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**Review of the doctoral dissertation by Seyedkeivan Nateghi
entitled „Analyses of selected methods of limiting the spread of air
pollutants in occupied ventilated rooms"**

1. Basis for review preparation

The basis for preparing this review of the doctoral dissertation entitled "Analyses of Selected Methods of Limiting the Spread of Air Pollutants in Occupied Ventilated Rooms" is the Resolution of the Council of the Discipline of Environmental Engineering, Mining and Energy of the Silesian University of Technology dated June 12, 2025, regarding the appointment of reviewers for the doctoral dissertation of M.Sc. Eng. Seyedkeivan Nateghi.

2. Structure and content of the evaluated doctoral dissertation

2.1. Assessment of the dissertation's structure and information on its constituent parts

The dissertation was prepared in English, with a summary in Polish. The main part comprises 64 pages. Additionally, it includes an introductory section (14 pages) and 6 appendices. The appendices consist of a collection of six original articles from the Journal Citation Reports (JCR) list, in which the doctoral candidate is the second author (Article 1) and the first author (Articles 2–6). The publications appeared in the following journals: *Energies* (IF = 3.0), *Journal of Building Engineering* (IF = 6.7), *Building and Environment* (IF = 7.1), and *Sustainable Cities and Society* (IF 2023 = 10.5).

According to the provided statements, the doctoral candidate's contribution to the creation of the articles amounts to: 35% (Articles 1, 4, 6), 50% (Article 5), 70% (Article 3), and 80% (Article 2). This contribution included manuscript preparation, conducting research and analyses, developing the research concept and methodology, obtaining funding, data visualization, and validation of the results.

2.2. Title and subject matter of the doctoral dissertation

The evaluated doctoral dissertation is entitled "Analyses of Selected Methods of Limiting the Spread of Air Pollutants in Occupied Ventilated Rooms." The title is consistent with the content of the work and relates to the scientific discipline of environmental engineering. However, it could be noted that the title might be further specified by indicating that the research was conducted for an educational building (a classroom).

The subject matter of the dissertation concerns ensuring an appropriate indoor environment in school classrooms. This is an important and current issue. The quality of the indoor environment has a direct impact on human health and well-being, and in the case of children and adolescents, also on their development. The influence of air quality on students' perception should also not be underestimated. During the COVID-19 pandemic, interest in research on the role of ventilation systems in limiting the

spread of infections increased significantly. This topic remains relevant even outside epidemic situations, especially during the autumn-winter season. Ensuring proper air quality in terms of chemical, particulate, and biological factors is extremely important, and any solution contributing to the improvement of the indoor environment should be considered valuable from the perspective of societal development. The dissertation addresses research whose results can be applied not only in new buildings. The topic of the dissertation is consistent with the goals of sustainable development and primarily supports the goal of Good Health and Well-Being, as well as, to some extent, the goals of Quality Education and Sustainable Cities and Communities (SDG 3, 4, 11).

2.3. Assessment of the individual constituent parts of the dissertation

The introductory part of the dissertation includes acknowledgements, a summary in English and Polish, a table of contents, a list of attached scientific articles, a description of the doctoral candidate's contribution to the creation of the articles, a list of used notations, and a general description of the structure of the main part of the dissertation.

The introduction presents the motivation for undertaking comprehensive research on limiting the spread of infections in enclosed spaces, taking into account ventilation and filtration, thermal comfort, and economic aspects, in the context of sustainable development. The necessity of conducting research in educational buildings, where children spend many hours a day, is emphasized. Chemical, particulate, and biological pollutants are characterized, along with a review of methods for their mitigation. The introduction also highlights the impact of indoor air quality (IAQ) management and infection control strategies on comfort, energy efficiency, and sustainable development goals. The aim and scope of the dissertation are defined in Section 1.6.

