ANNEX 78

EBC
Energy in Building and Communities Programme

International Energy Agency

Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications (Annex 78)

Energy in Buildings and Communities Technology Collaboration Programme

Technology Collaboration Programme
by iea

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Energy in Buildings and Communities Technology Collaboration Programme

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Authors

Bjarne Wilkens Olesen, DTU.SUSTAIN, Denmark (bwol@dtu.dk)

Pawel Wargocki, DTU.SUSTAIN, Denmark (paw@dtu.dk)

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www.iea-ebc.org
essu@iea-ebc.org

Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

- the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
- benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
- improving smart control of building services technical installations, including occupant and operator interfaces;
- addressing data issues in buildings, including non-intrusive and secure data collection;
- the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: ☼ Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: ☼ Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62: Ventilative Cooling (*)
Annex 63: Implementation of Energy Strategies in Communities (*)
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66: Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67: Energy Flexible Buildings (*)
Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (*)
Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale (*)
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements (*)
Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings (*)
Annex 73: Towards Net Zero Energy Resilient Public Communities (*)
Annex 74: Competition and Living Lab Platform (*)
Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables (*)
Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions (*)
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting (*)
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79: Occupant-Centric Building Design and Operation
Annex 80: Resilient Cooling
Annex 81: Data-Driven Smart Buildings
Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
Annex 83: Positive Energy Districts
Annex 84: Demand Management of Buildings in Thermal Networks
Annex 85: Indirect Evaporative Cooling
Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings
Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings
Annex 89: Ways to Implement Net-zero Whole Life Carbon Buildings
Annex 90: ☼ EBC Annex 90 / SHC Task 70 Low Carbon, High Comfort Integrated Lighting
Annex 91: Open BIM for Energy Efficient Buildings
Annex 92: Smart Materials for Energy-efficient Heating, Cooling and IAQ Control in Residential Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities (*)
Working Group - Building Energy Codes

IEA EBC Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications

The IEA EBC Annex 78 explored the integration of gas-phase air cleaning technologies to supplement traditional ventilation systems, focusing on balancing IAQ and energy efficiency

Ventilation accounts for approximately 20% of the global energy use for providing an acceptable indoor environment. The requirements for ventilation in most standards and guidelines assume acceptable quality of (clean) outdoor air. Worldwide, there is an increasing number of publications related to air cleaning and there is also an increasing sale of gas phase air cleaning products. This puts a demand for verifying the influence of using air cleaning on indoor air quality, comfort, well-being and health. It is thus important to learn whether air cleaning can supplement ventilation with respect to improving air quality i.e. whether it can partly substitute the ventilation rates required by standards. The energy impact of ventilation by using air cleaning as supplement of ventilation needs to be estimated.

IEA-EBC Annex 78 was divided in 4 Subtasks:

Subtask A: Energy benefits using gas phase air cleaning

Subtask B: How to partly substitute ventilation by air cleaning

Subtask C: Selection and testing standards for air cleaners

Subtask D: Performance modelling and long-term field validation of gas phase air cleaning technologies

Organisation and Participation

Project duration
July 2018 – June 2025

Operating Agents
Bjarne W. Olesen and Pawel Wargocki, Technical University of Denmark

Subtask leaders
Subtask A: **Energy benefits using gas phase air cleaning**
Subtask leader: Alireza Afshari, Denmark
Co-leader: Sasan Sadrizadeh, Sweden

Subtask B: **How to partly substitute ventilation by air cleaning**
Subtask leader: Pawel Wargocki, DTU, Denmark
Co-leaders: Shin-Ichi Tanabe, Waseda, Japan
Alireza Afshari, AAU, Denmark

Subtask C: **Selection and testing standards for air cleaners**
Subtask leader: Paolo Tronville, PolitecItaly
Co-leader: Jinhan *Mo, Tsinghua University, China*

Subtask D: **Performance modeling and long-term field validation of gas phase air cleaning technologies**
Subtask leader: Karel Kabele, Czech
Co-leader: Jianshun Zhang, Syracuse University, USA

Participating countries

Country	Organisation
China	Tsinghua University
	Tianjing University
	Tongji University
Czech Republic	Czech Technical University
Denmark	Technical University of Denmark
	Aalborg University
Italy	Politecnio Torino
Japan	Waseda University
	Tokyo Inst. Tech
Singapore	National University Singapore
Sweden	KTH, Stockholm
USA	Syracuse University

