Impact Assessment of Controlled Mechanical Ventilation Systems for Air Quality in School Buildings: A Study Protocol

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SUMMARY

Background: Indoor air is an important public health issue and the COVID-19 pandemic has highlighted even more the importance of indoor air quality in schools. One of the main measures to preserve good indoor air quality is to maintain adequate indoor air exchange, and energy-efficient mechanical ventilation has been shown to be effective in improving indoor air quality and health of the occupants.
Methods: A pre-post study and trend analysis will be carried out. As the project involves the installation of Controlled Mechanical Ventilation (CMV) systems in schools, the primary aim of the study is to assess the perceived indoor air quality in classrooms in a population of primary and secondary school students without (pre-installation) and with (post-installation) CMVs. The secondary aim is the assessment of health outcomes, investigating the prevalence of dermatological, respiratory, ocular and general disorders reported before and after the intervention, and stratifying by sociodemographic variables. The evaluation of the effectiveness of CMV systems on air quality will be evaluated through chemical-physical and microbiological sampling after the installation of CMVs. The perceived air quality and health assessment will be performed through a survey, distributed before and after CMVs installation.
Conclusions: The present study protocol aims to highlight the importance of indoor air quality for students and school personnel, as well as propose new strategies and measures to deal with this raising issue, enacting measures and systems that will be sustainable from an environmental, energetical, and acoustic point of view, while still ensuring the best possible health outcomes.

Keywords: indoor air quality, controlled mechanical ventilation, prevention, public health, school.

INTRODUCTION

Indoor air is an important public health issue, particularly in school buildings where students spend much of their time. Indoor air quality can be affected by multiple factors, such as human activity, humidity and ventilation, having negative long-term health consequences in individuals who are exposed to it. Epidemiological studies have shown that exposure to indoor air pollutants, such as dust mites, moulds, volatile organic compounds (VOCs), and nitrogen oxides, can cause respiratory or cardiovascular diseases, allergies, as well as it can have neurobehavioral effects in children [1–3]. Although the role that indoor air can play in the transmission of airborne pathogens was already known

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[4], the COVID-19 pandemic has made the importance of indoor air quality in schools even more apparent, as the virus is transmitted by air [5]. Italy was greatly affected by the COVID-19 pandemic [6], underlining the importance of emergency preparedness [7] and the need to establish prevention strategies concerning indoor air quality [8].

One of the main measures to preserve good indoor air quality is to maintain adequate indoor air exchange. This process is not always satisfied by simply opening the windows, but requires the use of specifically dedicated systems and strategies, which must at the same time minimize their impact from an energetical, environmental and acoustic point of view, as well as ensure the health and safety of the occupants. In this regard, energy-efficient mechanical ventilation has been shown to be effective in improving indoor air quality [9,10] and occupant health [11].

From an occupational medicine perspective, the health aspects related to air quality are key for safe and healthy working environments. In particular, healthcare professionals and occupational physicians are essential to assess indoor air quality, collaborate to identify sources of pollution, as well as proposed solutions to improve air quality and prevent negative health consequences for indoor occupants [3].

The importance of indoor air quality and wellbeing of occupants can be traced in several national and international policies. At the international level, the World Health Organization (WHO) issued in 2009 and 2010 two guidelines on indoor air quality for dampness and mould [12] and selected pollutants [3]. In the European landscape, the importance of the well-being of occupants of living environments has been emphasized in the document "Towards a strategy for a sustainable urban environment" (COM 2004-60) in which the indoor air quality in buildings is listed as a priority [13].

The "European Environment and Health Strategy" (COM/2003/338), also known as the SCALE (Science, Children, Awareness, Legal Instrument, Evaluation) initiative, is aimed at combating the increase of chronic diseases in childhood through cross-sectoral and multidisciplinary initiatives aimed at reducing risk factors present in indoor living environments and in particular in the home, school, and daycare centers, where children spend most of their time [14].