Chapter 2 describes the achievements presented in three articles concerning ventilation methods and their control. The studies are based on simulations of various ventilation solutions for a classroom used by 30 students, located in different climates (Warsaw, Bangkok, Delhi, and Stockholm). The benefits of a hybrid ventilation strategy integrated with an EMS system (dynamic switching between natural and mechanical ventilation depending on pollutant concentration) were demonstrated, both in terms of air quality, energy consumption, and thermal comfort. For example, compared to a scenario with only mechanical ventilation, energy consumption was reduced by approximately 65% (Warsaw), 57% (Stockholm), and 13% (Delhi), while air quality improved (e.g., the share of time in category I according to EN 16798-1 in Warsaw increased to 43%) and comfort was maintained (PMV within the recommended range). The limitations of natural ventilation in cities with high PM2.5 concentrations were also demonstrated.

Chapter 3 describes the achievements presented in three subsequent articles concerning strategies for reducing infection risk. The studies focus on the assessment and optimization of various strategies enabling control of infection spread in the enclosed classroom. The subject of the research was the same classroom examined in Chapter 2. The analysis considered the use of physical barriers and individual exhaust systems, as well as the effectiveness of ventilation under different air distribution methods (mixing and displacement ventilation). Experimental validation was also conducted with CFD simulations, which were applied in the optimization of the system considering physical barriers and individual exhausts.

Chapter 4 describes research concerning the life cycle assessment of selected infection control strategies. This part of the study is unpublished. The research was conducted in the same classroom,

equipped with a ventilation system and the use of air purifiers, disposable masks, and an integrated system of physical barriers and individual air exhausts (the studies described in Chapter 3). The Wells-Riley model was used to analyze the effectiveness of the applied solutions. The results showed that combined measures (masks + air purifiers) minimize the risk of infection but generate the highest environmental impact, while individual exhausts and physical barriers are the most advantageous.

Chapter 5 contains conclusions summarizing the obtained results and recommendations for the operational practice of educational facilities.

3. Assessment of the important parts of the dissertation

3.1. Assessment of the aim and theses of the dissertation

The objectives of the dissertation are clearly formulated and appropriate to the subject matter; they include deepening knowledge and developing effective and sustainable strategies for improving indoor air quality and reducing infection risk in classrooms, while simultaneously considering thermal comfort and energy consumption. The theses are formulated as hypotheses and research questions; they are verifiable and coherently linked to the methodology as well as to the scope of the subsequent chapters and publications in the series.

The scope of objectives and theses also includes all key dimensions of the problem: indoor air quality, thermal comfort, energy efficiency and environment, and the adopted structure of the work enables their verification. Research questions concern: (i) possibilities of ensuring adequate air quality and infection control through natural ventilation; (ii) optimization of the ventilation system in terms of energy while maintaining thermal comfort; (iii) adaptation of the hybrid ventilation system to variable indoor and outdoor conditions; (iv) influence of physical barriers on ventilation efficiency and the spread of pollutants; (v) the validity of combining local exhaust ventilation (PE) with physical barriers (PB) in order to control the transmission of pathogens.

The research hypotheses assumed that: intelligently controlled natural ventilation can limit the spread of infection in buildings without mechanical ventilation; multi-criteria optimization makes it possible to select system parameters so as to ensure the required air quality, comfort and rational energy consumption; hybrid ventilation improves environmental conditions and reduces energy demand; physical barriers limit the transmission of pathogens, and their combination with local exhaust significantly reduces exposure.

I assess the theses and objectives as precise, measurable, and achieved within the presented research. A possible clarification – increasing transparency – could be an explicit assignment of each hypothesis to a specific article and an indication of the adopted success measures in the summary of the chapter with objectives.

Based on the results from Chapters 2–4, I state that the objectives of the dissertation have been achieved, and the hypotheses confirmed in majority: fully – the validity of multi-criteria optimization and EMS-controlled hybrid ventilation (benefits for IAQ and energy); conditionally – the effectiveness of natural ventilation alone (limited by the quality of outdoor air and energy compromises); partially – the universality of physical barriers (effectiveness depends on the air distribution system);

clearly – the effectiveness of the PB+PE configuration and the possibility of its optimization in terms of resources.

3.2. Evaluation of the applied literature

The list of references includes 97 items. Most are articles from peer-reviewed journals in English.

