Exploring the Energy-Saving Benefits of Gas-Phase Air Cleaning in Nordic Buildings

Sasan Sadrizadeh
KTH Royal Institute of Technology, Stockholm, Sweden
Mälardalen University, Västerås, Sweden

SUMMARY

This manuscript discusses the energy-saving benefits of gas-phase air cleaning in Nordic buildings. Ventilation systems are crucial in creating a healthy and comfortable indoor environment. These systems account for around 30% of building heat losses in cold climate regions. Indoor emissions from materials, occupants, and outdoor pollutants are key to ensuring acceptable indoor air quality levels. Therefore, this study focuses on using gas-phase air cleaning technologies in low-energy centralized air handling units. By simulating the heating performance of a typical residential and office building in central Sweden, we examine the impact of indoor air recirculation rates and air changes per hour on heating demand and indoor gaseous air pollution concentration. The results indicate that indoor air recirculation can reduce heating demand by approximately 10% for residential buildings and 20% for office buildings while maintaining acceptable indoor air quality.

KEYWORDS

Gas-phase air cleaning, Energy-saving benefits, Nordic buildings, Indoor air quality, Heating demand

1 INTRODUCTION

Meeting indoor air quality requirements and reducing indoor pollutants are crucial for ensuring a healthy and comfortable indoor climate for building occupants [1]. Heating, ventilation, and air-conditioning (HVAC) systems play a vital role in achieving these goals, but their configuration depends on factors such as building type, resident requirements, and climate conditions [2]. The transformation of the building sector towards zero-energy buildings that prioritize occupants' health, comfort, and productivity aligns with the United Nations' Sustainable Development Goals [3]. Ventilation accounts for approximately 9% of total primary energy use in some countries, with residential buildings in the U.S. consuming 30% of their energy for ventilation, heating, cooling, and domestic hot water needs [4]. However, increasing building airtightness has increased the significance of ventilation energy use, as well as the concern for carbon dioxide emissions [4, 5]. In order to reduce energy use to heat the ventilated air in cold climates, strategies such as improving building envelope airtightness, heat recovery, and preheating outdoor air have been implemented [6, 7]. However, these strategies can lead to increased concentrations of pollutants and the need for air-cleaning technologies. Integrating air cleaners into ventilation systems can improve indoor air quality and energy efficiency [8].

Nevertheless, optimization is required to balance parameters such as filtration pressure losses, fan power demand, and heating or cooling requirements [9]. The impact of ventilation rates, filter performance, and air exchange effectiveness on indoor air quality and energy usage in buildings has been studied [10].

This study aims to investigate the impact of recirculation rates on the energy usage of centralized air handling units (AHU) and buildings' heating demand in the central Swedish climate.

2 METHOD

To conduct our analysis, we used the TRNSYS software to perform annual transient simulations and assess variables. Additionally, a MATLAB code analyzed TVOC and CO_2 concentrations based on the building requirements modeled in TRNSYS. The study covered both residential and office buildings. Furthermore, we assessed the impact of implementing gas-phase air cleaners without a heat recovery system. More details can be found in an article by Nourozi et al. [11].

3 RESULTS AND DISCUSSIONS

Residential buildings with a heat recovery ventilation (HRV) system showed lower heating energy demand than those without. Recirculating indoor air had no significant effect on heating demand, with the energy requirement remaining unchanged. However, without heat recovery, the heating demand decreased by 3% increments for each 20% increase in the recirculation rate. In office buildings, the heating energy demand decreased with higher recirculation rates due to higher air change rates per hour (ACH). A 20% increase in the recirculation rate resulted in an approximately 8% reduction in energy demand. Gas-phase air cleaning and increased recirculation rate reduced heating demand for buildings without heat recovery. The effectiveness of heat recovery systems can vary based on heat recovery efficiency and different building types. Real-time monitoring of air pollutants can optimize recirculation schedules.

