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Evaluating air cleaning in Dutch primary schools: study design and preliminary results of the Clean Air for Everyone (CLAIRE) project

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Introduction
Children in Europe spend a substantial amount of their time in classrooms, where indoor air quality (IAQ) guidelines are often not met. Poor IAQ —shaped by factors such as bioaerosols (including bacteria, viruses), particulate matter (PM), and volatile organic compounds —has been associated with respiratory morbidity and infectious disease transmission. While ventilation plays a key role in improving IAQ, since the COVID-19 pandemic, mobile air cleaners equipped with high-efficiency particulate air (HEPA) filters or alternative technologies, such as ionizers, are increasingly considered as a supplementary measure to protect against acute respiratory infections.

To date, air cleaner efficiency has been predominantly assessed in controlled environments using artificial aerosols, with limited real-world evidence of their effectiveness in occupied classrooms. Moreover, feasibility of integrating air cleaners into school settings remains unclear. This study aims to address these gaps by evaluating the impact of air cleaners on airborne bioaerosols and general IAQ indicators in primary school classrooms through a large-scale randomized controlled trial (RCT).

Methods
The RCT utilizes classrooms within a school as the randomization unit. At each school, sets of three classrooms with similar building characteristics are selected and randomly assigned to one of the three study regimes: 1) intervention with HEPA filter air cleaners, 2) intervention with air cleaners using an alternative technology, and 3) no intervention (control).

Bioaerosol samples from classrooms are passively collected using electrostatic dust fall collectors (EDCs), suspended 30 centimeters from the ceiling for a three-week sampling duration. A baseline (pre-intervention) measurement is followed by three repeated measurements during intervention. After DNA and RNA extraction of EDCs, levels of total 16S rRNA, S. aureus, S. epidermis, S. salivarius, M. catarrhalis, Influenza A/B and RSV are quantified by qPCR.

Concurrently, PM10, PM2.5, PM1, CO2, temperature, and relative humidity are continuously monitored in each classroom at one-minute intervals using IAQ sensors. Additionally, student absenteeism is recorded, and respiratory health of the pupils is assessed via a parental survey before and after intervention.

Results
From December 2023 to April 2024, a total of 12 schools were enrolled in the study. Data collection continues from October 2024 through April 2025, expanding the study to a total of 26 schools. The implementation of air cleaners in school environments presents practical challenges, including issues related to device size and sound levels.

Preliminary analysis of bioaerosol markers from the initial measurement period (December 2023–April 2024) showed the following bioaerosol detection rates: Influenza A (0%), Influenza B (1.5%), RSV (8%), 16S rRNA (97%), *S. epidermidis* (40%), *M. catarrhalis* (55%), *S. aureus* (49%), and *S. salivarius* (55%). Upon completion of data collection in April 2025, the study will assess the impact of air cleaners on bioaerosol concentrations and PM levels.

Conclusion
This large-scale RCT will address a critical knowledge gap, providing real-world evidence on the efficacy of

air cleaning technologies in reducing airborne microbial, viral, and PM levels in primary school classrooms. Ultimately, findings from this study will offer crucial insights into the feasibility and public health implications of air cleaners in school environments, informing future evidence-based public health strategies to enhance IAQ and mitigate airborne disease transmission in educational settings.

Primary author: JANSSEN, Esmée (Utrecht University, Institute for Risk Assessment Sciences)

Co-authors: HEEDERIK, Dick (Utrecht University, Institute for Risk Assessment Sciences); Dr WOUTERS, Inge (Utrecht University, Institute for Risk Assessment Sciences); LINDE, Kimberly (Utrecht University, Institute for Risk Assessment Sciences); SMIT, Lidwien (Utrecht University, Institute for Risk Assessment Sciences); Dr LOOMANS, Marcel (Eindhoven university of Technology, Department of the Built Environment); Dr DOHMEN, Wietske (Utrecht University, Institute for Risk Assessment Sciences)

Presenter: JANSSEN, Esmée (Utrecht University, Institute for Risk Assessment Sciences)

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