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How do outdoor air pollutants affect the indoor air quality in a high-rise building? A case study in Suzhou, China

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1 Introduction

Outdoor air pollutants can easily infiltrate into buildings through the ventilation system and building envelop where people are spending lots of time in offices fully filled with indoor particulate matter (PM) of outdoor origin. It has raised great concerns for personal health harmed by indoor pollution. Moreover, with the help of stack effect and wind effect, as the two main mechanisms for developing pressure differences between inside and outside, the pollution can access the building with different infiltration rates, further cause even worse indoor air quality (IAQ) conditions for some floors. However, there is rare research about how the vertical variation of the air infiltration rate affects the indoor pollutants' concentration on each floor in a high-rise building. In summary, this study aimed to investigate the impact of outdoor air pollutants on IAQ in a high-rise building, considering factors related to the seasons and air infiltration.

2 Materials/Methods

A model of an office building was developed. In detail, the footprint plan area of the building was 259.64 m^2, and the volume of each floor was 865.60 m^3. The building was 30 storeys high (about 100 m in total). The weather conditions of Suzhou in 2018 were used to analyse the impact of outdoor air pollutants on IAQ along season change. Moreover, the target indoor temperature was set at 22 ℃, 24 ℃, 22 ℃, 20 ℃ over four seasons (ASHRAE, 2010). In addition, the mass balance equation was used to describe the variation of the indoor PM concentration in this study. The main assumptions of simulations were: 1) It was assumed that the indoor particle concentration is distributed uniformly in the room; 2) The leakage was uniformly distributed on the south facade of the building, and there was no leakage in the other three facades; 3) The power low equation was used to estimate the building infiltration rate (ASHRAE, 2017).

3 Results and Discussion

By applying the proposed air infiltration rates on each floor, the hourly variation law of indoor $PM_{2.5}$ level on four selected specific days in 2018 was modelled. Based on the simulation, the results of the indoor $PM_{2.5}$ level on five selected floors are present in the Figure 1. Each plot indicates the case at different dates and the five horizontal lines in each indicate the results of maximum value, 3rd quartile, median, 1st quartile, and minimum value, respectively. Accordingly, the minimum indoor particle levels on the four selected days occurred when the stack-effect was at its maximum, while when the stack-effect is minimum, the level is maximal. Moreover, Figure 2 indicates the combined effect of air infiltration rate and filter on the indoor particle level. The red line indicates the limit value of the indoor particle level of 35 μg/m^3, given in the WHO guideline. The dangerous area above this curve highlights that the indoor $PM_{2.5}$ levels are too high to harm human health according to guideline. In addition, the results indicate that the indoor $PM_{1.0}$ and $PM_{2.5}$ levels can exceed the limit value even in a low infiltration rate if the outdoor air is extremely polluted. In the Figure 3, the simulation results of the indoor $PM_{2.5}$ level at a steady state are display with contour plots. Each contour plot represents the indoor $PM_{2.5}$ level varied with the air filter efficiency and air infiltration rate when the outdoor $PM_{2.5}$ level was from 75 μg/m^3 to 300 μg/m^3. The results indicate that the impact of filter efficiency and air infiltration rate on indoor particle levels are non-linear. If the infiltration rate increases steadily and equably, the amplification of indoor particle levels enlarges if the air filter efficiency rises. This result reveals that the air infiltration rate can significantly affect the efficiency of the air filter.

4 Conclusions

Overall, there are seasonal effects on the IAQ that, on each floor of a building, the IAQ is the worst in winter, followed by spring, autumn, and summer. The IAQ also depends on the height since it is better on higher floors than on the lower floors. The results from both case study and numerical model indicate that a high-efficiency filter is necessary to maintain a healthy IAQ in objective buildings in Suzhou. As well, a double-filter system is recommended considering the worst outdoor pollution in winter. The experience from this study also highlights that the numerical model is helpful with predict air filter efficiency and airtightness of the objective buildings, but it is worth to be noted that the strategy of the air recirculation process should be considered to increase the accuracy of models in future research.

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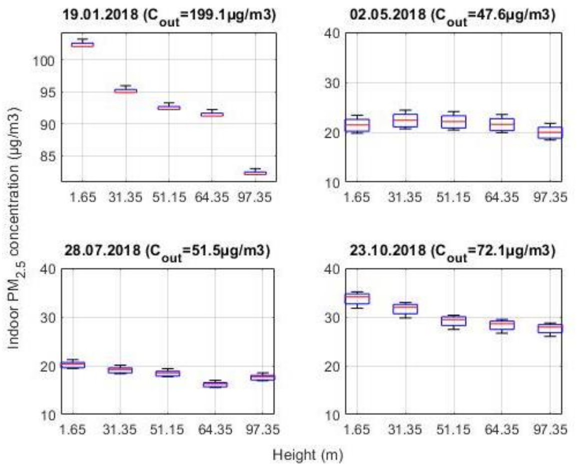

Figure 1: The value range of indoor $PM_{2.5}$ level on five selected floors (in order from left to right is 1st, 10th, 16th, 20th, 30th floor) between 6:00 and 21:00 (ASHRAE, 2013) in four seasons when NPL locates at 50% of the building height

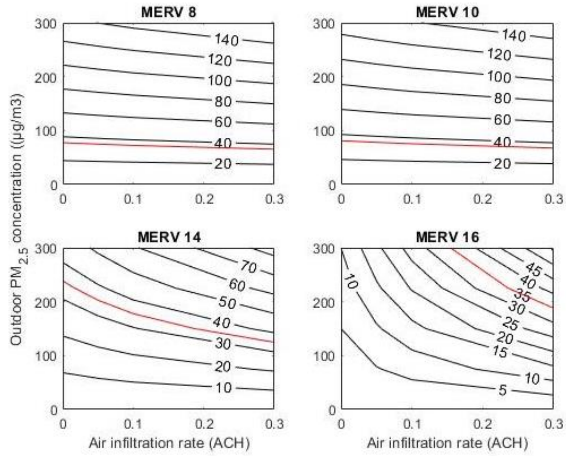

Figure 2: Combined effects of air infiltration rate and filters on indoor $PM_{2.5}$ level under outdoor concentration from 0 to 300 μg/m^3

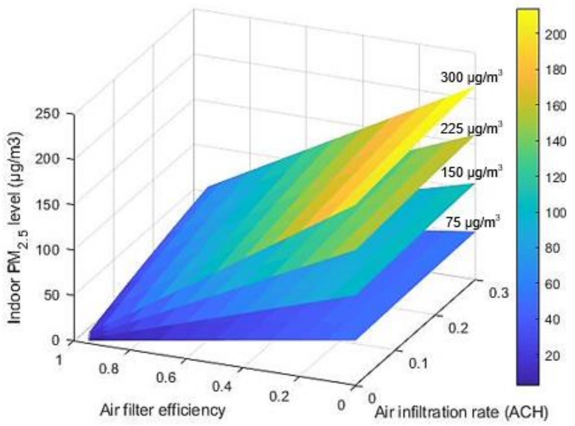

Figure 3: The increasing proportion of indoor $PM_{2.5}$ levels varies with air infiltration rate and filter efficiency.

6 References

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