaning materials
Dry-cleaned textiles, curtains, carpets	tetrachloroethylene	Use washable textiles for classrooms instead of textiles that require dry-cleaning
Air fresheners	dichlorobenzene, limonene	Do not use air fresheners in classrooms,
Human activities (cooking)	formaldehyde, acetaldehyde, benzo(a) pyrene	Install extractor fans in kitchens to be on during cooking activity
Secondary formation	formaldehyde, acetaldehyde	Reduce ozone emissions indoors

Interventions

- Source control as a first step.
- Mechanical ventilation can:
 - help achieve a desired air flow rate
 - decrease concentrations of indoor pollutants (e.g., PM₁₀, formaldehyde, TVOC) by up to 45% ([Choo et al., 2014](#))
 - reduce PM_{2.5} and UFP concentrations by up to 43%, if system is operated 1 hour before start of rush-hour traffic ([Fernandes et al., 2023](#))
 - contribute significantly to the building's energy budget ([Toyinbo, 2023](#); [Salthammer, 2016](#))
- Air cleaning technologies
 - High MERV (e.g., HEPA) filters in tandem with HVAC air recirculation can be very effective
 - Standalone air purifiers can decrease PM concentrations in classrooms and daycare centres by 35 – 86% ([Fernandes et al., 2023](#), [Shree et al., 2024](#))
 - Reduction of fungal spore counts with HEPA filter

Interventions – associations with outcomes

- Limited and inconsistent evidence for whether the reduction of pollutants through air filtration is associated with impacts on academic performance and/or absenteeism ([Vakalis et al., 2021](#))
- Doubling outdoor air supply rate improved school task completion speed; using electrostatic air filters had no significant effect – is this due to PM or NO₂? ([Wargocki & Wyon., 2017](#))
- Significant positive effect on cognitive performance after 1 hour of NAI intervention in college students (reasoning skills, short-term memory) – suggested due to reduction in PM ([Guo et al., 2023](#))
- Evidence of associations between VR and illness-related absenteeism ([Mendell et al., 2013](#))
- Estimated reduction in relative risk of infection and less coughing with air purifiers present ([Banholzer et al., 2024](#))
- Ventilation interventions reducing pet-related allergens associated with reduced asthma symptoms ([Salo, 2009](#))
- HEPA filters in classrooms improved FEV1% test results by ~ 4% ([Vesper et al., 2023](#))

Intervention studies: limitations

- Some inconsistent findings, dependent on study design, quality and strength
- Confounders e.g., socio-economic status
- Attribution of improved performance from air cleaning without fully understanding effectiveness
- Intervention studies may not give enough time for potential outcomes to become evident.



Quantifying economic benefit

- Cost benefit analysis should incorporate:
 - Inputs: initial student health, social conditions, school site
 - Outputs: tangible, difficult to quantify attendance and performance outcomes
- Analysis of benefits:
 - Increased attendance-linked funding from ventilation improvements
 - 4 to 7.1 l/s/person -> 3.4% decrease in absenteeism -> \$33mil/yr. ([Mendell et al., 2013](#))
 - Reduced healthcare by following WHO PM guidelines in 25 EU countries
 - Improved lung function -> €31bil in healthcare saving ([Salthammer et al., 2016](#))
 - Country-level benefits: ventilation improvements (average -> building code)
 - Danish GDP increase of €173mil/yr., public finances €37mil/yr. for 20 years ([Wargocki et al., 2014](#))
 - Reduced teacher absences, completion of studies, performance improvement

Quantifying economic costs

- Analysis of individual costs:
 - % of school budget required for improvements
 - Energy/capital costs of improving HVAC/filtration <0.1% of US educational spend ([Fisk, 2017](#))
- Additional costs of increasing ventilation/air cleaning:
 - Operation: Heat (cool climates), dehumidify (warm) and drive air
 - Doubling ventilation from 2.8 -> 5.6 l/s/person increases energy by 37%, total by 26% ([Ito et al., 2010](#))
 - Design and construct systems
 - Basic (MERV5) to most efficient (MERV 14) filters has marginal cost of \$20-32/year/asthmatic student ([Martienes et al., 2018](#)), well below benefit of avoided asthma exacerbation of \$49-79



Current limitations to knowledge

- Relationships can be analysed but causal pathways are more challenging
 - Improved ventilation can improve health, however link to academic performance reliant on large number of contrasting factors (socio-economic, attendance)
 - Hard to isolate effect of individual pollutants (e.g., VOCs) on performance
 - Potential differences in attainment / performance due to pollutants from different sources (e.g., indoor-generated PM vs ingress of traffic-related PM from outdoors)
 - Few studies link consequences of poor IEQ through to economic costs/benefits
- Key challenges
 - Low availability of long-term measurements
 - Failure to report key details of study design in individual schools
 - Predominance of self-reported data over quantifiable health measurements

Key recommendations

- Implementation of current national regulations for ventilation.
- Eliminating or controlling sources of outdoor and indoor pollutants.
- Ensuring provision of adequate classroom ventilation, through hybrid or mechanical systems to conform, with existing ventilation guidance.
- Use of air cleaners in naturally ventilated buildings.
- Regular cleaning of classrooms and maintenance of air filters.
- Provisions for cooling indoor spaces during hot weather.
- Implementation of existing research findings into practice, in terms of both national regulation and local guidance, e.g., working with relevant stakeholders such as local authorities, headteachers and parent groups to encourage change.

Acknowledgements

- UKHSA Knowledge and Library Services, particularly Michael Cook
- Eurovent (Stijn Renneboog and Francesco Scuderi) for commissioning and funding the work.





UK Health
Security
Agency



EUROVENT
EUROPEAN INDUSTRY ASSOCIATION

Thank you for your attention

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Examples of select studies of IEQ vs performance

Study	Key question	Key findings
Gignac et al., 2021 High schools, Barcelona	Does purifying the air of classrooms produce short-term changes in attention?	No substantial difference found in median hit reaction time standard error (HRT-SE) and other secondary attention outcomes, despite short-term PM _{2.5} and BC concentrations reduced by up to 87% **
Sunyer et al., 2015 Primary schools, Barcelona	Chronic TRAP exposure effects on development of working memory.	Lower improvement in cognitive development (7.4%) in children attending highly-polluted than less polluted schools (11.5%). Working memory significantly affected by UFP.
Toftum et al., 2015 Elementary schools (Denmark)	Associations between ventilation mode and learning.	Higher national test scores for pupils in schools with mechanical ventilation than those with only natural ventilation. Lowest achievement indicator (Danish and maths), and highest CO ₂ concentrations found in naturally ventilated schools.
Wargocki et al., 2020 Elementary schools	Estimating the magnitude of effects of learning and sick-leave due to changes in classroom IAQ	School task performance speed improved by 12% and accuracy by 2% when CO ₂ reduced from 2100 ppm to 900 ppm. Improved performance in national tests by 5% and attendance by 1.5% upon increasing VR from 2 to 7.5 l/s per person.

CATHERINE NOAKES

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*'Understanding the effectiveness of air
cleaners in schools'*



UNIVERSITY OF LEEDS

Understanding the Effectiveness of Air Cleaners in Schools

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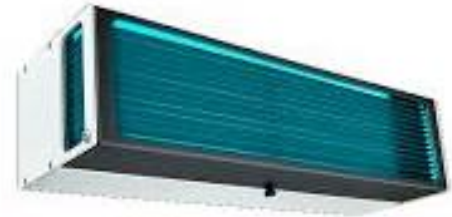
January 2025

Air cleaning technologies



Filter based

UVC based



What is the goal?

Reducing the transmission of infectious disease?
Reducing exposure to pollutants?

OR

Reducing absences from schools?

Which hazards? Which settings? Which people?

What evidence do we need for a given challenge?

What evidence is needed to take a decision to implement?

Approaches to understanding

- Lab scale data
 - Baseline safety and feasibility
- Room scale data – chambers, real-world
 - Impact on bioburden, particles
 - Noise, secondary emission
- Modelled Risks
 - Potential for exposure reduction
 - Interaction with airflows
 - Energy/cost-benefit

How do we
translate to
real world
health effects?

Putting humans in the loop

- Direct measurements from people recruited into studies
- Real-world
 - Homes, schools, workplaces, hospitals...
 - Measure the environments, data on health and wellbeing
 - Multiple exposures at the same time – need large data sets
- Case-control studies – backwards, observational, start with condition and compare settings
- Intervention trials – forwards, allocated to groups, look at outcomes

Designing a trial

Measures

- Infections
- Proxy for illness (absence, GP visits)
- Symptoms
- Self-reported or measured?

Participants

- Single group – before/after
- Comparable groups across settings
- Pupils/teachers
- Individuals or clusters?

Cofounders

- Infection rates
- Co-infection
- Built environment
- Environmental conditions
- Socio-economic factors
- User actions
- Devices

School environments

Pros

- Consistent - regularly attended by the same groups
- Well defined setting and people
- Places where infections are common

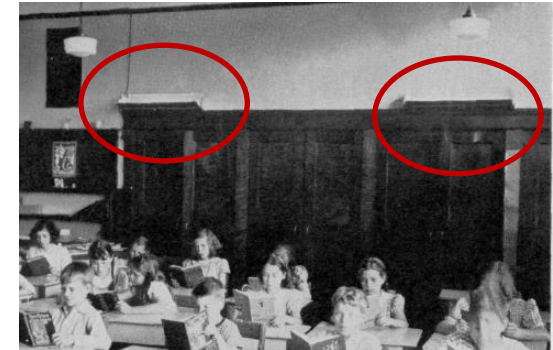
Cons

- Participants are children – consent and exposure issues
- Schools are overwhelmed with other things – research is a low priority
- The same children interact in other places

Early school studies

Wells et al 1937-41

- Two schools with primary (GUV) and upper classes
- Four + one study years + prior data
- Track measles, chicken pox, mumps

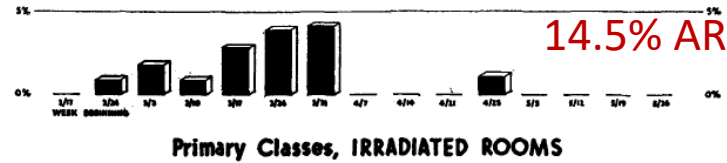


Wells et al, 1941

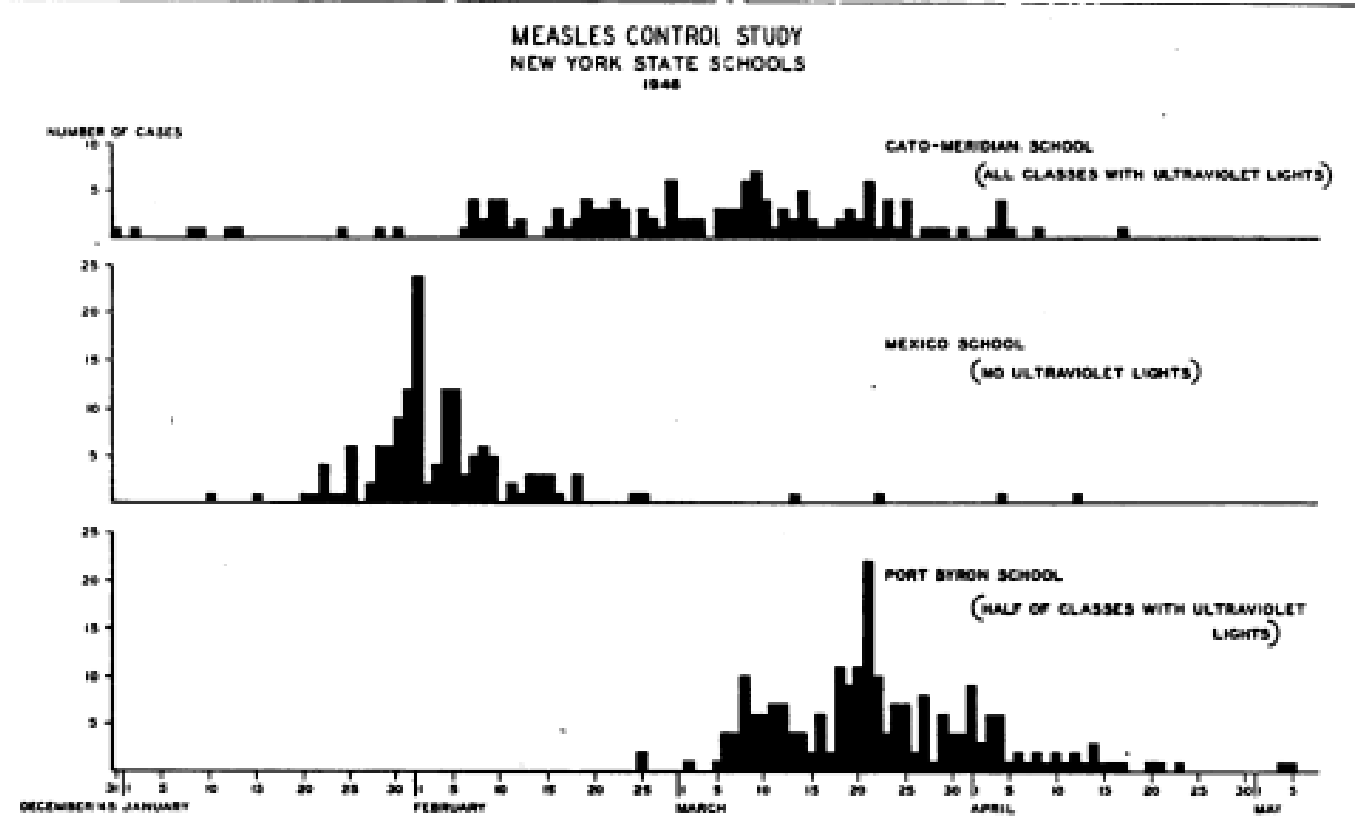
Perkins et al 1945-46

- Three schools, mechanically ventilated, one GUV, one partial GUV, one control
- Track cases of measles
- Many children travelled on buses

Wells et al Measles rates



Perkins et al Measles rates



Class ACT study

- 31 primary schools in Bradford – 335 classrooms
- Control group (11), HEPA filter group (10), UVC group (10)
- Measuring **IAQ parameters** in every room
- Measuring **illness absence** due to Covid-19
- Evaluating practicalities of implementing and using air cleaners



Selecting schools

Cluster study – unit of measure is school

- All naturally ventilated
- Majority 1.5 or 2 form entry
- Years 1-6 only – exclude Nursery and Early Years
- Groups balanced as far as possible by size, demographics, architecture
- Data analysis from Sept 2021-March2022

How many?

Estimate conservative reduction of 10% based on 1954 MRC study

Power calculation estimated min 92 classrooms per arm – increased to 120 for diversity of schools

Interventions

HEPA filters

- Sized to give 3-6ACH per room
- Typically 3 units per room

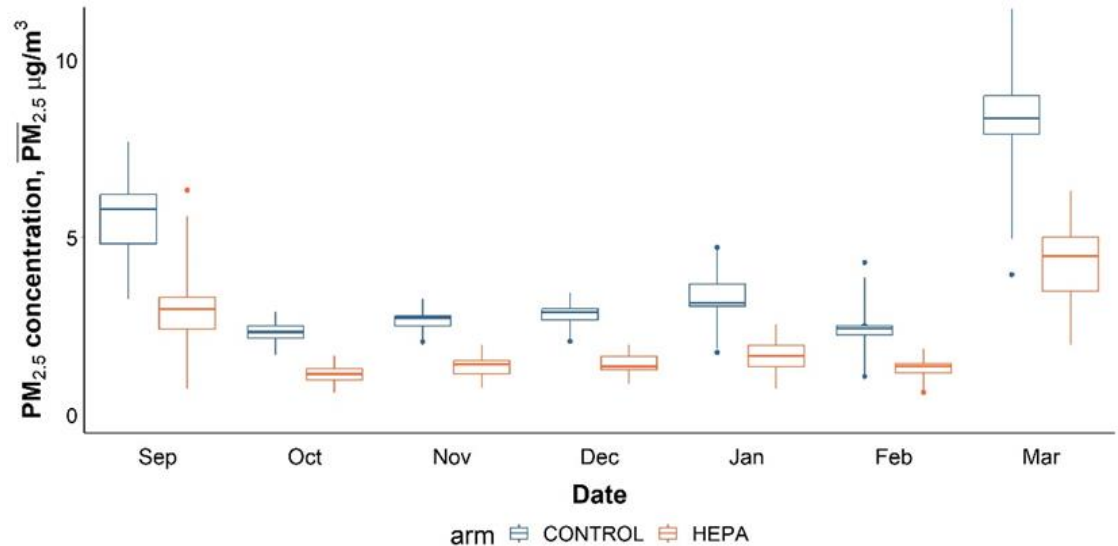
	Philips AC3033	
	CADR [m ³ /hr]	Sound level [dB[A]]
Sleep mode	62	15
Speed 1	160	31
Speed 2	290	42
Turbo mode	520	56

UVC units

- Initial plan for upper room to give 20 ACH
- Large % of rooms not suitable – move to active air at 4 ACH
- Installation and regulatory issues with UR GUV...

Filter effectiveness

- Filters remove particles and pathogens
- Comparable ventilation across groups
- Evidence for reduced illness risks
- Relatively low cost

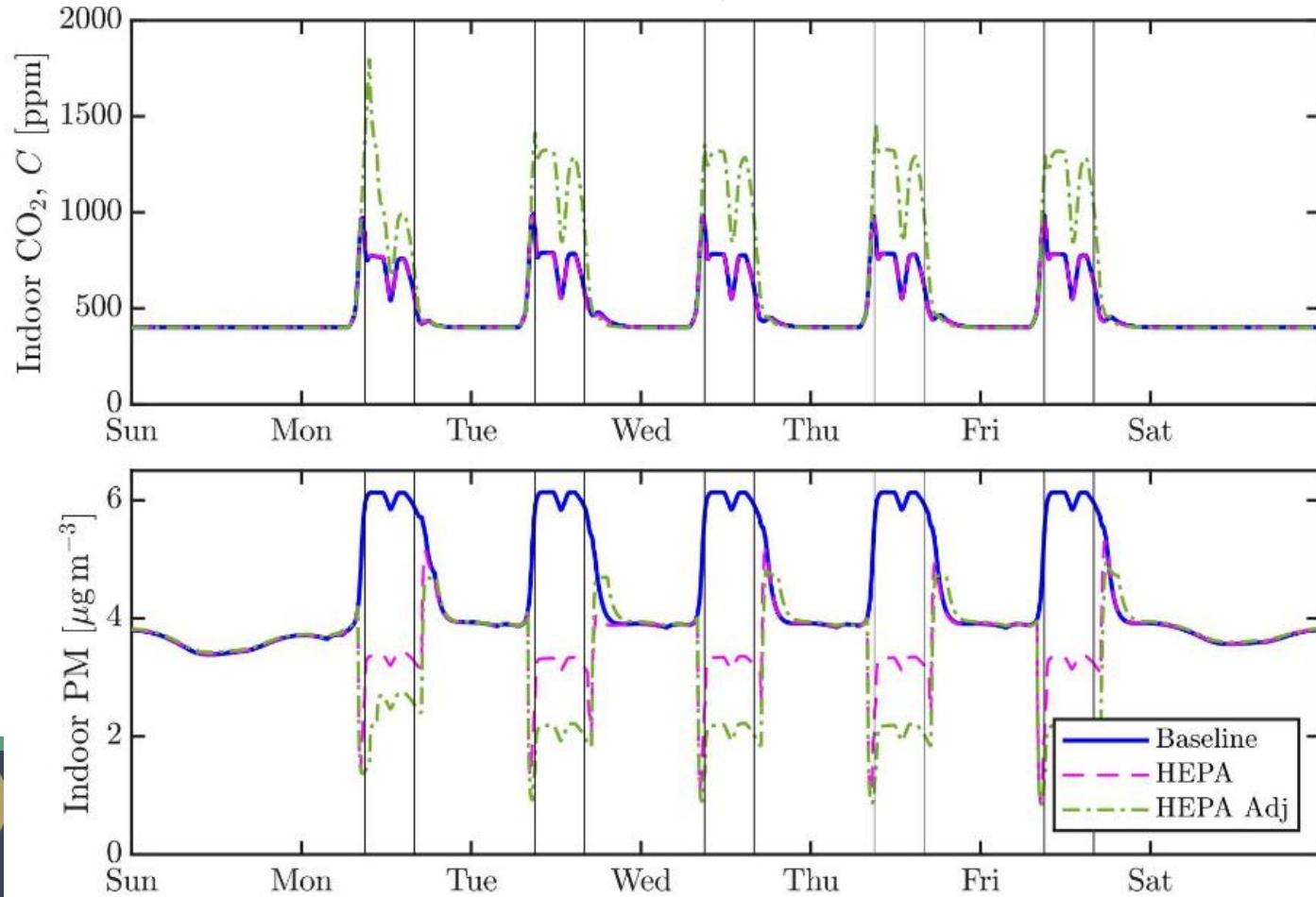


What about cost effectiveness?

- Fabric and ventilation dynamic thermal model
 - Natural ventilation, modern/Victorian
 - TRY weather data for Leeds/London
- Indoor air model
 - Concentration of CO₂, PM, viral RNA
 - Impact of HEPA filters + window opening
- Energy for heating/ventilation + HEPA

Burridge H et al, Coupled indoor air quality and dynamic thermal modelling to assess the potential impacts of standalone HEPA filter units in classrooms , Indoor Environment, Oct 2024

Impact of HEPA on IAQ



Model findings

- HEPA filters improve indoor air exposures
 - PM reduced 40-60%
 - Viral RNA reduced 30-50%
- Energy cost of HEPA filter 1-2% of classroom heating costs
- HEPA filter + reduced window opening can reduce heating costs by up to 46% with lower PM/RNA but higher CO₂
- Trade-off is important – model can help work out and support optimal balance

How hard can it be?

Capability

Knowledge, skills and abilities to engage in a behaviour

Awareness of importance of ventilation

Awareness of how to manage devices

Objects in devices

Opportunity

External factors which make a behaviour possible

Electrical power and plug sockets

Space in classrooms

Legislative gaps around upper room UVC

Motivation

Internal processes which influence decision making

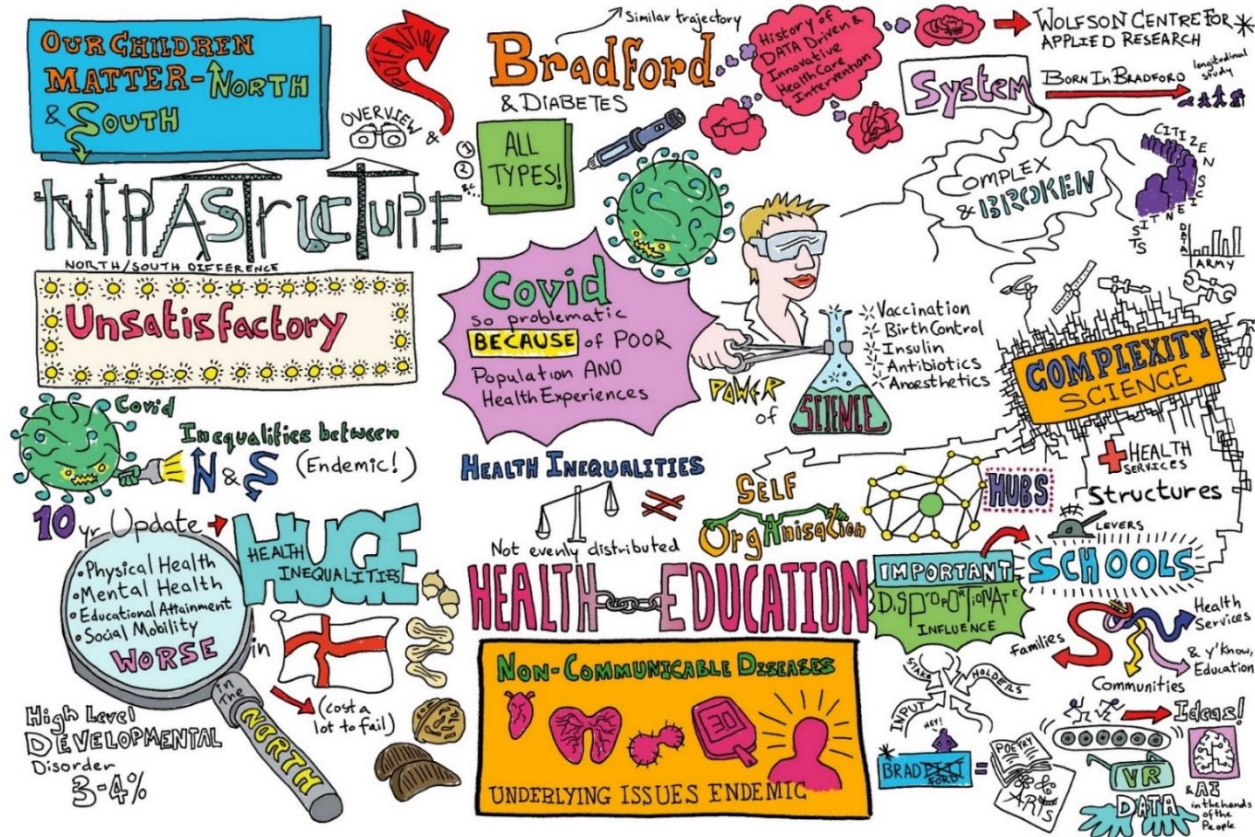
Other priorities for teachers and janitors

Switched UVC off due to noise and heat

Actual and perceived costs

What have we learned?

- We need data to understand real-world effects
- We lack good real-world data on harms and practicalities
- Intervention studies are necessary - but they are challenging
 - Study design needs stats and epi expertise in from the beginning
 - Collaboration to bring together the engineering/physics and health/biological aspects
 - Studies take time and resources to do well
 - We need effective engagement with study sites



Thank you to the Class-ACT team and all of our schools



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*'SAMHE air quality monitoring in more than
600 schools across the UK, including on
ventilation rates and indoor pollution levels'*

Imperial College
London

Air quality in UK schools

Dr Henry Burridge &
The SAMHE Team



SAMHE

SCHOOLS' AIR QUALITY MONITORING
FOR HEALTH AND EDUCATION

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What is SAMHE?

- **SAMHE** stands for **Schools' Air quality Monitoring for Health and Education**.
- **SAMHE** started in 2022 and is a research project working with UK schools to improve understanding of indoor air quality.
- **SAMHE** was started by a collaboration between Imperial College London, University of Cambridge, SEI/University of York, University of Surrey, University of Leeds, and the UK Health Security Agency

What is Air Quality and why does it matter?

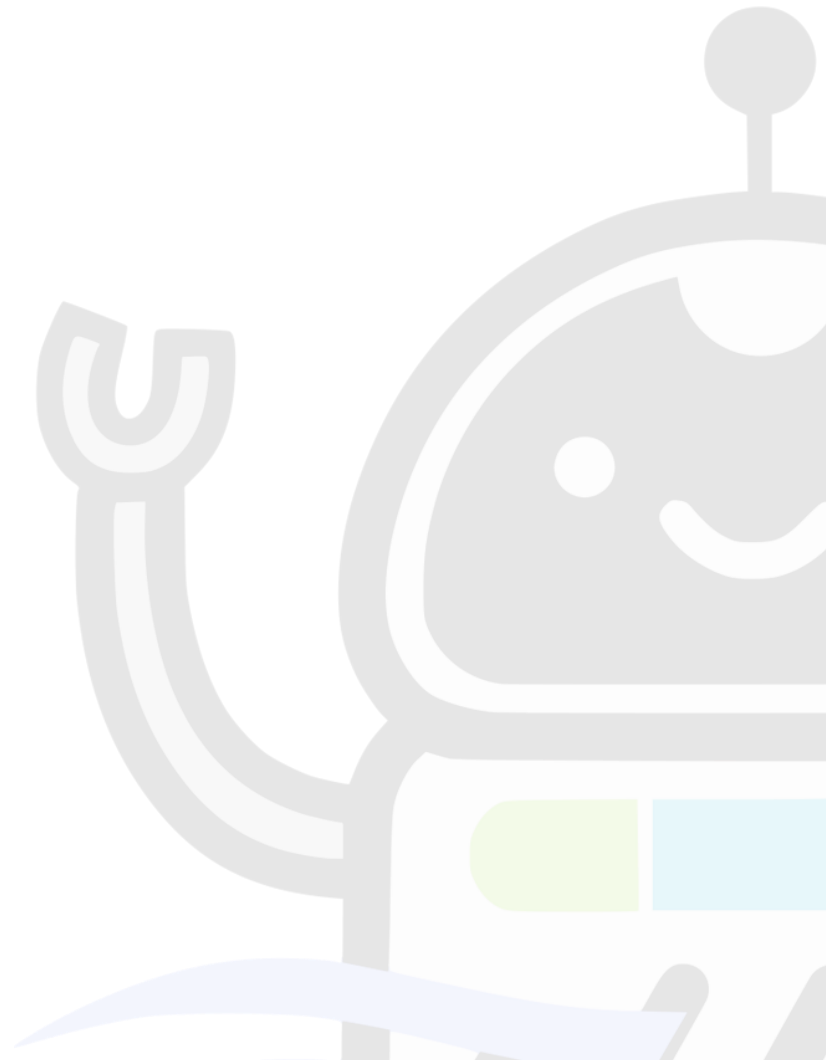
- Air quality describes how clean or polluted the air we breathe is.
- Indoor air quality is very important as most of us spend more than **80%** of our time indoors.
- High CO₂ levels indoors can cause drowsiness and impaired cognitive performance



How else does poor air quality affect us?

Poor air quality can affect our health and wellbeing. In particular, poor air quality is linked with:

- Impacts for the lungs and heart
- Making asthma worse
- Headaches and drowsiness
- Reduced ability to concentrate



How does SAMHE measure air quality?

To measure school air quality at scale, SAMHE uses citizen science. 1000+ schools have been sent air quality monitors which measure:



The SAMHE monitor

- Carbon Dioxide (CO₂)
- Relative Humidity
- Temperature
- Total Volatile Organic Compounds
- Particulate Matter (PM_{2.5})



The SAMHE method: working *with* schools

Schools received and set up a SAMHE monitor



SAMHE team set activities on the co-designed SAMHE Web App



Pupils complete fun activities (24), learning about air quality and inputting important contextual data



SAMHE scientists analyse data to report on air quality in UK classrooms, schools can download own data



SAMHE uses citizen science, why?

- **Allows us to gather real-world data from hundreds of classrooms**
- **Pupils and teachers gain knowledge and understanding of air quality**
- **Pupils gain skills in interpreting graphs, analysing data, doing experiments, writing creatively, etc.**
- **Pupils and staff can see the air quality in classrooms and know what action to take to improve it**
- **Collaborative co-design ensured the SAMHE Web App meets pupil and teachers' needs and that they use it!**



SAMHE engagement and reach



1321

Recruited
schools



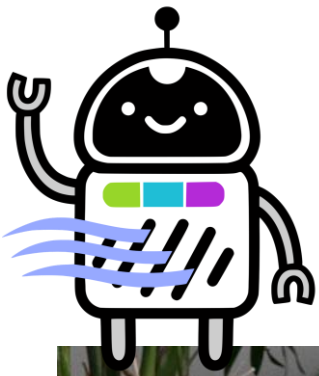
885

Monitors, in
584 schools,
have sent us
data



742

Monitors, in
428 schools,
still sending us
data



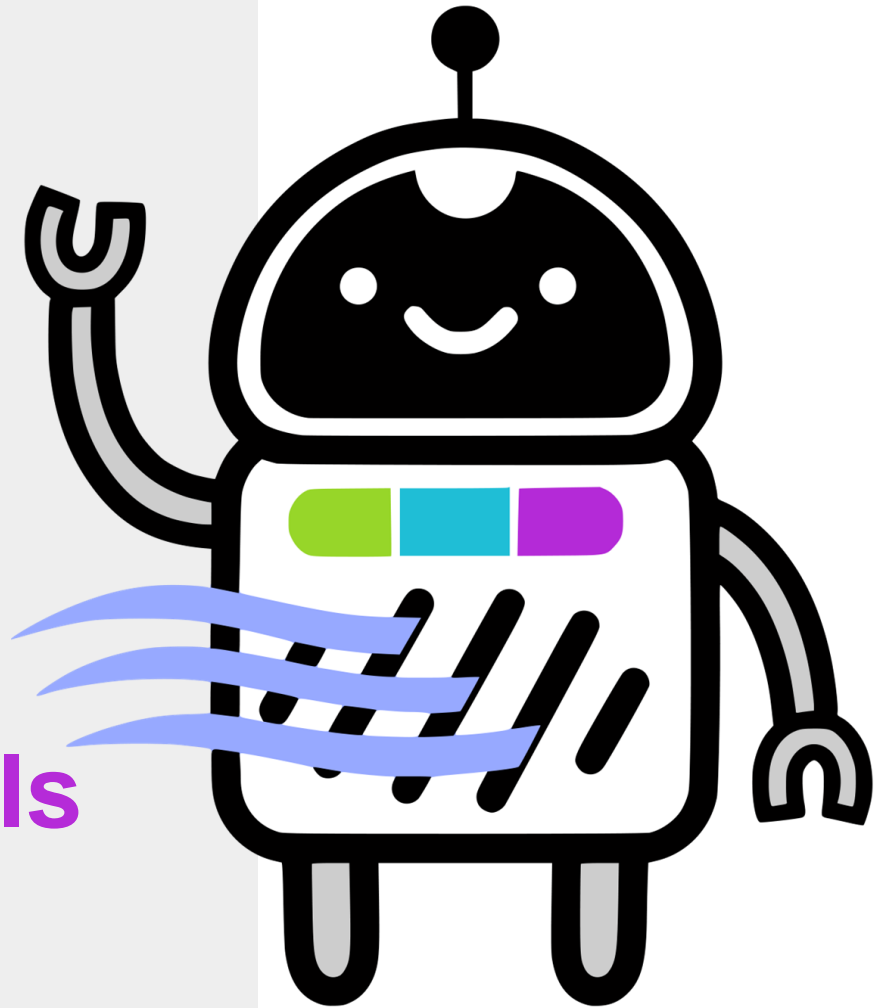
SAMHE: engagement to impact



- These monitors in schools are now gathering around 100,000 'school data days' every year
- Each 'school data day' provides a day's worth of measurements every minute of:
 - Carbon dioxide
 - Temperature
 - Humidity
 - Particulate Matter
 - TVOCs



SAMHE findings & recommendations for ventilation and air quality in schools



Why does ventilation matter?