Official deliverables
Deliverable A: Energy Benefits of Using Gas-Phase Air Cleaning
Deliverable B: The Concept for Substituting Ventilation by Gas Phase Air Cleaning
Deliverable C: A method for testing gas-phase air cleaners
Deliverable D: A report on the long-term performance of gas phase air cleaning
Deliverable E&F: Performance of Portable Gas-Phase Air Cleaners and Impact on Indoor Air Quality. A Literature Review

Summary

The worldwide use of gas-phase air cleaning has been growing in recent decades. There is little information, however, on the performance of gas-phase air cleaners, especially in-situ, on whether they can substitute ventilation, whether there are any potential risks associated with their use, and how their use contributes to energy savings and reduced carbon footprint. Moreover, there are, at present, no standards that allow systematic and repeatable benchmarking for the performance of gas-phase air cleaners. These challenges set out the project's direction, which provided the answers on the energy benefits of using gas-phase air cleaners, how the air cleaners can substitute ventilation, standards for testing air cleaners, and the long-term performance of gas-phase air cleaners. The project was the IAE Annex, combining partners from different institutions, allowing the sharing of the experience and publishing ordinary papers based on the ongoing activities funded locally by different funding agencies. The major outcomes of the projects are papers summarizing the activities that have been pursued during the execution of the project, as well as webinars and workshops that took place along the course of the project. A concept for partly substituting ventilation with gas-phase air cleaning technology has been established and published. Additionally, the energy performance of gas-phase air cleaning technologies has been studied in investigations based on computer simulations without any data for systems in operations. A metric, CADR per kWh, i.e., clean air delivery rate divided by the energy used for heating, cooling, and ventilation, was developed to compare the energy performance of using an air cleaner compared to the energy used for increasing the airflow of a ventilation system with and/or without an energy recovery unit.

1. Introduction

1.1 An introduction to Annex 78 and the importance of gas phase air cleaning.

Ventilation accounts for approximately 20% of the global energy use for providing an acceptable indoor environment. The requirements for ventilation in the most standards and guidelines assume acceptable quality of (clean) outdoor air.
Worldwide, there is an increasing number of publications related to air cleaning and there is also an increasing sale of gas phase air cleaning products. This puts a demand for verifying the influence of using air cleaning on indoor air quality, comfort, well-being and health. It is thus important to learn whether air cleaning can supplement ventilation with respect to improving air quality i.e. whether it can partly substitute the ventilation rates required by standards. Finally, the energy impact of using air cleaning as supplement of ventilation needs to be estimated. This project will focus on gas phase air cleaning. The project will not include filtration.

In many locations in the world, the outdoor air quality is so bad that it is better to avoid ventilation. In such cases, the alternative to use ventilation is to substitute it with air cleaning so that the indoor air can be kept at high quality. Even when outdoor air is of a good quality, the use of air cleaning substituting ventilation air could reduce the rate of outside air supplied indoors and thereby energy for heating/cooling the ventilation air and for transporting the air (fan energy) can be saved.

Since it is expected that air cleaning may in parallel improve the indoor air quality and reduce energy use for ventilation, it should be considered as a very interesting technology that can be used in the future. There is however a need for better evaluation of its potential to improve indoor air quality (and substitute ventilation rates) and the energy implication of using gas phase air cleaning. There is also a need to develop standard test methods of the performance of air cleaning devices.

1.2 Standards and test methods for gas-phase air cleaners.

Air cleaning is not directly considered in a new ISO standard for indoor environmental quality ISO17772-1; but the corresponding guideline TR 17772-2 opens for the possibility to partly substitute ventilation air with air cleaning. ASHRAE 62.1, by using the analytical indoor air quality procedure, allows some ventilation rate credits for air cleaning. Besides, there is an increased interest in the development of air cleaning equipment and several products are available on the market. The reason is that air cleaning may be an acceptable way of reducing the rate of outside air delivered indoors by ventilation and saving energy, and still maintaining acceptable (high) indoor air quality.