At a national level, the Italian Ministry of Health has been promoting and developing important initiatives for years in the field of protection and promotion of health in confined spaces. In 2020, the National Plan for the protection and promotion of health in confined environments was issued, and the following year, with the Agreement of 27/02/21 the priority areas of intervention were identified and fed the National Prevention Plan in indoor environments. The plan, in line with the European Commission and the WHO, provided indications for regulatory and technical actions, design and construction of buildings, research and training actions for professionals and health communication and education for citizens. The National Prevention Plan 2010-2012 and 2014-2018 provided strategic guidelines to improve the hygiene requirements of IAQ in schools and other environments frequented by children. In addition to the numerous guidelines and initiatives funded, the Ministry of Health participates in the work of the National Indoor Study Group set up at the National Institute of Health, which has produced reference documents on monitoring strategies for VOCs, Particulate Matter (PM) and its chemical characterization, microbiological pollutants and allergens in indoor environments [15–20].

This protocol is inscribed in the context of the activities of the project "necessARIA: need for efficient air exchange strategies for the health of occupants in school buildings" winner of the call for proposals for the Italian National Plan for Complementary Investments (PNC). The project envisages collaboration, integration of skills and synergistic study of Italian schools through the involvement of four types of expertise: Health Operational Units (OU), Engineering OU, Environment Laboratory OU, as well as three Italian Regional Administrations and one Autonomous Province.

The project pays particular attention to the possible clinical consequences of low-quality indoor air, exploring the role of confounding factors and evaluating the relationships between technical parameters, and chemical, physical and microbiological samplings. The main goal is to promote strategies aimed at the improvement of indoor air quality in schools, which will result in a significant health benefit for students, as well as teaching, technical and administrative staff, as highlighted in the Prime Ministerial Decree of 26 July 2022 [21] .

MATERIALS AND EQUIPMENT

The project involves the installation of Controlled Mechanical Ventilation (CMV) systems in schools. With this system the exhaust air, saturated with humidity, carbon dioxide and harmful substances, is sucked out of the system, enters the exchanger where it transfers its thermal energy to the new air taken from the outside and filtered before arriving at the exchanger. This system allows a reduction in the concentration of indoor pollutants and an improvement in indoor air quality. An impact assessment will be carried out, through the evaluation of the effectiveness of CMV systems on air quality and health outcomes, performing a pre-post and trend analysis. The primary objective of the study is to assess the perceived indoor air quality in classrooms in a population of primary and secondary school students with and without CMV. Health outcomes will be declined in the secondary objective of assessing health status in the selected population, investigating the prevalence of dermatological, respiratory, ocular and general disorders reported before and after the intervention and stratifying by sociodemographic variables.

METHOD DETAILS

To serve the stated objectives a three-step methodology will be adopted, consisting of: (1) Indoor air quality (IAQ), Indoor Environmental Quality (IEQ) evaluation and survey (pre-intervention); (2) CMV installation; (3) IAQ and IEQ evaluation, and survey (post-intervention).

Population sampling

The population will consist of specific classrooms of primary and secondary schools recruited in the area of competence of the following OU related to the necessARIA project: the Autonomous Province of Bolzano - South Tyrol, the Marche Region, the Abruzzo Region, the Polytechnic University of Marche, the University of Bari Aldo Moro and the G. D'Annunzio University of Chieti-Pescara.

Population will be recruited according to the following two inclusion criteria: being students belonging to primary and secondary schools in the Regions/Autonomous Provinces involved; the parents/legal guardians have accepted the informed consent and to the processing of data, self-declaring that they have read and understood the information.

Failing one or both the aforementioned criteria will lead to exclusion.

Considering the methodology adopted, based predominantly on an exploratory survey, a formal estimate of the sample of subjects to be enrolled is not necessary.