Ventilation, the process of refreshing indoor air with air from outdoors, is the most important means of maintaining good indoor air quality

Ventilation dilutes and removes pollutants from the air indoors.

Good ventilation reduces the risk of airborne illness (such as flu and COVID-19), and has been linked to better concentration.



Ventilation and carbon dioxide

People give off CO₂ when they breathe, and it is removed by ventilation.

The number of people in a room, their age, and their activities affect the amount of CO₂ they produce.

We can estimate how well-ventilated a classroom is from the level of carbon dioxide measured on SAMHE monitors.



Ventilation and the weather

Many SAMHE classrooms use windows to provide ventilation - with the government guidance for classrooms coming from BB101.

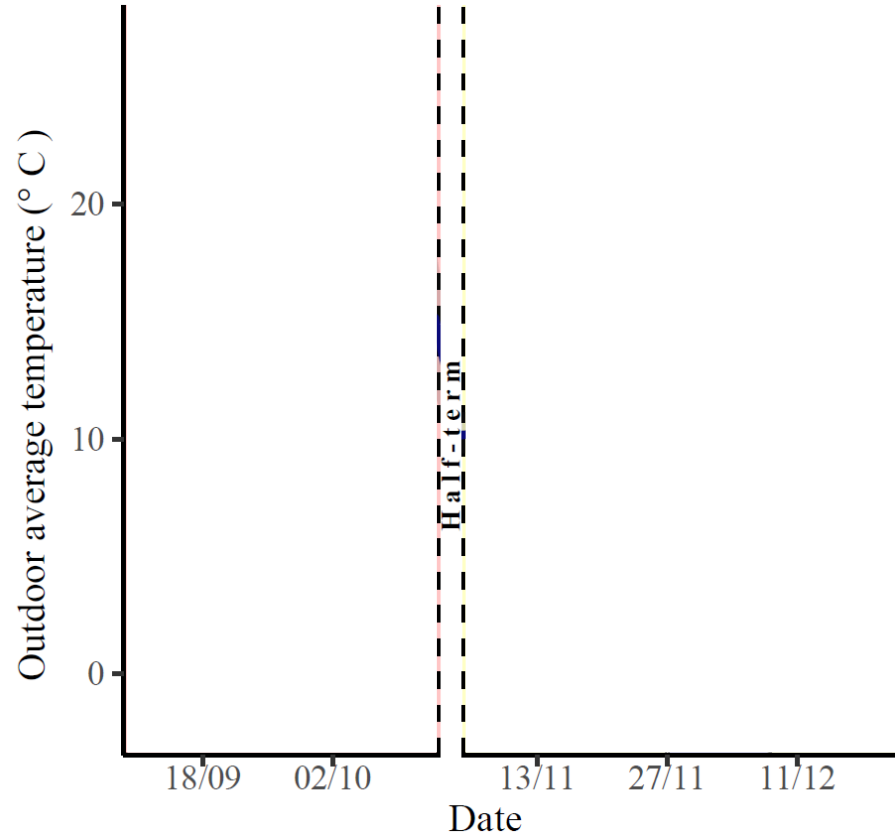
People open windows more when it's warm, so ventilation rates are closely linked to outdoor temperatures.

So we started by looking at the outdoor temperature across the UK over the Autumn 2023 school term.



Ventilation and the weather

Over last Autumn's school term, there were four distinct weather periods:



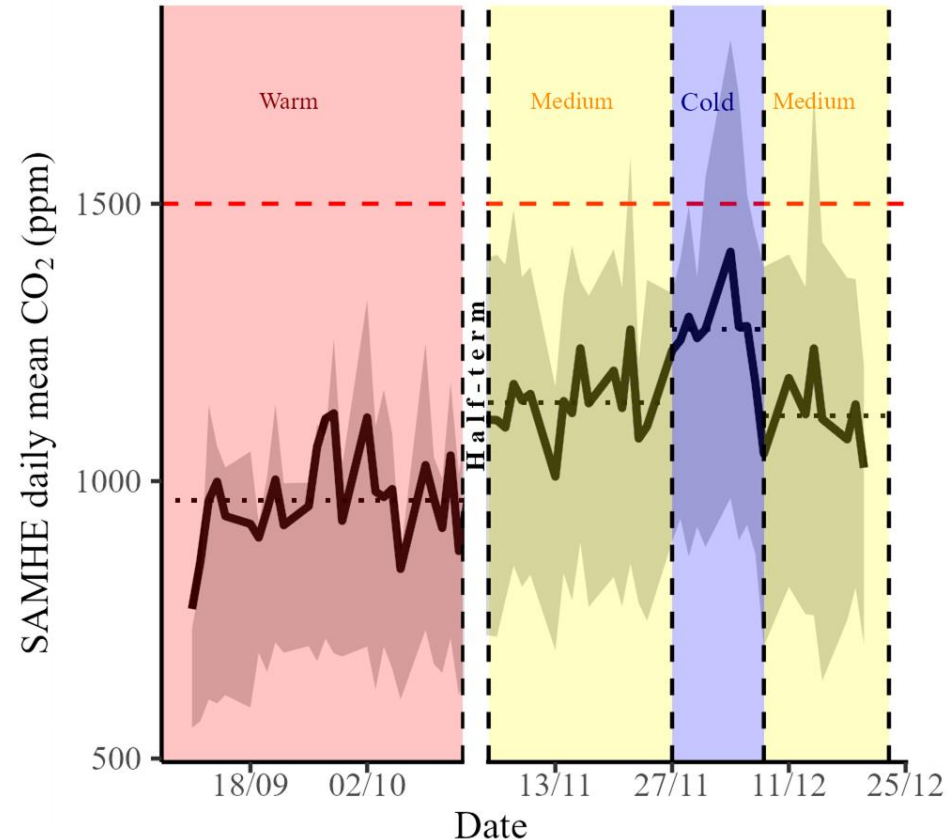
Ventilation and the weather

Using these same weather bands, the SAMHE CO₂ concentrations are:

- Lower during the warm weather period, and
- Higher during the cold weather period,
- Levels during the medium weather periods fall in between.

In the cold period, SAMHE monitors sometimes measured CO₂ levels higher than the government guidelines.

Recommendation: establish training classroom staff on air quality; provide monitors and encourage staff to use them



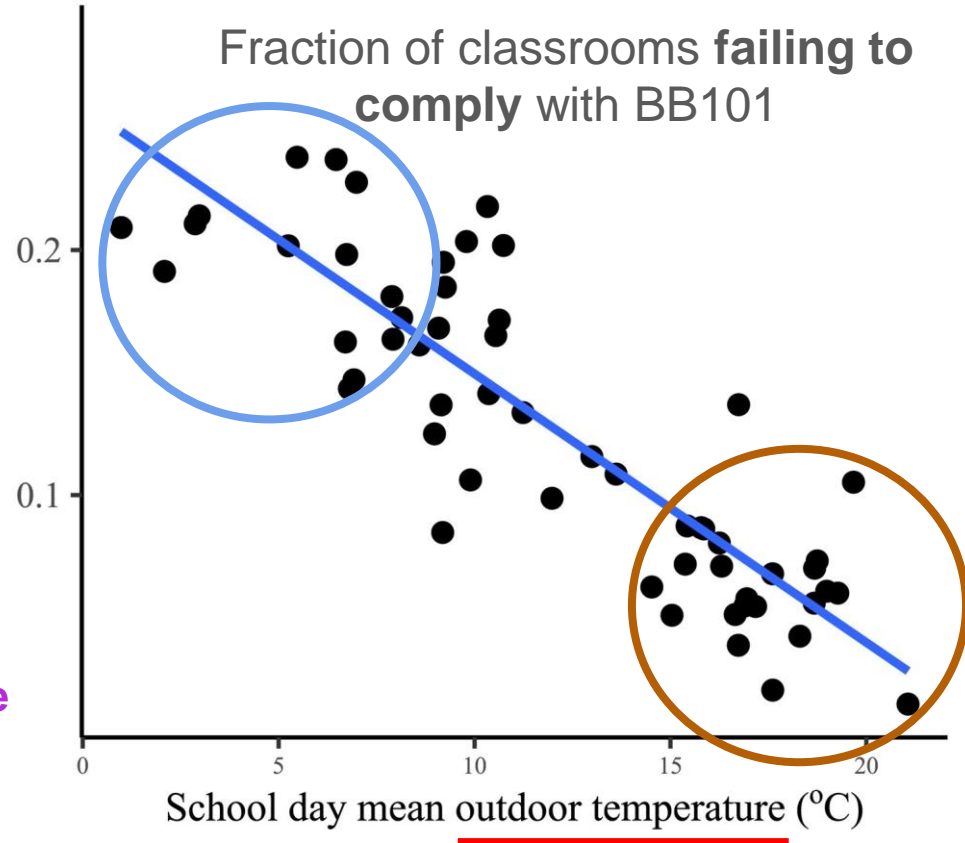
Adherence to BB101 guidance

BB101 specifies that CO₂ levels averaged over the school day fall below 1,500 ppm within naturally ventilated (95% of UK) classrooms

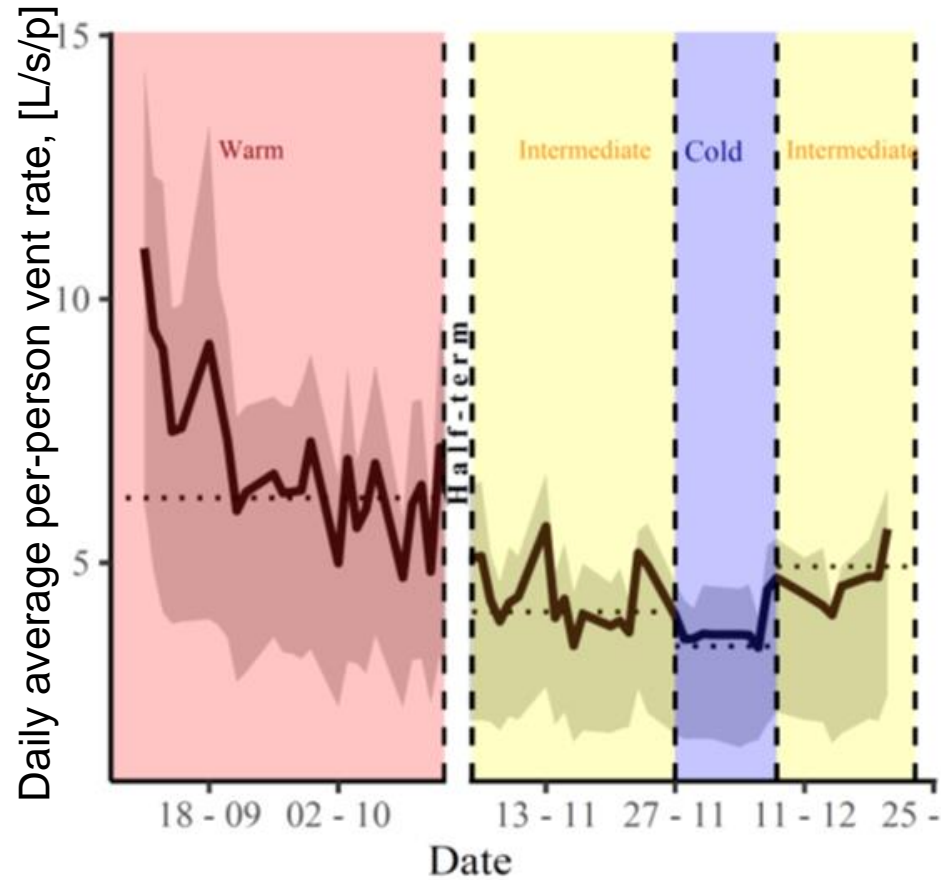
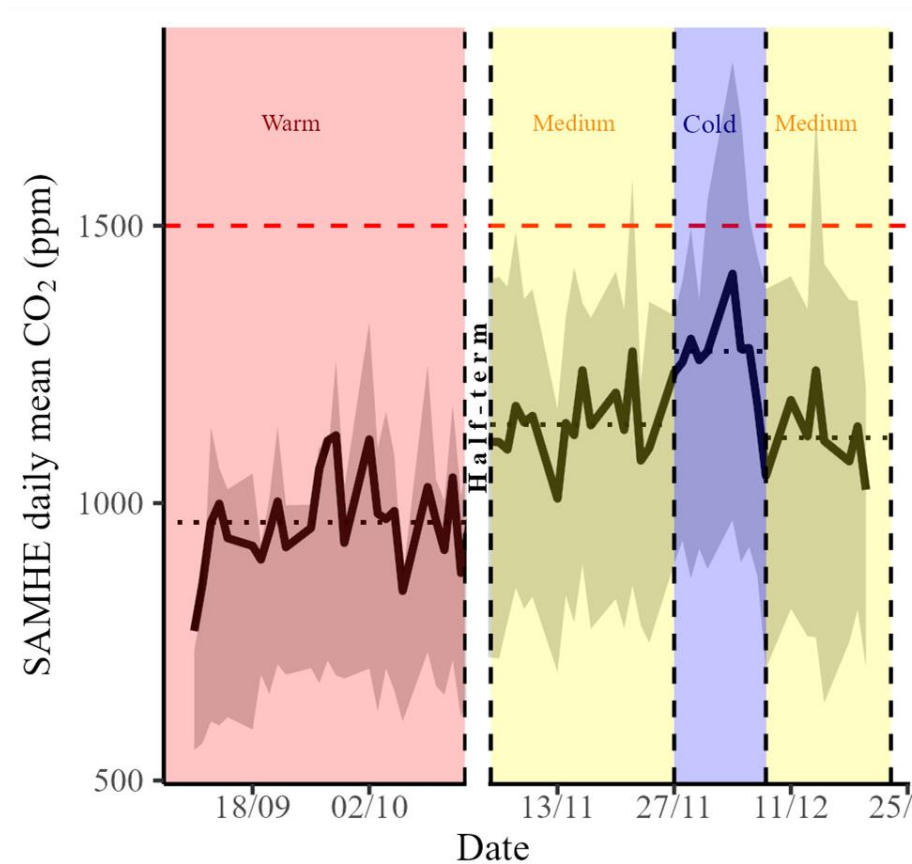
When warm outside most classrooms can comply with BB101

When cold outside about 20% of classrooms fail to comply with BB101

Recommendation: provide training and improve support of school staff to manage good ventilation even on cold days



From CO₂ to per-person ventilation



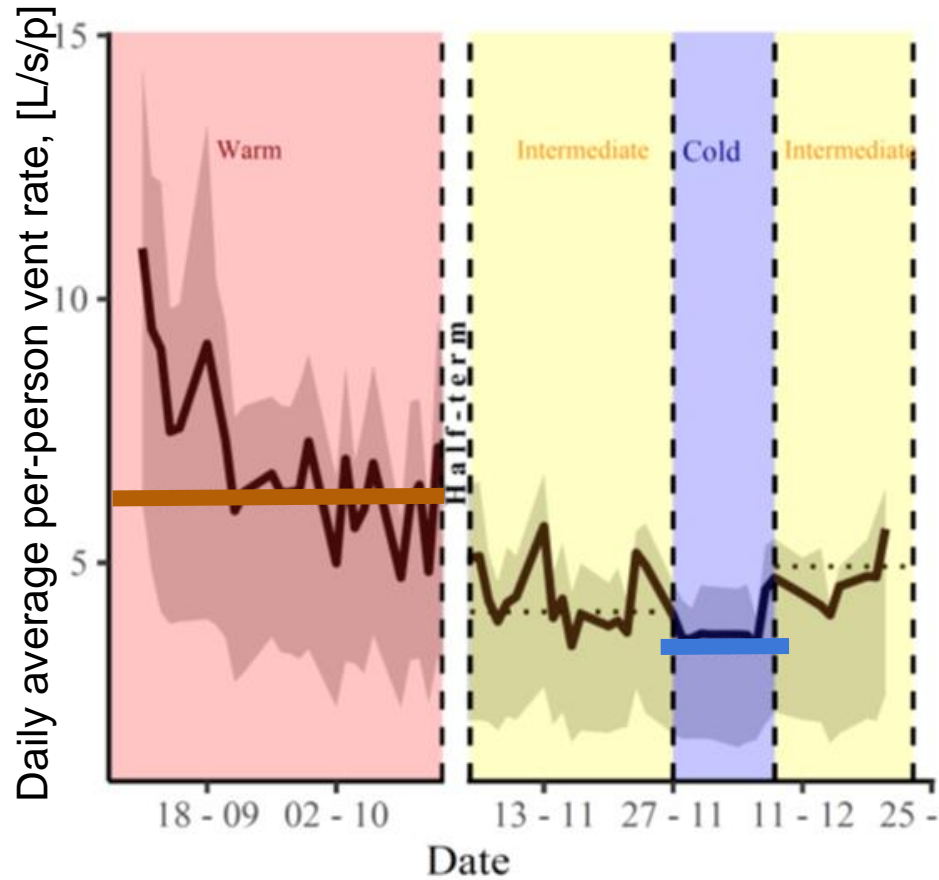
From CO₂ to per-person ventilation

When warm outside almost classrooms
are able to comply with BB101
BUT ventilation rates are about 6 L/s/p

When cold outside ventilation rates fall to
about 4 L/s/p

UK Government regulations state a
minimum of 10 L/s/p for offices

**Recommendation: update BB101 to focus
on achieving 'good' levels of ventilation**



What we learnt about levels of classroom ventilation

As we have such a lot of data, we can carry out a regression analysis controlling for the outdoor temperature and determine what factors significantly affect ventilation:

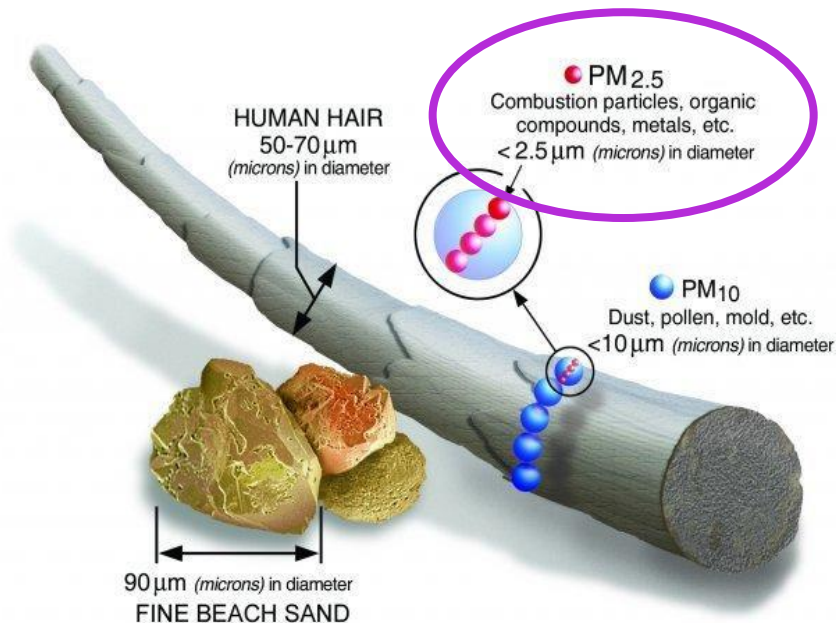
- Secondary schools showed higher CO₂ levels than primary schools but, when analysed appropriately, per-person ventilation rates in secondary and primary schools do not differ significantly .
Recommendation: when updating BB101 consider pupils' development carefully.
- Schools with more pupils than their 'school capacity' target, showed higher CO₂ levels than those which did not.
- **Recommendation: keep pupil numbers below the published 'school capacity'.**

*Good ventilation does not guarantee 'good' air quality -
what more should be done?*



Particulate matter in classrooms

- “Particulate matter” is the mixture of solid particles and liquid droplets found in the air
- Particulate matter $PM_{2.5}$ is a key pollutant present indoors
- We know that exposure to $PM_{2.5}$ can affect people’s health



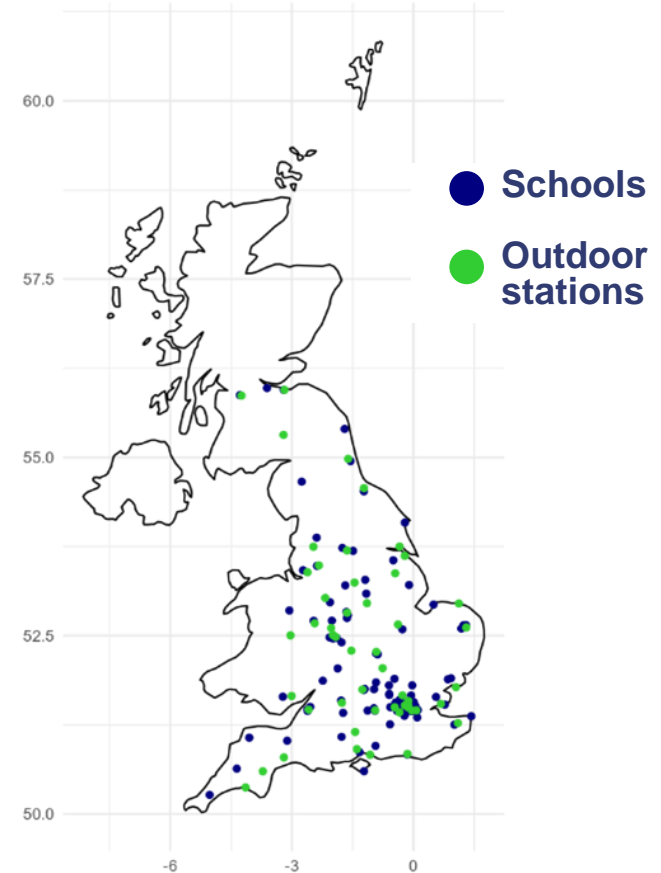
Most PM_{2.5} comes into classrooms from outside

We looked at data from selected SAMHE schools during autumn and spring terms 2023-2024.

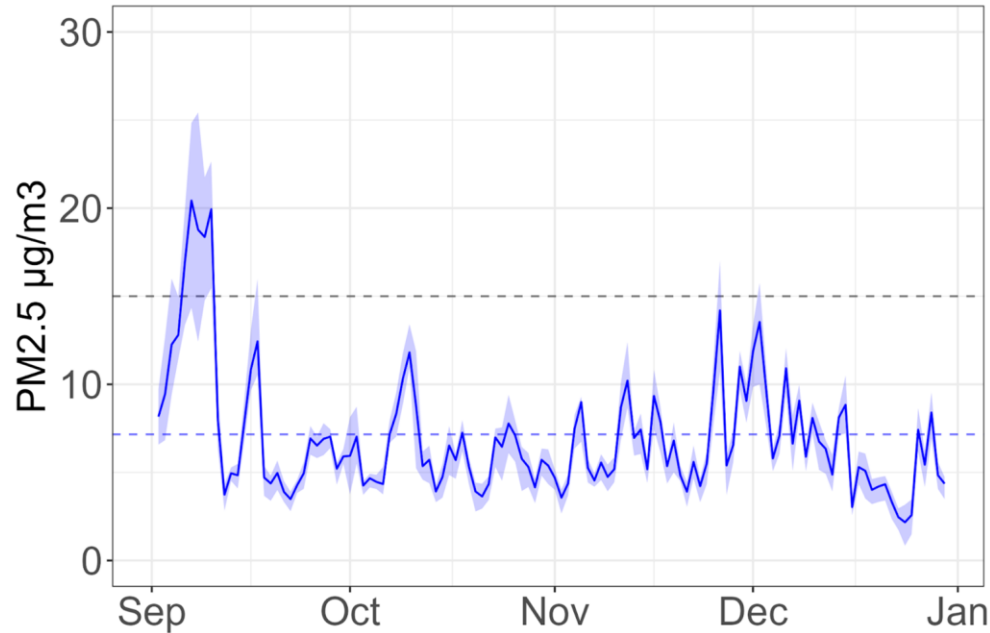
We know PM_{2.5} can come into schools from outdoors...

- We compared the SAMHE schools data set to outdoor PM concentrations at weather stations near schools.

Let's begin by examining autumn term ...

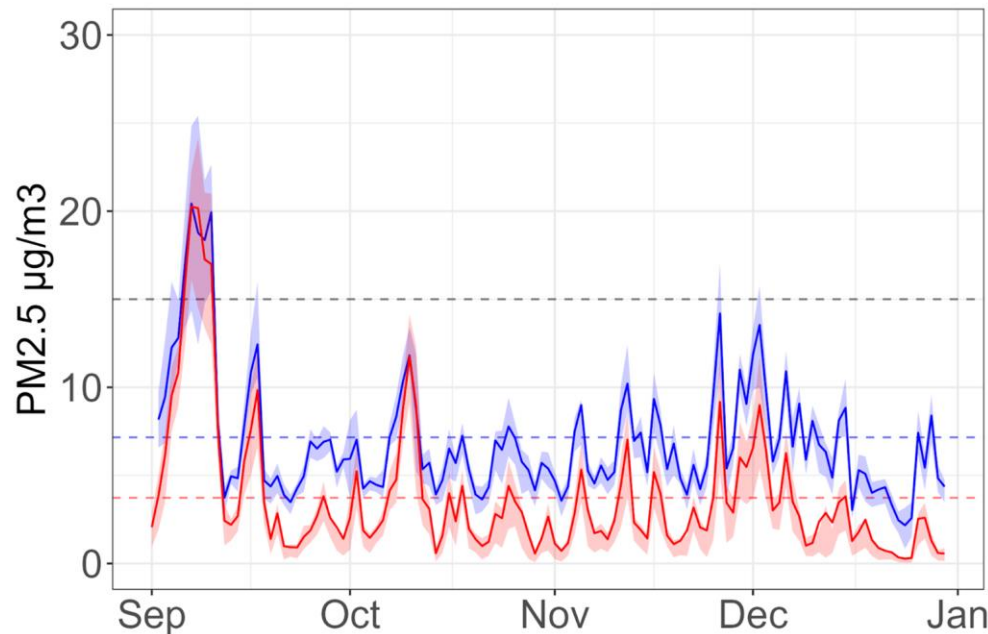


Outdoor levels of PM_{2.5}



Outdoor average: 7.3 $\mu\text{g}/\text{m}^3$

SAMHE schools' levels of PM_{2.5}

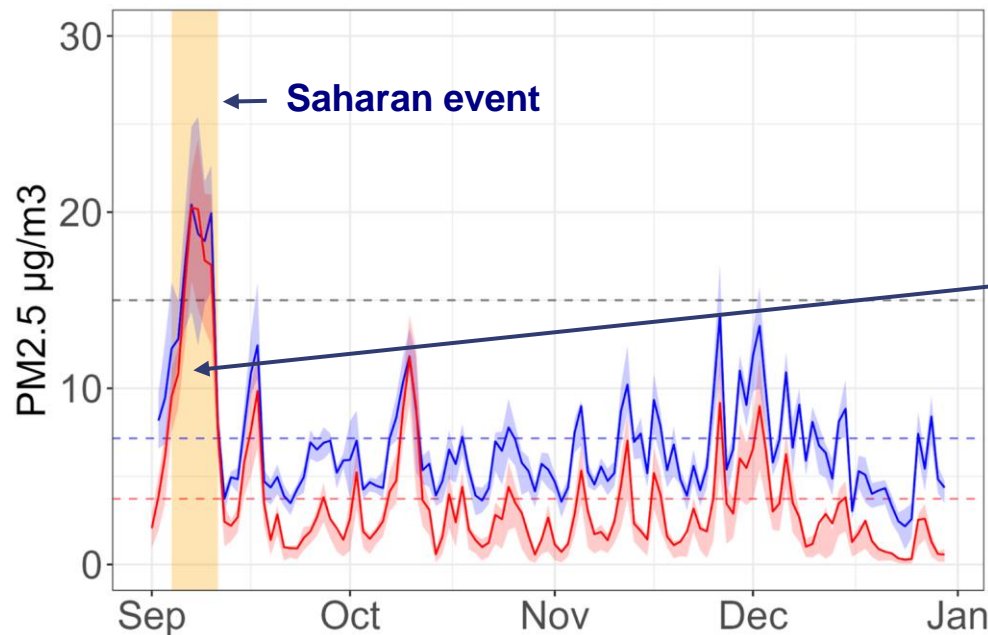


WHO daily average guideline: 15 µg/m³

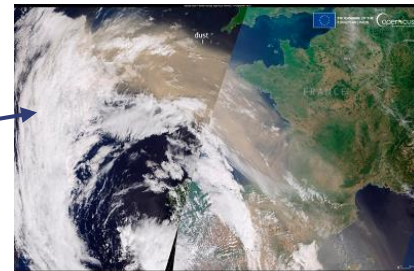
Outdoor average: 7.3 µg/m³

SAMHE school average: 3.6 µg/m³

Large weather events raises $PM_{2.5}$ in schools



Saharan dust blown to the UK



Saharan dust came into SAMHE classrooms



At the start of school term settled dust is brought back up into the air



What do we know about school PM_{2.5} levels?

- SAMHE classroom PM_{2.5} levels can be affected by outdoor events that happen nearby and large events that affect the entire country
 - Important to consider levels during school hours
 - Recommendation: actively monitor PM_{2.5} levels in classrooms
- Estimates of the lower bound suggest least 75% of PM_{2.5} in schools comes from outdoors
 - Recommendation: establish a legal right to clean air within the UK
- Outdoor 'events' contribute significantly to long-term exposure
 - Recommendation: enforce 2021 WHO Air Quality Guidelines

Deciding what is 'good' air quality

- Good ventilation dilutes indoor pollutants, including airborne infections like flu, Covid, etc.
- BUT increasing ventilation costs money as we need to heat the air coming in.
- Ventilation can also bring pollutants into schools (e.g. $\text{PM}_{2.5}$) so we can never aim for perfect air quality in schools.



So how should we decide what is good? Some facts:

- For most classrooms, BB101 states daily mean CO_2 should fall below 1,500 ppm.
- During the pandemic, SAGE suggested CO_2 levels below 800 ppm were indicative of 'good' ventilation - this is very far from current BB101 guidance.
- CO_2 levels are not routinely recorded in classrooms so, even as it is, BB101 is unenforceable.
- BB101 provides no quantitative measures of air quality (beyond CO_2).
- Air quality metrics (e.g. $\text{PM}_{2.5}$) aren't routinely monitored in classrooms.
- WHO health-based guideline value to manage long-term exposures to $\text{PM}_{2.5}$ is $5\text{g}/\text{m}^3$.

Improving ventilation and air quality in UK schools

- CO₂ data during clement weather indicates that classroom architectures can typically deliver reasonable ventilation rates (but at what energy cost?).
- Engineering retro-fit technologies, which provide a greater control of ventilation rates, are available both at classroom and building level.
- Air filters can reduce the concentrations of PM_{2.5} in classrooms by 40%-50% during wintertime. Air filters significantly reduced illness-related absence during the pandemic.



