Anna Bogdan, PhD, Eng., university professor
Faculty of Environmental Engineering,
Warsaw University of Technology,
ul. Nowowiejska 20, 00-653 Warsaw

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REVIEW
of the doctoral dissertation by Seyedkeivan Nateghi, MSc Eng.,
entitled "Analyses of selected methods of limiting the spread of air pollutants in the occupied ventilated rooms"

Introduction

This review was prepared on the basis of a letter (ref. RIE-BD.512.32.2025 dated 24 June 2025) from Prof. Krzysztof Labus, PhD, Chair of the Discipline Council for Environmental Engineering, Mining and Power Engineering at the Silesian University of Technology, in connection with my appointment by the Discipline Council for Environmental Engineering, Mining and Power Engineering at the Silesian University of Technology (resolution of 12 June 2025) as a reviewer of the doctoral dissertation by Seyedkeivan Nateghi, MSc, entitled "Analyses of selected methods of limiting the spread of air pollutants in the occupied ventilated rooms."

The doctoral dissertation was prepared under the scientific supervision of Jan Kaczmarczyk, PhD, Professor of SUT. The main body of the dissertation consists of 62 pages, which include: a summary of the dissertation with a list of keywords, a list of publications forming the basis of the dissertation and confirmation of the Candidate's level of involvement in the preparation of each publication, a list of symbols, information on the supplementation of analyses beyond the scope presented in the publications, as well as five chapters which present the entire work, including: an introduction containing the objectives of the paper, the substantive basis for ventilation strategies and intelligent control, local infection level control strategies and an assessment of the life cycle of individual strategies; the final chapter is a summary. The appendix to the dissertation contains six publications with detailed information on individual studies and analyses.

Assessment of the structure of the doctoral dissertation

The structure of the doctoral dissertation is logical, clear and consistent with the clearly defined research objectives. The structure of the paper was planned in a cause-and-effect manner, allowing for a clear understanding of the successive stages of the analysis.

The first chapter presents the motivation for choosing the topic, discussing current problems of effective ventilation in rooms with a large number of users. The candidate also justifies his approach to the work, pointing out that the issue of effective ventilation cannot be considered only from the perspective of user safety and comfort. It is equally important to reduce the energy consumption of buildings and the impact of the solution on the environment. This chapter also presents problems with current ventilation strategies and the basics of indoor air pollution, ways to limit its spread through ventilation in the building and air distribution in individual rooms, personal protective equipment, including masks, screens and gloves used during the COVID-19 pandemic, physical barriers and partitions introduced at workstations, air purification methods and building automation systems used to control air occupancy levels. The chapter is supplemented with an analysis of additional issues related to the impact of indoor air quality maintenance techniques on energy efficiency and the environment. The presented analyses, which identify research gaps, are summarised by the main objective of the dissertation, supported by specific

objectives and hypotheses. The concept of the approach used throughout the dissertation is also well illustrated by a graphical summary.

The second chapter discusses the research conducted to answer the question of how to ventilate school rooms efficiently and with low energy consumption. The candidate discusses the research methods used, simulations and multi-criteria optimisation and presents the results obtained.

In the third chapter, the candidate focuses on local solutions for limiting the spread of pollutants, i.e. the use of desk partitions with various mixing and displacement ventilation solutions in the room and desk partitions integrated with local exhaust ventilation. The chapter discusses the methods used in the laboratory tests and CFD simulations, as well as the results obtained.

The fourth chapter analyses the environmental aspects of individual solutions with the use of life cycle assessment, taking into account air purifiers, masks and a local partition system integrated with local exhaust ventilation. The results show the environmental impact, sensitivity analysis of the LCA results and the overall environmental footprint of the life cycle. The chapter also presents a summary of the research conducted, together with the main conclusions and directions for further consideration that this research may have initiated. Details of the individual studies and analyses can also be found in six publications included in the appendix, which are also referenced in the individual chapters of the dissertation.

