Prospective research

How to limit the influence of outdoor air pollution in mechanical residential ventilation?

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Key messages

1. Outdoor air quality has an effect on inside air quality through ventilation and therefore requires ongoing policy attention in accordance with the prevention principle.

2. The proportion of particulate matter in outdoor air and its impact is currently highly underestimated.

3. With balanced ventilation, filters or capturing systems offer the possibility of limiting the supply of particulate matter through the ventilation system.

4. With extraction ventilation, numerical simulations show that smart control based on outdoor air pollutants has potential to reduce the impact of particulate matter on indoor air quality.

5. Additional research is needed on technological solutions for limiting the inflow of outdoor chemical pollutants.

Introduction

The topic of indoor air quality is receiving more and more attention within the construction field. This is partly due to the realisation that, on average, people spend over 80% of their time indoors. This means long-term exposure for building occupants to the pollutants present in indoor air. National and international bodies alike recognise that certain pollutants have a negative impact on our comfort, cognitive performance and/or health in general. Ventilation plays an important role in obtaining good indoor air quality. The principle of ventilation in building is to replace polluted indoor air with outdoor air as a source of fresh 'clean' air. Although outdoor air quality has already improved in recent decades, concentrations of certain pollutants, including peak concentrations of ozone (as well as nitrogen oxides and – its precursors – volatile organic compounds) and particulate matter, remain a concern. Ventilation systems may play a role in introducing these outdoor air pollutants, which can have adverse effects on indoor air quality and the health of occupants.

The Out2In project investigated the extent to which ventilation introduces outside air pollutants, and especially the influence that air filters and/or outdoor air pollutant control have.

Methods, approaches and results

The research approach followed a three-step bottom-up approach.

In a first stage, measurements were taken on filters as components separate from a ventilation system.

These were conducted at a test station built in our research facilities at Greenbizz Brussels. The test station consisted of twelve parallel test lines, each composed of one or a combination of two filters or capture systems targeting particulate matter or chemical pollutants. Feeding the station with Brussels ambient air meant that a real-life pollutant load was measured, which gave a realistic picture of the efficiency against pollutants. Monthly follow-up measurements over a period of one year also allowed us to examine how this efficiency as well as the pressure drop over the filter evolved over time. The results provided numerous relevant technical insights. Generally speaking, when it comes to the capture of particulate matter, there are major differences between the various filter types that belong to the same filter class, and

Methods, approaches and results

there are filter types that are less advisable. Given that efficiency for the capture of particulate matter increases over time for most filters, it is primarily the increasing pressure drop that is the determining factor for filter replacement. Also, the results showed that a one-time filter cleaning can extend the service life of a filter. Based on the findings, electrostatic precipitation is a very promising innovative capture technique for both fine and ultrafine particulate matter. With regard to the capture of chemical pollutants, the results were inconclusive.

In a second stage, in situ measurements, in the air flows of the ventilation system as well as in the indoor and outdoor environments of balance and extraction ventilated houses, complemented the lab measurements. For balanced ventilation, where filtration on the supply air is possible, the results showed a lower performance, in particular for the finer dust fractions, of the associated system filters compared to the equivalents tested in the laboratory. Furthermore, the results also provided a picture of the role of ventilation in the supply of outdoor air pollutants.

A third stage involved numerical simulations at the level of buildings with input variables that included, among others, real-life filter efficiencies determined in situ and in the lab. The results give an indication of the potential of daily outdoor air pollutant control and manual shutdown of the ventilation system in case of peaks in particulate matter pollutants.

Conclusions

The *in situ* measurements performed in mechanically ventilated homes show that ventilation does bring in outdoor air pollutants. These pollutants can also enter the home, albeit in a less controlled manner, through other means (e.g. windows and doors, air leaks). Outdoor air quality therefore remains a major concern. For particulate matter, there are filters and capturing systems that can be connected to balanced ventilation systems and that, based on their real-life performance, allow the PM2.5concentration in the air supply to be reduced at least to the recent annual average guideline value (5 µg/m^3) of the World Health Organisation –if the building owner so wishes. Indoor sources of particulate matter also remain a concern, as they can increase the concentration of particulate matter in indoor air again. For extraction ventilation, where filtration of the air supply is not possible, daily outside air pollutant control and manual switching off at peak fine dust pollution levels appear to have potential for limiting the influence of outdoor air. Further research in this area is needed to find the balance with the associated accumulation of indoor air pollutants.

Policy recommendations

The concrete recommendations below are divided according to the regional issues related to the project domain.

1. Environment - an outdoor air quality monitoring effort with a focus on particulate matter

The project results show that ventilation does in fact introduce outside air pollutants. In addition, particulate measurements, which took place in outdoor air within the scope of this project, show that in terms of numbers, its particle load is systematically dominated by smaller particles (99% < 0.5 µm). The current common monitoring of particulate matter loads in outdoor air, following the European Air Quality Directive 2008/50/EC, is done using mass concentration measurements for the PM $_{2.5}$ and PM $_{10}$ fraction. Given that small particles have a limited mass and given the definition of the $PM_{2.5}$ and PM_{10} fraction (= both a lower limit of 0.3 µm), the importance of the very smallest particles is currently underestimated. However, this is in stark contrast to the potentially greater health risks associated with, for example, particulate matter (- 100 nm, suspected penetration of the blood stream).