Recommendations

- We need to work together to set suitable targets for 'good' - balancing energy consumption with health and attainment concerns will be challenging, but doing nothing should not be an option
- We need to monitor the air in our schools.
- Provide school staff with the training they need to understand the benefits of ventilation & air quality, and how they can help manage them.
- Take action when monitoring indicates either the air quality or ventilation rates are not good, mitigation measures should be provided to schools. These should first seek to improve ventilation, but where this is not possible or sufficient, other measures should be explored (e.g. air cleaners).



Thanks for listening!

Find out more:



www.samhe.org.uk



[@SAMHEProject](https://twitter.com/SAMHEProject)



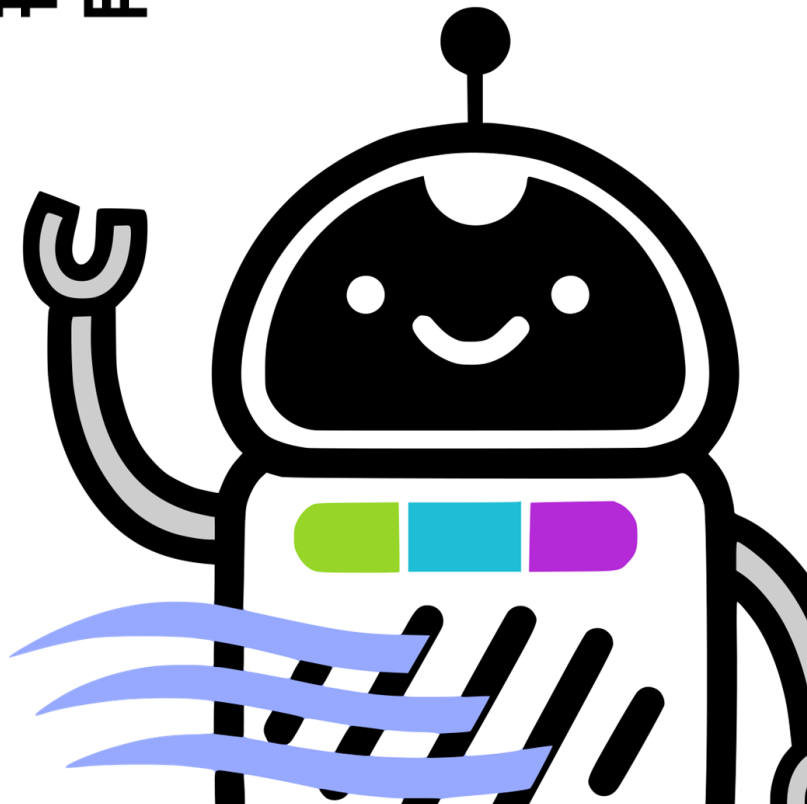
[SAMHE schools UK](#)



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PAWEL WARGOCKI

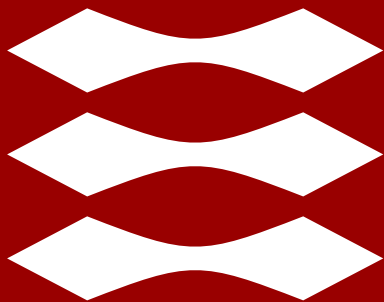
PROFESSOR AT TECHNICAL UNIVERSITY OF DENMARK

*'What we know and should know about
classroom air quality, ventilation, and
thermal environment in relation to
learning and monitoring'*



Technical University
of Denmark

DTU



What we know and should know about classroom air quality, ventilation, and thermal environment in relation to learning and monitoring

Pawel Wargocki

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Technical University of Denmark



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Preamble

- A good education system constitutes one of the fundamentals of modern society because poor learning can have lifelong consequences for a student and society
- Early childhood experiences impact behavior later on in life
- Buildings must promote health, reduce energy, and be sustainable, health being a sustainability component
- The primary purpose of a school building is to provide optimal conditions for learning, and then (in parallel) energy use should be minimized
- Indoor environmental quality in many schools worldwide is inadequate
- Poor indoor environmental quality in schools is linked not only to health problems but also to decreased concentration and poor test results
- All children and teachers, independent of their socio-economic status, have the right to breathe healthy air (also in schools)

Objective

Question 1: What is the optimal learning environment?

- Question 2: How to examine that learning environment is optimal?
- Question 3: How to advance research and implement the knowledge?

Question 1

What is the optimal learning environment?

Research-based recommendations for achieving high indoor environmental quality in classrooms to promote learning

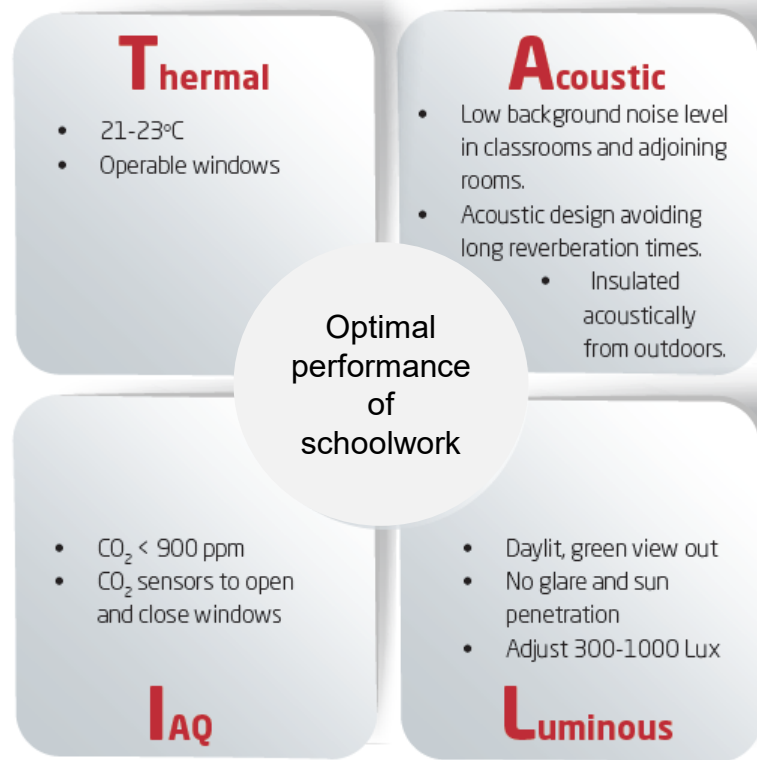
- **Meta-analysis of all available data on children's performance of schoolwork**



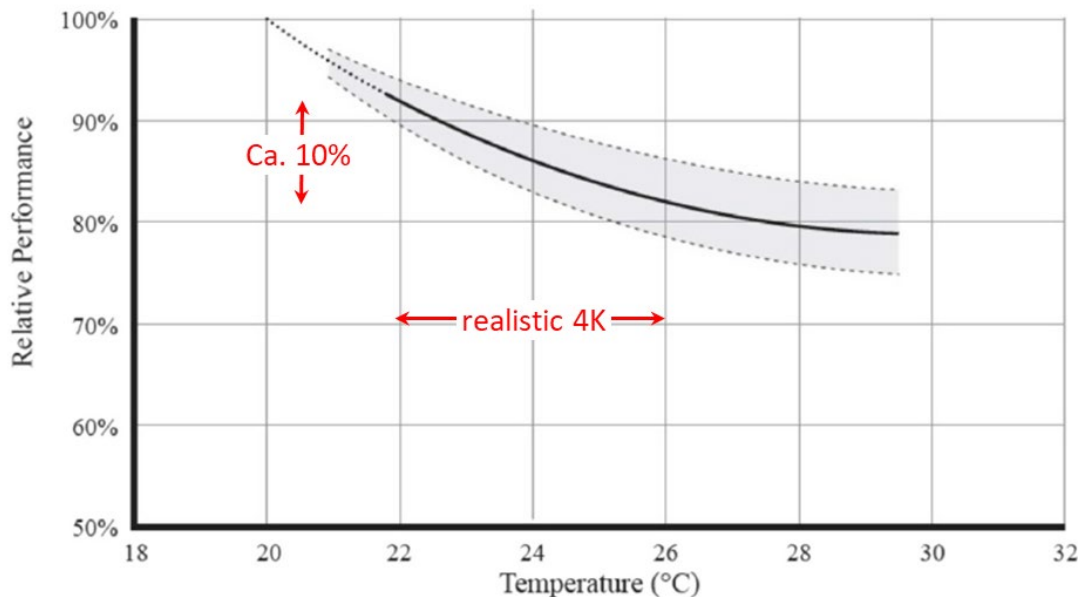
Classroom conditions securing optimal performance of schoolwork

Research-based
recommendations for
achieving high indoor
environmental quality
in classrooms to
promote learning

Summary



Raised temperatures have progressively negative effects on children, twice the effects on schoolwork as on office work



The relationship between classroom temperature and children's performance in school

Pawel Wargocki^{a,*}, Jose Ali Porras-Salazar^{b,c}, Sergio Contreras-Espinoza^d

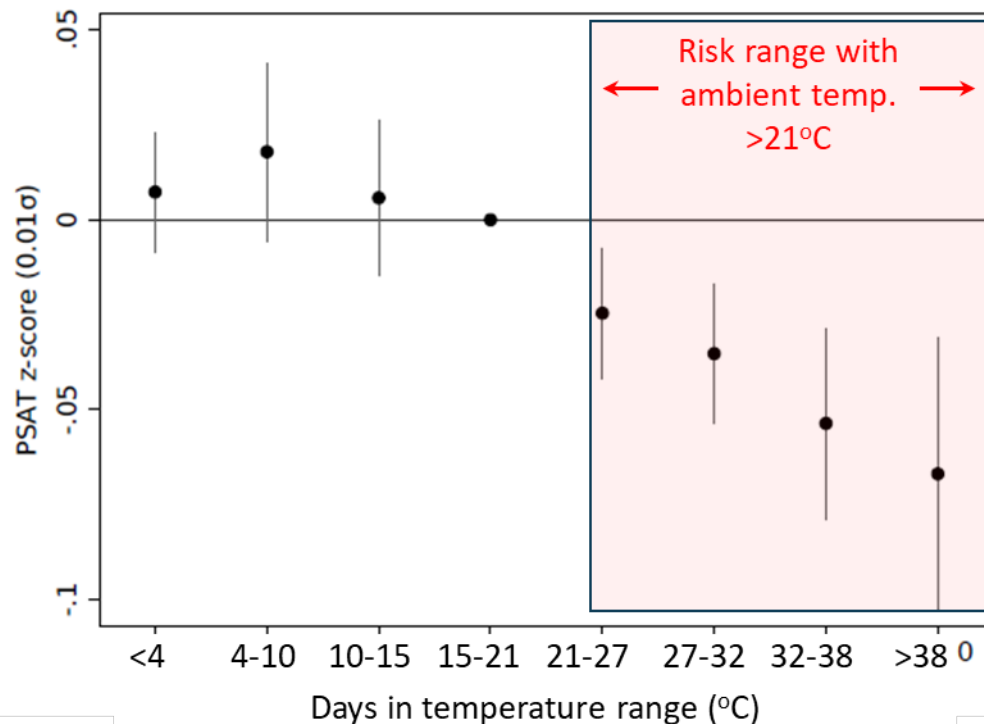
^a International Centre for Indoor Environment and Energy, DTU Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark
^b School of Architecture, University of Costa Rica, San Pedro de Montes de Oca, Costa Rica
^c Department of Design and Theory of Architecture, University of Bio-Bio, Bio-Bio, Chile
^d Department of Statistics, University of Bio-Bio, Bio-Bio, Chile

ARTICLE INFO

Keywords:
 Children
 Learning
 Cognitive performance
 Elementary schools
 Temperature
 Thermal environment

ABSTRACT

The present paper reports a meta-analysis of published evidence on the effects of temperature in school classrooms on children's performance in school. The data from 18 studies were used to construct a relationship between thermal conditions in classrooms and children's performance in school. Psychological tests measuring cognitive abilities and skills, school tasks including mathematical and language-based tasks, rating schemes, and tests used to assess progress in learning including end-of-year grades and the examination results were considered as indicators of children's performance. Due to the lack of complete measurements, thermal conditions were characterized by measured classroom temperatures. To create the relationship, the fractional change in performance of psychological tests and school tasks was regressed against the average temperature at which the change was recorded; all published data were used regardless of whether the change in learning outcome changed significantly with temperature. For other learning outcomes, no relationship was created because the data were insufficient. The relationship derived in the analysis shows that the performance of psychological tests and school tasks can be expected to increase on average by 20% if classroom temperatures are lowered from 30 °C to 20 °C and that the temperature for optimal performance is lower than 22 °C. The relationship is valid only for temperate climates. It requires verification for other climates and extensions to temperatures lower than 20 °C and higher than 30 °C.



**SD of the score on math and language exit exam (US)
as a function of overheating (ambient temperature)**



NBER WORKING PAPER SERIES

HEAT AND LEARNING

Joshua Goodman
Michael Hurwitz
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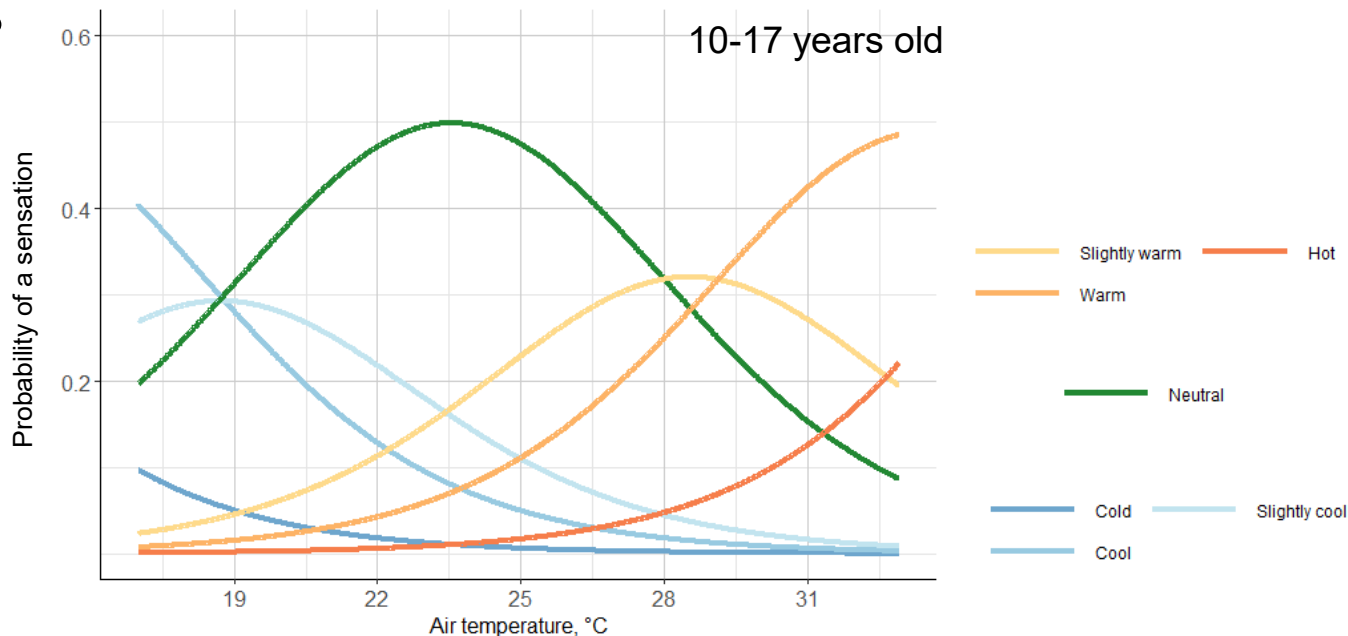
Working Paper 24639
<http://www.nber.org/papers/w24639>

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2018

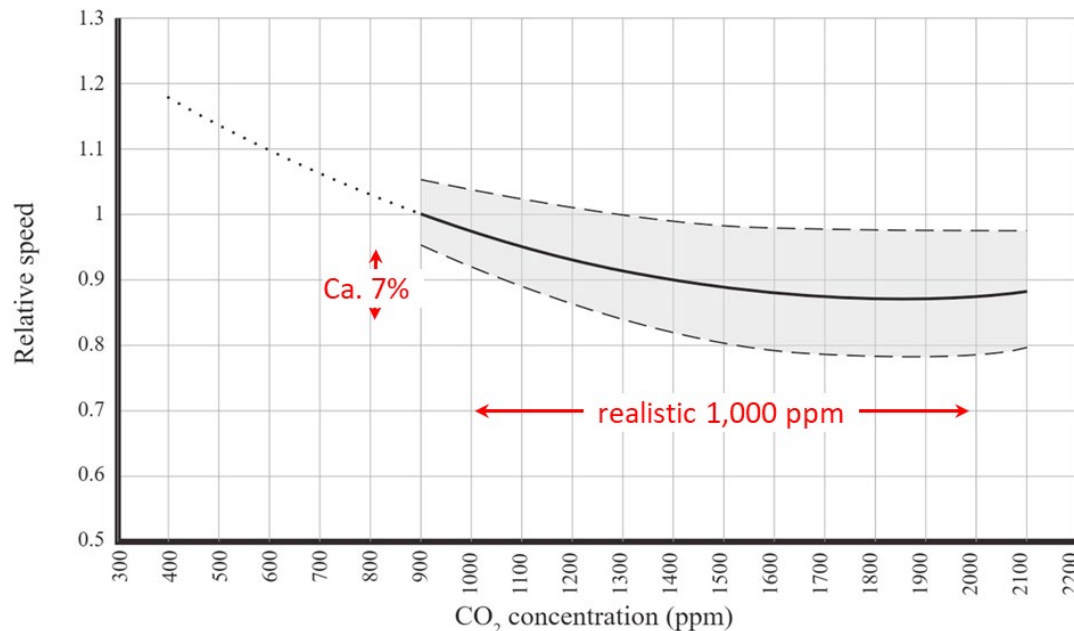
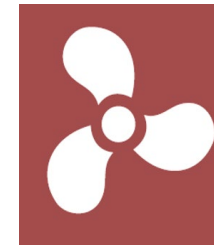
ABSTRACT

We provide the first evidence that cumulative heat exposure inhibits cognitive skill development and that school air conditioning can mitigate this effect. Student fixed effects models using 10 million PSAT-takers show that hotter school days in the year prior to the test reduce learning, with extreme heat being particularly damaging and larger effects for low income and minority students. Weekend and summer heat has little impact and the effect is not explained by pollution or local economic shocks, suggesting heat directly reduces the productivity of learning inputs. New data providing the first measures of school-level air conditioning penetration across the US suggest such infrastructure almost entirely offsets these effects. Without air conditioning, each 1° F increase in school year temperature reduces the amount learned that year by one percent. Our estimates imply that the benefits of school air conditioning likely outweigh the costs in most of the US, particularly given future predicted climate change.

The optimum temperature for schoolwork is 2-3K lower than it is for office work, and children in school subjectively prefer lower temperatures than are preferred in offices



Poor air quality has progressively negative effects on children, the effects being 5 to 12% improved schoolwork when outdoor air supply rates increased



The relationships between classroom air quality and children's performance in school

Pawel Wargocki^{a,*}, Jose Ali Porras-Salazar^b, Sergio Contreras-Espinoza^c, William Bahnfleth^d

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^c Department of Statistics, University of Rio, Rio de Janeiro, Brazil

^d Department of Architectural Engineering, Pennsylvania State University, PA, United States

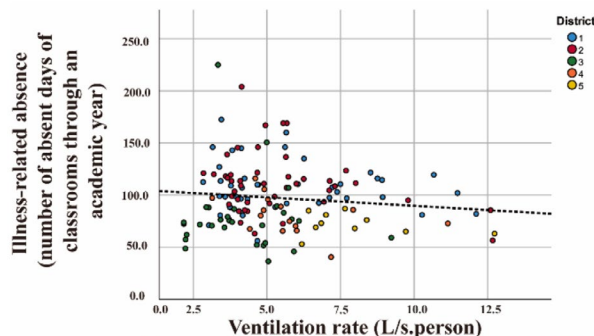
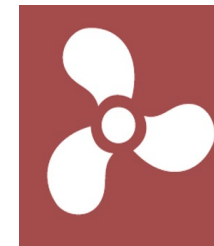
ARTICLE INFO

Keywords:
Children
Learning
Cognitive performance
Elementary schools
Carbon dioxide

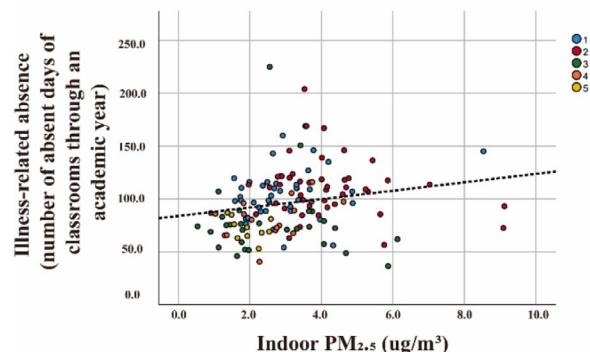
ABSTRACT

The data from published studies were used to derive systematic relationships between learning outcomes and air quality in classrooms. Psychological tests measuring cognitive abilities and skills, school tasks including mathematical and language-based tasks, rating schemes, and tests used to assess progress in learning including end-of-year grades and exam scores were used to quantify learning outcomes. Short-term sick leave was also included because it may influence progress in learning. Classroom indoor air quality was characterized by the concentration of carbon dioxide (CO₂). For psychological tests and school tasks, fractional changes in performance were regressed against the average concentration of CO₂ at which they occurred; all data reported in studies meeting the inclusion criteria were used to derive the relationship, regardless of whether the change in performance was statistically significant at the examined levels of classroom air quality. The analysis predicts that reducing CO₂ concentration from 2,100 ppm to 900 ppm would improve the performance of psychological tests and school tasks by 12% with respect to the speed at which the tasks are performed and by 5% with respect to errors made. For other learning outcomes and short-term sick leave, only the relationships published in the original studies were available. They were therefore used to make predictions. These relationships show that reducing the CO₂ concentration from 2,100 ppm to 900 ppm would improve performance on the tests used to assess progress in learning by 5% and that reducing CO₂ from 4,100 ppm to 1,000 ppm would increase daily attendance by 2.5%. These results suggest that increasing the ventilation rate in classrooms in the range from 2 L/s-person to 10 L/s-person can bring significant benefits in terms of learning performance and pupil attendance; no data are available for higher rates. The results provide a strong incentive for improving classroom air quality and can be used in cost-benefit analyses.

Absenteeism is 1.5% higher with a 2 L/s/p outdoor air supply rate than with 7.5 L/s/p



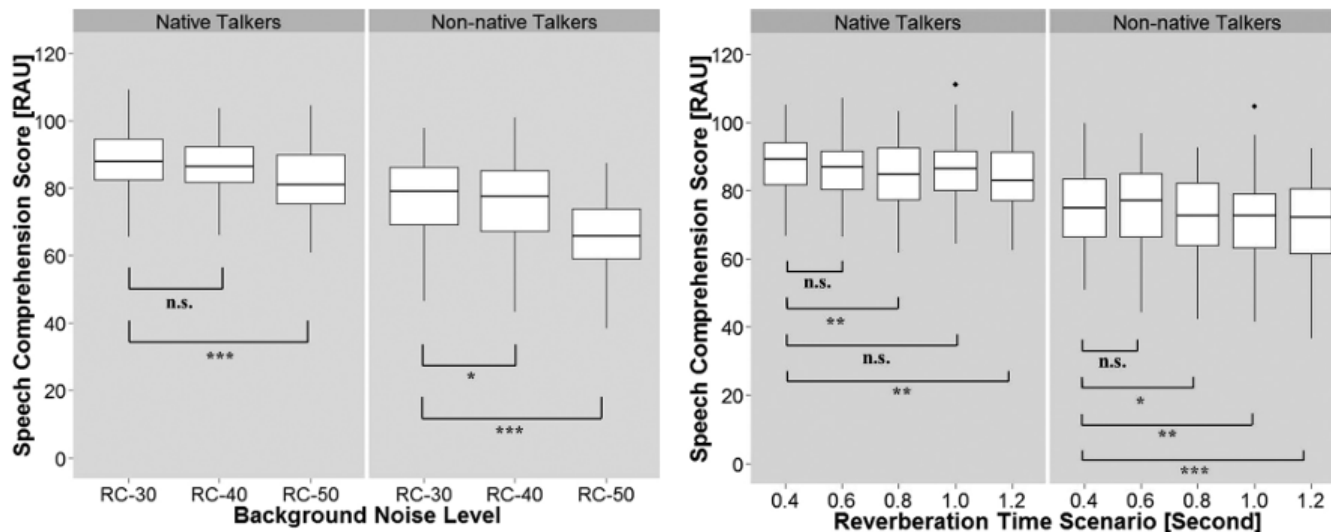
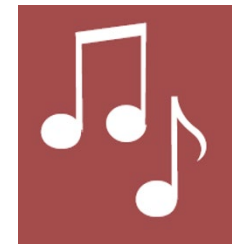
a: Linear relations between ventilation rate and IRA



b: Linear relations between indoor PM_{2.5} and IRA



Classroom noise (background and reverberation time) has progressively negative effects on speech intelligibility, comprehension, and memory



Younger children, children with hearing or attentional difficulties, and children being taught in their second language are more negatively affected

Daylight, a green view-out, and good artificial lighting can improve children's performance of schoolwork



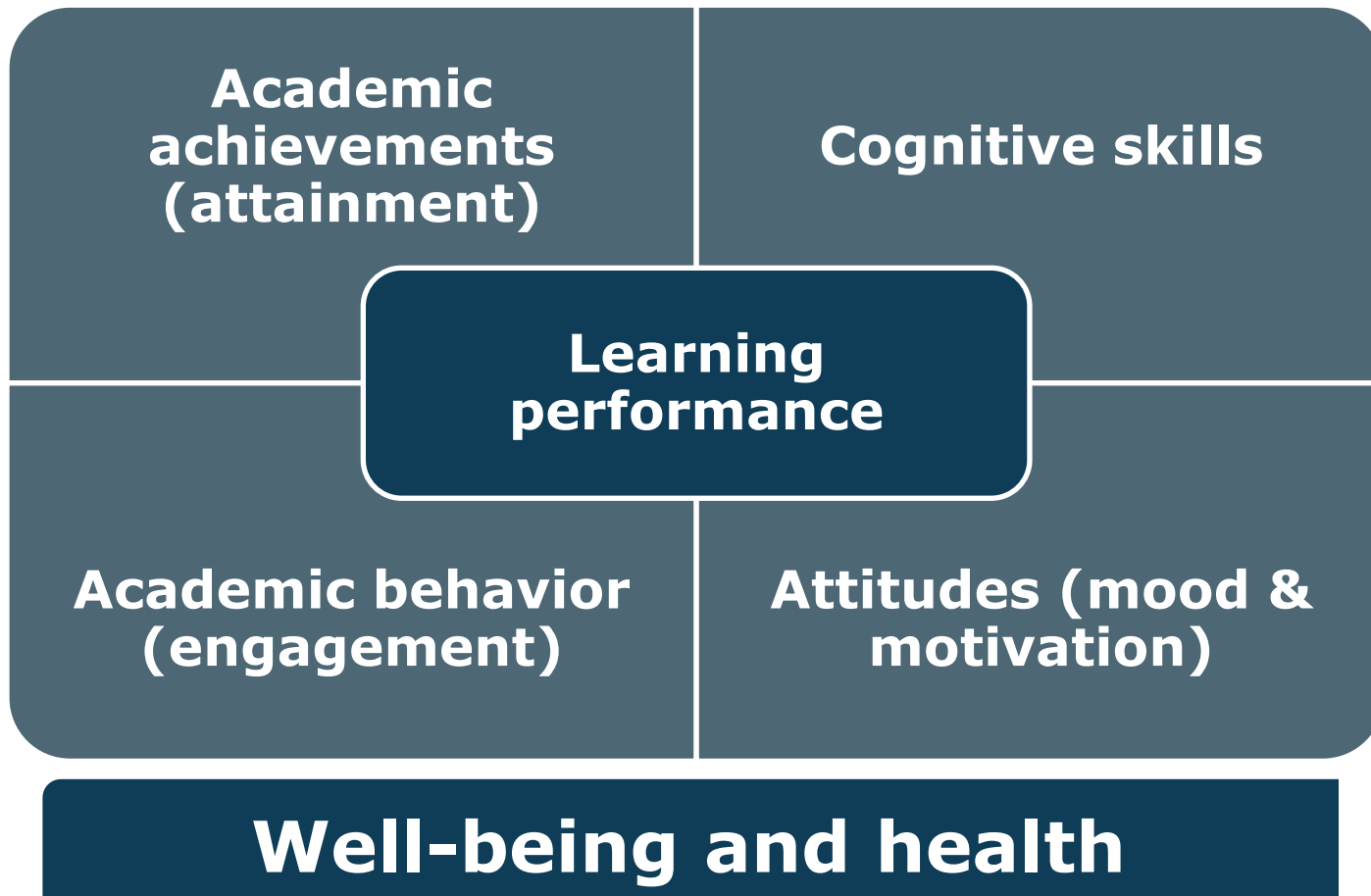
Table 3. Strength and significance of the association between the continuous lighting indicators and the performance test mean score. The coefficient represents the strength of association.

Variable	Coefficient	SE	t	p	CI (95%)	
Window /Floor Area Ratio	23.51	3.62	6.5	<0.01	16.41	30.60
Type of Shading	6.64	0.52	12.88	<0.01	5.63	7.65
Latitude	1.18	0.08	15.11	<0.01	1.03	1.34
Percentage of Windows facing South	0.04	0.01	3.51	<0.01	0.02	0.06
Daylight Index	-0.25	0.16	-1.57	0.12	-0.57	0.06
Direct Sunlight	-0.002	0.87	0	1.00	-1.70	1.70
Glazing	3.41	0.50	6.84	<0.01	2.44	4.39
Open-able Windows	0.57	0.38	1.49	0.14	-0.18	1.32

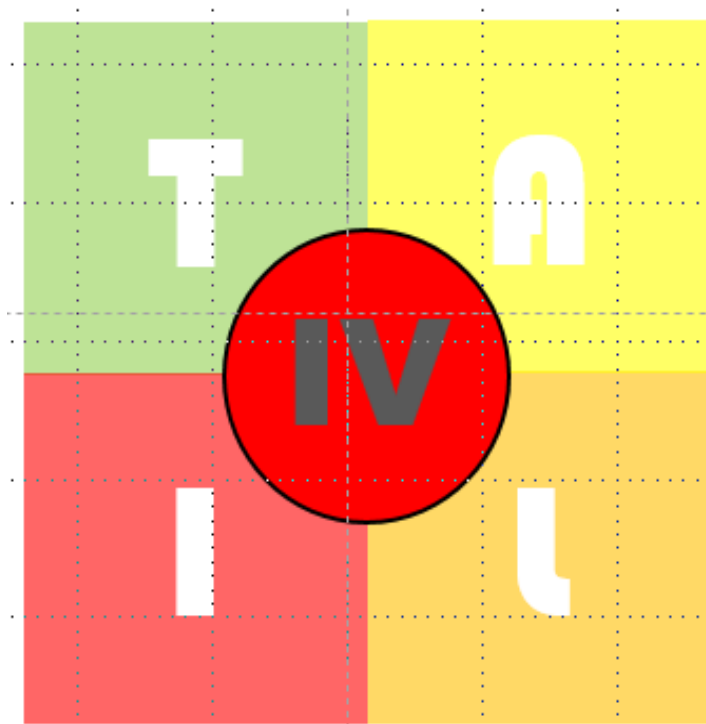
Adjusted on age, gender, race, and maternal education.

Question 2

How to examine that learning environment is optimal?



The TAIL rating scheme for benchmarking IEQ in schools



Energy & Buildings 244 (2021) 111029



Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/enb



TAIL, a new scheme for rating indoor environmental quality in offices and hotels undergoing deep energy renovation (EU ALDREN project)

Pawel Wargocki^{a,*}, Wenjuan Wei^b, Jana Bendžalová^c, Carlos Espigares-Correa^d, Christophe Gerard^e, Olivier Greslou^b, Mathieu Rivallain^b, Marta Maria Sesana^c, Bjarne W. Olesen^a, Johann Zirngibl^b, Corinne Mandin^b

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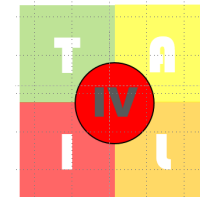
Public buildings

ABSTRACT

To avoid health risks and discomfort, the European Energy Performance for Building Directive (EPBD) mandates that "Member States should support energy performance upgrades of existing buildings that contribute to achieving a healthy indoor environment." There is, however, no widely accepted method for rating the overall level of indoor environmental quality (IEQ), although several different approaches are proposed by standards, guidelines, and certification schemes. To fill this void, a new classification rating scheme called TAIL was developed to rate IEQ in offices and hotels undergoing deep energy renovation during their normal use; the scheme is a part of the energy certification method developed by the EU ALDREN project. The TAIL scheme standardizes rating of the quality of the thermal (T) environment, acoustic (A) environment, indoor air (I), and luminous (L) environment, and by using these ratings, it provides a rating of the overall level of IEQ. Twelve parameters are rated by measurements, modelling, and observation to provide the input to the overall rating of IEQ. Their quality levels are determined primarily using Standard EN-16798-1 and World Health Organization (WHO) air quality guidelines and are expressed by colours and Roman numerals to improve communication. The TAIL rating was shown to discriminate IEQ levels when its feasibility was examined in eleven buildings across Europe to provide support for its applicability and input for further modifications. Opportunities for using the scheme in other types of buildings and for its further development and application are discussed.