The list also includes items authored/co-authored by the Doctoral Candidate (publication cycle). The literature corresponds well to the subject of the dissertation (IAQ, ventilation, aerosol transmission, CFD, standards) and is up-to-date – dominated by the years 2020–2024, supplemented with classic works (Riley 1978; Gammaitoni & Nucci 1997). The literature was used in an appropriate manner.

3.3. Indication and evaluation of the applied research methods and parts of the dissertation with results and conclusions from the research

For the implementation of the research, the Doctoral Candidate used methods commonly applied in the discipline of environmental engineering, mining, and energy, combining energy and airflow modeling, multi-criteria optimization, full-scale experiments, CFD modeling, infection risk assessment (Wells–Riley), and life cycle analysis (LCA). Both the simulation and experimental parts referred to the same reference space – a full-scale classroom – which ensured comparability of scenarios and results.

The first part of the research concerned simulations and optimization of the proposed solutions. EnergyPlus was applied for energy simulations and CONTAM for modeling airflow and pollutant concentrations. A strategy of intelligent window control (natural ventilation) was developed, as well as variants of hybrid ventilation with an EMS (Energy Management System), which switched modes between natural and mechanical depending on indoor conditions and outdoor air quality. Different climates were considered (Warsaw, Bangkok, Delhi, Stockholm), a representative number of users (30 students), and decision thresholds based on CO₂ concentration, thermal comfort, and PM_{2.5} concentration.

The second part of the research included experiments with tracer gases, aerosols, and bioaerosols. The effectiveness of air exchange and pollutant distribution was evaluated with the tracer gas method (CO₂, N₂O) and by measurements of aerosol/bioaerosol concentrations in a full-scale room with six thermally active manikins. Air changes per hour (ACH) were determined by the decay method; additionally, air change effectiveness (ACE) indicators were calculated. Aerosols were generated with a Collison nebulizer; in the bioaerosol studies, *Micrococcus luteus* was used as a safe biological surrogate. Ventilation conditions were maintained constant: ACH = 3 h⁻¹, supply air temperature 20 °C, RH 40%. Air distribution variants were tested: three mixing ventilation systems (MV1–MV3) and displacement ventilation (DV), which allowed assessment of the influence of distribution mechanism on the effectiveness of local strategies. In CFD modeling, the Discrete Phase Model (DPM) was applied, including molecular diffusion (Brownian motion) and particle characteristics (Stokes number), which enabled realistic representation of trajectories and deposition in turbulent flow. Calculations were validated with experimental data; the verified models were used for flow analyses and evaluation of the effectiveness of PB+PE systems.

Subsequently, infection risk assessment was carried out. The risk of pathogen transmission by airborne route was estimated using the Wells–Riley model, defining scenarios relevant to classroom activities (including a lesson lasting 45 minutes). The model parameters were linked with the defined scenarios and data from the simulation/experimental part.

The last part of the research concerned the evaluation of solutions in the life cycle (LCA). A comprehensive assessment was carried out in OpenLCA (v2.3.1) using the Environmental Footprint (EF) v3.0 database, covering the entire life cycle (from raw material extraction to end of life). Three strategies were compared: portable HEPA purifiers, disposable masks, and the integrated PB+PE system. Environmental and classroom usage conditions were identical to the assumptions of the earlier stages of the research. The environmental impact results were normalized and weighted into a single-point indicator (Pt), which enabled combining the environmental assessment with risk assessment (Wells–Riley) in a decision-making tool.

The results confirmed that EMS-controlled hybrid ventilation reduced energy consumption compared to the variant with mechanical ventilation by about 65% in Warsaw, 57% in Stockholm and 13% in Delhi, while maintaining or improving air quality and thermal comfort. The effectiveness of natural ventilation was limited by outdoor air quality and could be applied approximately for 11% of the year in Delhi, 44% in Warsaw and 31% in Stockholm. In the studies of local strategies, the PB+PE system consistently reduced exposure to infection; an exhaust flow of around 9 L/s per person proved effective, and reducing the barrier height from 65 to 45 cm caused only about a 5% decrease in effectiveness.