I welcome the clearly structured layout of the chapters, whose order and content form a coherent scientific narrative. The theoretical part is well developed. In it, the Candidate comprehensively presents the current state of knowledge in the field of indoor air quality, ventilation, aerosol control strategies and related health risks. The description of the methodology and research results is presented in a precise manner and the illustrations, charts and diagrams used support the understanding of the issues discussed. The chapter summaries, well-thought-out transitions between sections and clear presentation of the final conclusions testify to the good structuring of the material and the high editorial quality of the dissertation. The structure of the paper also facilitates the identification of the practical value of the results obtained and their relation to the hypotheses put forward. In summary, the structure of the dissertation should be assessed as well thought-out, functional and fully adequate to the substantive content of the work.

Assessment of the literature

The bibliography used in the dissertation is extensive, up-to-date and well-chosen in terms of content. The dissertation uses 97 references, including 90 scientific articles, 3 standards and a total of 4 textbooks and educational materials from software manufacturers; majority of the source materials has been published in recent years, but there are also older references that form the basis of knowledge. To sum up, it should be concluded that the selection and use of literature in the dissertation was carried out at a high level and that the bibliography is fully adequate for the scope and objectives of the dissertation.

Assessment of the aim of the dissertation

The aim of the dissertation was *to deepen knowledge and develop effective and sustainable strategies for improving indoor air quality (IAQ) and reducing the risk of airborne infections, especially in educational environments*. The objective was also to develop a compromise between issues related to user safety and comfort, as well as the energy efficiency of buildings and sustainable development. The specific objectives presented in the dissertation are as follows:

- *To evaluate different ventilation strategies for maintaining indoor air quality (IAQ) and reducing the risk of airborne infections in high-occupancy spaces.*

- *To investigate local risk mitigation measures, such as physical barriers, personal ventilation, masks and portable air purifiers, in controlling aerosol transmission in high-occupancy spaces.*
- *To analyse the impact of different indoor air quality improvement and infection control strategies* on energy consumption and comfort.

The following hypotheses have also been defined:

- *Natural ventilation through the use of smart windows can control the risk of infection when mechanical ventilation is not available.*
- *Multi-criteria optimisation of specific ventilation system parameters can lead to simultaneous control of indoor air quality, thermal comfort and energy demand.*
- *Controlled integration of natural and mechanical ventilation (hybrid ventilation) can improve indoor environmental quality and reduce energy consumption.*
- *Physical barriers can reduce the risk of airborne transmission of infections between people in a room.*
- *Local control strategies, such as personal exhaust ventilation in combination with physical barriers, can significantly reduce exposure to air pollution.*

The issue of indoor air quality and the reduction of airborne infection risks in shared spaces, especially educational ones, has gained enormous importance in the context of the COVID-19 pandemic, climate change and growing public health awareness. The objectives of the doctoral dissertation address these challenges in a systematic manner, taking into account related aspects. The objectives are logically organised, comprehensive and well balanced; the analysis of ventilation strategies forms the basis for the evaluation of new possible solutions for ventilation control, the study of local measures (barriers, masks, personal ventilation, purifiers) extends the scope of the analysis to include currently used and innovative solutions, while the analysis of the impact on the environment and energy consumption introduces a sustainable development perspective. Thanks to this comprehensive approach, the paper not only identifies the problem but also seeks sustainable and feasible solutions.

The hypotheses are defined accurately and logically linked to the objectives and refer both to the challenges of the modernisation of existing buildings, where mechanical ventilation infrastructure is often lacking and to the use of computational tools to find compromises between comfort, air quality and energy efficiency, which is a current challenge in HVAC design.

In summary, I believe that the objectives and hypotheses of this dissertation respond to real needs in the field of building design and operation. They can also serve as a basis for the development of design guidelines and recommendations, providing data for the research of innovative technical solutions and the support for investment decisions in the modernisation of existing facilities. For this reason, I confirm that the objectives and hypotheses of the doctoral dissertation are accurate, up-to-date and valuable and have both scientific and practical significance, which makes this work an important contribution to the development of knowledge in the field of environmental engineering.

Evaluation of the research methods used

The dissertation uses research methods of a high substantive and technical level, adequate to the complexity of the analysed problem and in line with contemporary research standards in the field of environmental engineering and indoor air quality. The work is distinguished by its multi-faceted methodological approach, combining:

- assessment of airborne infection risk based on a well-known transmission model (Wells-Riley) and empirical data,

- numerical modelling (CFD) to analyse the spread of pollutants and aerosols in rooms with different configurations and ventilation methods,
- energy and thermal comfort analyses, using simulation tools to assess the effectiveness of different strategies under variable operating conditions,
- laboratory experiments on the effectiveness of physical protective measures (barriers, personal ventilation) and the impact of local interventions on user exposure.