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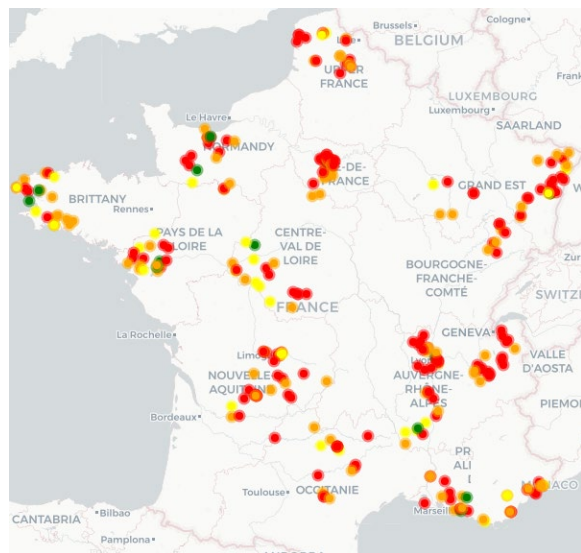
Selected parameters defining TAIL components



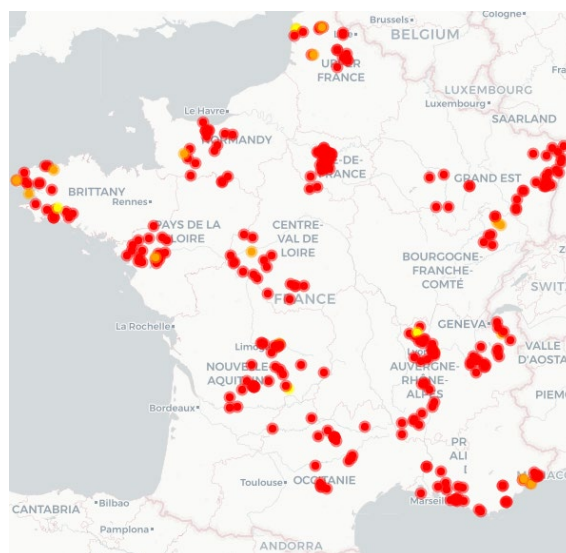
	IEQ parameter	Measured	Modelled	Visual inspection
<u>T</u>	Indoor temperature (°C)	x		
<u>A</u>	Noise level (dB(A))	x		
	Reverberation time (s)	x		
<u>I</u>	CO ₂ (ppm)	x		
	Ventilation rate (L/s)	x		
	Formaldehyde (µg/m ³)	x		
	Benzene (µg/m ³)	x		
	PM _{2.5} (µg/m ³)	x		
	Radon (Bq/m ³)	x		
	Indoor air relative humidity (%)	x		
	Visible mold (cm ²)			x
	Nitrogen dioxide (µg/m ³)	x		
<u>L</u>	Daylight factor (%)		x	
	Illuminance (lux)	x		

Example of TAIL application: 308 schools in France

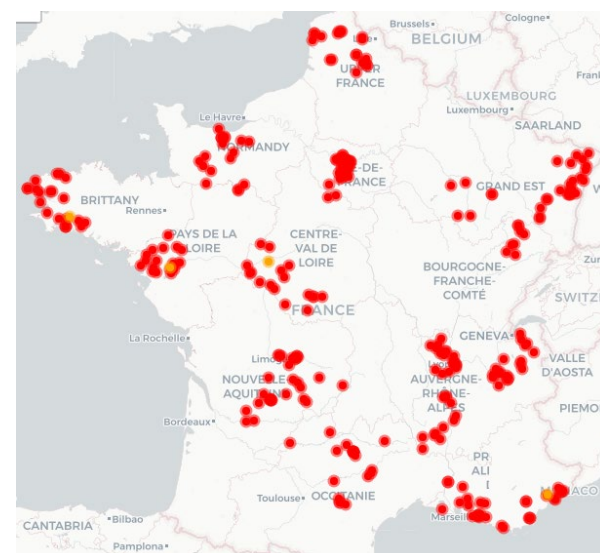
Category	Green (I)	Yellow (II)	Orange (III)	Red (IV)
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Quality of thermal environment (T)



IAQ (I)



IEQ (TAIL)

Question 3

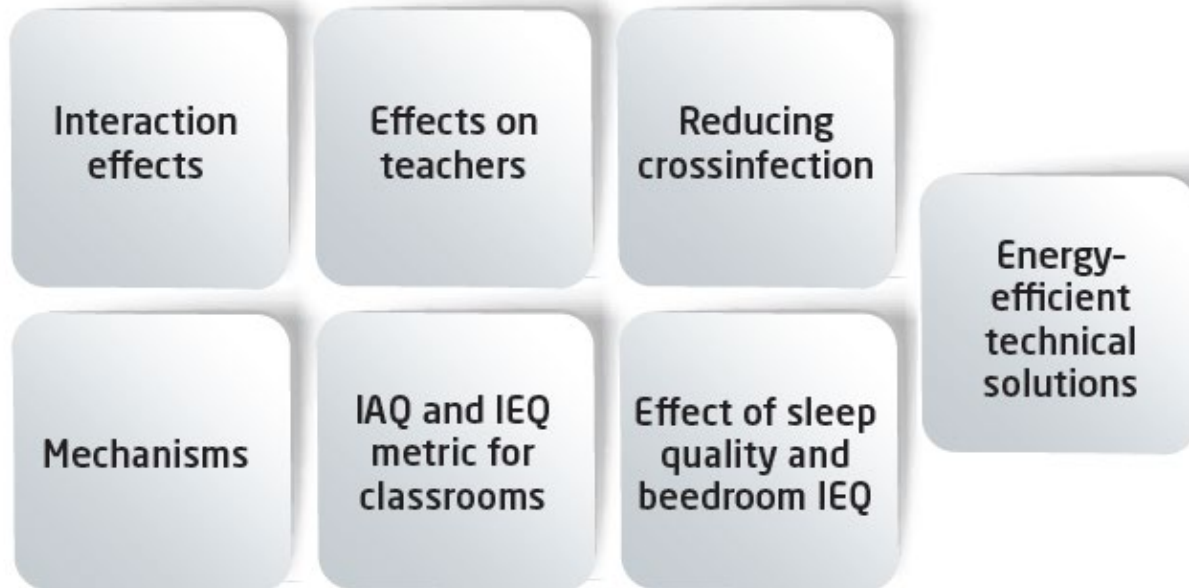
**How to advance research
and implement present
findings?**

We have enough knowledge and arguments (incl. economic) to take actions

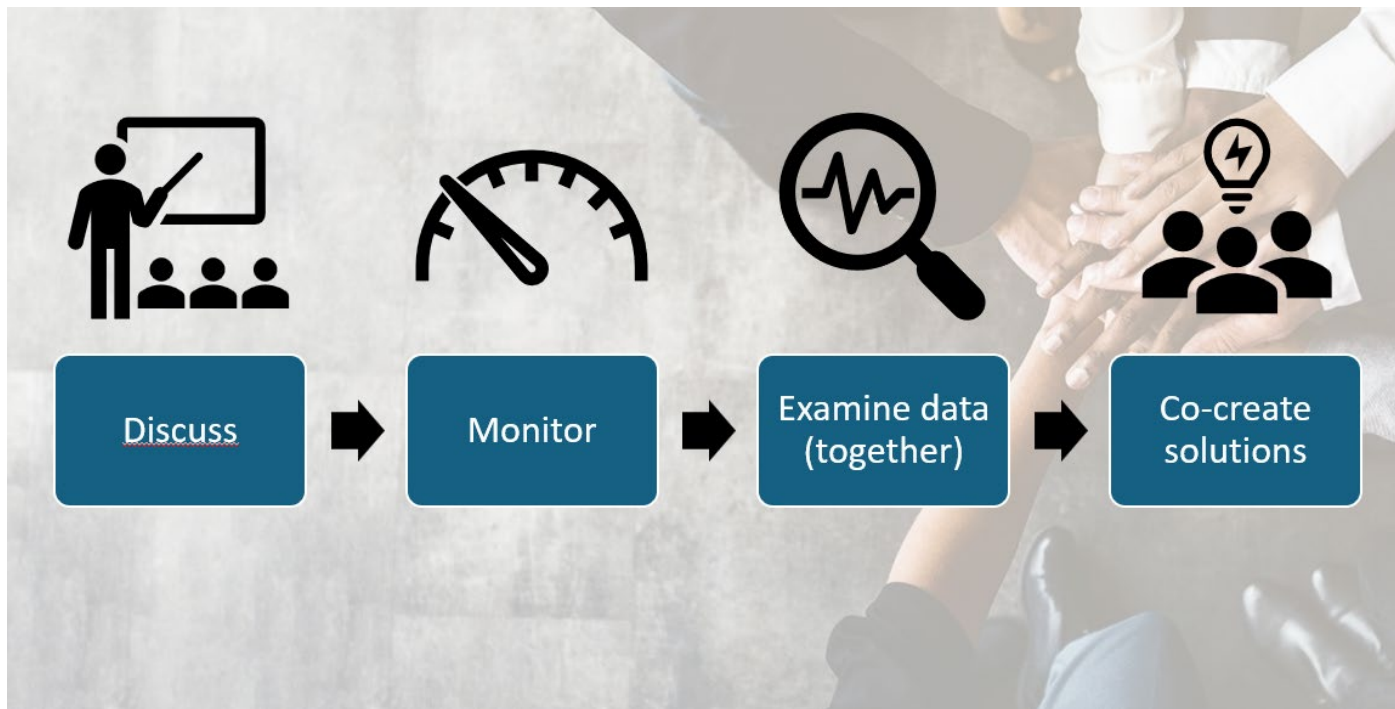
OECD: countries with better test school results have a higher growth rate



Future research and development needs

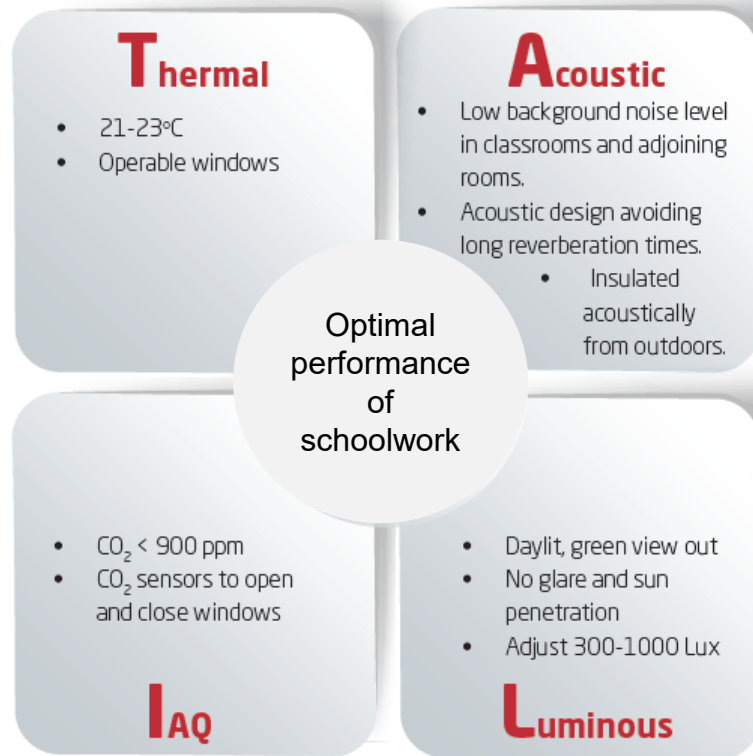


Immediate action: Benchmark and educate



Summary

Classroom conditions securing optimal performance of schoolwork



Requirements are not sufficiently ambitious

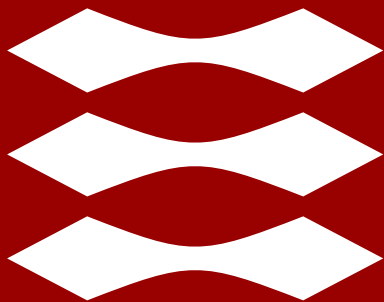
- Overdependence on the existing rather crude technological solutions and minimum standards.
- Based on population data, thus addressing the needs of an average person and neglecting individual preferences and differences
- Comfort (satisfaction) is the main design criterion, other outcomes not addressed sufficiently
- Infection control measures can be a strong argument

"We must think of clean air as we think of clean water and fresh food. Here we do not compromise, nor should we do so with the indoor climate." [@WargockiPawel](#)

Questions and comments



DTU





CORINNE MANDIN

ENVIRONMENTAL HEALTH RESEARCHER

*'Indoor air quality in French schools: 15
years of research to improve
knowledge'*

**IAQmatters conference by Eurovent
Breathing Achievement into Every Classroom**

INDOOR AIR QUALITY IN FRENCH SCHOOLS: 15 YEARS OF RESEARCH TO IMPROVE KNOWLEDGE

Corinne Mandin
January 22nd, 2025



The French IAQ Observatory

- A research program created in 2001
- **Objective: To coordinate and develop indoor air research activities at a national scale**
 - To improve knowledge on IAQ in buildings
 - To provide support to policymakers
 - To publish recommendations for professionals and general public
- **Public funding** from the Ministries in charge of Housing, Health, and Environment, the Agency for Ecological Transition (ADEME), the Agency for Food, Environmental and Occupational Health & Safety (Anses)

1

Descriptive studies in schools

To have a better knowledge on indoor air pollutant **sources** in classrooms and on **ventilation**

Many specific indoor air pollution sources in classrooms



High density of furniture ... and occupants!



School supplies



Cleaning products

Credit: Pixabay

Example of cleaning products used in classrooms

- Nationwide survey carried out in 2009-2011 in 101 nursery schools (3-6 years old) and 108 elementary schools (7-11 years old)

- School audit by a building expert

(Wei et al, Indoor Air, 2016)

	Cleaning frequency	Nursery schools	Elementary schools
Furniture	1/Year	0%	0%
	1/Month	1%	0%
	1/Week	3%	4%
	Every day	94%	83%
	Others	2%	13%
Floors	1/Year	0%	0%
	1/Month	0%	1%
	1/Week	2%	13%
	Every day	84%	63%
	Others	14%	23%
Windows	1/Year	5%	14%
	1/Month	13%	15%
	1/Week	20%	14%
	Every day	8%	5%
	Others	54%	52%

	Cleaning time	Nursery schools	Elementary schools
Furniture	Morning	25%	27%
	Evening	52%	60%
	Presence	2%	0%
	Absence	17%	9%
	Missing	4%	4%
Floors	Morning	15%	25%
	Evening	75%	58%
	Presence	1%	0%
	Absence	9%	14%
	Missing	0%	3%
Windows	Morning	15%	12%
	Evening	37%	31%
	Presence	0%	2%
	Absence	29%	35%
	Missing	19%	20%

Morning: before children arrive; **Evening:** after children leave; **Presence:** during the day in children's presence; **Absence:** during the day when children are not in the room

Example of cleaning products used in classrooms

- **Nationwide survey carried out in 2009-2011 in 101 nursery schools (3-6 years old) and 108 elementary schools (7-11 years old)**
- **School audit** by a building expert: commercial references and pictures of cleaning products
- **584 different cleaning products were listed.**
From 1 to 7 per building; 3 or 4 on average
- **Only 218 safety data sheets available (37%)**
- **In these SDS, 152 different chemical substances**
- **Among these substances:**
 - 49% classified as irritant according to EU classification system (CLP)
 - 1 classified as carcinogen Group 1 (carcinogen to humans) by the IARC
 - 2 considered as endocrine disruptors according to EU classification

**Not all information is available.
Cleaning products used in classrooms may
contain hazardous chemical substances**

What about ventilation in school buildings?

- **Nationwide survey carried out in 2010-2011 in 2,000 schools** randomly selected (sample stratified on climate zones and urbanization)

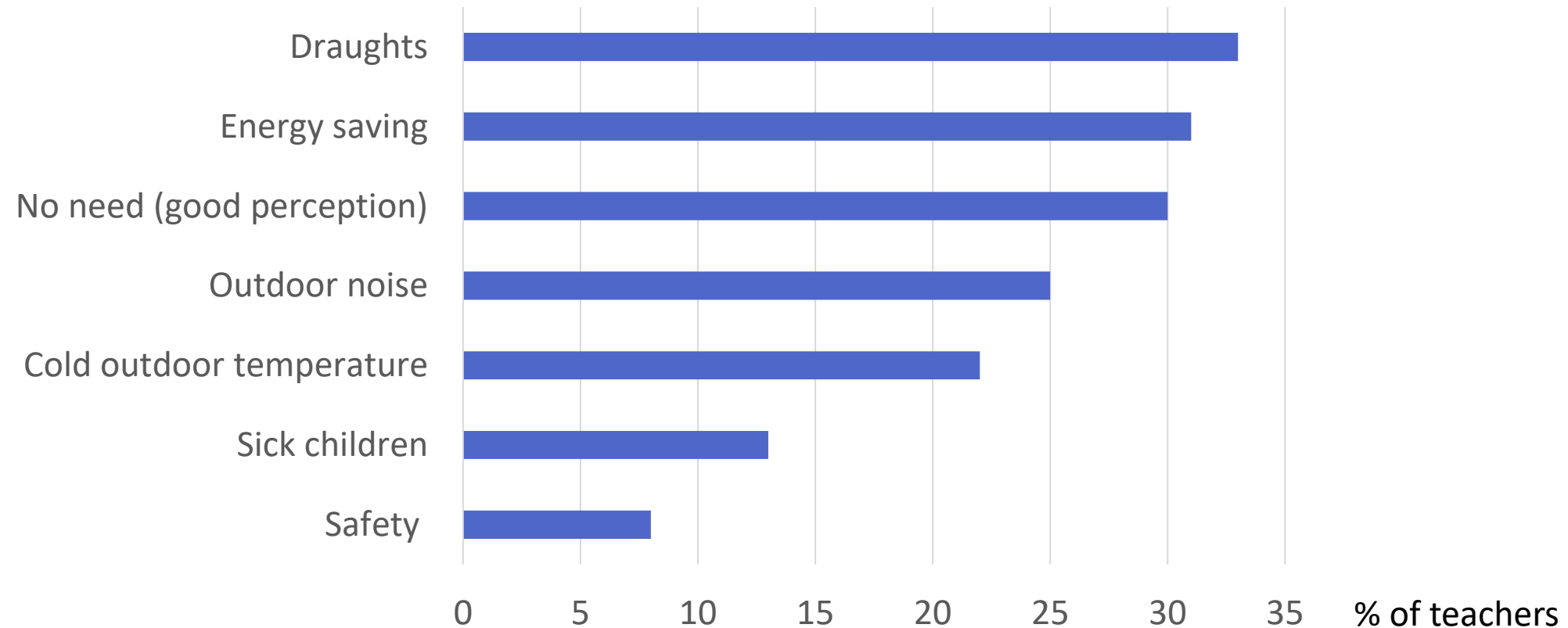
	% (2010-2011) Classrooms
No system	89%
Stack-effect ventilation (passive ventilation)	0.5%
Mechanical ventilation with exhaust only	7.7%
Mechanical ventilation with supply only	1.3%
Mechanical ventilation with supply-and-exhaust	0.5%

Reports available online in French on www.oqai.fr

Infrequent window opening

- Reason(s) why you don't open the classroom window in winter**

n=985 teachers from 2,000 schools interviewed by questionnaire in 2010-2011



Source: French IAQ Observatory; Report available online in French

2

Large monitoring surveys

First nationwide survey in schools (2009-2011)

- To assess the feasibility of a nationwide monitoring of IAQ in classrooms
- **Three parameters: formaldehyde** (indoor source tracer), **benzene** (outdoor air pollution tracer) and **CO₂** (proxy of ventilation in normally occupied rooms)
- Measurements over **one week** (formaldehyde and benzene) and **two weeks** for CO₂
- **Repeated at two seasons** (heating and non-heating)
- **101 nursery schools and 108 elementary schools** including in overseas territories



First overview of poor IAQ and poor ventilation in some classrooms

Annual average concentration of formaldehyde ($\mu\text{g}/\text{m}^3$)	% of schools
0 – 30	89
30 – 50	9
50 – 100	2
> 100	0

Annual average concentration of benzene ($\mu\text{g}/\text{m}^3$)	% of schools
0 – 2	45
2 – 5	53
5 – 10	2
> 10	0

Distributions of CO ₂ concentrations (ppm)*	In nursery schools	In elementary schools
Percentile 25	800	859
Median (P50)	969	1202
Percentile 75	1170	1555
Percentile 95	1728	2065

*During occupancy, measurement time interval = 10 minutes

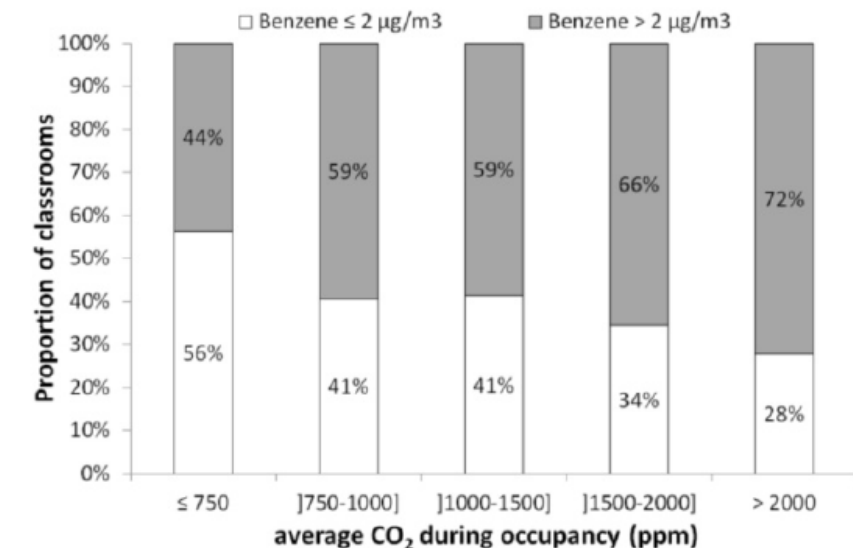
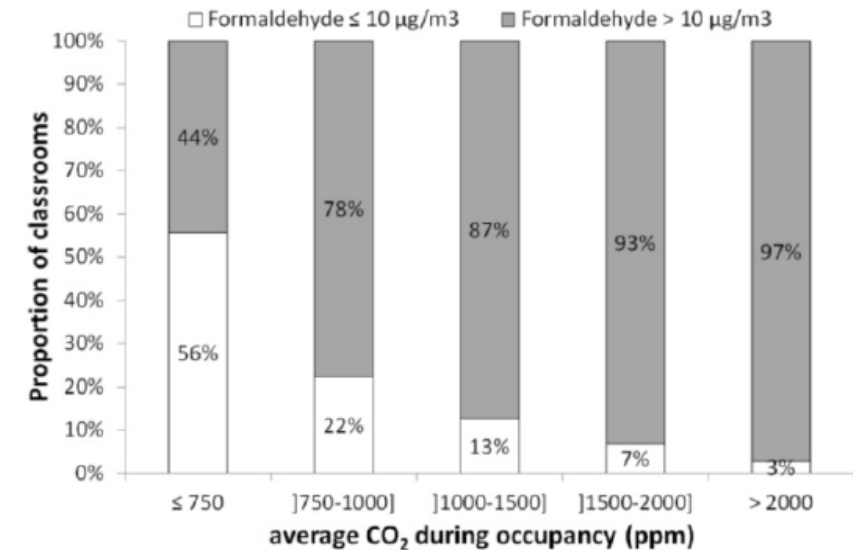
(Michelot et al, HVAC&R Research, 2013)

Relation between indoor pollution and ventilation

Median CO ₂ concentrations (ppm)*	Without mechanical ventilation	With mechanical ventilation
Nursery schools	954	776
Elementary schools	1329	1223

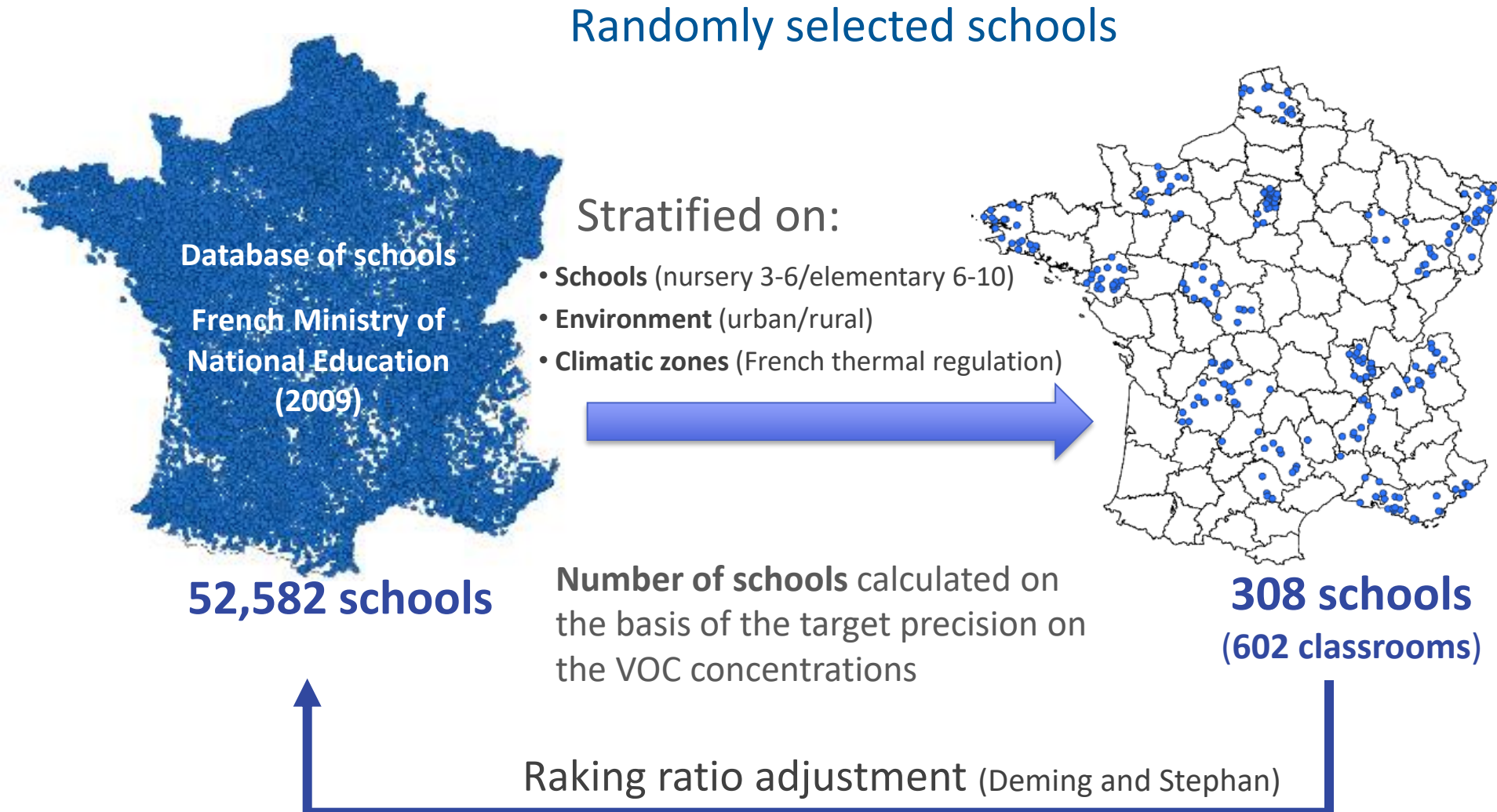
*During occupancy, measurement time interval = 10 minutes

(Ramalho et al, Int J Ventil, 2013)



(Ramalho et al, Build Env, 2015)

French nationwide survey in schools (2013-2017)



(Courtesy of CSTB) 13

Measurements in school survey (2013-2017)

One week: from Monday to Friday

Real-time measurements

- ⇒ Carbon dioxide (CO₂)
- ⇒ Temperature and relative humidity
- ⇒ Particle counting (0,3 to 20 µm)
- ⇒ Noise level (7 days, starting the Friday before the monitoring week)

Air samples

- ⇒ **Active sampling:** PM_{2,5} and SVOCs
- ⇒ **Passive sampling:**
 - VOCs and aldehydes
 - Nitrogen dioxide (NO₂)



(Courtesy of CSTB)

Measurements in school survey (2013-2017)

Settled dust sampling

- ⇒ With a wipe for lead
- ⇒ With a specific vacuum cleaner: metals and SVOCs



Punctual measurements

- ⇒ Illuminance on tables and boards (illuminance meter)
- ⇒ Lead in paint by X-Ray fluorescence
- ⇒ Electromagnetic fields



+ **Questionnaires:** Building and classroom description; Occupancy and activities; Perception of teachers

French nationwide survey in schools (2013-2017)

Main results at a glance

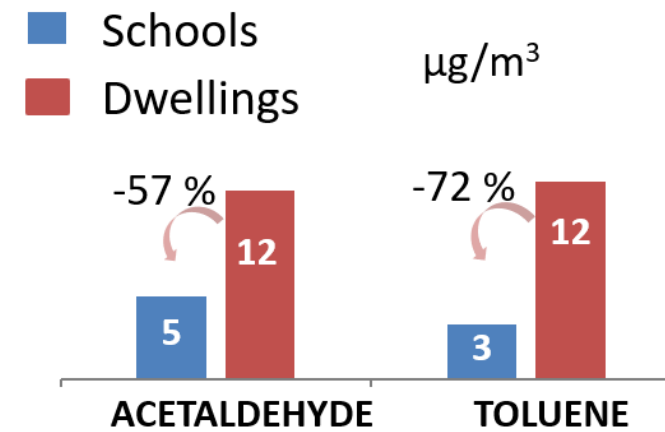
Positive aspects

- Low NO₂ concentrations
- Lower VOC concentrations compared to dwellings in France

- Indoor median NO₂ concentration < LOQ = 5 µg/m³
- Percentile 75 = 11.5 µg/m³

Indoor air quality guideline for NO₂ in France (2013) = 20 µg/m³

WHO Air Quality Guideline (2021) = 10 µg/m³ for annual exposure



Source: French IAQ Observatory newsletter Nr 11, June 2018

French nationwide survey in schools (2013-2017)

Main results at a glance

Positive aspects

- Low NO₂ concentrations
- Lower VOC concentrations compared to dwellings in France

Critical issues

- Semi-volatile organic compounds
- PM_{2,5}
- Lack of ventilation
- Lead in paint

Source: French IAQ Observatory newsletter Nr 11, June 2018

Phthalates are present in all classrooms both in air and settled dust

Phthalate	AIR		FLOOR SETTLED DUST	
	Detected in % of schools	Quantified in % of schools	Detected in % of schools	Quantified in % of schools
BBP	84%	42%	99%	99%
DBP	99%	99%	100%	100%
DEHP	6%	6%	100%	100%
DEP	100%	100%	100%	100%
DiBP	100%	100%	100%	100%
DiNP	43%	43%	100%	100%

Indoor air median concentrations: several hundreds of ng/m³ (0.1 to 0.8 µg/m³)