The sample will be represented by the students at the schools recruited within the necessARIA project. Thirty-five classrooms equipped with CMV systems for monitoring indoor air quality will be recruited, in the 4 regions involved (Autonomous Province of Bolzano, Abruzzo, Marche, and Puglia). Considering an average of 15 children per class, providing for the recruitment of 35 classrooms, it is estimated that about 525 children are for the group of those "exposed" to CMV implants. The control group will be represented by the same classes but with CMVs off. The sampling is expected in consecutive days, one day with CMVs off and the next day with CMV on.

IAQ and IEQ evaluation

IAQ and IEQ are related concepts that focus on the quality of the indoor environment, particularly in buildings. These parameters are crucial for the health, comfort, and well-being of occupants. Their evaluation will be performed by experimental measurements and numerical analyses before and after the installation of CMV in the Schools' rooms.

The evaluation of the effectiveness of CMV systems on air quality will be evaluated also through the correlations with numbers of air volume changes per hour (n) and maximum flow rate (m3/h).

IAQ is influenced by various factors, including the concentration of pollutants such as: PM, VOCs, Carbon dioxide (CO2), Radon, formaldehyde, and other indoor pollutants.

In addition to IAQ, IEQ considers factors such as: Thermal Comfort (by measuring air temperature, relative humidity, thermal radiation symmetry), Lighting Quality, Acoustic and Occupant Comfort, and Well-being factors like ergonomic design, aesthetics, and psychological aspects.

Measurements will be carried out in accordance with EN ISO standards (Table1) and the reporting of results will use the interval limits of Ministerial Decree 18/12/75 and EN standards.

These data will be integrated into an operational checklist along with classroom occupancy profile, heating and ventilation system switch-on profile (if present), window opening profile, test start and end date and time, total test duration, data acquisition interval, instrument/sensor name with its technical data sheet and installation data, identification of the instrument/sensor on the floor plan with installation height and distance from perimeter walls.

For the flow rate, it will be calculated on supply and extract air flow rate and air velocity, and

Table 1. Normative references measurement and limits of indoor variables studied

Measure	Measure: Normative reference (ref)	Limits: Normative reference (ref)
Air temperature	EN ISO 7726:2002 [22]	DM 18/12/75 [23] EN 16798-1:2019 [24]
Relative humidity	EN ISO 7726:2002 [22]	DM 18/12/75 [23] EN 16798-1:2019 [24]
CO_2	EN ISO 16000-26:2012 [25]	EN 16798-1:2019 (24]
Radon	ISO 11665 series [26]	D.Lgs n. 101/2020 [27] DM 23/06/2022 n. 256 [28]
Air change rate (ACH)	UNI EN 12599:2012 [29]	DM 18/12/75 [23] UNI EN ISO 10339 [30]
RT, C_{50}, STI, $L_{ic,int}$, $L_{id,int}$	UNI 11532-2:2020 [31]	DPCM 05/12/97 [32] DM 23/06/2022 n. 256 [28]

technical data sheet. Other data will be collected: type of ventilation system (centralised, decentralised, decentralised with ducts, etc.), type and position of filters, number of available ventilation plant speeds, efficiency of heat recovery unit, ventilation plant documentation, date and time of test start and end, total test duration, data acquisition interval, instrument/sensor name with its technical data sheet and installation data.

The assessment of acoustic comfort in building environments pertains to the subjective satisfaction or well-being of individuals in relation to the acoustic conditions of a given space. It gauges how well the sound environment aligns with the expectations and preferences of the occupants.

Specifically, in a school environment, the main indices to be examined include reverberation time (RT), Speech Transmission Index (STI), clarity (C50), sound pressure level from service equipment (i.e. HVAC systems) and outdoor noise.

These parameters are crucial for evaluating the overall acoustic quality and ensuring an environment conducive to effective communication and learning.

Microbiological sampling

Microbiological monitoring of air and classroom surfaces with CMVs will be performed in each school selected for the study. Specifically, sampling will be performed in the same classrooms on different days, with students present and CMVs on, and with students present and CMVs off.