The Candidate skilfully selected the analysis tools for the purposes of the individual stages of the research and demonstrated the ability to critically interpret the results. The use of an interdisciplinary and systemic approach is particularly valuable, as it allows the effects of the proposed solutions to be assessed not only in technical terms, but also in terms of health and usability.

In summary, I consider the methods used to be reliable and appropriate and their selection and implementation fully confirms the Candidate's high level of research competence.

Assessment of the parts of the dissertation containing a discussion of the research results

The discussion of the research results is presented partially in chapters 2 - 4, depending on the solution analysed. Chapter 2 uses an analysis based on three performance indicators: infection risk based on the Wells-Riley model, heat demand and periods outside the thermal comfort zone assessed on the basis of PMV. It was demonstrated that there are real possibilities for simultaneously improving air quality and thermal comfort with a limited increase in energy consumption, provided that ventilation and heating are optimally managed. At the same time, ineffective strategies (e.g. too low CO_2 threshold, too wide heating temperature range) lead to a significant increase in energy consumption without significant health benefits. Chapter 3 shows that local air pollution control strategies can effectively reduce the risk of infection, especially in environments where full mechanical ventilation is difficult to implement. In addition, it was found that partitions can be useful, but their effectiveness depends on the airflow context and the best results are achieved with an integrated approach combining several protection methods while taking into account the ventilation background. Chapter 4 establishes that the use phase dominates the total environmental footprint of solutions with local exhaust ventilation and purifiers, while electricity consumption during operation (local exhaust ventilation, purifiers) accounts for over 70% of the total environmental impact. At the same time, although partitions have a significantly lower environmental impact, they are less effective in scaling down exposure. The solution is to combine local exhaust with a partition, which can cut down the operating time of the exhaust, thereby reducing the environmental footprint while maintaining protection. HEPA purifiers, although effective for purifying the entire space, had the greatest environmental impact, mainly due to the need for continuous operation.

The indicated part of the dissertation was prepared in a reliable, insightful and convincing manner. The Candidate presents the results in the form of clear tables, graphs and visualisations, enabling a thorough understanding of the relationships and effects of the strategies studied. The interpretation of the data is consistent with the methodology presented earlier and referred directly to the formulated hypotheses and research objectives. The conclusions drawn from the analyses are well justified and their reference to the literature on the subject demonstrates a critical approach to the research problem.

In summary, the part of the dissertation which discusses the research results meets high scientific standards and constitutes a strong element of the dissertation, demonstrating the Candidate's research maturity and deep understanding of the analysed problem.

Information on the practical application of the research results

The results presented in the doctoral dissertation have high application potential and can be directly applied in the design and modernisation of ventilation systems in public buildings, in particular in educational institutions. The developed solutions and strategies, such as the integration of natural and mechanical ventilation (hybrid systems), the use of smart windows and local physical barriers integrated with local exhaust ventilation, can be implemented in both newly designed and existing buildings.

Another significant advantage of the work is the use of a multi-criteria approach, which takes into account not only the effectiveness in reducing the risk of airborne transmission, but also user comfort and energy efficiency. This approach responds to the current challenges of indoor environment design in the context of public health and sustainable development. The results obtained can serve as a basis for developing guidelines and standards for building designers and managers, supporting investment decisions in the education sector and for developing innovative HVAC products and technologies tailored to the needs of public buildings. In summary, it can be concluded that all the results obtained in this work are of significant practical importance and stand out for their implementation potential, both at the technological and systemic levels.

Information on possible irregularities

During the analysis of the doctoral dissertation, no formal, substantive or ethical irregularities were found. The work was prepared in accordance with the applicable academic standards and the content, research results and literature citations are reliably documented and correctly presented.