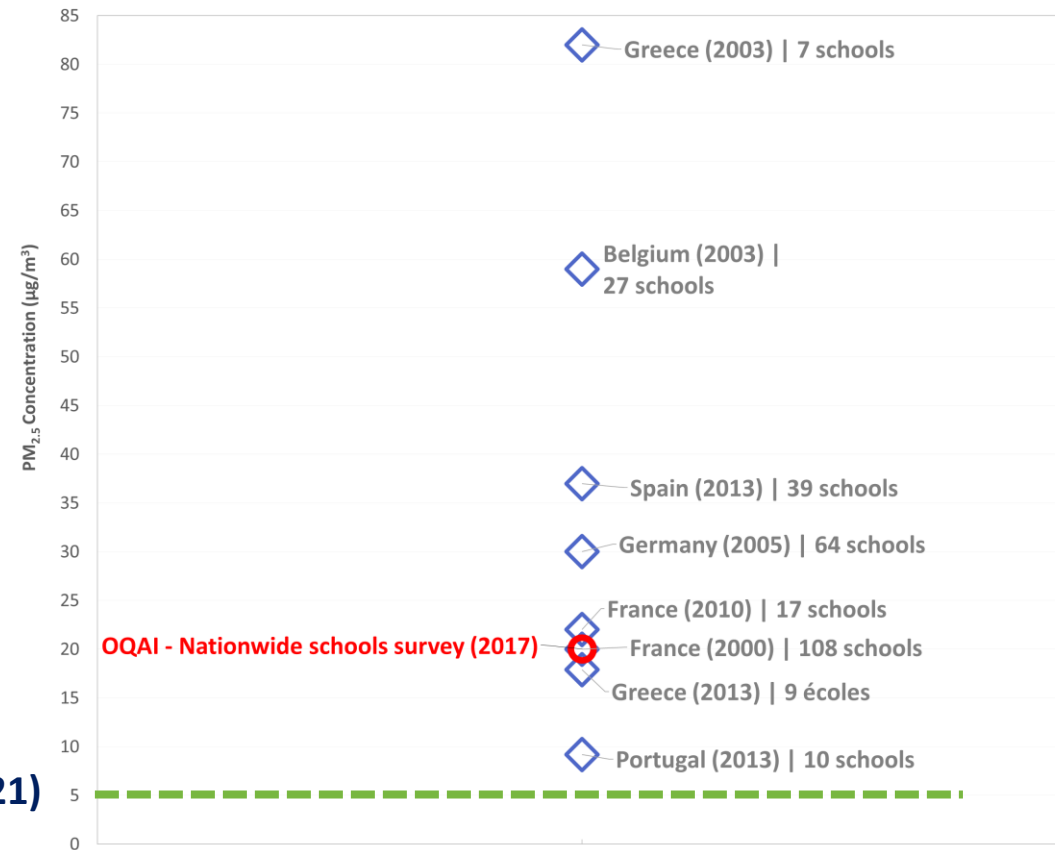
(Wei et al, Indoor Air, 2020)

Particles PM_{2.5}

Median = 18 µg/m³

100% > 5 µg/m³, WHO Air Quality Guideline for outdoor air applicable to indoor air (2021)

WHO (2021)



Mean concentrations of PM_{2.5} measured in European schools (2010-2018)

Ventilation

Air stuffiness index (ICONE)

(Canha et al, Indoor Air, 2016)

ICONE Indoor air stuffiness index	Frequency of CO ₂ concentrations
0 = non-stuffy air	100% CO ₂ values < 1000 ppm
1 = low	~ 1/3 values > 1000 ppm but < 1700 ppm
2 = moderate	~ 2/3 values > 1000 ppm but < 1700 ppm
3 = high	~ 2/3 values > 1000 ppm of which 1/3 > 1700 ppm
4 = very high	~ 2/3 values > 1700 ppm
5 = extreme	100 % of the values > 1700 ppm

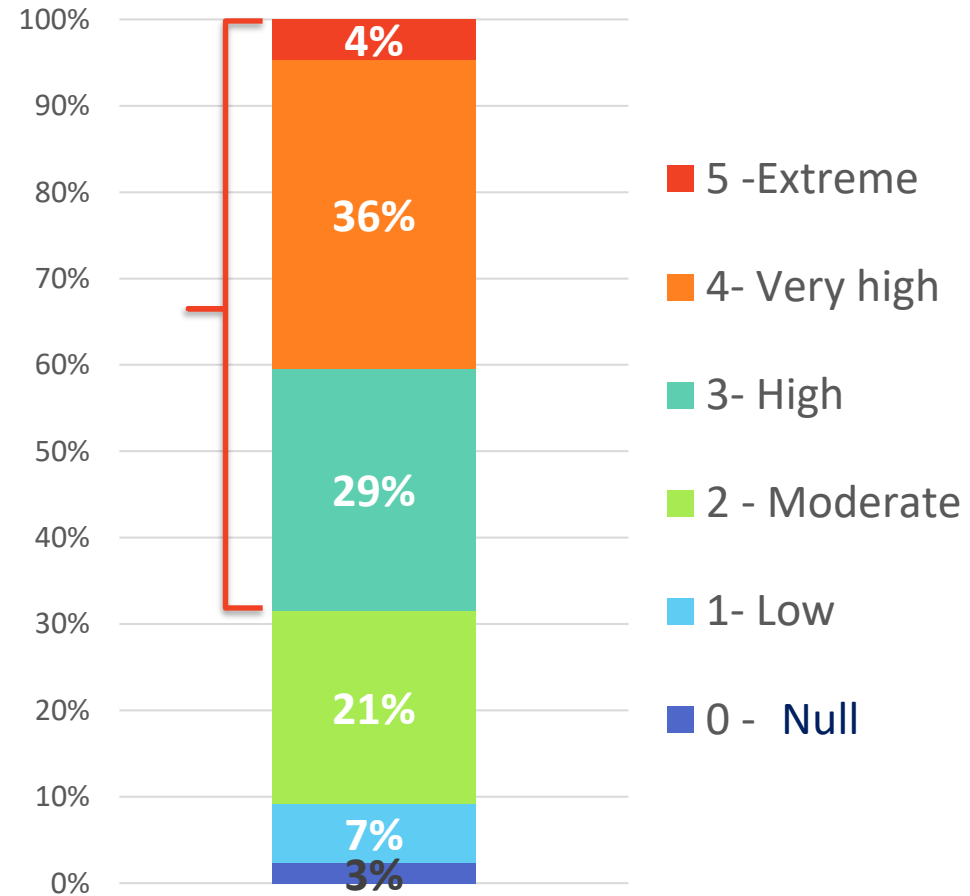
Concentrations during normal occupancy of the classrooms

Ventilation

69% of schools have at least one classroom with a high ICONE index (≥ 3)

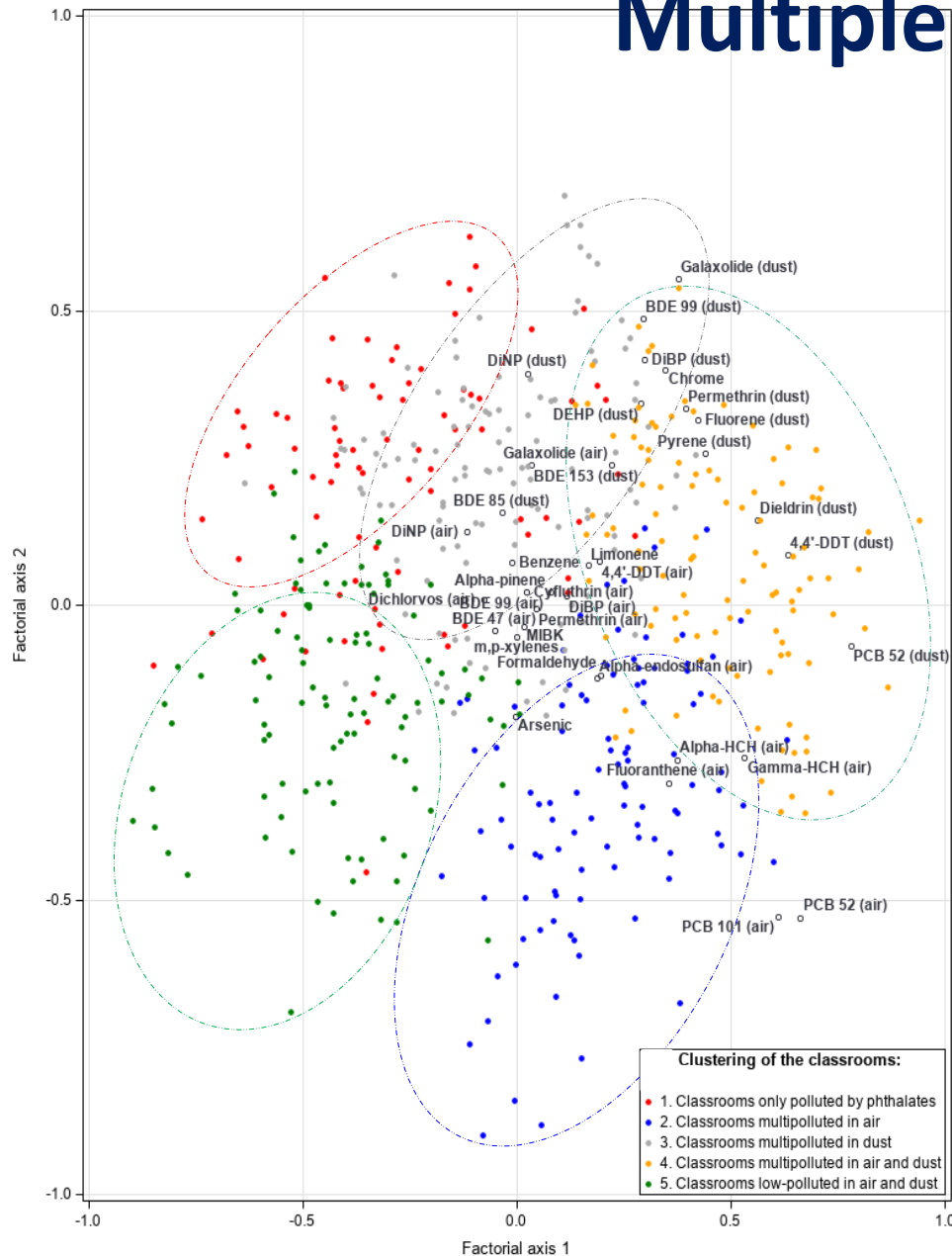
Air stuffiness index (ICONE)

(Canha et al, Indoor Air, 2016)



Highest value per school among the instrumented classrooms

Multiple exposure at schools



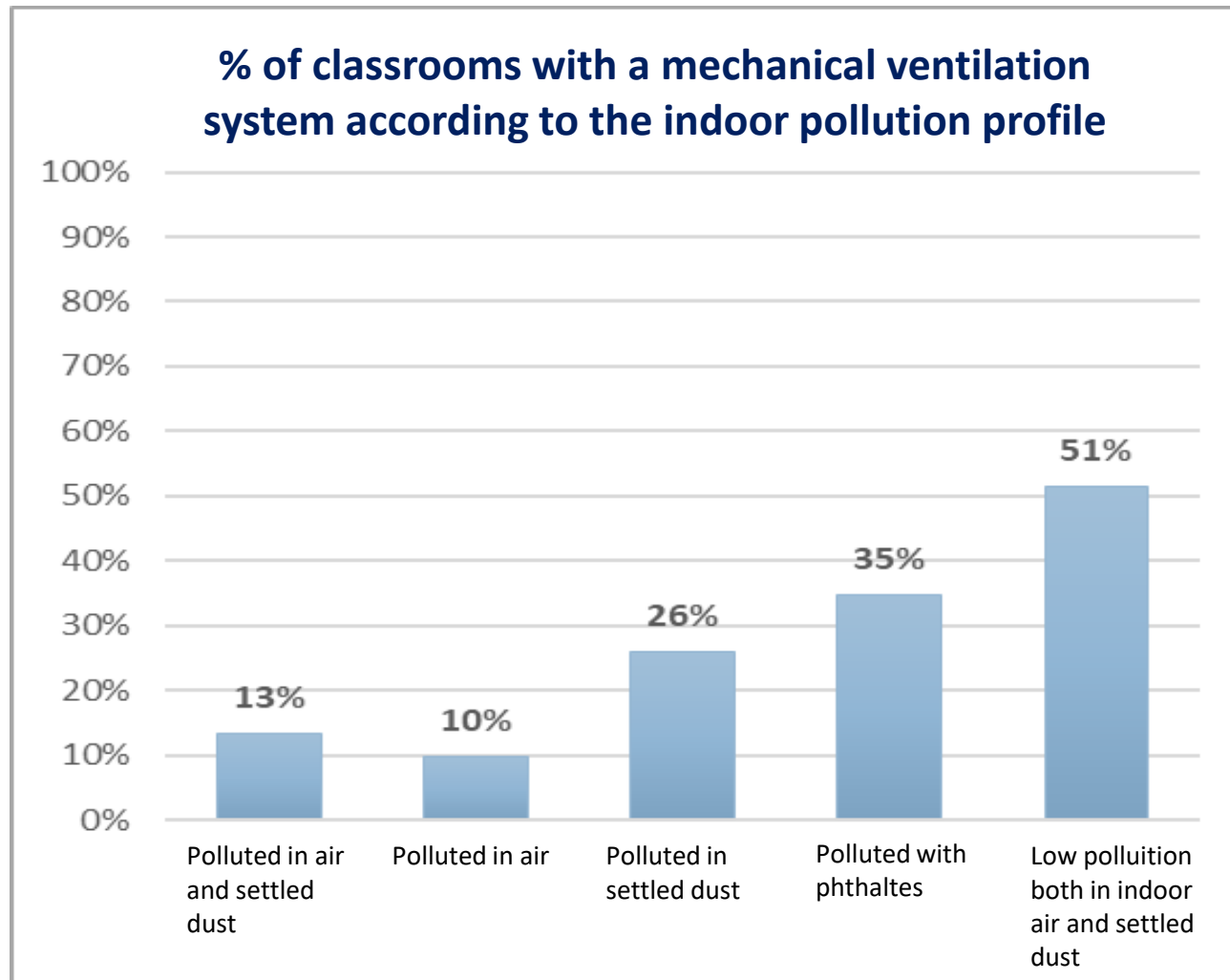
- 21% of classrooms with higher concentrations of pollutants in both air and dust
- 19% with higher concentrations in air
- 24% with higher concentrations in dust
- 17% with higher phthalate concentrations only
- 19% with lower concentrations in both air and dust

old schools, with a lower occurrence of mechanical **ventilation**, higher **outdoor** concentrations and more signs of building **dampness**

→ Higher proportion of synthetic plastic flooring

(Sivanantham et al, Energy & Buildings, 2021)

Multiple exposure at schools and building characteristics



(Sivanantham et al,
Energy & Buildings, 2021)

3

Practical implications

These results raised awareness among stakeholders

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA
TRANSITION
ÉCOLOGIQUE

How to choose school supplies to avoid any health risk?

CERTAINS COMPOSANTS SONT NOCIFS POUR LA SANTÉ

Des phtalates, perturbateurs endocriniens
dans les vernis des crayons, certaines gommes...

Des solvants toxiques pour le système nerveux
dans la colle, les marqueurs, les correcteurs :
cétones
hydrocarbures

Les enfants sont exposés
par ingestion
par inhalation
par voie oculaire
par contact cutané

Des conservateurs très allergisants
dans les colles, peintures, feutres, encres :
chlorométhylisothiazolinone (CMIT), méthylisothiazolinone (MIT)
bronopol, formaldéhyde

Attention au « slime » fabriqué maison
Cette pâte composée de produits détournés de leur usage habituel (colle, lessive, mousse à raser, collant...) surexpose la peau des enfants à des substances allergisantes ou toxiques.

LES PRODUITS À PRIVILÉGIER

Colle
à base d'amidon et en bâton plutôt que liquide

Feutre, stylo, roller
non parfumés

Gomme
sans phtalate, ni latex, ni parfum

Crayon
en bois naturel et non vernis

Marqueur
effaçable plutôt que permanent

Peinture
aquarelle plutôt qu'acrylique

Correcteur
en ruban plutôt que liquide

Cahier, feuilles de papier
avec l'Écolabel européen ou le label Ange Bleu

Pâte à modeler
non parfumée

Les bons repères

- les labels environnementaux
signalent les produits moins impactants pour l'environnement et la santé.
agirpourlatransition.ademe.fr/particuliers/labels-environnementaux
- les indications et recommandations sur les étiquettes
- le marquage CE pour les fournitures considérées par les fabricants comme des jouets, soumis à une réglementation stricte. Il signifie que le produit est conforme aux normes européennes.

CONJUGUER SANTÉ ET PROTECTION DE L'ENVIRONNEMENT

- 1 Ne pas jeter ce qui peut encore être utilisé : pages vierges des cahiers, feutres rescapés, trousse de l'année passée...
- 2 Acheter les produits les plus simples et les moins odorants, éviter les marqueurs très émissifs, gommes et feutres parfumés...
- 3 Opter pour des fournitures solides et sans plastique : pochettes cartonnées, gommes sans coque en plastique, règles en métal...
- 4 Apprendre aux enfants à bien utiliser le matériel : reboucher les feutres, fermer les pots, ne pas mettre à la bouche, se laver les mains après utilisation...

POUR ALLER PLUS LOIN
Plus d'informations et de conseils avec le tuto de l'ADEME « Prêts pour l'École » et dans la fiche « Choisir des fournitures scolaires sans risque pour la santé »
Pour informer vos enfants sur la protection de l'environnement, découvrez le site www.mtaterre.fr

CESE POUR AGIR | 10/2024 | 12 février 2024 | Conception : Agence Olympe

MINISTÈRE DE LA SANTÉ ET DE L'ACCÈS AUX SOINS
Liberté
Égalité
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MON ENVIRONNEMENT, MA SANTÉ

Airing classrooms: a health daily habit



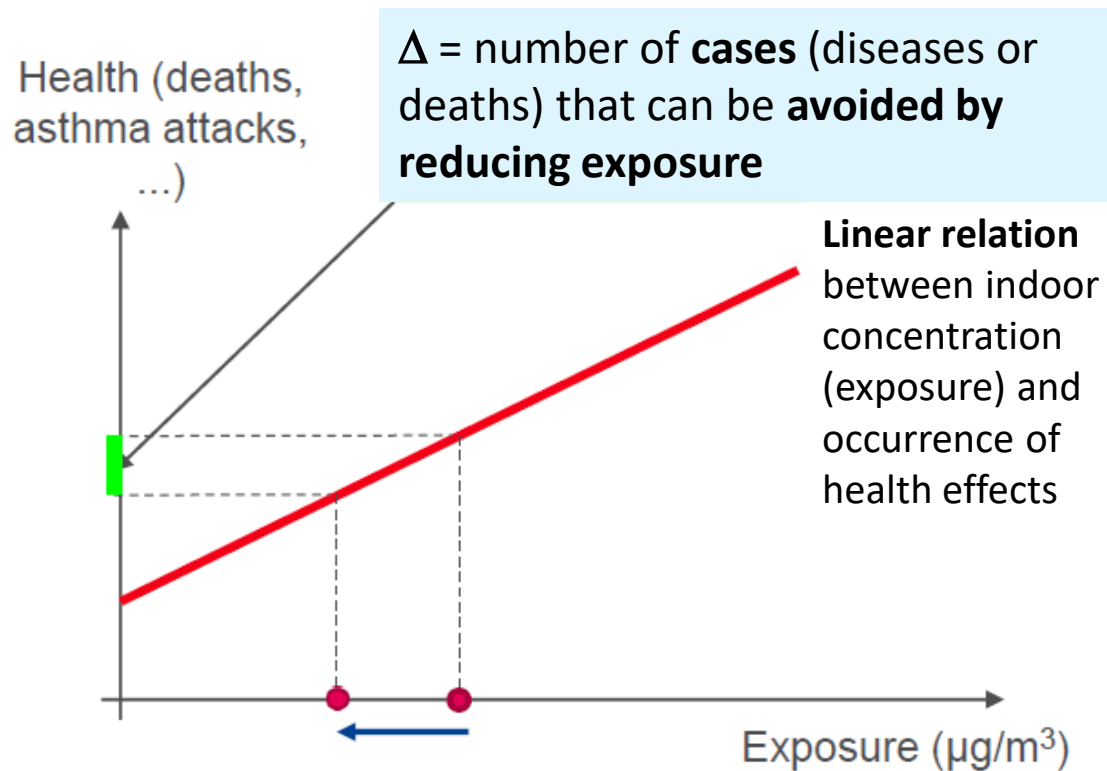
Une qualité de l'air intérieur favorable à la santé et au bien-être des occupants des établissements scolaires -élèves et personnels- est un enjeu de santé publique important.

Dans la grande majorité des classes, le renouvellement d'air est assuré par l'ouverture des ouvrants (fenêtres, portes), très peu d'établissements étant équipés de système de ventilation mécanique.

Une mauvaise qualité de l'air intérieur peut favoriser l'apparition de symptômes (maux de tête, fatigue...) et la transmission de certaines maladies infectieuses. Elle peut aussi avoir des répercussions sur l'apprentissage des élèves.

Il est donc essentiel de maîtriser les pratiques d'aération et de contrôler périodiquement les moyens d'aération et de ventilation des locaux.

These results were used to quantify the health benefits associated with improved IAQ in schools



- **Formaldehyde** exposure at school and **asthma** in children
- **Mold** exposure at school and:
 - **wheezing**
 - **asthma** in children
- Based on the school survey (2013-2017), Public Health France assessed the **health benefits of reducing formaldehyde and mold in schools** [2024, in French] = tangible results to convince the school managers to take action to improve IAQ

Quantification of the decrease of asthma cases with the reduction of formaldehyde concentration in schools

- **Baseline:** distribution of indoor formaldehyde concentrations in French schools (2013-2017)
- **Scenario 1:** the indoor concentration in classrooms where the formaldehyde mandatory guideline is exceeded ($30 \mu\text{g}/\text{m}^3$) is reduced to the guideline value
- **Scenario 2:** the indoor concentration in classrooms where the CO_2 concentration limit value is exceeded is reduced to the mean formaldehyde concentration measured in classrooms where the CO_2 concentration limit value is respected

Scenario	Number of avoidable cases of current asthma in children (confidence interval 95%)	Attributable fraction
❶ “Formaldehyde regulation”	9,028 [990; 16,850]	2%
❷ “Ventilation regulation”	27,923 [3,127; 51,060]	7%

French IAQ regulation in day-care centers and schools

From January 2023

1. **Every year:** visual inspection of windows and ventilation systems + one-day CO₂ measurement
2. **Every 4 years:** building checklist to identify specific sources likely to degrade IAQ
3. **Mandatory measurements** of formaldehyde, benzene, and carbon dioxide (one week, repeated at two seasons) **as soon as there is a modification/an event in the building likely to impact IAQ** (e.g., renovation, building extension, new flooring, fire, etc.)
4. **Development of an action plan regularly updated**

+ a regulation dedicated to radon with **mandatory measurement every 10 years in radon-prone areas**

As a conclusion

- **French schools show high indoor pollution for some pollutants**
- **Ventilation is a problem and needs to be improved**
- **We know enough to act to improve IAQ at school**
- **Political willingness for an ambitious regulation is needed**

THANK YOU FOR YOUR ATTENTION

corinne.mandin@gmail.com





CONFERENCE by Eurovent

BREATHING ACHIEVEMENT INTO
EVERY CLASSROOM

COFFEE BREAK





ADAM TAYLOR

CHAIRMAN OF THE BESA GROUP ON IAQ

*'Teachers' attitude to IAQ, and
installation and maintenance concerns'*

Teachers attitude to IAQ

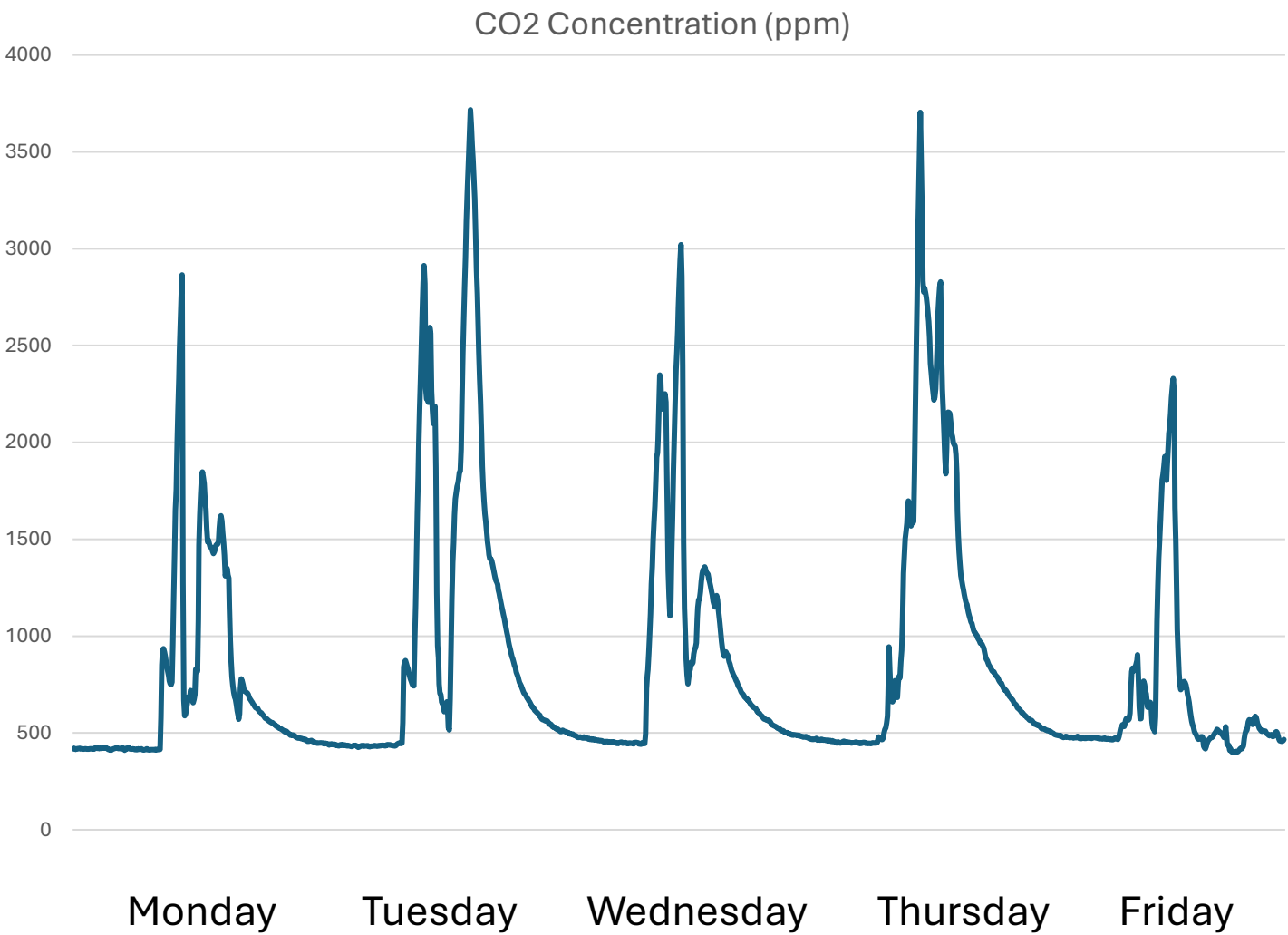
Installation and maintenance concerns

Adam Taylor B.Eng I.Eng MCIBSE

Managing Director – ARM Environments

Chair – BESA IAQ Specialist Group





School Ventilation

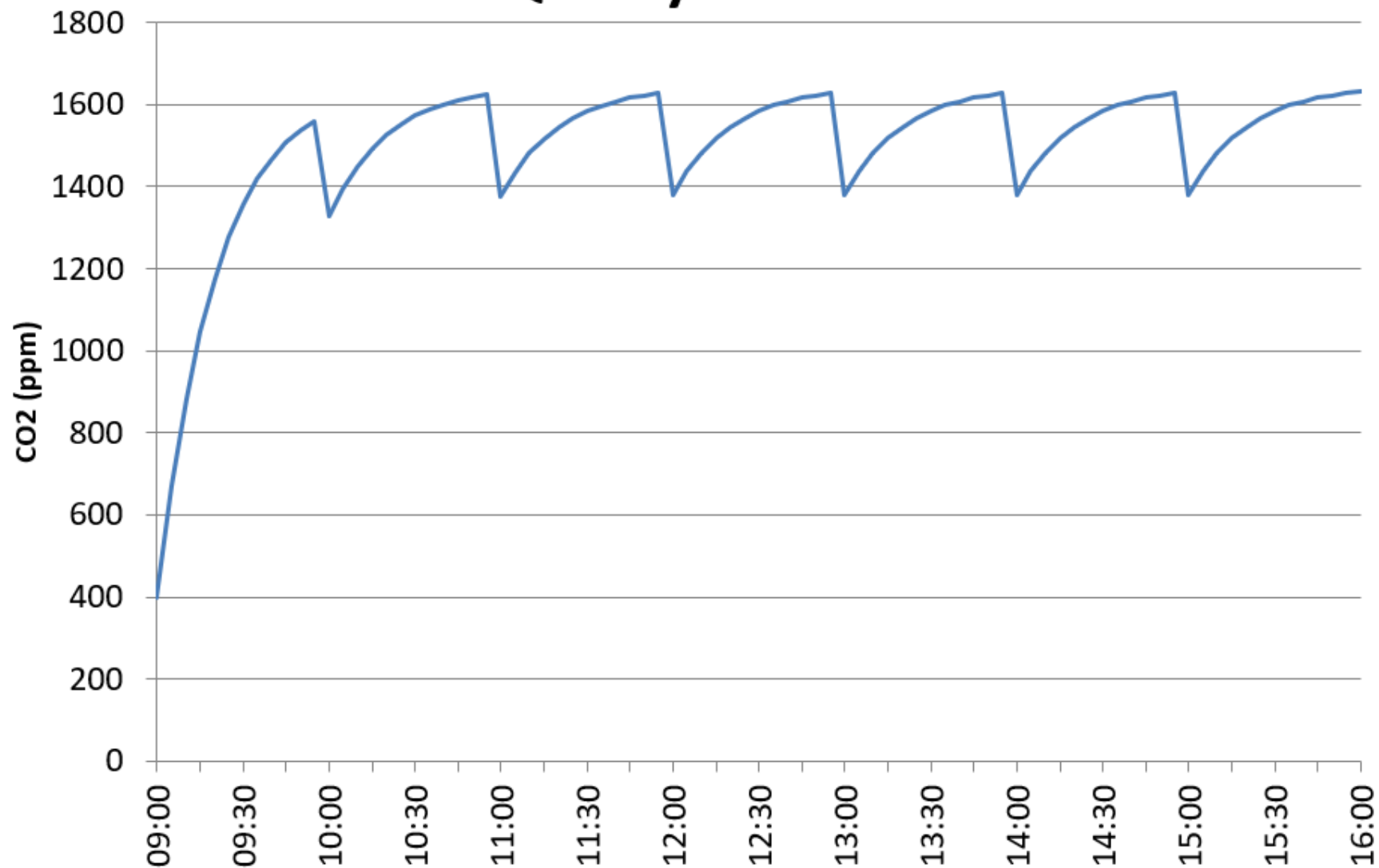
- Very unique situation
- 38 weeks a year
- Monday – Friday only
- Vent 08:30-15:00
- Heating only required a few mornings a year (in South East)