Microbiological sampling of air

The microbial contamination of the classroom air and the effectiveness of the CMVs will be assessed by active sampling.

Active sampling will be performed on solid substrates using the Surface Air System instrument, SAS Super ISO 180 (PBI International, Milan, Italy) and on liquid substrates using the Coriolis®μ instrument (Bertin Technologies, Montigny le Bretonneux, France). For each sampling, 200 L of air is aspirated through the SAS and the Coriolis®μ. The devices should be positioned at a height of approximately 1 metre from the floor and in the centre of the classroom. For each point a double sampling by SAS will be performed both to evaluate the total bacterial load and the total mycotic charge. The number of colony-forming units will be expressed in colony-forming units per cubic meter (CFU/m3).

For SAS, the Total Bacterial Count (TBC) will be determined on 55 mm and 90 mm plates containing Plate Count Agar (PCA; Becton-Dickinson, Heidelberg, Germany), while for Total Fungal Count (TFC) / Total bacterial count (TBC), plates containing Sabouraud gentamicin-chloramphenicol agar (Liofilchem, Roseto degli Abruzzo, Italy) and DG18 respectively will be used. According to UNI EN ISO 4833-1:2013 [33], PCA plates will be incubated at 30 ± 1 °C for 72 hours for research of bacteria. For fungi, according to NF V08-059:2002 (34) Sabouraud plates will be incubated at 25 ± 2 °C for 5 days. The results will be expressed as the mean of two plates in colony-forming units. The air bacterial and fungal load (AFL) will be defined as the number of captured CFU/m3 of air, respectively.

A cone containing 15 mL of liquid substrate (0.005% Triton X-100) will be used for Coriolis®μ analysis, as recommended by the manufacturer. This medium will be used to evaluate the presence of the microbial community present in the air using Next Generation Sequencing (NGS) technologies.

Microbiological sampling of surfaces

Microbiological analyses of surfaces will be carried out on desks, chairs and door handles. Sampling will be performed using contact plates containing Plate Count Agar + Neutralizing (Liofilchem, Roseto degli Abruzzo, Italy), to find bacteria, and contact plates containing Sabouraud CAF Agar + Neutralizing (Liofilchem, Roseto degli Abruzzo, Italy) to find fungi. After sampling, the plates will be transported to the laboratory in containers refrigerated at 4°C and the PCA plates will be incubated at 30 ± 1 °C and monitored daily for 72 ± 3 hours [33], while the Sabouraud plates at 25 ± 2 °C and monitored for 5 days [34]. After incubation, the presence of colonies will be expressed as colony forming units for cm^2 (CFU/cm^2).

The identification of suspicious colonies will be performed by matrix-assisted laser desorption/ ionization time-of-flight mass spectrometry (MALDI-TOF MS, Biomèrieux, Marcy l'Etoile, France). The filamentous fungi no identifiable by MALDI-TOF MS, will be identified based on their macroscopic and microscopic morphological features, in accordance with the methods described by de Hoog et al [35]. The macroscopic examination will be based on visual observation of morphological characteristics and color of aerial mycelium, while the microscopic analysis will be performed by preparation of lactophenol cotton blue-stained slides. The slides will be prepared with tape that adhered to aerial mycelium and placed on the lactophenol cotton blue-stained slides.

CMV characterization

Smoke test

The smoke test will be carried out using a particle counter and a smoke generator. The objective is to evaluate the decay time of the particles generated using the ventilation system. A checklist will be adopted to collect: test start and end date and time, total test duration, data acquisition interval, air volume used for each measurement, start and stop time of smoke generator, ventilation system speed used during the test, sensor/instrument name and data sheet, identification of the sensor/instrumentation on the floor plan, specifying the installation height of the particle counter and distance from perimeter walls. The test procedure will involve the following steps:

1. during the first phase, the particle counter will be positioned outside the classroom to evaluate the external environmental condition. A data acquisition at 1 minute intervals will be used and an air sample equal to 1 litre will be taken for measurement. This step will be carried out until a stationary condition of the measured particles is reached;
2. during the second phase, the particle counter will be moved inside the classroom, centrally positioned on top of a desk, to evaluate the internal stationary condition;
3. during the third phase, before turning on the smoke generator, all the windows, doors and any existing shielding (e.g. roller shutters) in the classroom will be closed in order to evaluate only the influence of the ventilation system. Once all the openings will be closed, the smoke generator will be turn on until the classroom is completely saturated, then it will be turn off. The measurement continues until the stationary conditions obtained before turning on the smoke generator are reached.