However, the lack of lab or real-life research on the proposed ventilation strategies leaves something to be desired. This part was performed exclusively by means of analyses using EnergyPlus and CON TAM software and, although it is a correct solution for the objectives of the dissertation, empirical research supported by simulations could clearly verify whether the proposed solutions have practical potential. Currently, the answer to this question is not unambiguous, because although the conclusions indicated may be a guide, physical measurements should still be carried out to verify the application possibilities. Similar questions arise in relation to the proposed solution of a local partition with local extraction: tests with volunteers, even conducted with only one workstation, could answer the question of the actual feasibility of the solution. Moreover, the tests were performed under fixed conditions and it would be interesting to test variants with variable loads, different user dwell times, etc. At the same time, I would like to emphasise that the above comments do not affect my overall positive assessment of the work carried out by the Candidate.

Assessment of whether the doctoral dissertation constitutes an original solution to a scientific problem

The doctoral dissertation presents an original and comprehensive approach to solving a current scientific problem, namely ensuring high indoor air quality while reducing the risk of airborne transmission of infections, especially in rooms with high user density, such as classrooms. The Candidate not only analysed existing ventilation solutions and personal protective equipment, but also proposed innovative concepts, including the integration of local aerosol control strategies with hybrid ventilation systems and multi-criteria optimisation of environmental parameters, taking into account comfort, energy efficiency and health safety.

The originality of the work is mainly manifested in the proposal of new methods for controlling ventilation systems and the development of an innovative solution for personal exhaust ventilation, but also in the assessment of the environmental impact of the proposed solutions.

The results of the research make a significant contribution to the development of knowledge in the field of environmental engineering and the design of safe public spaces and their originality is reflected both in the approach to the problem and in the proposed solutions. In view of the above, it should be concluded that the dissertation meets the criteria for a scientific work containing an original solution to an important scientific problem.

Assessment of whether the doctoral dissertation presents general theoretical knowledge in the discipline and the ability to conduct independent scientific work

The doctoral dissertation confirms that the Candidate has thorough and structured theoretical knowledge in the field of environmental engineering. The literature review was conducted in a comprehensive manner, taking into account both classical theoretical approaches and the latest scientific research results, including international publications, which demonstrates a good understanding of the current state of knowledge and the ability to draw relevant conclusions from the work of other researchers.

With regard to the ability to conduct independent research, two issues should be noted: the average contribution of the doctoral student to all publications is 50.8%. Furthermore, an analysis of the CRediT Authorship Contribution section shows that the candidate was the main author or co-author with a significant substantive contribution to all works, both in terms of formal analysis, methodology, model development and visualisation of results, as well as preparation of the text for publication. A particularly significant contribution was noted in analytical and modelling works, i.e. articles entitled: *Multi-objective optimization of window and thermostat control* (Article 2 - 80%) and *Optimal control strategy for a cutting-edge hybrid ventilation system in classrooms: Comparative analysis based on air pollution levels across cities* (Article 3 - 70%). In addition, the Candidate made a significant contribution to the research described in Articles 4 - 6, i.e. co-led the research, analysed the data and prepared the results and conclusions, which demonstrates competence not only in numerical modelling but also in laboratory work. The Candidate independently conducted the analyses presented in Chapter 4, which have not been published as a separate article. The entire paper demonstrates the ability to independently conduct complex, multi-stage scientific research, as well as the ability to integrate different methods and tools to solve practical engineering problems.

In summary, I believe that the candidate has achieved the set goal, demonstrated a high level of theoretical knowledge in the field of environmental engineering, mining and energy and the ability to conduct independent scientific work.

Final conclusions

The doctoral dissertation by Seyedkeivan Nateghi, MSc, entitled: *"Analyses of selected methods of limiting the spread of air pollutants in occupied ventilated rooms"* meets the requirements specified in Article 187 of the Act of 20 July 2018 on Higher Education and Science. The doctoral dissertation falls within the field of engineering and technology, in the discipline of environmental engineering, mining and power engineering. The submitted doctoral dissertation is a comprehensive, reliably documented and scientifically valuable study on strategies for improving indoor air quality and reducing the risk of airborne infections, with particular emphasis on educational facilities. I hereby request that Mr Seyedkeivan Nateghi be admitted to the next stage of the doctoral procedure and that his dissertation be recognised as meeting the high standards of doctoral theses and presenting a comprehensive approach to multi-criteria analysis of infection risk, including environmental assessment.

[signature] Anna Bogdan