The above reasoning leads to the following concrete recommendation:

- To provide continuous monitoring of the particle-size distribution and number concentration in the Brussels outdoor air, within a wide measurement range (nm to µm), at a strategic measuring station of the telemetric network.

Within the prevention hierarchy, prevention (source control) is the most effective measure and is always preferred over collective protection measures such as, for example, in this case, filtration and/or smart ventilation strategies. Moreover, particles and other pollutants enter our home not only through ventilation, but also through other less controlled pathways. Hence, the following recommendation:

- Identify the main sources of microparticles (< 0.5 µm) and take measures to reduce their release and/or formation.

2. Housing - make building owners aware of the influence they themselves can exert on indoor air quality and, together with building professionals, educate them on the technical options available to reduce inflow through ventilation

The fact that (indoor) air pollution has a major health impact and corresponding socio-economic cost is now widely documented. However, awareness of this is lagging behind, especially regarding the influence of individual activities and the influx of outdoor pollutants. The project results show that while ventilation

Policy recommendations

can cause the influx of outdoor air pollutants, such as particulate matter and nitrogen dioxide, indoor sources can also increase (e.g. in the case of nitrogen dioxide) or decrease (in the case of particulate matter and capture) indoor air concentrations.

- Further raise citizens' awareness of the importance of indoor air quality and the impact that their own activities and outdoor air have on it.

The project output describes the possibilities that exist for permanently limiting the inflow of particulate matter via ventilation and/or at peak concentrations (reported by the media). It is important to note that these options are different depending on the type of ventilation system. With balanced ventilation, filters or capturing systems offer the possibility of limiting the supply of particulate matter through the ventilation system. In the case of extraction ventilation, where filtration is not possible, smart control based on outdoor air pollution has potential, but requires additional research.

- Make citizens and building professionals aware of and familiar with the possibilities that exist for ventilation to reduce the influence of particulate matter as an outdoor pollutant on indoor air (in general) and at pollution peaks. One way to do this is through inclusion in the Sustainable Buildings Guide (Gids Duurzame Gebouwen).

3. Scientific research - starting points from the findings

The numerical simulations at the building level show that for extraction ventilation, outdoor air pollutant control and shutting down the system during a particulate matter pollution peak event has potential to reduce exposure in the home.

However, reducing the flow rate or shutting down the system completely also has implications for indoor air quality. In this area, therefore, a compromise between the potential degradation due to the introduction of outdoor air pollutants on the one hand and the degradation due to the accumulation of indoor air pollutants on the other needs to be found. To estimate this compromise, a system needs to be designed.

- Further research into the potential of external air pollution-controlled ventilation control in extraction ventilation and the compromise that needs to be found with indoor air quality.

Policy recommendations

The recent CurieuzenAir study shows that air pollution from nitrogen dioxide (NO2) has a significant impact on the health of the population in the Brussels Capital Region and will continue to do so in the future. According to this study, only 1.6% of the Brussels population currently lives in a district where the new WHO guideline of 10 µg/m^3 is respected. The results from Out2In show that in mechanically ventilated buildings, the prevailing nitrogen dioxide concentration in indoor air is strongly dependent on the outdoor air concentration and indoor sources. Moreover, based on the results of the evaluated technological solutions, it is not possible to formulate concrete recommendations in this area.

- Research into the technological possibilities of capturing nitrogen dioxide in the ambient air and elaboration of a performance-based classification.

List of publications

Van Herreweghe, J., Caillou, S., Haerinck, T., Van Dessel, J. (2019, October). *Out2In: impact of filtration and air purification on the penetration of outdoor air pollutants into the indoor environment by ventilation.* 40th AIVC - 8th TightVent - 6th venticool Conference, Ghent, Belgium.

Hyperlink

Van Herreweghe, J., Caillou, S., Haerinck, T., Van Dessel, J. (2020). *Real-life ventilation filter performance in a city environment.* REHVA-journal, 02/2020, 4-7.

Hyperlink

Van Herreweghe, J., Caillou, S., Haerinck, T., Graindorge, F., Delmez, C., Van Huffel, P. (2022, october). *Real-life ventilation filter performance: final results of an in-depth study*. 42nd AIVC - 10th TightVent - 8th venticool Conference , Rotterdam, The Netherlands

About

The author & project

The Anticipate project Out2In was implemented by the Indoor Air Quality & Health competency pool of the Scientific and Technical Centre for the Building Industry (WTCB). This competence pool links the expertise of three WTCB laboratories around the topic of indoor air quality. The employees of Labo Bouwchemie were responsible for the in-lab and in situ measurement of chemical pollutants within the project. The Heating and Ventilation (HVAC) Lab staff was responsible for setting up the test station, technical support for in lab and in situ measurements, and numerical simulations. The staff of the Microbiology and Microparticles Laboratory for the particulate analyses and general project management.

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Disclaimer

This research was conducted with funding from Innoviris. Any opinions, beliefs and recommendations expressed in this brief belong entirely to the author. Innoviris cannot be held accountable for them.

Prospective research

Through the Prospective Research programme, the Brussels-Capital Region is hoping to fund research projects from a dual perspective: to provide a solid regional prospective vision; to build solutions to the specific challenges it will face in the years to come. The solutions proposed by the funded projects must take into account Brussels' urban complexity as well as the Region's environmental, social and economic transition objectives. The programme targets researchers in human science as much as researchers in exact or applied science.

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