Healthier Classrooms: Integrated IAQ, Hygiene and Infection-Risk Mitigation in European School Environments

Indoor air quality • Hygiene • Ventilation • Portable air treatment • Occupancy-aware risk mitigation

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Why this work matters

Schools combine high occupancy, variable ventilation, and frequent contact; it is a setting where environmental conditions can influence respiratory comfort, learning, absenteeism, and infection risk.

Core question

Which interventions can improve air quality while remaining practical for real classrooms?

The work treats risk as a combined environmental system, not as a single pollutant problem.



Source: InChildHealth D4.5

What the work covers

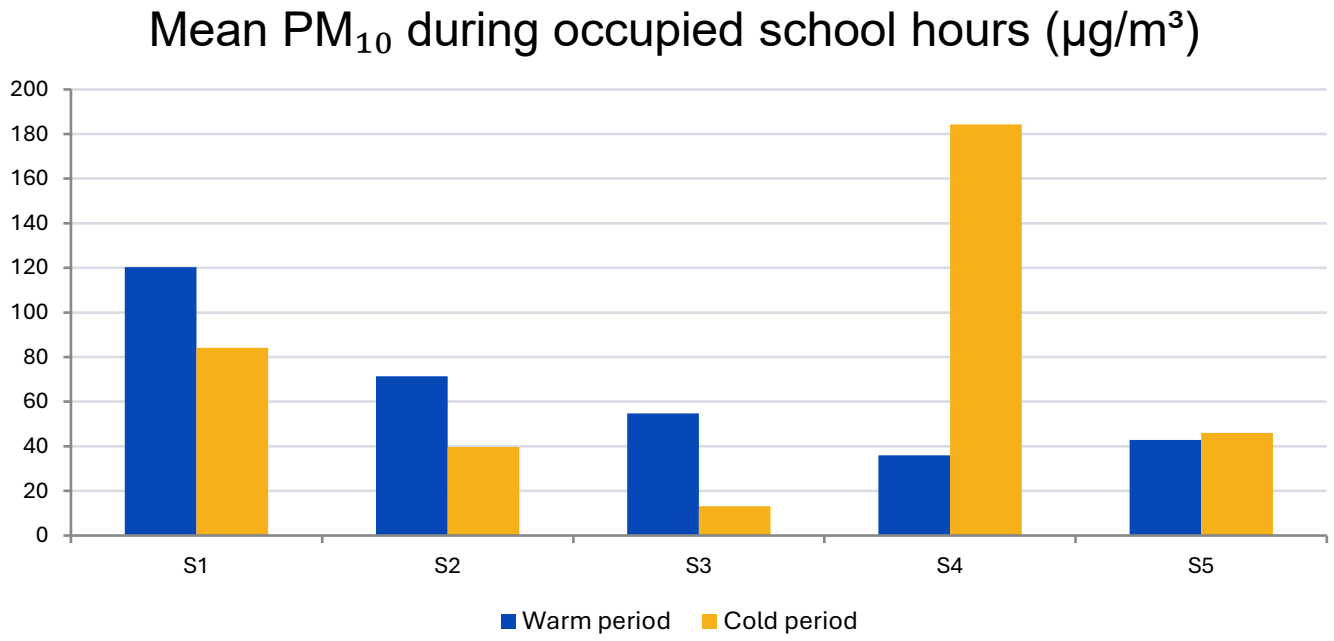
The work moves from measurement to intervention testing to decision support.

1	2	3	4	5	6
Monitor	**Assess**	**Intervene**	**Treat air**	**Link health**	**Guide action**
CO_2, $PM_{2.5}$, PM_{10}, BC, UFP, T, RH	ATP on high-contact surfaces	Ventilation settings & humidity	Purifiers and portable HVAC	Positioning, SpO_2, heart rate	Algorithmic IAQ risk framework

Source: InChildHealth D4.5

Baseline IAQ: key signals from the Greek case study

PM_{10} stood out as the most critical pollutant in the Athens school example, with wide spatial and seasonal variability.



Reference: PM_{10} daily outdoor limit = 50 µg/m³; annual outdoor limit = 40 µg/m³.

PM_{10}

frequently exceeded guideline values

CO_2

short peaks indicated ventilation gaps despite acceptable averages

Temp.

overheating and underheating also observed

RH

seasonal humidity differences

Interpretation

Average CO_2 alone can mask short periods of elevated CO_2 associated with occupancy. Particle, humidity, temperature, and activity patterns need to be interpreted together.

Source: InChildHealth D4.5

Surface hygiene: ATP monitoring complements IAQ data

High-contact surfaces were sampled before and after cleaning to evaluate cleaning effectiveness.