The selection of research methods is very broad and adequate to the purpose of the work; the use of one reference classroom model and the combination of simulations, experiments, CFD, infection risk model and LCA ensures methodological consistency and allows a reliable assessment of recommended solutions to limit the spread of infection in a ventilated classroom.

The formulated conclusions are consistent with the objectives of the work and result directly from the conducted research. They can be divided into general and detailed conclusions. There is somewhat a lack of formulation of limitations regarding the generalization of the results. I would kindly ask for clarification of the limiting conditions for the formulated conclusions. The limitations do not undermine the conclusions, but their indication allows to determine their universality.

3.4. Information concerning practical application of the obtained results

The obtained results and formulated conclusions are valuable and have implementation potential, while the directions of further research indicate the need for conducting additional work before implementing specific solutions in practice. The Doctoral Candidate indicated that validation of the proposed strategies in diverse classroom layouts and operating conditions, pilot implementations of the PB+PE system and hybrid ventilation control in schools, as well as long-term measurements of indoor air quality, noise, and cost assessment, as well as verification of assumptions using field data, are necessary.

In this part I kindly ask for clarification of:

- 1) which elements of the presented solutions can be implemented in an existing school already now without the need for further research;
- 2) which actions of a universal nature the Doctoral Candidate would recommend for immediate application in schools in Poland, along with a related description of the expected effect, potential limitations, and expenditures that schools would have to incur.

4. Evaluation of the doctoral dissertation

4.1. Evaluation of the originality of solving the scientific problem

In the dissertation, the scientific problem was solved in a comprehensive manner, introducing into the analysis issues related to ventilation, its proper control, ensuring adequate indoor air quality while simultaneously maintaining thermal comfort, as well as limiting the risk of infection spread (with the use and validation of local solutions: physical barriers PB and personal exhausts PE, supported by CFD modeling). Attention was also paid to the energy and environmental aspects of the proposed solutions (life cycle assessment – LCA, integration with the Wells–Riley model). Such a broad approach to the problem of improving environmental conditions in school classrooms made it possible to obtain very valuable results, which – when applied in practice – may bring significant benefits to room users. The results show, among others, the limitations of natural ventilation in heavily polluted cities and the effectiveness of the PB+PE system in reducing exposure to infection, while maintaining acceptable energy and environmental costs.

The scientific achievement should be considered significant, and the proposed solution to the problem – original.

4.2. Evaluation of whether the dissertation presents the general theoretical knowledge of the Doctoral Candidate in the discipline of environmental engineering, mining and energy, as well as his ability to conduct independent research

The subject matter undertaken in the dissertation is closely related to the research area of the discipline of environmental engineering, mining and energy. The Doctoral Candidate carried out a number of studies that led to the solution of the posed scientific problem. The results were published in a cycle of six scientific articles, thematically related and developing successive aspects of the research.

From the statements on the author's contribution, it follows that the share of the Doctoral Candidate in the publications in renowned scientific journals was significant – from 35% to 80% – and included, among others, preparation of the manuscript, development of the concept and research methodology, conducting analyses, data visualization, validation of results, and obtaining funding. Such a broad scope of work proves that the Doctoral Candidate has general theoretical knowledge in the discipline of environmental engineering, mining and energy, as well as the ability to conduct independent scientific research.

5. Final conclusion

The reviewed dissertation of Mr. M.Sc. Eng. Seyedkeivan Nateghi entitled “Analyses of selected methods of limiting the spread of air pollutants in occupied ventilated rooms” I evaluate positively and I state that it meets the formal requirements defined in the Act on Higher Education and Science, i.e., it presents general theoretical knowledge in the discipline of environmental engineering, mining and energy as well as the ability to conduct scientific research by the Doctoral Candidate, and at the same time constitutes an original solution to a scientific problem. On this basis, I request that Mr. M.Sc. Eng. Seyedkeivan Nateghi be admitted to the next stage of the procedure.

Taking into account the comprehensiveness of the conducted research, in which not only ventilation strategies limiting the spread of infection in enclosed spaces were considered, but also the necessity of ensuring thermal comfort for users while simultaneously emphasizing the importance of energy and economic aspects of the proposed solutions, I request that the doctoral dissertation be awarded a distinction.