The test can be repeated for each available speed of the ventilation system. Since the time available in schools is usually not enough to carry out multiple tests, at least one test will be carried out at the speed that is normally used during teaching activities or at the speed that guarantees the flow rate required by the regulations. Moreover, since this test is the most demanding from a temporal point of view, it will be always carried out at first and, at the end of all the tests, the equipment used inside the classroom will be collected.

Blower door test

The blower door test is conducted to assess the air permeability of the classroom envelope according to UNI EN ISO 9972:2015. The test consists in generating a pressure difference equal to 50 Pascal between inside and outside, using a fan temporarily mounted on the door through an adaptable frame and a sheet that seals the door itself. The air flow generated by the set pressure difference defines the infiltration air flow rate at 50 Pa (q_{50}). By calculating the ratio between the q_{50} value and the internal room volume, the number of air changes at 50 Pa (n_{50}) will be obtained. The data related to flow rates at different pressure differences, will be integrated into a checklist along with test start and end date and time, total test duration, sensor/instrument name and data sheet, identification of the sensor/instrumentation on the floor plan. In particular, the test procedure will involve the following steps:

1. the frame is installed in the door compartment and the sheet positioned, avoiding infiltration points;
2. the fan is inserted into the sheet and fixed to the frame horizontal bar;
3. the tubes are screwed onto the sheet and onto the pressure gauge depending on the test type to be carried out (pressure or depression, depending on the direction of the air flow generated by the fan). In the case of classrooms with a false ceiling, the test will be carried out only in depression;
4. to start the test the fan will be turn on. To obtain the value of n_{50}, various flow-pressure points must be defined to construct a straight line and obtain the flow rate at 50 Pa (q_{50}). At least 5 points will be always considered, in a pressure difference range between 20 Pa and 60 Pa;
5. once the straight line will be constructed, the value of q_{50} will be obtained. The value of n_{50} will be obtained calculating the ratio between q_{50} and the room volume.

Indoor Fluid-Dynamics (IDF)

IFD will include three different tests: the measurement of the flow rate provided by the ventilation system, the smoke test to assess the efficiency of the system and the blower door test to evaluate the permeability of the room (standard references in Table 1).

In addition to the experimental campaign, Computational Fluid-Dynamics (CFD) simulations will be performed for better understanding and optimising the thermal conditions within educational facilities. Specifically, COMSOL Multiphysics (version 6.2) [36] will be employed for the analyses due to its capability to integrate various physics modules, including fluid dynamics, heat transfer, and environmental conditions. This enables the creation of comprehensive models for evaluating complex systems like indoor environments.

The fluid dynamics simulations for indoor thermal comfort will consider several parameters and variables, such as classroom layout, geometry, material properties, outdoor weather conditions, occupancy patterns, and the presence or absence of mechanical ventilation systems. By inputting these factors into COMSOL Multiphysics, different ventilation scenarios can be modelled, and direct comparisons conducted, aiming to identify more efficient mechanical ventilation systems compared to traditional natural ventilation mechanisms.

EXPECTED OUTCOME

For the evaluation of health aspects, a questionnaire will be developed and administrated, concerning health problems arising in students belonging to the recruited classrooms, and will be answered by the children through the help of their parents/legal guardian. In addition, the questionnaire will investigate the perceived air quality during school hours. Data collection of perceived air quality and state of health (respiratory, dermatological, ocular and general disorders) will take place through the multiple administration of the questionnaire, repeated every six months for two years. In total, the questionnaire will be administered 5 times: at time 0, at 6 months, at 12 months, at 18 months, at 24 months.