However, better methods for testing of air cleaners are required because at present the testing is usually based on chemical measurements of specific compounds which does not capture the overall effect of air cleaning on perceived odour intensity or perceived air quality, the latter being referred to in ventilation standards. Testing does not either account for potential risks (breakthrough or production of new compounds). Some air cleaners may be efficient in removing particles, bio contaminants (microorganisms – pollens moulds, allergens) and/or VOC's (emission from materials or resulting from external air pollutants infiltration in the building such as PAH (Poly Aromatic Hydrocarbons)) but they may have zero or even a negative effect if the source of pollution is people (bio effluents).

VOCs may adsorb on the surface of particles acting as a vector. Therefore, air cleaners combining particle and gas filtration technologies are an interesting technology for reducing the concentration of VOCs and at the same time the levels of particles.

There is an increasing development of different cleaning methods and products for particle and gas phase air cleaning including both particle or adsorptions filters and air cleaners using a chemical reaction to remove certain gasses and pollutants.

CEN-ISO and ASHRAE are developing standard test methods which will measure the air cleaning efficiency by using references substances as pollutant. AFNOR XPB44-200 standard for requires, for example, evaluating the level of CO, Formaldehyde, NO2, NO and Ozone, potential PCO reaction by products, as part of the testing procedure for portable air cleaners. Available information and compliance to the standard would have to be retrieved from air cleaner manufacturer technical information.
One aspect of air cleaning technology used is the potential release in the indoor environment of chemical by products that can be harmful for occupants.
Working with indoor environmental quality classes (like in ISO 17772-1) one option could be that with air cleaning a level of ventilation corresponding to the lowest class would suffice, the remaining effect on air quality will be provided by air cleaning, which will increase a class to a higher level without increasing the rate of outside air. It is therefore recommended that the standard specifying indoor air quality incudes the possibility to partly use air cleaning as a supplement to outside air supply or as a complementary function to reduce PM and VOCs.
Portable air cleaners recirculating the indoor air contribute to the reduction of existing allergens and microorganisms indoors. Same testing principle can be applied to evaluate the device efficiency against known allergens (e.g. cat allergens), bacteria and moulds aerosols.
None of existing standards for testing gaseous air cleaners include human bio effluents as a source and the perceived indoor air quality is not used to evaluate the performance. As bio effluents from occupants are an important source of pollution and becoming major source with the trend to reduce emissions from other sources, and as most criteria for ventilation is based on perceived air quality there is a need to establish new and more relevant test methods for gaseous air cleaners.

1.3 Energy performance of gas-phase air cleaners.

The energy implications of supplementing ventilation by air cleaning need to be better quantified. A possible scenario is that half of the required ventilation rates in existing codes and standards can be substituted by air cleaning. This will require less energy for heating/cooling the supply air and reduce the fan energy use. Depending on the air cleaning technology the equipment itself will use some energy. In total, a significant reduction of energy use for ventilation in the order of 10-20% is likely.

2. Deliverables from Annex 78

2.1 Energy Performance.

The energy performance was in annex 78 only studied by building simulations. No measurements was made in existing buildings.
The energy impact of using gas phase air cleaning must be studied further. By reducing the ventilation rate energy use can be reduced for:

- pre-heating or pre-cooling of outside supply air
- humidifying or de-humidifying
- fan energy for air transport

Energy use may be increased due to:

- Additional fan energy for stand-alone air cleaners
- Additional fan energy due to increased pressure drop over the device
- Reduced potential for cooling by outside air

To accurately assess the energy efficiency of gas-phase air cleaners, it is essential to consider all energy flows, including heating, cooling, and fan energy use. In cooling load-dominated climates, the potential for free cooling without air cleaners can result in substantial energy savings, potentially superior to the savings from reduced heating and transportation of outdoor air. In heating load dominated climates, air cleaning systems can substantially reduce energy use especially in buildings without heat recovery systems.
The energy savings are dependent on the system and control employed, which require further investigation. The integration of gas-phase air cleaning with Personalised Environmental Control Systems (PECS) shows promising potential; however, current research is limited, emphasizing the need for more extensive studies.
A wide range of air cleaning systems are available on the market with varying CADRs and power use for a wide range of applications. Establishing standardized baselines for key performance indicators such as the clean air delivery rate (CADR), clean air effectiveness (CAE), and overall energy use will facilitate consistent evaluation and comparison of air cleaning systems and their integration in buildings. These efforts will contribute to a more robust understanding of the energy benefits and operational efficiencies of gas-phase air cleaning technologies, ultimately guiding the development of more effective and sustainable indoor air quality management strategies.
Further research is required to comprehensively understand the energy implications of gas-phase air cleaners, requiring field studies to validate current findings. The long-term resilience and performance with respect to air quality and energy use of gas-phase air cleaning systems under various conditions warrant additional investigation.