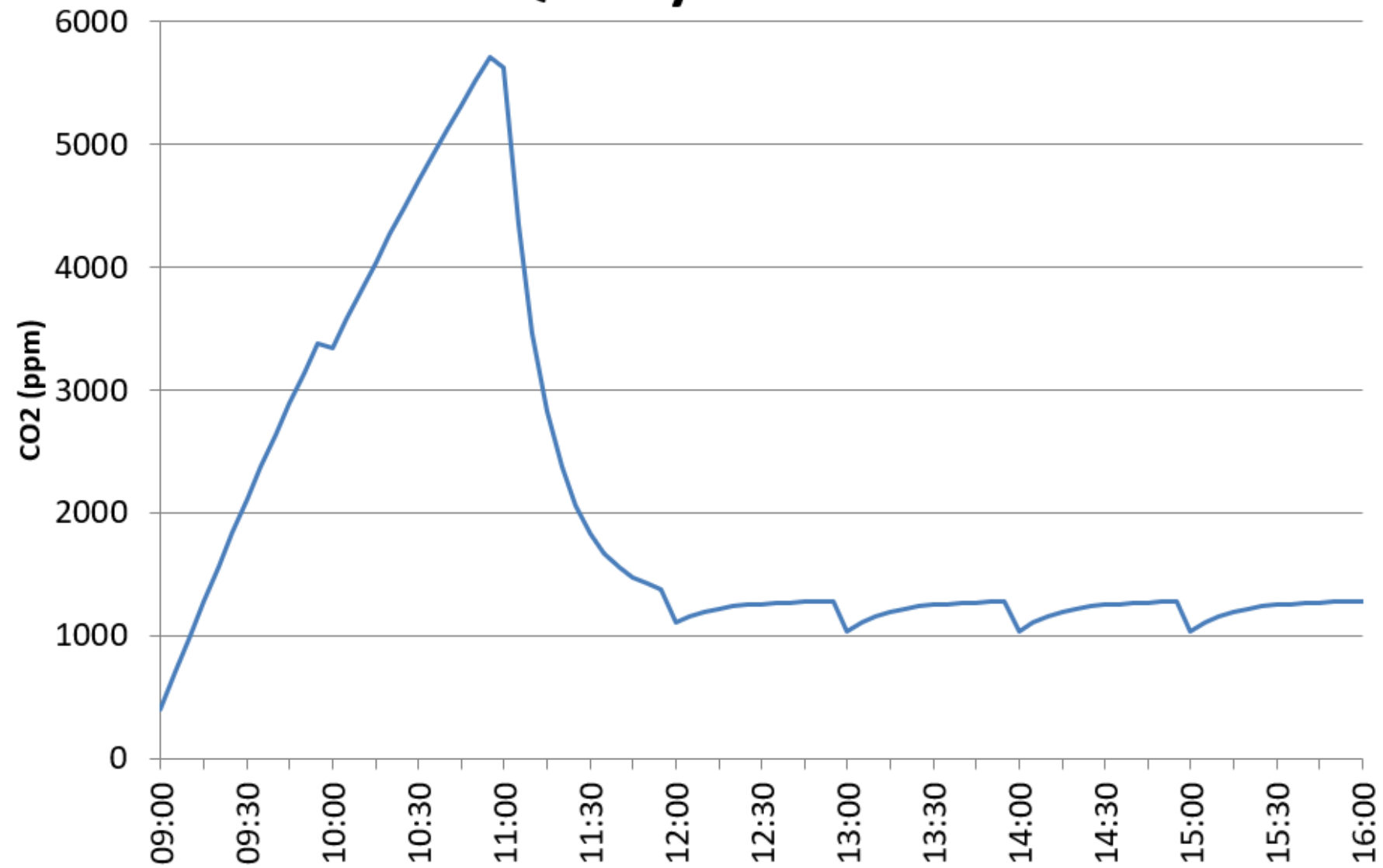
Adult – Child Ratios

- Beavers 1:6
- Cubs 1:8
- Scouts 1:12
- Schools 1:32

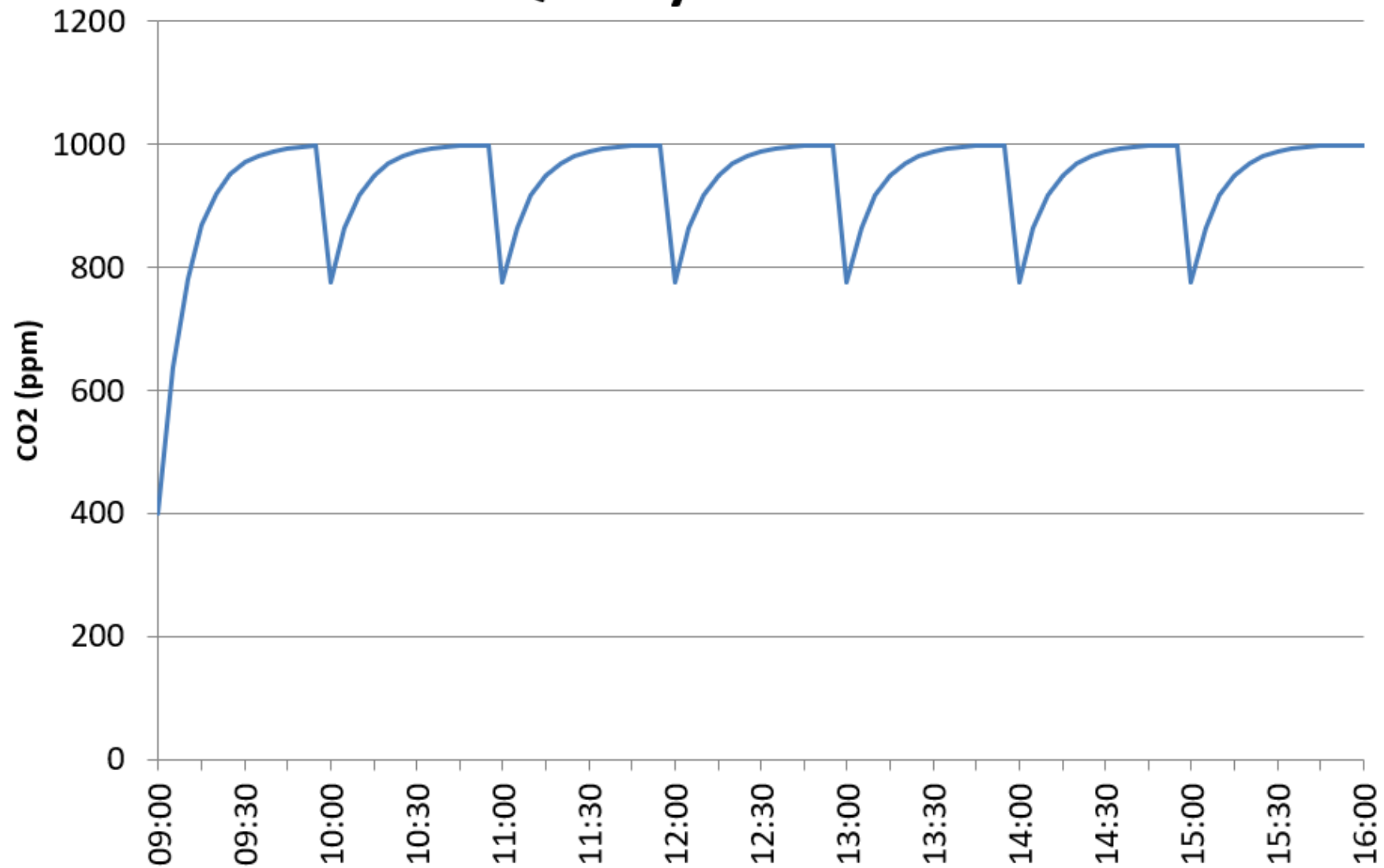
Air Quality Calculation

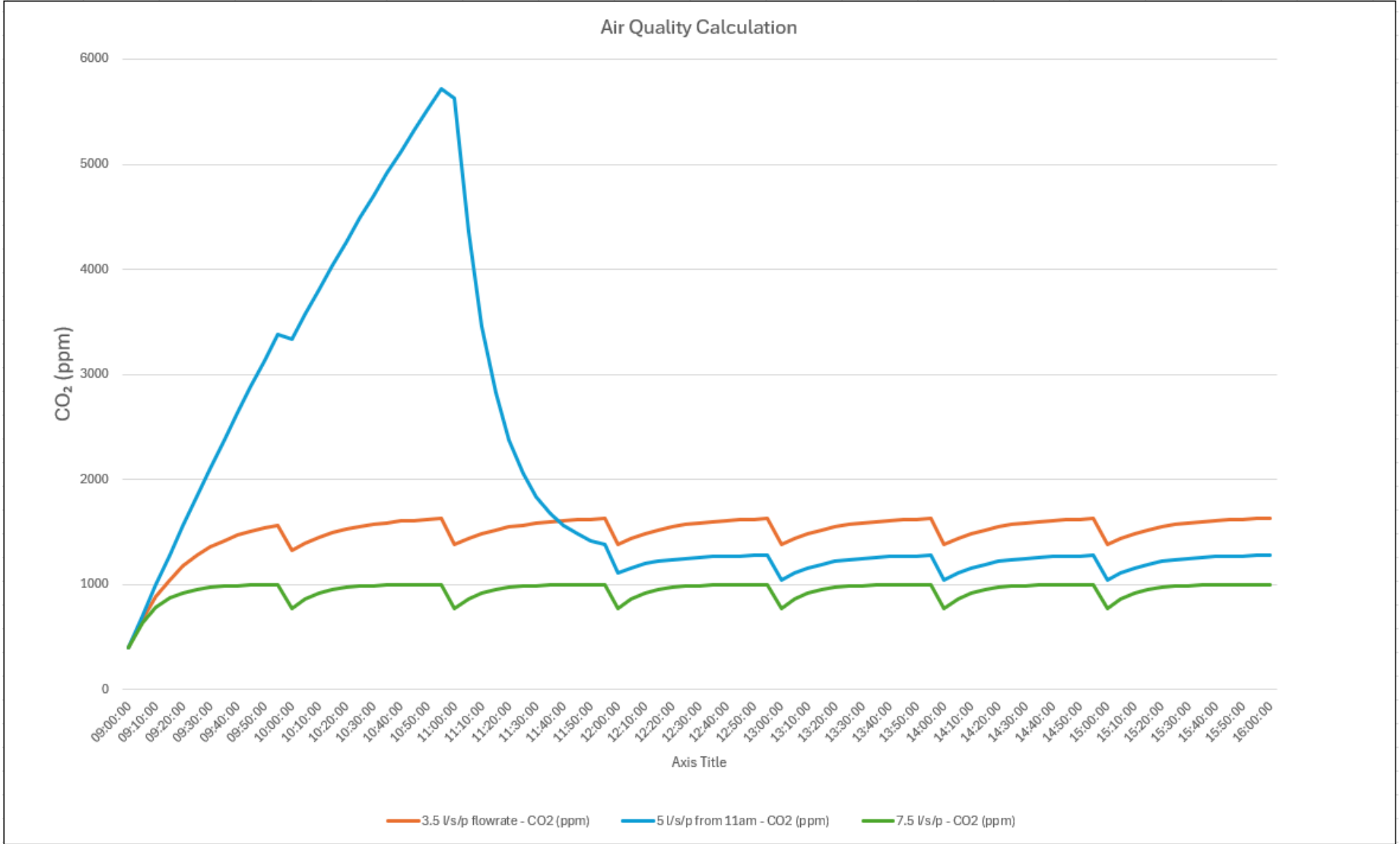


Air Quality Calculation

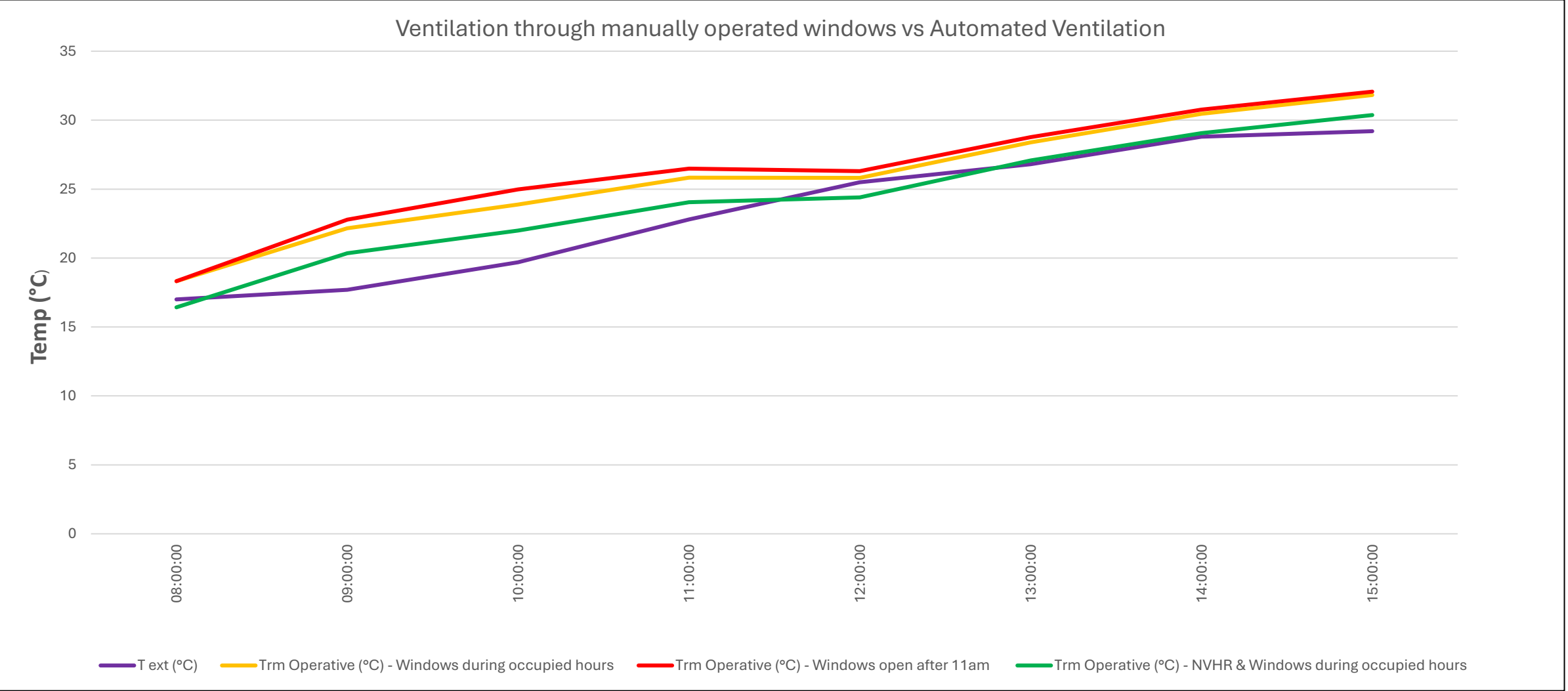


Air Quality Calculation





Summer scenario

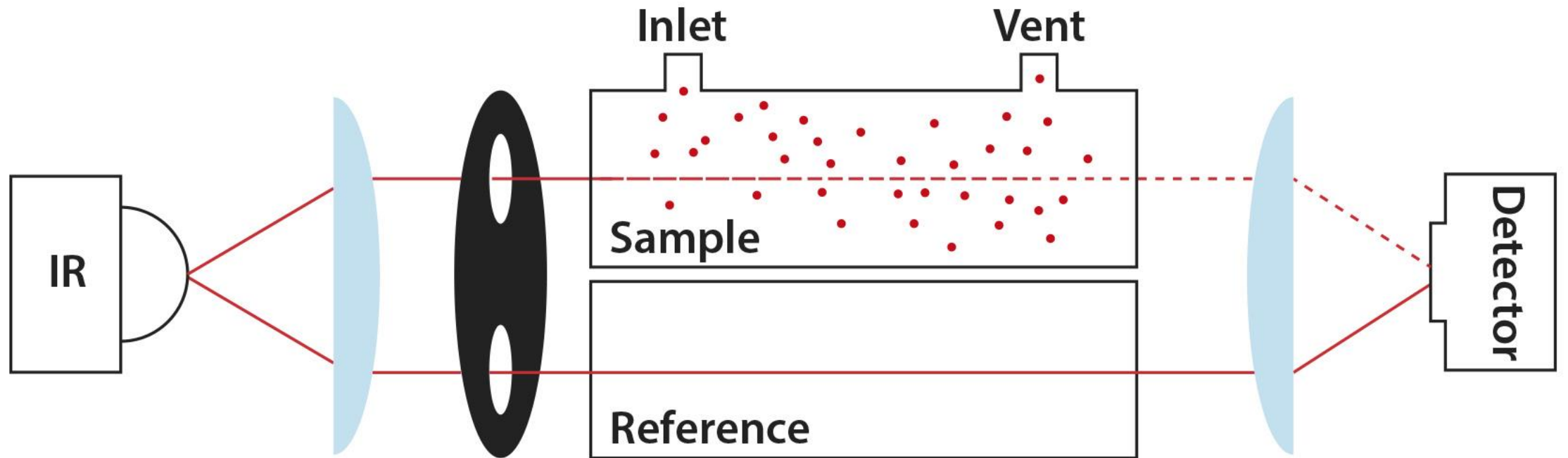


Operational requirements

- Ventilation systems need to be automatic
- There needs to be an element of user control
- Those controls need to be intuitive
- Instructions for the ventilation system need to be readily available at point of use (QR code)
- We have to accept that the school staff will be unaware of the need for maintenance.

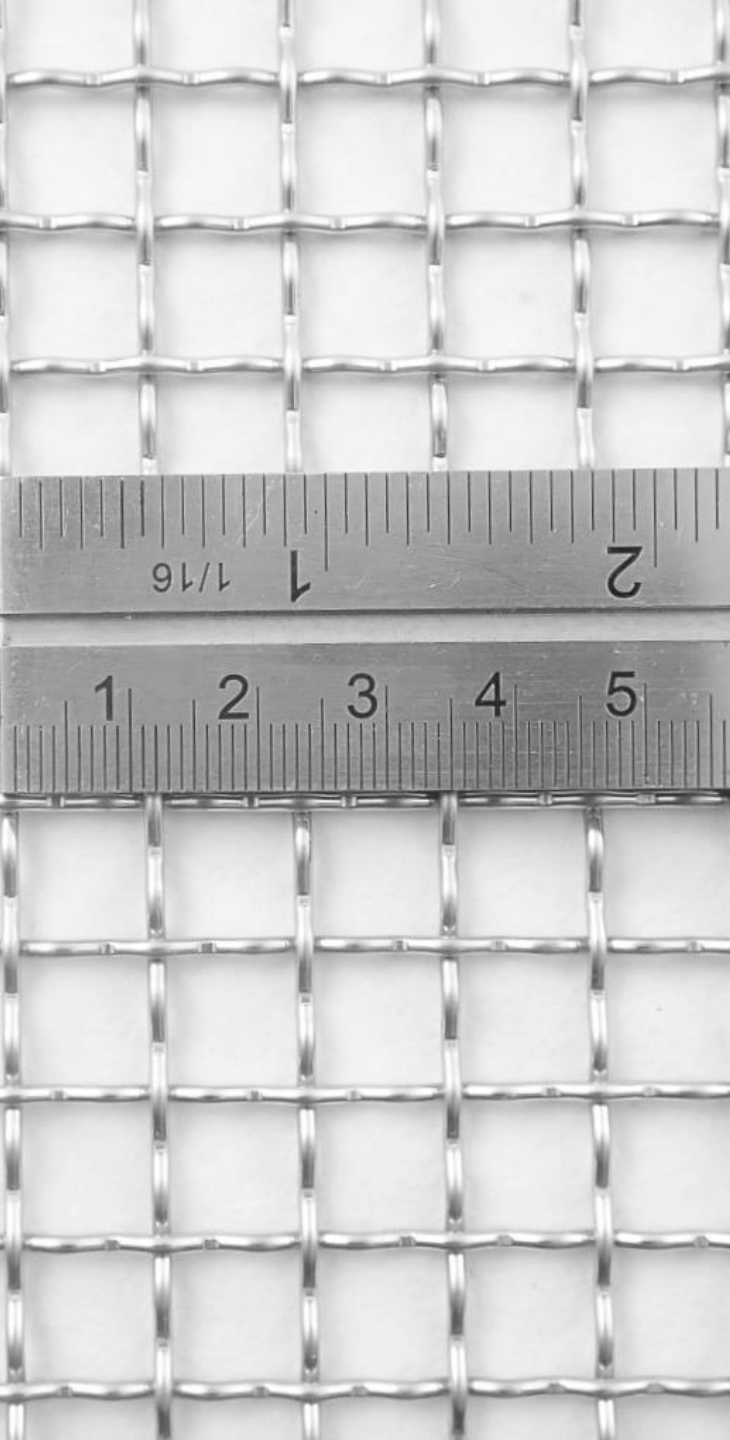


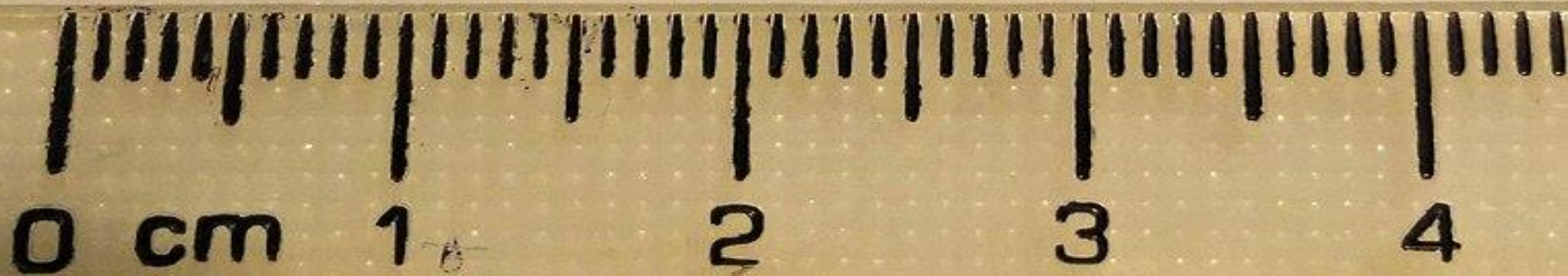
Advances in NDIR technology



#SEETHEAIR









- Between 1998 and 2010 the private finance initiative (PFI) became the favoured option to procure school buildings and facilities in the UK. Under the scheme, responsibility for financing, building and managing infrastructures and services is transferred by the state to a private consortium, including banks, financiers and a construction company. Such contracts often extend to twenty-five or thirty years.
- The rising cost of debt finance, equity, and other factors over the duration of a PFI contract means that for a group of schools procured through private financing, costs were shown to be 40 per cent higher over a twenty-five-year period than those of publicly financed operations.

- There always seems to be CAPITAL available for schools (typically when a housing development is built)
- There seldom seems to be money available for maintenance in schools.
- Inspections of school ventilation systems are as important as a TM44 inspection (carried out every 5 years)

BESA

BUILDING ENGINEERING
SERVICES ASSOCIATION

Schools Workshop initiative



EMMA GIBBONS, PETER WALSH



CIBSE

*'Filters in classrooms and intrusion of
externally polluted air'*

Indoor air quality

CIBSE Air Quality Group

Emma Gibbons, UCL

Peter Walsh, WSP



About CIBSE

CIBSE (The Chartered Institution of Building Services Engineers) is a pioneer in responding to the threat of climate change. We support engineers in finding innovative ways to make buildings perform for individuals, the community, and the planet. Our membership is diverse and comprises a broad range of specialisms. CIBSE consults the government on construction, engineering, and sustainability, providing the resources needed to meet net zero targets in the UK, Europe and worldwide.

- Over 21,000 members in 100+ countries
- Seven grades of membership
- Five Societies
- 18 Special Interest Groups



CIBSE Vision and Mission

Better performing buildings for society and the environment.

To advance and promote the art, science and practice of building services engineering, to invest in education and research, and to support our community of built environment professionals in their pursuit of excellence.



CIBSE Air Quality Group

Mission Statement

To use engineering skill to support the pursuit of healthy air in the built environment.

What does the group do?

The task group has been formed to help CIBSE be an advocate for improvements in air quality, both inside and out, to build links to other organisations with similar goals, and to raise awareness of the issue of air quality in the built environment. We inform CIBSE's technical output – feeding into guidance document, consultation responses and documenting best practice to improve the standard of air in buildings.



Filtration in classrooms

WSP closely monitored Indoor Air Quality in 6 Nursery Schools across London, testing the performance of six different indoor Air Filtration Devices.

Trial Air Filtration Systems in Classrooms

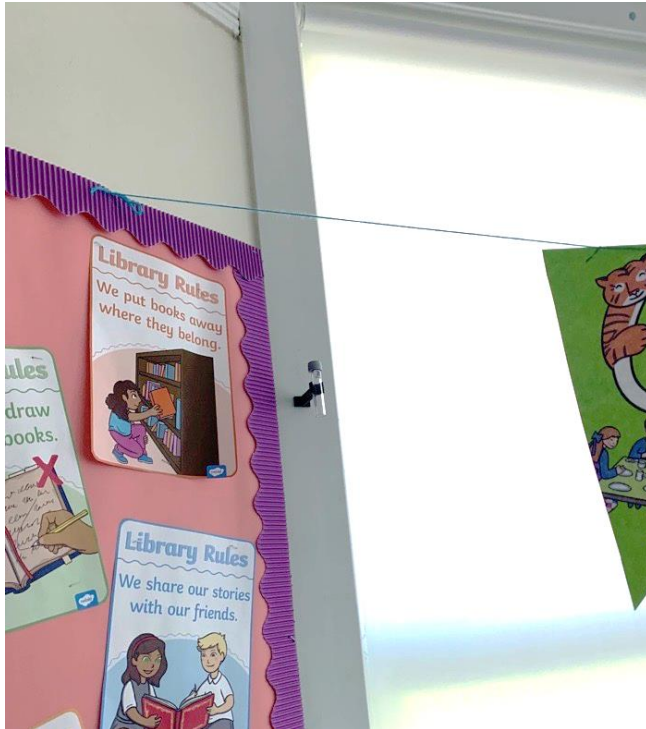
WSP undertook a 6-month trial of Air Filtration Systems (AFS) in six nursery schools.

Trial objectives were:

- Assess the context and feasibility of installing filtration systems at the selected nurseries.
- Install, trial and monitor the effectiveness of filtration systems in six nurseries, including consideration of installation and maintenance.
- Consider whether the technology was effective and appropriate for wider use.



Monitoring Strategy

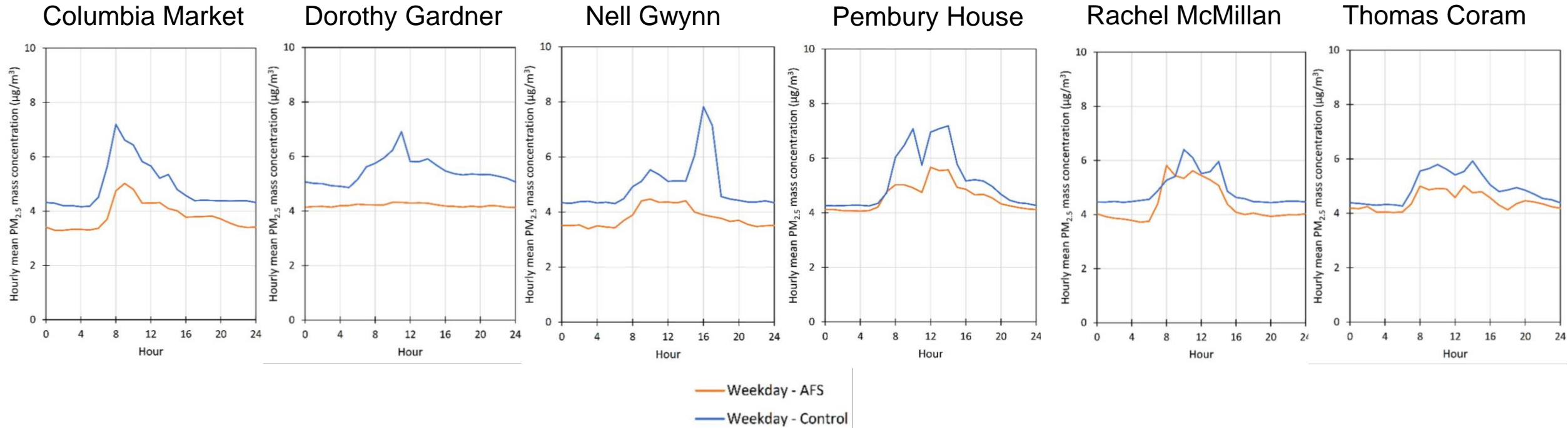


Diffusion tube in classroom (@Gradko)

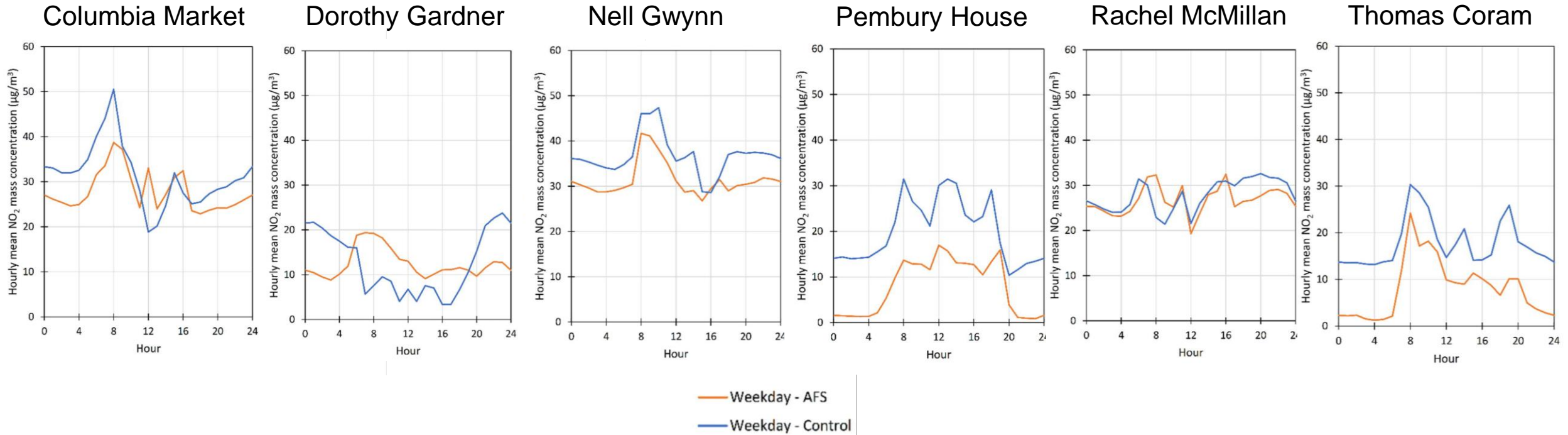


Zephyr indicative low-cost sensor (@EarthSense)

Results at Differing Nurseries – PM_{2.5}



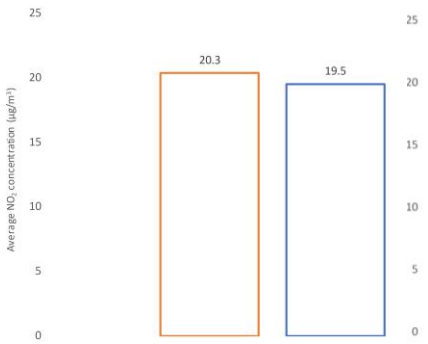
Results at Differing Nurseries – NO₂



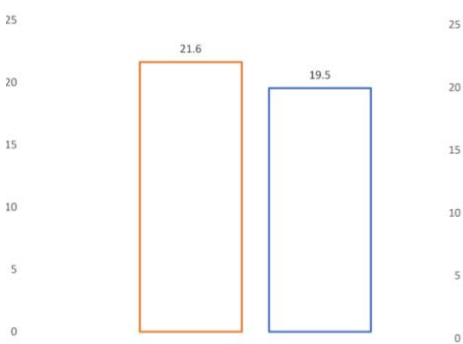
Results at Differing Nurseries – NO₂



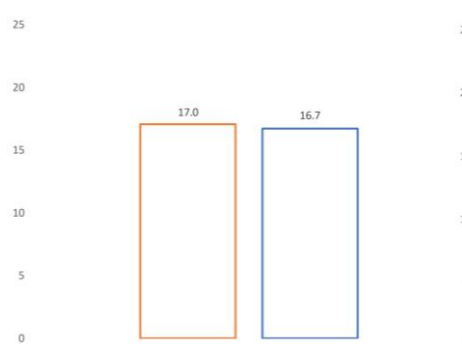
Columbia Market



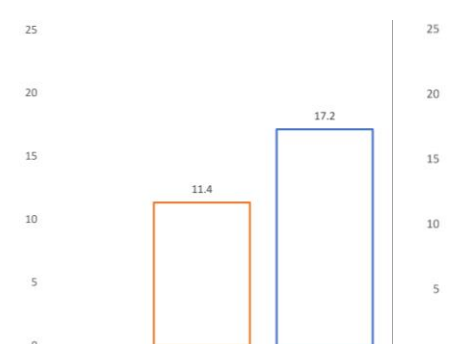
Dorothy Gardner



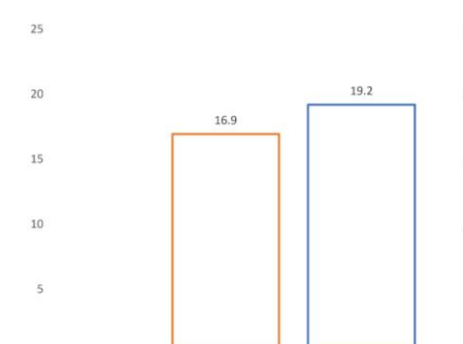
Nell Gwynn



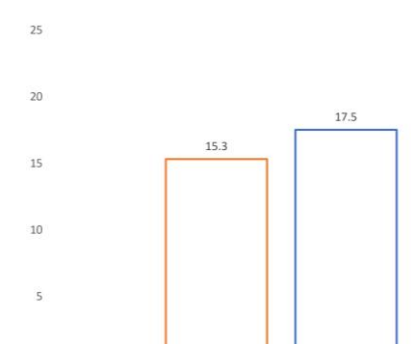
Pembury House



Rachel McMillan



Thomas Coram



AFS
Control

Nursery Feedback



Participating nurseries were invited to provide feedback and comments regarding the AFS trial and their experiences:

Unobtrusive. No discernible noise & they haven't got in anyone's way.

Children and staff were initially curious about what it does and asked questions, but no longer noticed it.