The questionnaire administered will consist of three sections, described below:

a. General questions about the child. This section consists of 7 questions (from A1 to A7) and analyses the socio-demographic characteristics of the population in question (date of compilation, region of birth, municipality of residence, school and class data, age, gender);
b. Questions about the child's school environment. This section consists of 17 questions (from B1 to B17) with a 5-point Likert scale, to be filled in by the students belonging to the recruited classrooms. To make it easier for primary school students to fill them in, the answers are represented with a visual scale. This section investigates the conditions of the school environment, in terms of lighting, noise, and microclimatic parameters.
c. Questions about the child's health status and home. This section consists of 21 multiple-choice questions (C1 to C21). This section is expected to be completed by the child's parents. It investigates the state of health of the pupils included in the study with regard to problems related to indoor air quality. The investigated health problems are:
   – Respiratory disorders (9 questions);
   – Skin disorders (1 question);
   – Eye disorders (1 question);
   – Other health issues (4 questions).

   Questions C16 to C21 explore the home environment and the extracurricular environment, assessing the presence of family members who smoke, ventilation and heating systems in the home, heavy traffic conditions near the home and the habit of physical activity.

The questionnaire consists of a total of 45 questions, with an average completion time of about 20 minutes.

The questionnaire, developed in collaboration with the OUs involved and validated through focus groups of experts (engineers, public health physicians, occupational medicine physicians, biologists), will be further validated through a pilot study on two classes (one with CMV and one without CMV), evaluating the internal validity of the questionnaire through the calculation of Cronbach's alpha.

The questionnaire, built and validated in Italian, will be translated and adapted to the English and German versions according to a forward/backward translation process and then to a pre-test ("cognitive debriefing"), to facilitate its compilation in the Autonomous Province of Bolzano - South Tyrol.

The questionnaire will be distributed in paper form, through agreements with the administrative staff of the schools recruited by the OUs related to the project. An online version will also be developed, through Microsoft Forms, generating a QR code to facilitate dissemination. In this case, the questionnaire will be sent to the children's parents/legal guardians, also using the digital class register tools.

Responses will be made pseudo-anonymous, through progressive coding, to avoid multiple completion by the same person at each deadline. However, adjustments will be made during statistical analysis to control the bias.

The questionnaire will be accompanied by a factsheet describing the objectives of the project and of the present study, the impact of air quality on the health of school building occupants, and the intended use of the data collected. The questionnaire compilation requires the signing of the informed consent by a parent/legal guardian of the enrolled student.

The paper-form completed questionnaires will be collected and archived for ten years at the Università Cattolica del Sacro Cuore after computerization of the data on a spreadsheet (Microsoft Excel).

QUANTIFICATIONS AND STATISTICAL ANALYSIS

The sample will be described in its clinical and demographic characteristics by means of the appropriate descriptive statistical indexes. In detail, qualitative data will be expressed as absolute frequency and relative percentage, while quantitative variables such as mean and standard deviation (SD) or median and interquartile range (IQR), as appropriate. To verify the Gaussian distribution of quantitative variables, the Shapiro-Wilk test will be applied.

To compare data between exposed and unexposed subjects, Student's t-test for independent samples or Mann Withney's U-test, depending on their distribution, will be used in case of comparisons between quantitative data. Qualitative data will be compared using the Chi-Square test or the exact Fisher-Freeman-Halton test, as appropriate.

The incidence over time in respiratory, dermatological, ocular and general disorders will be analyzed in terms of incidence rates and compared between exposed and unexposed through the incidence rate ratio. ANOVA test will be deployed to analize the variance across the 5 time-points. Appropriate graphs will also be drawn to evaluate the trend in the 5 time-points. Poisson regression models can be fitted to assess the influence of children's age, in relation to the classes involved, gender, geographical location and housing data.