Sampling protocol

1. Pre-clean ATP swab
2. Routine cleaning
3. Post-clean ATP swab
4. Compare RLU thresholds

ATP is not a viral test

Indicator of cleaning effectiveness and organic residue

Study cities

Athens

Classrooms & bathrooms mean ATP values met thresholds

Lisbon

Classrooms & cafeterias mean ATP values exceeded thresholds

Helsinki

Classrooms & cafeterias mean ATP values exceeded thresholds

Vienna

Cafeteria mean ATP values met thresholds; classroom and door-handle means did not.

Bottom line

Cleaning results varied by city and surface type, supporting more consistent, standardized hygiene practices.

Source: InChildHealth D4.5

Surface hygiene: ATP monitoring data

Log_{10} ATP (RLU) thresholds used to classify surface cleanliness (ISSA Clean Standard 0714-2014

Surface type	Clean	Needs improvement	Not clean
Classroom desks	≤ 2.04	2.04–2.40	≥ 2.40
Cafeteria tables	≤ 2.36	2.36–2.62	≥ 2.62
Restroom doors / door handles	≤ 2.00	2.00–2.34	≥ 2.34
Sink surroundings	≤ 1.77	1.78–2.18	≥ 2.18

Mean logarithmic ATP values by surface type and study city

City	Classroom desks	Cafeteria tables	Door handles	Sink surroundings	Water taps
Athens	1.96 → 1.59	—	2.18 → 1.70	2.32 → 1.54	2.07 → 1.36
Helsinki	2.68	2.66	—	2.01	2.24
Lisbon	2.85 → 2.61	3.25 → 3.41	—	—	—
Vienna	2.83	2.32	2.58	—	—

Source: InChildHealth D4.5

Intervention testing: three levers for healthier classrooms

Part of the study evaluated practical options that schools can deploy without full building renovation.

Ventilation settings

Night operation

Two Helsinki schools; constant and variable airflow tested at night.

↓

Night setting changes had no significant IAQ impact, suggesting energy optimization potential.

Humidity management

Winter RH

16 schools/156 classrooms: ventilation assessed; 32 classrooms in 5 schools: CO_2, temperature and RH continuously monitored.

↓

Ventilation was generally adequate, but winter humidity was often too low. Humidification was done.

Portable treatment

PM • microbes • CO_2

Air purifiers and portable HVAC evaluated in classrooms and controlled chamber conditions.

↓

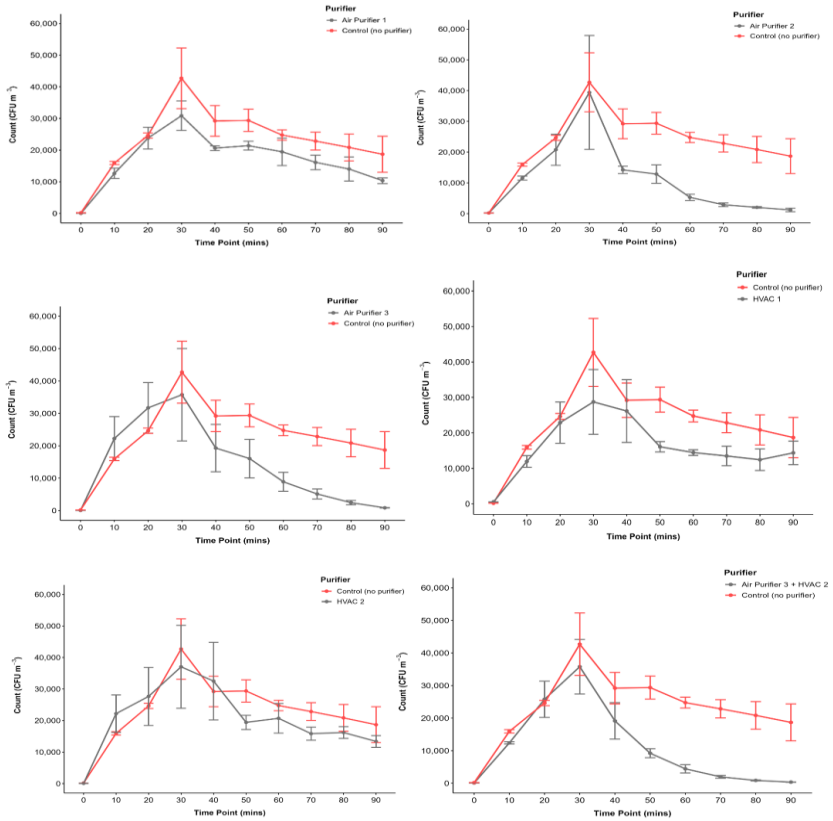
Purifiers reduced PM and microbes; portable HVAC lowered CO_2 when adequately sized.