Indoor CO_2 concentration was mainly influenced by outdoor concentration, with the occupancy rate having a minor effect. The recirculation rate had a negligible impact on indoor CO_2 concentration when outdoor concentration outweighed indoor sources.

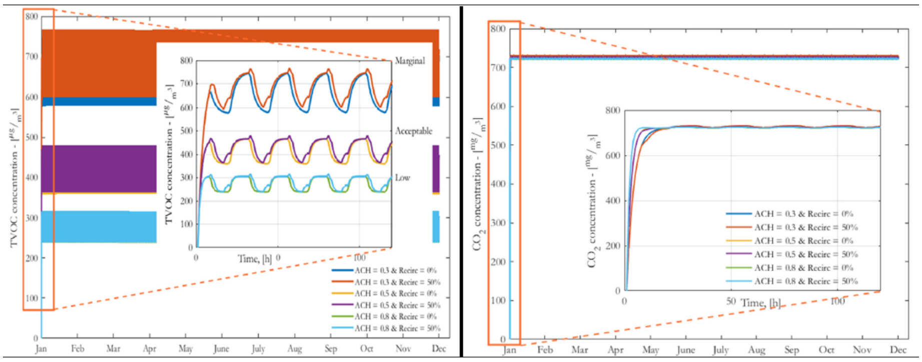

Figure 1: Impact of recirculation rate on TVOC and CO_2 concentration for different ACH values [11].

To conclude, using air cleaners as an extension to the building ventilation system can lead to energy savings and improved indoor air quality. Additionally, increasing the recirculation rate during rush hours in the mornings and evenings maintained CO_2 concentrations within acceptable ranges. In buildings without effective ventilation systems, gas-phase air cleaning and increased recirculation can be valuable strategies to optimize energy efficiency and indoor air quality.

4 ACKNOWLEDGEMENTS

This study contributes to the "IEA EBC Annex 78 - Supplementing Ventilation with Gas-phase Air Cleaning, Implementation, and Energy Implications" project. The financial support from the Swedish Energy Agency (Grant No. P50403-1) is greatly appreciated.

5 REFERENCES

[1] M. Liddament, A guide to energy efficient ventilation, Phys. Rev. B 51 (1996) 274.

[2] ASHRAE Environmental Health Position Document Committee, ASHRAE position document on infectious aerosols, Ashrae (2020) 1–24.

[3] A/RES/70/1 - Transforming Our World: the 2030 Agenda for Sustainable Development Goals (SDGs), 2021.

[4] F.M. Jesús, P.C. Irene, G.L.R. Alonso, et al., Methodology for the study of the envelope airtightness of residential buildings in Spain: a case study, Energies (2018)

(2018) 704, 2018; 11:704.

[5] O.A. Seppänen, Association of ventilation rates and CO_2 concentrations with health and other responses in commercial and institutional buildings, Indoor Air (1999)

(1999) 226–252.

[6] B. Nourozi, Sustainable Building Ventilation Solutions with Heat Recovery from Waste Heat, 2019.

[7] B. Nourozi, A. Ploskić, Y. Chen, et al., Heat transfer model for energy-active windows – an evaluation of efficient reuse of waste heat in buildings, Renew.

Energy 162 (2020) 2318–2329.

[8] Y. Zhang, J. Mo, Y. Li, et al., Can commonly-used fan-driven air cleaning technologies improve indoor air quality? A literature review, Atmos. Environ. 45

(2011) 4329–4343.

[9] ANSI/ASHRAE Standard 52.2-2007, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size, 2007.

[10] H. Willem, E.L. Hult, T. Hotchi, et al., Ventilation Control of Volatile Organic Compounds in New U.S. Homes: Results of a Controlled Field Study in Nine

Residential Units, 2013, pp. 1–64.

[11] B. Nourozi, et al. "Heating energy implications of utilizing gas-phase air cleaners in buildings' centralized air handling units." Results in Engineering 16 (2022): 100619.