2.2 Concept for Partly Substituting Ventilation by Gas-phase Air Cleaning

Gas phase air cleaning technologies are increasingly used to improve the indoor air quality.
Air cleaning is mentioned in EN 16798-1 and ISO 17772-1 and in the guidelines EN 16798-2 and ISO 17772-2 a concept for considering gas phase air cleaning is proposed; but the standards do not give directly the possibility for reducing the recommend ventilation or methods for showing the possible improvement in IAQ.

A concept for substituting part of the required ventilation with gas phase air cleaning technology has been presented in Annex 78. This requires however testing of air cleaners based on measured perceived air quality (PAQ).
There is a need for new testing standards that considers perceived air quality and human emissions as a source. Such a test method was developed in Annex 78 (see 2.3)

2.3 A test method using perceived air quality for measuring clean air delivery rate for an air cleaner

2.3.1 Test method

A prototype method for testing gas-phase air cleaners using sensory assessment was examined. This study generally followed methodologies proposed by the ISO 16000-44 standard and the results of this study validate and support them. More testing is still necessary before its full application in the practice.
The proposed method includes two phases. The results confirmed that Phase 1 effectively eliminates the air cleaners that do not improve air quality. Phase 2 is necessary since it provides detailed information on the actual performance of air cleaners in the form of Clean Air Delivery Rate (CADR). The recommended ventilation rates in ISO 17772-1/2 may then be reduced by the CADR of a gas phase air cleaner
The proposed method comprises two phases of testing of air cleaners. The first phase examines whether the air cleaner can improve or reduce air quality (qualitative testing). In contrast, second phase thoroughly examines the air cleaner performance (quantitative testing). The idea behind the proposal is the efficient use of resources: that air cleaners that do not pass Phase 1 should not be tested in Phase 2.
No firm recommendations can be made on whether the sensory evaluations of air quality when testing the performance of air cleaners should be made on the air extracted from the experimental rooms (facial exposures) or upon entering the rooms (whole-body exposures).
Although acceptability and odour intensity ratings were strongly correlated (Figure 9), the overall results of sensory evaluations for individual conditions were not always consistent. For that reason, at this moment, it can be recommended to use both sensory evaluations of odour intensity and acceptability of air quality when testing the performance of air cleaners using sensory methods. They both provide a more complex characterisation of sensory effects.
The relationship between ventilation rates and sensory ratings of acceptability of air quality and odour intensity was non-linear. Consequently, when determining the clean air delivery rate for air cleaners and comparing against the effects obtained by ventilation, it is necessary to perform the tests at different ventilation rates. Examining CADR only at one ventilation rate is insufficient and these results should not be extrapolated to other ventilation rates.
The ISO 16000-44 standard was approved in 2023. It describes test method for measuring perceived indoor air quality for testing the performance of gas phase air cleaners. The method in the standard is similar to the one examined in the present experiments. The perceived air quality is determined using the acceptability of the air quality and odour intensity. The air assessed by a panel is presented via a sniffing device (facial exposure). If measurement accuracy can be guaranteed, the panel can also enter a chamber directly to assess the air (whole-body exposure). The air change rate of the test chamber is set at 0.50/h (±0.03/h) and 2.0/h (±0.12/h) in ISO, which is the same as in the present study at 7.5 L/s and 30 L/s. The experimental methods used in this study are generally comparable with those proposed by the standard. Therefore, the methodology described and examined in the present paper supports and validates, to some extent, the approach proposed by ISO 16000-44.