Statistical significance is set for values of $p < 0.05$. Suggestive P values ($0.05 \leq P < 0.10$) will also be reported. The entire set of analyses will be conducted with STATA 18 software [37].

For the evaluation of the comfort of the occupants of indoor school environments, COMSOL Multiphysics software [36] will be used for numerical simulation of air quality by modelling thermo-hygrometric parameters, acoustic and HVAC (heating, ventilation and air conditioning) systems. To run simulations related to rooms or indoor environments using COMSOL Multiphysics, it is necessary to create geometric modelling, define initial and parameter conditions, choose physical models, define materials, configure a mesh, and, finally, run the numerical simulation. The results will be used to prepare reports for school leaders and project partners to make engineering or management decisions to optimize indoor air quality, energy efficiency, and room acoustics.

The data collected will be processed in compliance with the European Regulation 2016/679 on privacy (so-called GDPR), Legislative Decree 196/2003 ("Personal Data Protection Code" and subsequent additions) and Legislative Decree 101/2018. The data collected will be recorded on a single computerized database accessible by password only by researchers and kept according to current legislation. The data will only be kept for as long as is strictly necessary for the investigation and then deleted.

LIMITATIONS

The present study has some limitations. Some limitations concern the use of surveys, such as the lack of precise description of the population and the presence of bias among respondents. Among these, the risk of "self-selection bias" prevails, as participation implies the respondent's willingness to take an active part in the study and this willingness could be influenced by interest in the topic treated. A further limitation to consider is the possibility of "social desirability bias", according to which the respondent may tend to select the most socially acceptable answer rather than the most truthful. In addition, the low response rate could be an important limitation, as well as the willingness of the individuals interviewed to pay full attention to the questions asked for more than a certain amount of time (e.g., 5-10 minutes). Another limitation concerns sampling. A larger sample could provide an assessment of heterogeneity among respondents in more detail and provide coefficients with more precise estimates. Finally, a methodological limitation inherent in the use of surveys could be the reluctance of the students/family to fill in the questionnaire motivated by doubts relating to the processing of data despite the explicit guarantee of the anonymity of the survey itself.

TROUBLESHOOTING

The present study protocol aims to be a foundation for all future studies in the necessARIA project.

This project aims to assess efficacy and effectiveness of new measures to tackle the indoor air quality issue, by performing chemical-physical and microbiological assessment of indoor air quality post intervention (CMVs installation).

At the same time, this project aims to highlight the importance of perceived indoor air quality for students and school personnel from a health perspective, assessing the respiratory, dermatological, ocular, neurobehavioral and general health outcomes in this population.

Finally, necessARIA aims to propose new strategies and measures to deal with the raising issue of sustainability in indoor air quality improvement, enacting measures and systems that will be sustainable from an environmental, energetical, and acoustic point of view, while still ensuring the best possible health outcomes.

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AUTHOR CONTRIBUTIONS

Conceptualization: L.V., U.M.; Data curation: M.F.R., F.B., C.P., C.D.P., S.M., G.C.; Funding acquisition: U.M.; Methodology: M.F.R., F.B., C.P., C.D.P., S.M., G.C.; Writing – original draft: M.F.R., F.B., R.L., C.P., C.D.P., S.M., G.C.; Writing – review & editing: R.L., U.M, necessARIA working group.

DECLARATION OF INTEREST

The authors report no conflicts of interest.

ETHICS AND CONSENT

The study protocol received ethical approval from IRB of Università Cattolica del Sacro Cuore in Rome (ID: 5859).

SCOPE STATEMENT

This study focuses on the possible clinical consequences of low-quality indoor air and it promotes strategies to improve indoor air quality in schools by installing controlled mechanical ventilation systems. The aim of this research project is improving health outcomes related to indoor air quality in students, teachers, technical and administrative staff. It also includes considerations related to topics such as prevention in the workplace and energy sustainability.

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