Source: InChildHealth D4.5

Portable systems: strongest when matched to the problem



Experimental classroom setup for bacterial reduction testing



Bacterial reduction efficiency curves

Key result

Air purifiers performed best for microbes/particles, while HVAC units were stronger for CO_2 when sufficiently sized.

Purifiers → PM + microbes

HVAC → CO_2

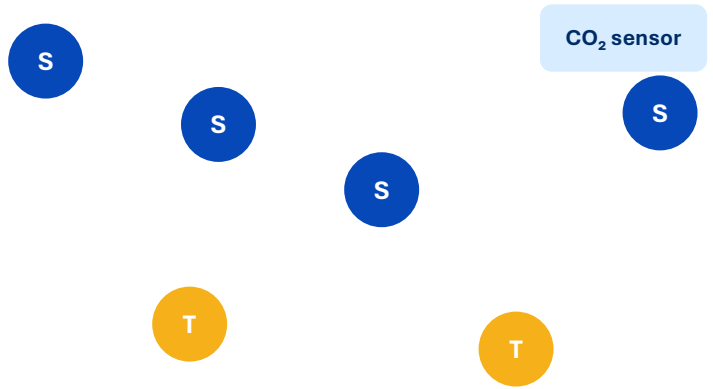
Combined → strongest bacteria reduction

Source: InChildHealth D4.5

Occupant-aware assessment: connecting spaces, people, and exposure

Fixed sensors tell us what happened in a room; positioning and wearables help explain who was exposed, when, and why.

Classroom position + IAQ data



close-contact episodes + environmental peaks

71

close-contact events observed

7.5h

cumulative close-contact duration

1,178 ppm & 1,079 ppm

short CO_2 maximum in spring and fall respectively

Wearables

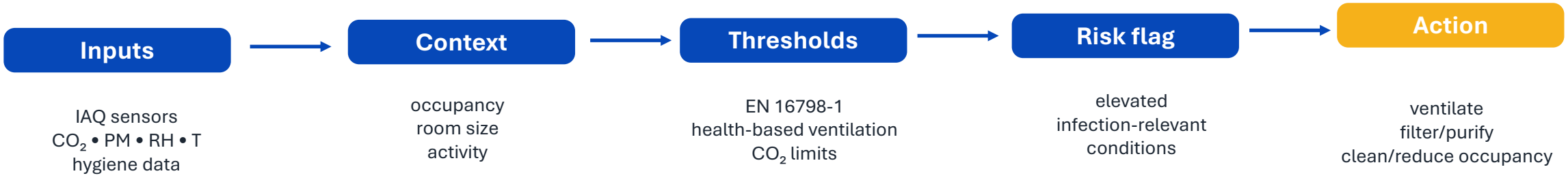
CSEM DELTA device captured usable heart rate and SpO_2 segments from 26 children across typical school days, but motion artefacts limited continuous uninterrupted monitoring.

Implication Mitigation should respond to occupancy patterns, not only daily averages.

Source: InChildHealth D4.5

Algorithm framework: from data to mitigation decisions

A conceptual framework translates real-time IAQ and hygiene signals into occupancy-aware risk interpretation and suggested actions.



Important nuance

The algorithmic framework is not yet fully implemented or tested. It establishes a foundation for future, data-informed school mitigation tools.

Final takeaways

Integrated strategies work best: adequate ventilation + pollutant removal + hygiene + occupancy-aware monitoring. Future analyses will refine the evidence base and peer-reviewed outputs.

Source: InChildHealth D4.5

Conclusion: what this work entails

Main message

Healthier classrooms need integrated, occupancy-aware IAQ management; not a single device or metric.

1 Assess the problem

Continuous IAQ monitoring showed strong spatial and seasonal variability.

PM_{10} was the clearest pollutant concern; short CO_2 peaks flagged ventilation gaps.

2 Match interventions to risks

Air purifiers reduced particles and microbes; portable HVAC lowered CO_2 when adequately sized.

Cleaning consistency and winter humidity management remain important supporting measures.

3 Use data to guide action

Occupancy, positioning and wearable sensing add context to IAQ measurements.

The proposed algorithm links IAQ, CO_2 thresholds and hygiene indicators to mitigation decisions.

Practical implication

Prioritize combined strategies: adequate ventilation + pollutant removal + surface hygiene + real-time, occupancy-based decision support.

Source: InChildHealth D4.5