2.3.2 Standardisation of test method

A prototype method for testing gas-phase air cleaners using sensory assessment was examined. This study generally followed methodologies proposed by the ISO 16000-44 standard and the results of this study validate and support them. More testing is still necessary before its full application in the practice. The proposed method includes two phases. The results confirmed that Phase 1 effectively eliminates the air cleaners that do not improve air quality. Phase 2 is necessary since it provides detailed information on the actual performance of air cleaners in the form of Clean Air Delivery Rate (CADR). The recommended ventilation rates in ISO 17772-1/2 may then be reduced by the CADR of a gas phase air cleaner

Standards:
ISO 16000-44 2023 Indoor air -Part 44: Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners
ISO 17772-1:2017. Energy performance of buildings — Indoor environmental quality — Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings.
ISO/TR 17772-2:2018. Energy performance of buildings — Overall energy performance assessment procedures — Part 2: Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings

2.4 Long Term Performance of Gas-phase Air Cleaners

2.4.1 Introduction

Air quality is a critical aspect of maintaining a healthy indoor environment, and portable air purifiers (PACs) can play a significant role in achieving this. The effectiveness of these units can vary widely based on environmental conditions and operational factors. Understanding these variables is essential for optimizing the performance of air purifiers over the long term.

One of the key considerations is the Clean Air Delivery Rate (CADR), which measures the efficiency of air purifiers in removing particles from the air. However, CADR may not be a sufficient characteristic for long-term use, as it primarily evaluates short-term performance and does not account for factors such as filter degradation over time.

The performance of gaseous air purifiers can vary significantly based on environmental conditions and operational factors. One of the most critical aspects affecting their efficiency is the location within a space. Placing air purifiers in areas with better airflow can enhance their ability to remove pollutants. Specifically, air purifiers positioned closer to pollution sources tend to perform better by capturing contaminants before they disperse throughout the space.

For optimal performance, it is recommended to place Portable air purifiers (PACs) in a central location within the room to ensure even distribution of clean air. It is also important to ensure that the PAC is not blocked by furniture or other objects, allowing for optimal airflow. Positioning the PAC at a height where it can effectively circulate air, typically at breathing level, can further enhance its efficiency.

The interaction between the air purifier and the HVAC system is crucial. Proper placement can optimize the combined effect of the air purifier and the HVAC system, thereby improving overall air quality. Factors such as relative humidity and temperature at different locations within a space can influence the effectiveness of the air purifier. For example, high humidity levels can reduce the effectiveness of certain filter materials.

Different air purifiers are designed to target specific types of pollutants. A purifier that is effective against particulate matter may not be as effective against gaseous pollutants, and vice versa. To maintain low particulate matter levels, it is advisable to run the PAC continuously, especially during times when the room is occupied. Regularly checking and replacing filters according to the manufacturer’s guidelines is essential to ensure the PAC operates efficiently.

If possible, using PACs in multiple rooms can enhance overall indoor air quality, particularly in homes with central air systems. Regular maintenance, such as filter replacement and cleaning, is crucial for

maintaining the performance of air purifiers. Neglecting maintenance can lead to reduced efficiency and even potential health risks.
These considerations highlight the importance of taking various factors into account when selecting and using air purifiers to ensure optimal performance.

2.4.2 An experimental field study

An office building at the Czech Technical University (CTU) in Prague was chosen for the study. The focus was on Indoor Environmental Quality (IEQ) in real-world office settings, specifically examining the effectiveness of various commercial air-cleaners utilizing phase change technology.
The experiment investigating the impact of air purifiers on indoor air quality in offices yielded several interesting findings. The results indicate that air purifiers can significantly improve air quality.
However, the experiment also revealed some weaknesses. Office users tend to leave doors and windows open, primarily for temperature regulation. This habit can reduce the effectiveness of air purifiers by allowing outdoor pollutants to enter or indoor pollutants to leave. Additionally, the office where the experiment was conducted is not a typical office with standard operations. Although only one person works there, students frequently visit, and they may wear perfumes, which can affect air quality measurements.
Another factor influencing the results was the duration of the experiment. The longer the experiment lasted, the more dissatisfied the users became, as the experiment-imposed restrictions on their usual activities.
This suggests that for long-term studies, it is essential to consider the comfort and habits of users to minimize their negative impact on the results.
For future research, it would be beneficial to focus on optimizing the use of air purifiers in environments where doors and windows are often left closed. Additionally, conducting experiments in various types of offices with different numbers of users and operational conditions would provide a more comprehensive understanding of the effectiveness of air purifiers.
In conclusion, it is recommended to conduct similar experiments in settings where people are not accustomed to leaving doors and windows open. This would help to better assess the true potential of air purifiers in improving indoor air quality without the interference of external factors.
There is a need to establish more knowledge on teh long term performance of using air cleaners. Only one study was done in the Annex; but further field studies are needed.