Once they had set them up there was nothing for us to do really. They just did their thing.

The cleaners unplugged it on occasions, not enough sockets.

Anecdotally, we feel there have been fewer asthma incidents.

Really good as we've ended up working them into our activities about pollution & the environment.

We experimented with the fan settings and it gets louder on the max setting, but still not that loud, and we only needed it on a low setting as it was a small room

Concerns over floor-standing units getting in the way and children being able to press buttons

The room smells better and feels fresher

A team member with bad asthma, felt better during the time the unit was switched on (not sure if this was a placebo effect though!)

Once they had set them up there was nothing for us to do really. They just did their thing.

The unit was big and clunky – it took up a lot of space, and could not be pushed compactly into a corner as it needed space for air to move around

Summary



From its 6-month trial of Air Filtration Systems (AFS) in six nursery schools, WSP found the following:

- AFS were successful in reducing $PM_{2.5}$ concentrations.
- Average NO_2 concentrations from the diffusion tubes in the AFS classrooms were lower than the control classrooms by between 1 to $4\mu g/m^3$, though slightly higher in 3 classrooms.
- Diffusion tubes, though a more precise monitoring system, were incapable of distinguishing exposure during school hours only.
- Zephyr data is less accurate in monitoring the overall levels of NO_2 , but does provide useful data on the relative changes in NO_2 .
- AFS units were suitable for installation and operation in a nursery environment.
- Generally AFS were welcomed by Nursery classroom staff.



UCL air quality projects

- Indoor air quality in nurseries (Dr Shuo Zhang)
- TOP project (Dr Sam Stamp)
- In-line filtration (Emma Gibbons)
- Passivhaus primary school (Chryssa Thoua)



Indoor air quality in nurseries (Dr Shuo Zhang, UCL)



The project involved evaluating the impact of air purifiers and window operation on indoor air quality in UK nurseries.

S. Zhang et al.

Building and Environment 243 (2023) 110636

Air quality monitoring was carried out in three nurseries in London during the Covid-19 pandemic (March 2021 to Feb 2022).

Key findings:

- There was a 63% mean reduction rate of $PM_{2.5}$ using the air purifier when the nursery windows were closed, and 46% reduction when the windows were open. Showing that air purifiers can be effective at reducing $PM_{2.5}$ when combined with suitable window operation.
- Average NO_2 concentrations were above the WHO LT guideline value in all classrooms (mean indoor level: $17.2 \mu g/m^3$).
- Concentrations of formaldehyde (ranging from 9.5 to $65.0 \mu g/m^3$) were above guideline values, with concentrations of other measured pollutants lower than previous nursery studies.
- Due to operational practices during the Covid-19 pandemic, windows were operated more frequently for ventilation needs rather than being driven by temperature alone.
- The increased ventilation in the monitored nurseries led to low levels of VOCs and aldehydes (except for formaldehyde and 2-ethylhexanol) but could bring thermal discomfort to occupants.
- Both temperature and noise levels were shown to be relevant factors impacting the operation of air purifiers.

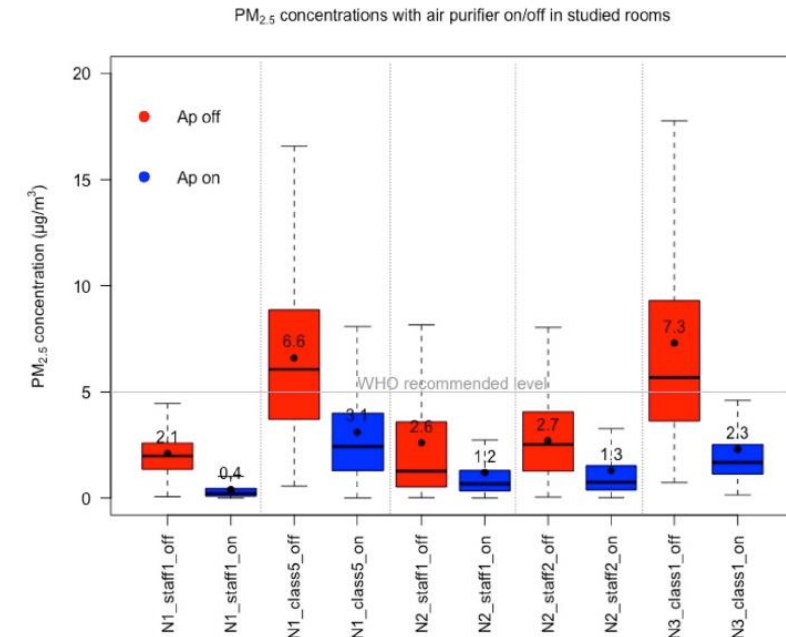


Fig. 4. $p.m._{2.5}$ concentrations in rooms with air purifiers; red boxes are when air purifiers were turned off; blue boxes are when air purifiers were turned on; the air flow rate of the air purifier selected is $320 m^3/h$, and the ideal ACH (air change per hour) for air purifier was kept around 3–4 in all studied rooms.

TOP project (Dr Sam Stamp, UCL)

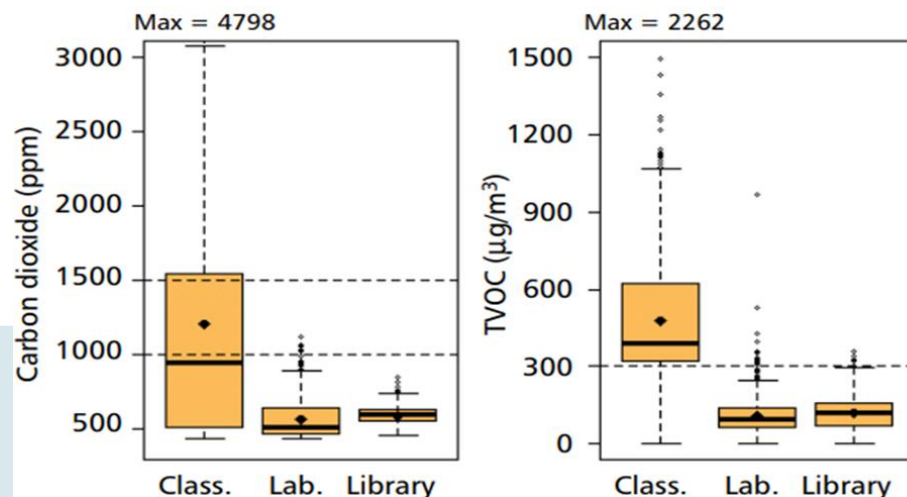


The TOP (Total Operational Performance of buildings) project looked at a cross-section of low energy domestic and non-domestic buildings, including schools.

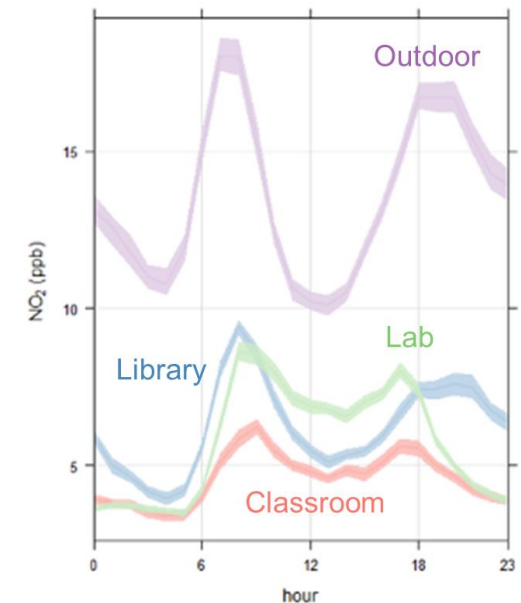
The project aimed to address the operational performance gap of buildings, evaluate how energy and IEQ performance varies between building type and country, and to determine the most cost-effective route to remedy the underlying root causes of energy/IEQ underperformance.

Data collected from one school showed how the CO₂ demand control ventilation system increased ventilation rates during occupied periods, increasing the ingress of NO₂ from outside, including from morning peaks in traffic.

Additionally, one classroom had a faulty CO₂ sensor, compromising the demand control ventilation strategy. As a result this zone had much higher CO₂ and VOC concentrations.



Impact of a faulty sensor on CO₂ and VOC concentrations



Increased NO₂ ingress from a CO₂ demand control ventilation system in a school

In-line filtration (Emma Gibbons, UCL)



Analysis of monitoring data from 5 mechanically ventilated office buildings shows that:

- PM filtration can achieve very low levels of PM_{2.5} indoors (average concentrations around 2 µg/m³).
- Indoor NO₂ concentrations are highest when the mechanical system is operational, suggesting ingress of NO₂ is not typically well controlled.
- Indoor concentrations of NO₂ in a mechanically ventilated building with in-line NO₂ filtration shows greatly reduced levels.

Indoor concentrations of NO₂ by building type (passive monitoring results, period mean) (unpublished results):

Building ventilation type	Average NO ₂ concentration (µg/m ³)
Mechanically ventilated (non-openable windows)	21.0 22.5
Mechanically ventilated with NO ₂ filtration	2.2
Hybrid ventilation (mechanical with openable windows)	10.3 13.3 15.6
Naturally ventilated (3 rd floor)	13.5
Naturally ventilated (7 th floor)	9.8
WHO air quality guideline value (annual mean)	10



Passivhaus primary school (Chryssa Thoua, UCL)



The project explores the operational performance of schools built to the Passivhaus standard, and historic schools, to determine possible implications to retrofit historic schools.

Monitoring was carried out in four new-build primary schools, Passivhaus-certified, in urban and suburban locations.

Air quality monitoring carried out in three classrooms and one outdoor location for each school, for 10 months.

Sensors installed: Temperature, relative humidity, CO₂, NO₂, PM_{2.5}, PM₁₀, CO, and VOCs.

Outdoor NO₂ concentrations were significantly lower in the non-heating season compared to the heating season, as expected, and indoor NO₂ concentrations were below the long-term standard of 40µg/m³.

The results of the study contributed to understanding the patterns and influencing factors of NO₂ concentrations in classrooms.

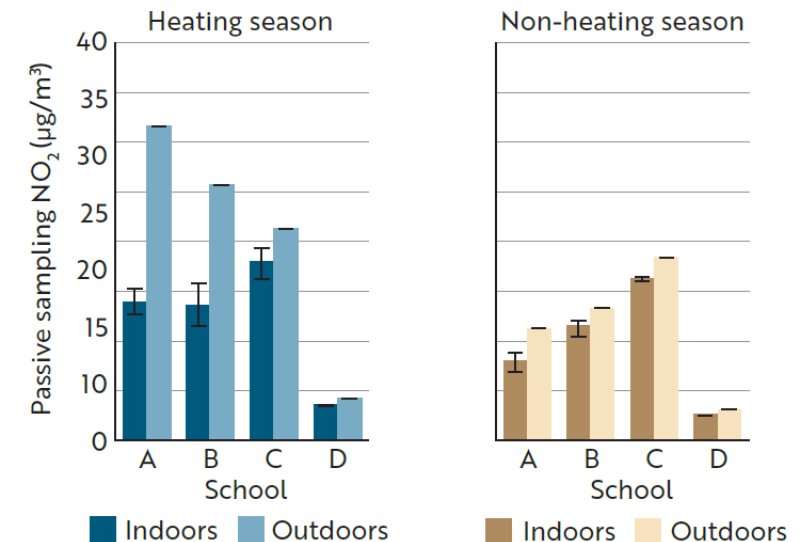


Figure 3.5 Indoor and outdoor concentrations of NO₂ in four Passivhaus primary schools in the heating and non-heating seasons (credit: Chryssa Thoua)

Included as a case study in CIBSE TM68: Monitoring indoor environmental quality (2022)

CIBSE TM57: Integrated school design

The aim of the Technical Memorandum is to provide guidance for all members of a school design team, including building services engineers, architects, client bodies, contractors and users.

Each chapter of the guide indicates best practice approaches as well as practical feedback from completed projects, with the aim of creating successful learning spaces.

It includes chapters on acoustics, lighting, ventilation, overheating and cooling, heating and thermal performance, energy and POE.

Air quality is discussed in the ventilation design chapter.

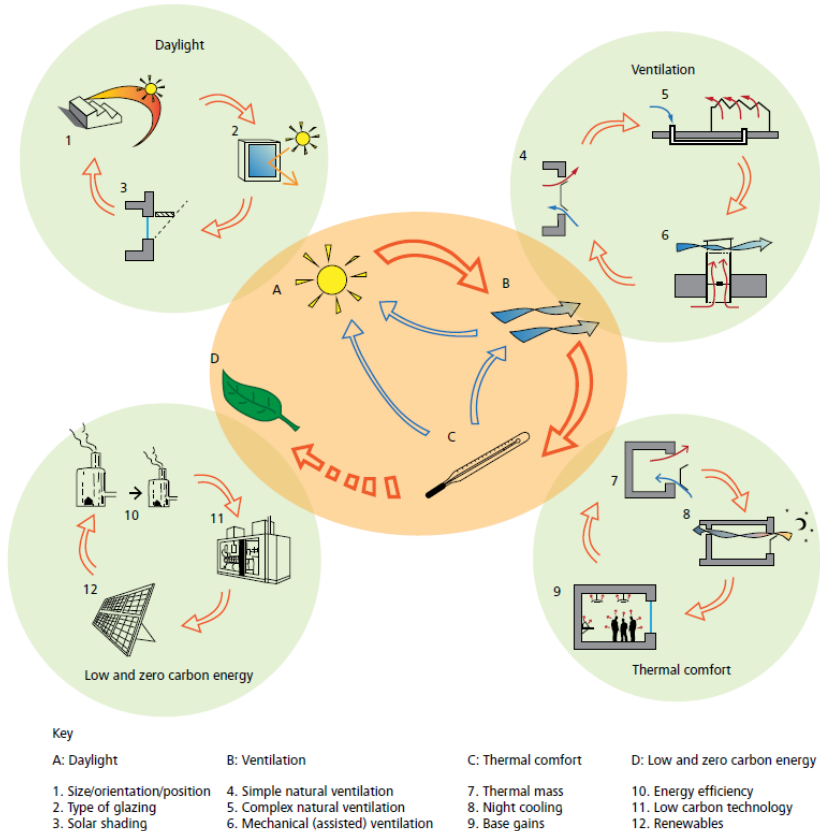


Figure 3 The design process for new school buildings, showing how the individual aspects are interrelated

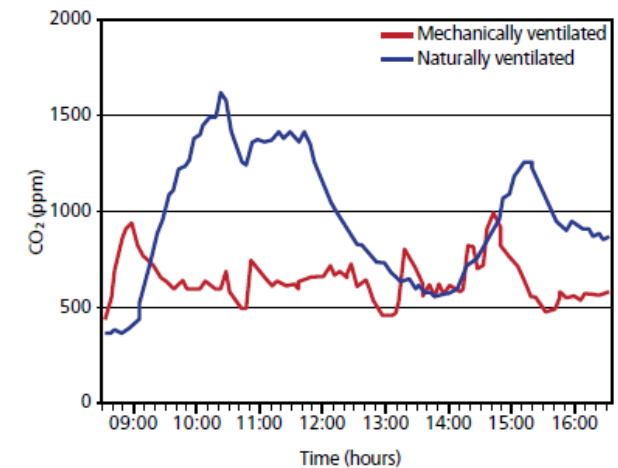


Figure 18 CO₂ dynamics in two rooms with different mechanical and manually controlled natural ventilation strategies



**Technical
Symposium
2025**

co-organised by CIBSE and IBPSA-England

24-25 April 2025

**UCL Bentham House
London**

Fit for 2050

Achieving net-zero through
intelligent, resilient and
sustainable design in the
built environment

EARLY BIRD OFFER ENDS 16 FEBRUARY



**SCAN
ME!**



Thank you





ALI ALEXANDRE NOUR EDDINE

SENIOR TECHNICAL MANAGER AT EUROVENT CERTIFICATION

*'Performance-based approach
simulation to predict IAQ and energy
performance of ventilation systems'*



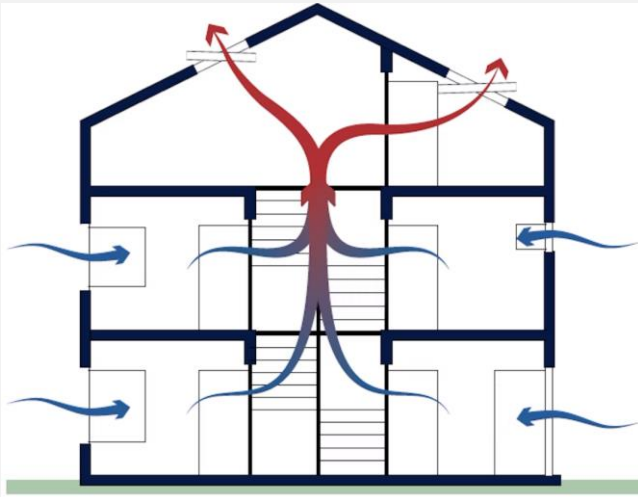


Performance-based approach simulation to predict IAQ and energy performance of ventilation systems.

IAQ matters conference : Breathing achievement into every classroom

Ventilation systems

Different ventilation strategies



Natural Ventilation

Components

- ❖ Windows
- ❖ Doors
- ❖ User dependent



Supply Ventilation

Components

- ❖ Exhaust fans
- ❖ Windows rebate ventilators
- ❖ Volume or humidity control
- ❖ User behaviour dependent



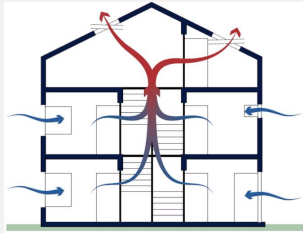
Balanced Ventilation

Components

- ❖ Exhaust fans
- ❖ Supply fans
- ❖ Supply and exhaust ducts
- ❖ Heat recovery

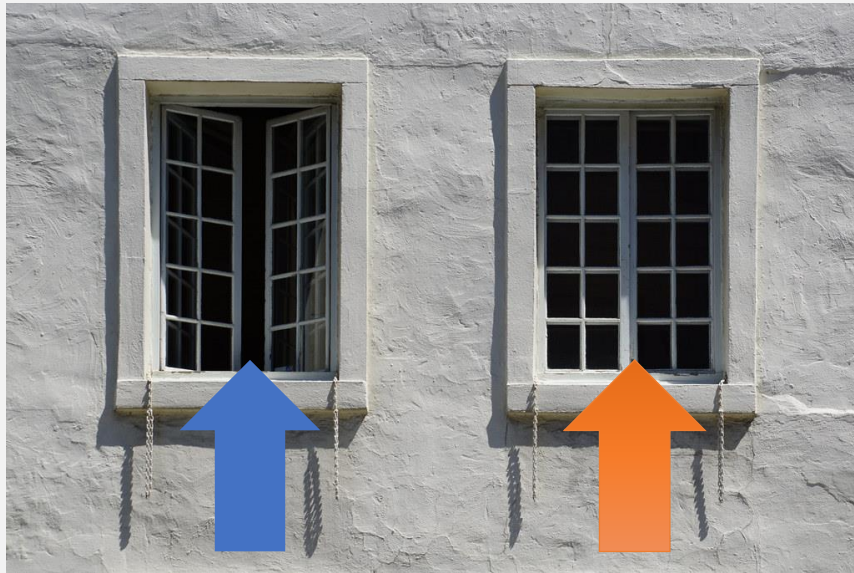
Ventilation systems

User Behaviour Before Covid 19



Natural Ventilation

Thermal Comfort Driven



Summer

Winter



Supply Ventilation

Thermal Comfort Driven

Unconsciousness Driven



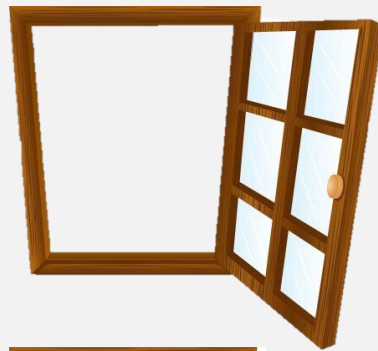
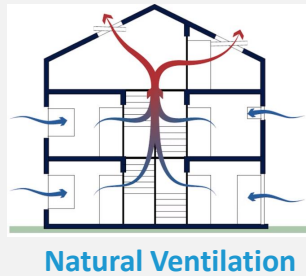
Block the windows rebate ventilator to stop fresh air



No cleaning of the air openings

Ventilation systems

User Behaviour During Covid 19



Opening the window could let the Covid in?



Closing the window could increase the spread of infection?

IAQ?

IAQ?

IAQ?

IAQ?

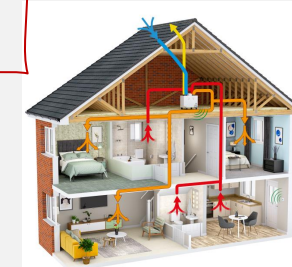


IAQ?

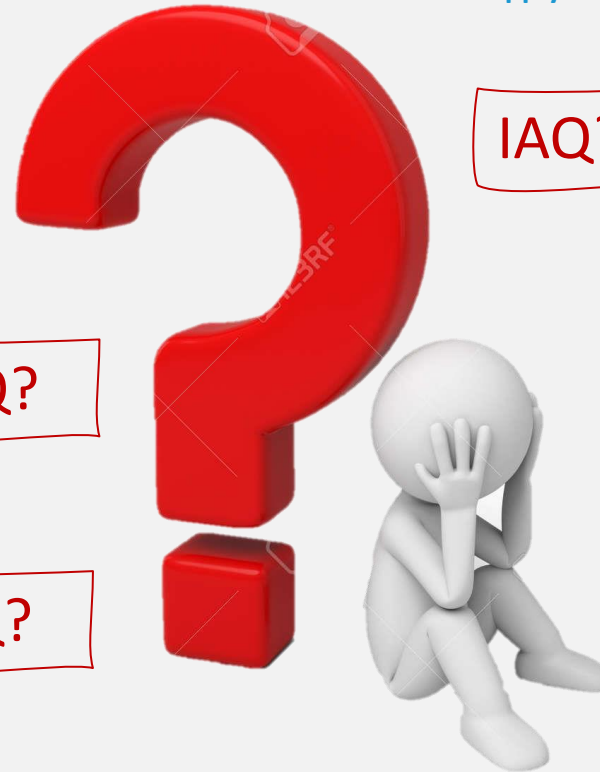


Should we close the air inlet or open the window?

IAQ?



Is my system efficient enough?

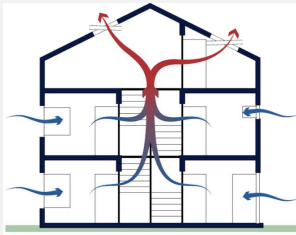


Ventilation systems

User Behaviour After the Energy Crisis



IEQ?



Natural Ventilation

How many times should I open the window to keep a good IAQ without increasing the bill

IEQ?



IEQ?



Supply Ventilation

Will the air inlet increase the heating bill?

IEQ?



Balanced Ventilation

Is the energy recovery enough to compensate for the additional electric consumption of the fan?

Ventilation systems

Using simulation to predict system performance



House



Multi-family dwellings



Hotels



Retails



Office buildings

What system could
provide the best IAQ
with optimum
energy
consumption?

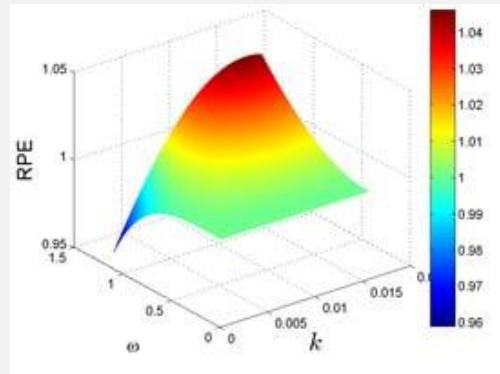


School

Ventilation systems

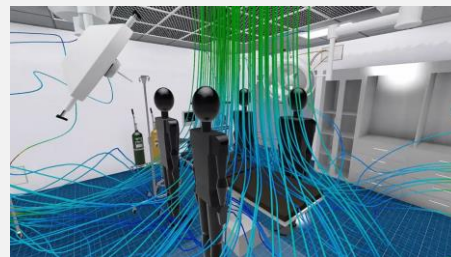
Using simulation to predict system performance

Which type
of
simulation?



Numerical simulation

- ✓ Acceptable computational time
- ✓ accurate



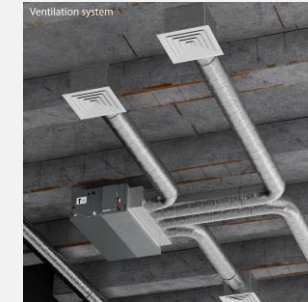
CFD modeling

- ✓ Requires 3D drawings
- ✓ Very high computational time
- ✓ More accuracy



Project-based

- ✓ Requires simulation for each project
- ✓ 29,9 million residences in the UK (77,9 % houses and 21,7% flats)*



System-based

- ✓ one simulation for each system
- ✓ The same ventilation system could be installed in a variety of applications

Eurovent IAQ project

- ❖ A performance-based approach is used to predict the **concentrations of pollutants** within the built environment via numerical simulation and evaluate them against acceptable values to prevent health risks.
- ❖ Reduction in the number of pollutants to consider by focusing on a target pollutant from each category:
 - ✓ CO₂
 - ✓ PM_{2.5}
 - ✓ Formaldehyde
- ❖ All the components of the ventilation system are considered in the simulation
- ❖ Each system is simulated on different types of dwellings
- ❖ The average energy consumption of each system is calculated per year

Eurovent IAQ project

Two-stage project



- ✓ Single-family dwellings
- ✓ Residential ventilation applications*

1

2



Office buildings



Hotels



Multi-family dwellings



Retails



- ✓ Multi-family dwellings
- ✓ Residential and tertiary ventilation applications

*airflow $\leq 1000 \text{ m}^3/\text{h}$

Eurovent IAQ project

Single-family house

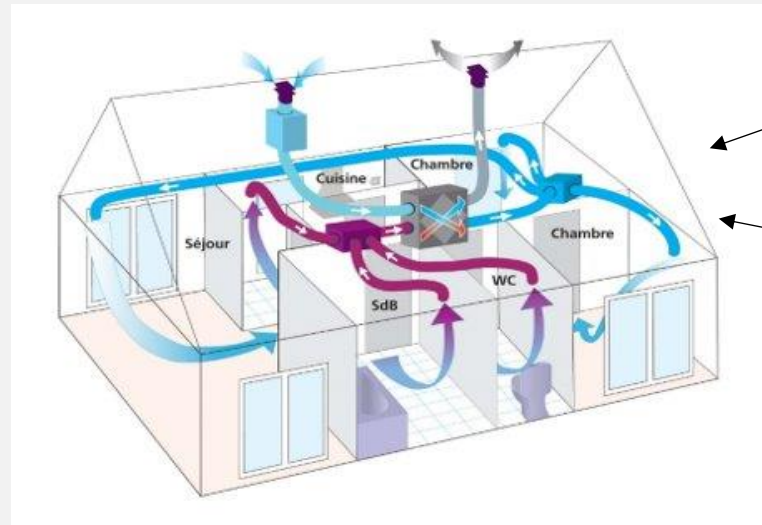
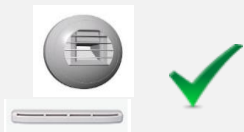
Ventilation
systems



Ducting



Air inlet and
outlet

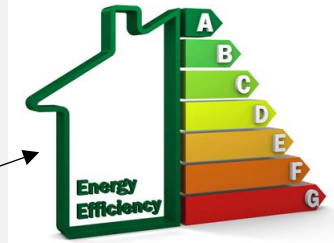


How do we evaluate the
performance of the whole
system?

1

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IAQ-VS
Application powered by MATHIS



Heat losses due
to air renewal

Electric consumption
of the motor



Indicateurs IAQ*



Concentration of
formaldehyde



Concentration of
CO₂

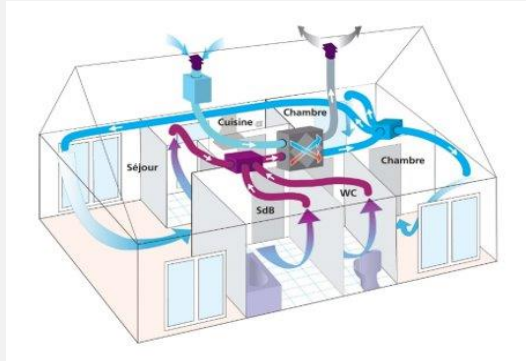


Relative humidity

**particulate matter indicator will
be added in the next revision*

Eurovent IAQ project

Single-family house



1

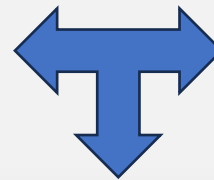
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IAQ-VS
Application powered by MATHIS

Simulation input data

- ❖ System type (supply, extraction, balanced...)
- ❖ Ventilation duct performances
- ❖ Air inlet and outlet performances
- ❖ Ventilation unit performances
- ❖ Climate condition (Moderate, Cold, Warm)




Detailed rating for
each type of
dwelling



Considered scenarios

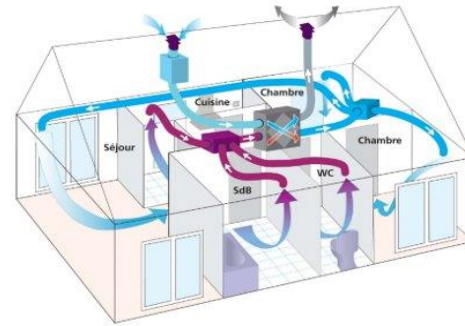
- ❖ Type and size of the Dwelling
- ❖ Specific environment (wind, orientation, ...)
- ❖ Weather conditions around the year
- ❖ Different activities scenarios (cooking, shower, laundry...)