2.5 Description of gas phase air cleaning technologies and modeling possibilities

Annex 78 made a comprehensive review of the performance of portable gas-phase air cleaning technologies used in non-industrial indoor environments. The study evaluates the effectiveness, limitations, and applicability of various technologies, including adsorbent-based filtration (e.g., activated carbon and chemisorbents), photocatalytic oxidation (PCO), air ion generators, ozone generators, and plant-based biofiltration systems. Performance indicators such as clean air delivery rate (CADR), single-pass removal efficiency, and VOC decay rates are critically assessed. The review integrates findings from both experimental and modelling studies to identify key factors influencing device performance, such as airflow characteristics, pollutant types, environmental conditions, and maintenance requirements. Emerging innovations, including thermally regenerable filters and hybrid systems, are also discussed. The analysis highlights that while several technologies demonstrate promising pollutant removal capabilities under controlled conditions, long-term performance, energy use, by-product formation (e.g., ozone), and practical deployment challenges remain significant. The report underscores the need for standardised testing protocols and comprehensive field studies to validate the real-world effectiveness of portable gas-phase air cleaners. This work contributes essential knowledge to Annexe 78, supporting informed decision-making for improved indoor air quality management.

Adsorbent-based gas-phase air cleaning is effective for removing a variety of gases, vapours and odours if appropriate types and amounts of adsorbents are used. This removal may impose quite a high pressure drop. Although the filter replacement interval is a critical operational factor—affecting both cost and performance—it was not extensively discussed in this review and warrants further investigation.
Available scientific evidence indicates that O3 is generally ineffective at controlling indoor air pollution at concentrations that do not exceed public health standards. In the process of reacting with chemicals indoors, O3 can produce other chemicals that can be irritating and corrosive. Many factors affect O3 concentrations produced by machines that generate O3, including the amount of O3 produced by the machines, size of the indoor space, amount of material in the room with which O3 reacts, outdoor O3 concentrations and ventilation. These factors make it challenging to control O3 concentrations, regardless of whether the technology used intentionally generates ozone or as a byproduct. PCO has high conversion efficiencies for VOCs at a low pressure drop.

2.6 Dissemination Activities of Annex78

The main dissemination activity was webinars, conference activities in the form of seminars or workshop. Altogether 15 such activities were made in the USA, Europe and Asia. About 20 papers were published in Journals or at scientific conferences. Another dissemination activity was to participate in standardisation related to testing of gas phase air cleaners. Under Technical Committee ISO/TC 146, Air quality, Subcommittee SC 6 the annex supported the development of standard ISO 16000-44:2022 "Test method for measuring perceived indoor air quality for use in testing the performance of gas phase air cleaners". Furthermore, Annex 78 members have initiated the development of a standard/Technical Specification for testing air cleaners using perceived air quality and human bio effluents as source. This work is continuing as a PWI 23743 (Preliminary Work Item) under ISO/TC142 "Cleaning Equipment for Air and other Gases" Working Group 8 "Gas-phase air cleaning devices".

3. Outlook for future implementation of Gas-phase air cleaning in buildings

The major outcomes of the projects are papers summarizing the activities that have been pursued during the execution of the project, as well as webinars and workshops that took place along the course of the project. A concept for partly substituting ventilation with gas-phase air cleaning technology has been established and published. Additionally, the energy performance of gas-phase air cleaning technologies has been studied in investigations based on computer simulations without any data for systems in operations. A metric, CADR per kWh, i.e., clean air delivery rate divided by the energy used for heating, cooling, and ventilation, was developed to compare the energy performance of using an air cleaner compared to the energy used for increasing the airflow of a ventilation system with and/or without an energy recovery unit. The test method will now make it possible to measure CADR (Clean Air Delivery Rate) and introduce that in EN16798-1 and ISO17772-1 as a supplement to the required ventilation rate for an acceptable level of indoor air quality.
The use of CADR is essential for evaluating the energy performance of gas-phase air cleaning products. It also is essential for the implementation of gas-phase air cleaning in buildings.
Two issues were not fully solved in Annex 78, and which need better verifications are energy and long-term performance of gas-phase air cleaning. The energy performance was only evaluated by computer

simulations and only one study did report on long term performance. There is a need for field data on both energy performance and performance regarding indoor air quality.

ANNEX 78

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