Detailed ratings (average climate) / Notes détaillées (climat moyen)⁽¹⁾

Number of habitable rooms / Nombre de pièces principales	Applicable	 Formaldehyde	 Carbon dioxide	 Relative Humidity	Global Indoor Air Quality	Fan electric consumption	Heat loss induced by air renewal
		[-]	[-]	[-]	[-]	[kWh/year]	[kWh/year]
1	Yes	4.2	5.0	4.6	4.6	94	1904
2	Yes	3.8	4.7	4.5	4.3	140	2489
3	Yes	3.5	3.6	4.3	3.8	171	2851
4	Yes	3.0	3.3	4.3	3.5	176	3056
5	Yes	2.9	3.0	4.1	3.3	195	3238
6	Yes	2.2	2.9	4.2	3.1	197	3470
7							

Eurovent IAQ project

Single-family house



1

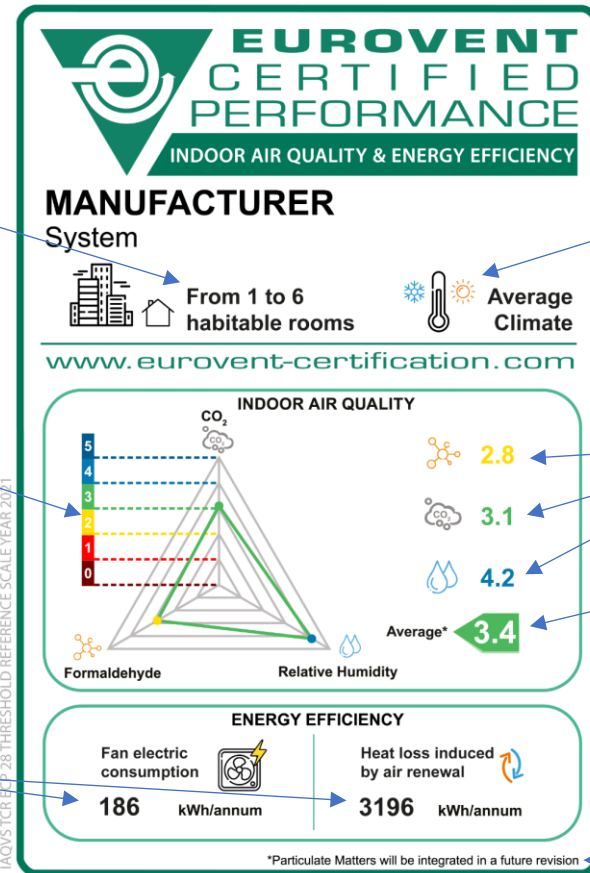
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Application powered by MATHIS

Dwelling type

Grading scale

Energy performances



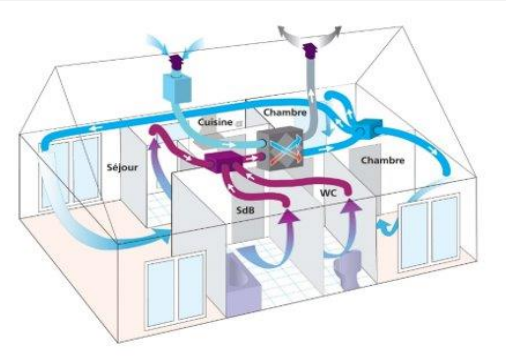
Climate

IAQ individual indicators

IAQ average grade

PM to be added in the next version

Eurovent IAQ project application

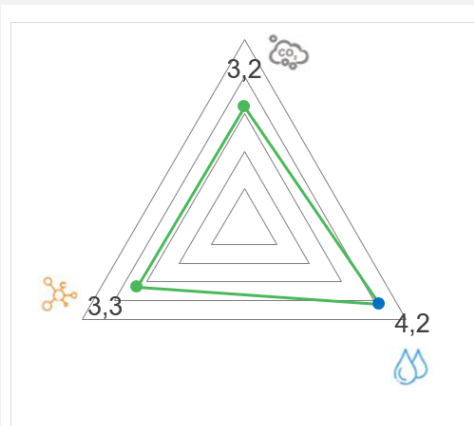


1

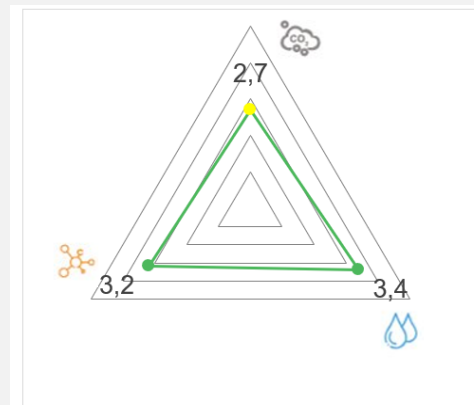


Comparing technologies

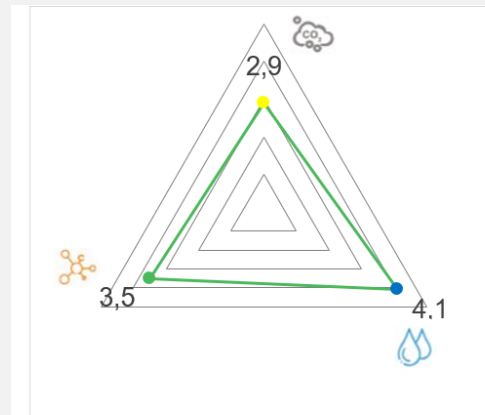
Hygroregulated



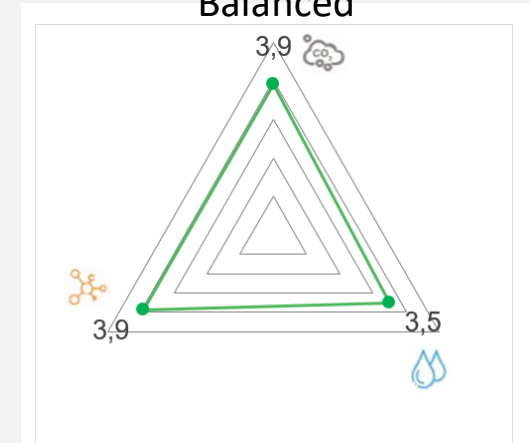
Extraction



Supply



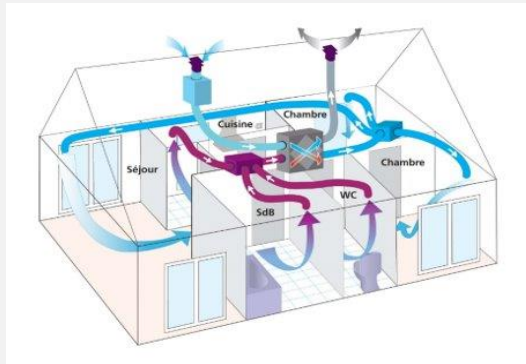
Balanced



Eurovent IAQ project

application

Comparing technology in different climates

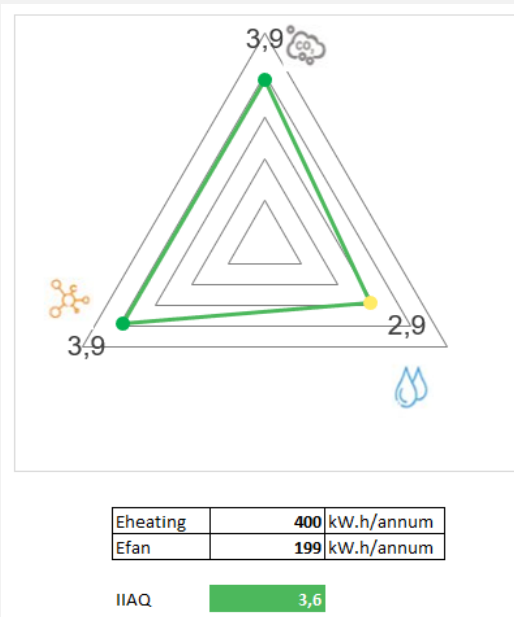


1

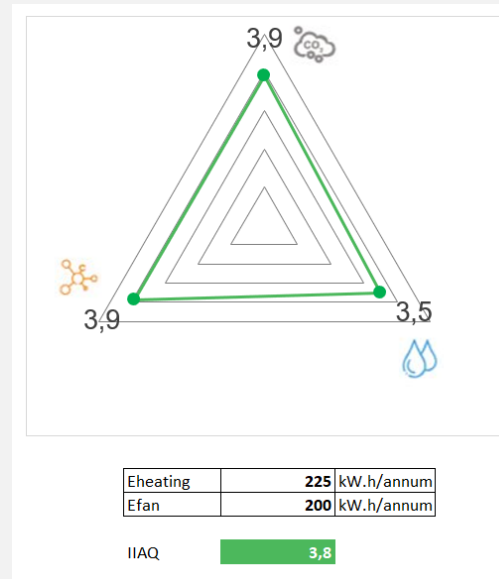
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IAQ-VS
Application powered by MATHIS

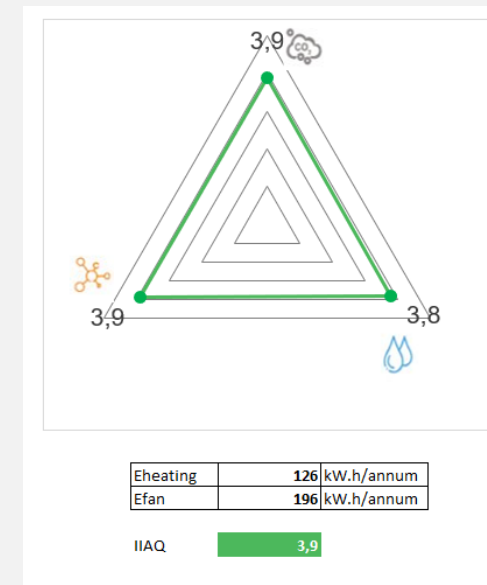
Cold



Average

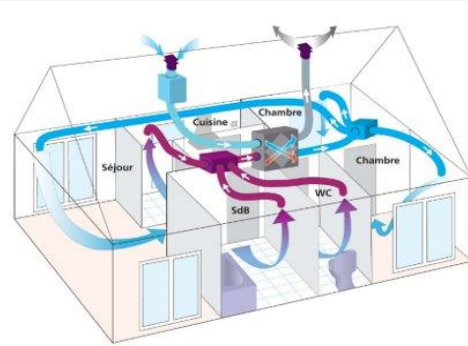


Hot



Eurovent IAQ project

application



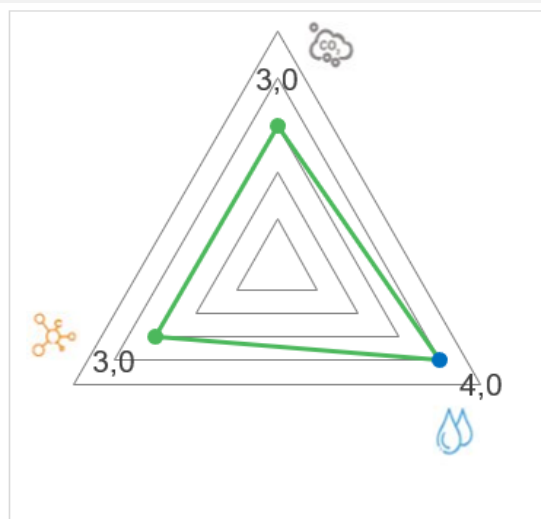
1

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IAQ-VS
Application powered by MATHIS

Comparing different systems using the same technology

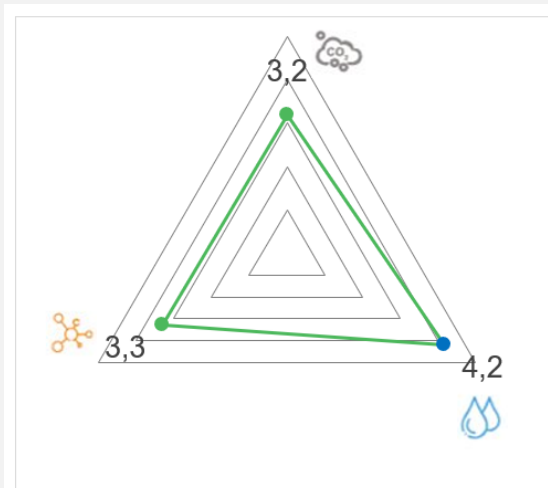
System 1



Eheating	2731	kW.h/annum
Efan	244	kW.h/annum

IIAQ 3,3

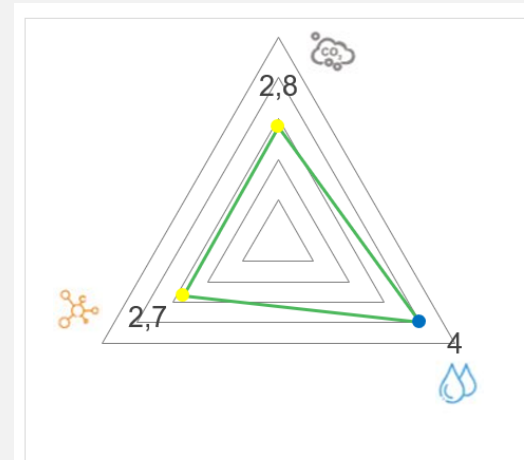
System 2



Eheating	3198	kW.h/annum
Efan	148	kW.h/annum

IIAQ 3,6

System 3

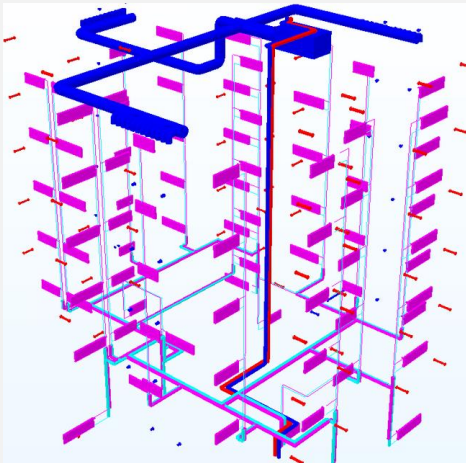


Eheating	2455	kW.h/annum
Efan	190	kW.h/annum

IIAQ 3,2

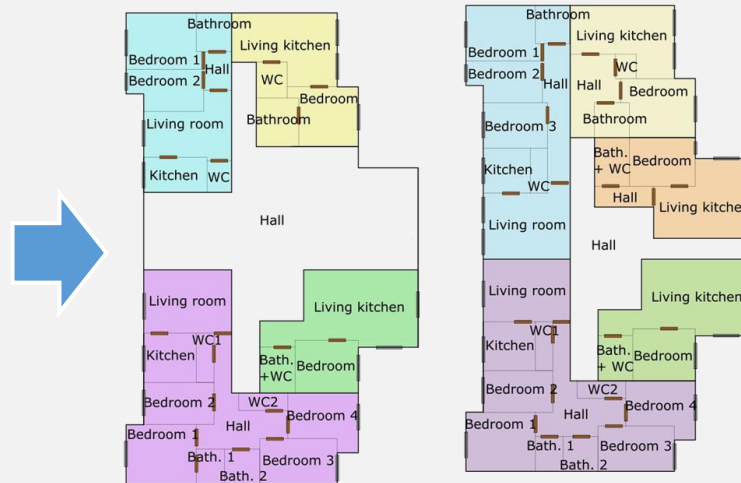
Eurovent IAQ project

Multi-family building



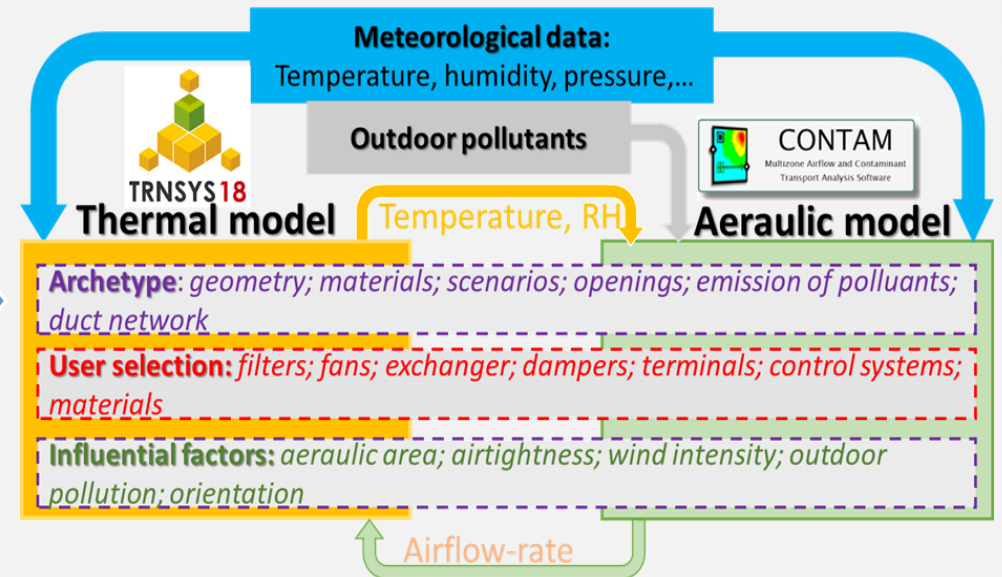
Multifamily building
Dwelling with defined outdoor conditions:

- Wind intensity
- Outdoor pollution level
- ..



Defined configuration for residential or tertial building, building conditions:

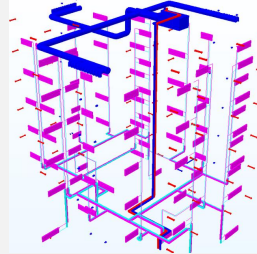
- Airtightness
- Wind exposure
- location



The building test bed encompasses TRNSYS-CONTAM building performance simulations. This means dynamic computations of heat, moisture, and pollutants (CO₂, HCHO, and PM_{2.5}) transport within a selected set of buildings equipped with user-adjustable ventilation systems

Eurovent IAQ project

Multi-family building



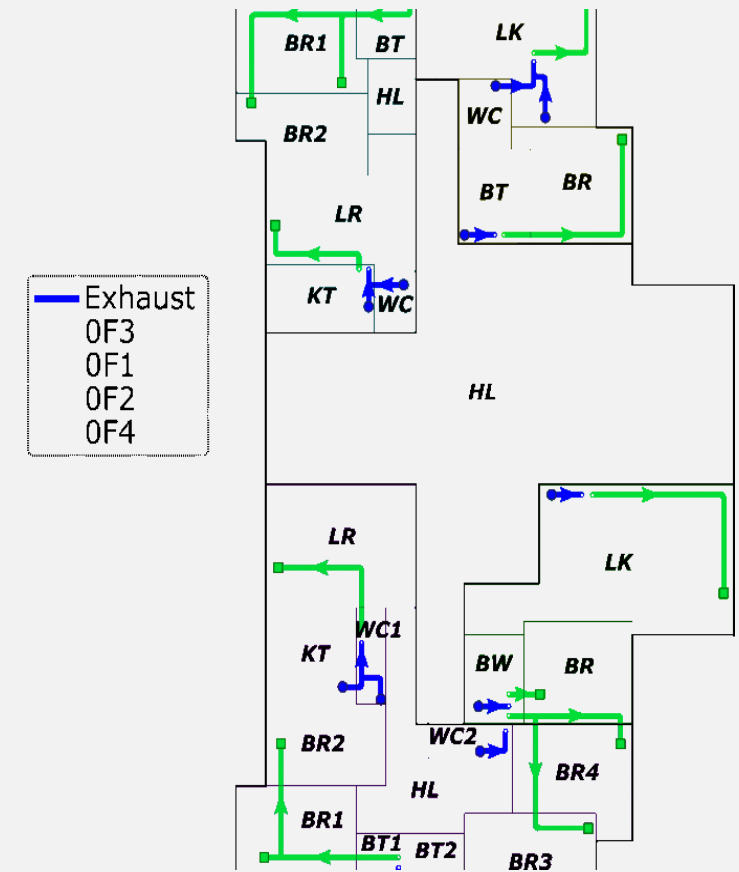
2

tipee

La Rochelle
Université

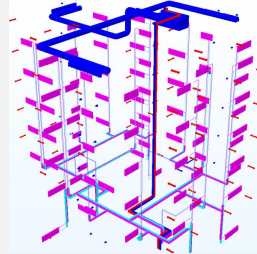
Comparing technologies

- ❖ **Building geometry:** two-story residential building
- ❖ **Ventilation Type:**
 - ❖ **First Case: Single-Flow** Ventilation System
 - ❖ **Second Case: Balanced ventilation** with Heat Recovery System
- ❖ **Boundary conditions:**
 - ❖ Wind Intensity: Strong
 - ❖ $PM_{2.5}$ pollutions: $> 20 \mu g/m^3$
 - ❖ Building Wind-exposure: Covered
 - ❖ Building tightness: Low
 - ❖ Location: Urban
 - ❖ Heat recovery efficiency 70%



Eurovent IAQ project

Multi-family building



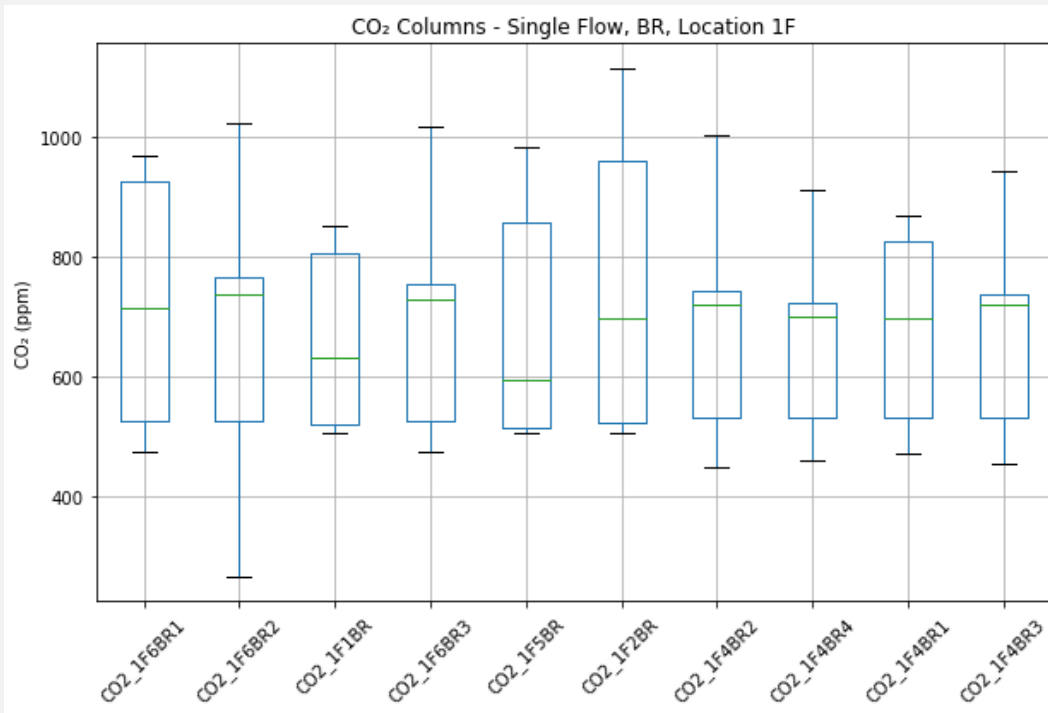
Comparing technologies

2

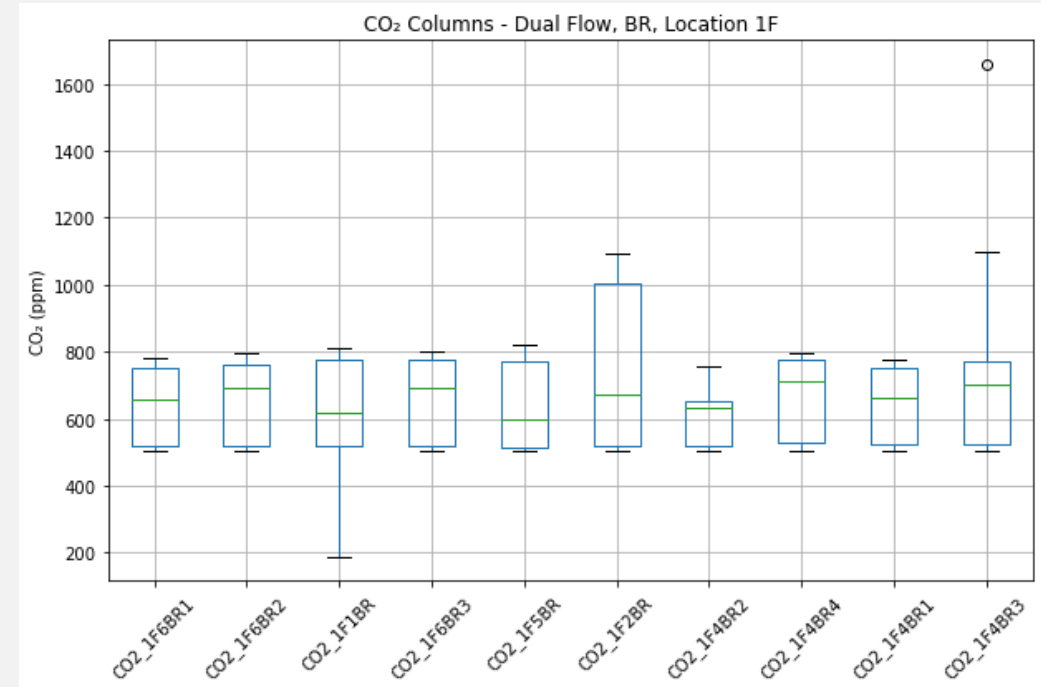
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Single Flow



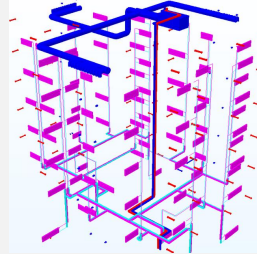
Balanced



- ❖ Single-Flow struggles with air quality
- ❖ **Dual-Flow** maintains CO₂ control (< 1000 ppm)

Eurovent IAQ project

Multi-family building



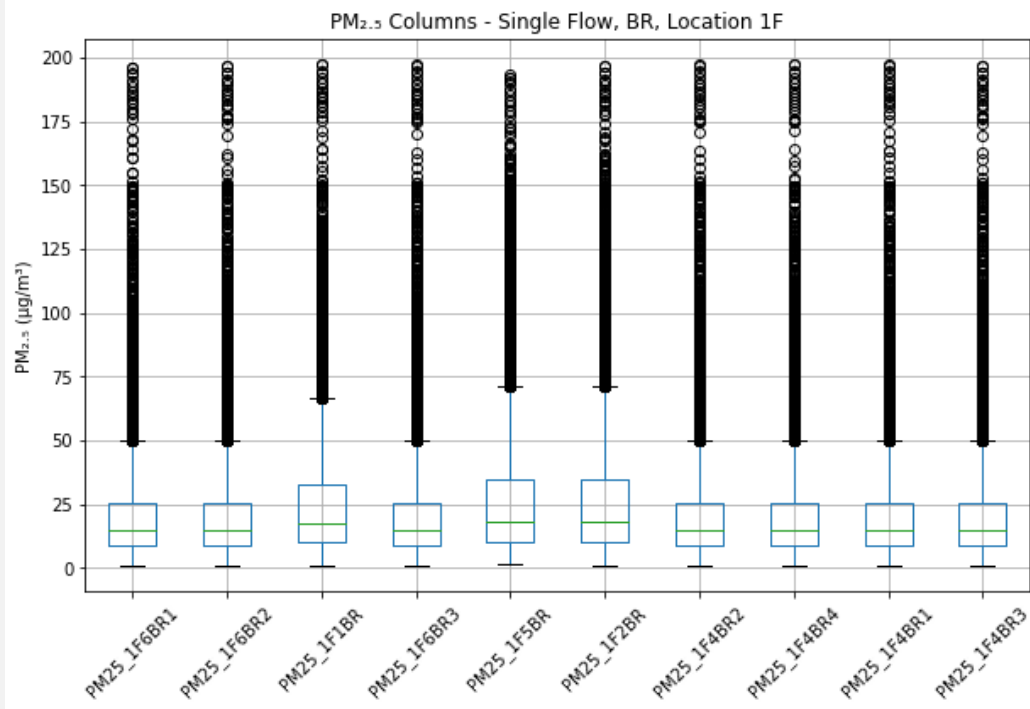
Comparing technologies

2

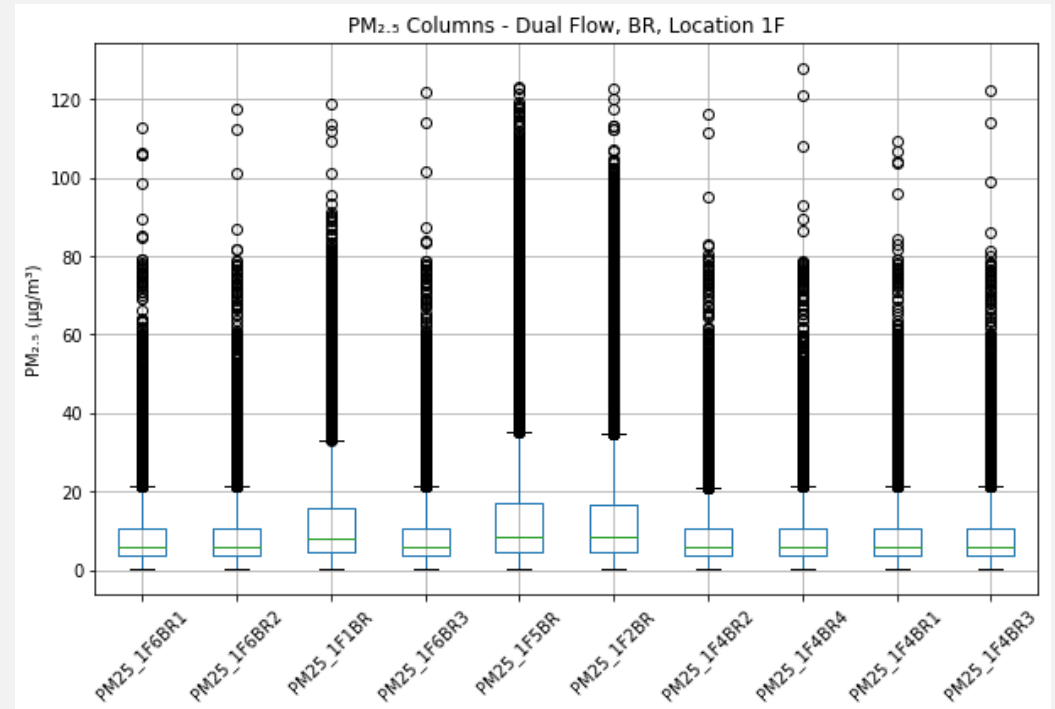
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Single Flow



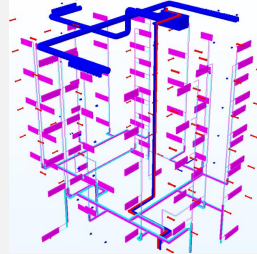
Balanced



➤ **Dual-Flow with 60% filtration significantly reduces PM_{2.5} concentration**

Eurovent IAQ project

Multi-family building

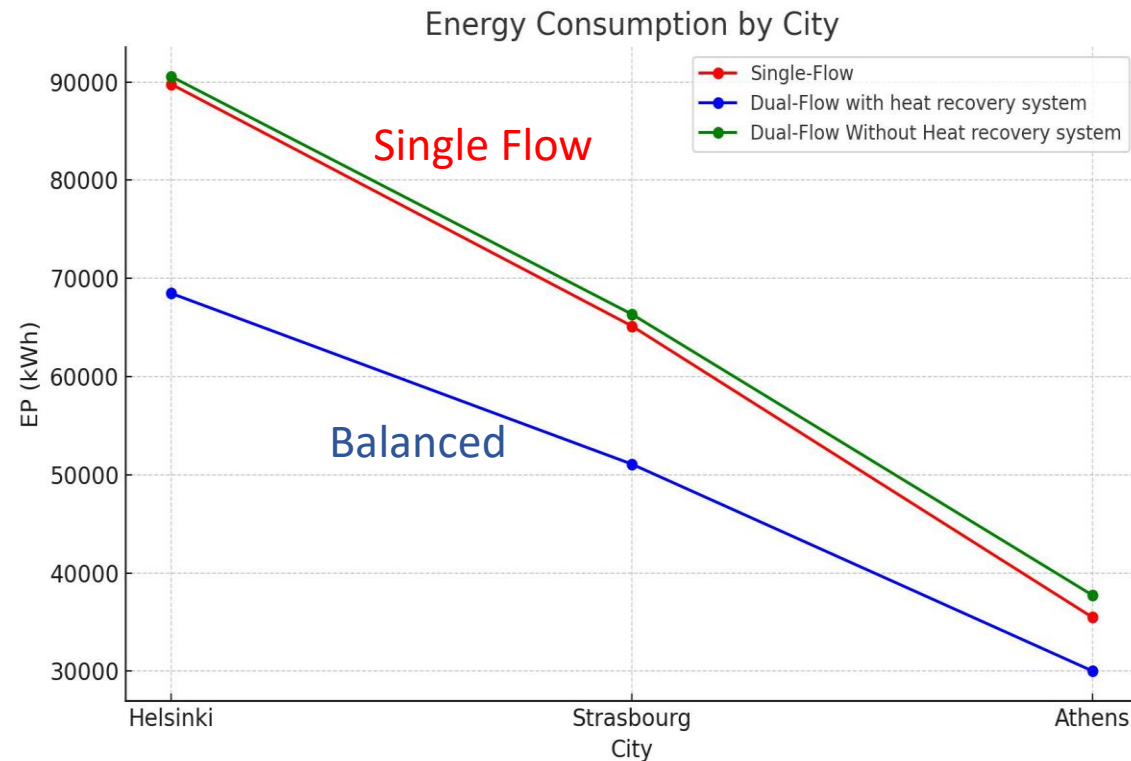


Comparing technologies

2

tipee

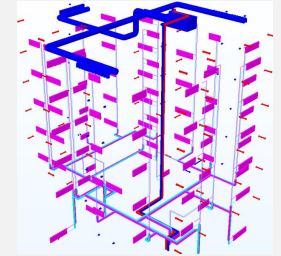
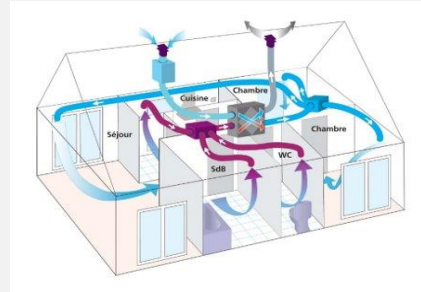
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- ❖ **Best Performance** for Dual-Flow with Heat Recovery
- ❖ **Single-flow** is better than Dual-Flow **without** heat recovery

Eurovent IAQ project

Conclusion



- = Comparing different ventilation system technologies in single and multifamily dwellings
- = Comparing the performances of different products on the same application condition
- = Providing insights on the impact of the ventilation systems configuration on the IAQ and Energy performance (such as airflow)
- = Providing an end user-friendly grading system for the IAQ and Energy performance
- = Making an educated choice of the right ventilation system

Thank you

aa.nour-eddine@eurovent-certification.com



PANEL DISCUSSION AND AUDIENCE Q&A

SEE YOU LATER!

NETWORKING EVENING WITH DRINKS & FOOD

17:15-19:00h

Maxwell Library



THANK YOU!



CONFERENCE by Eurovent

BREATHING ACHIEVEMENT INTO
EVERY CLASSROOM

