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The effect of energy efficient measures on rhinovirus transmission

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Abstract: The UK government is improving the energy efficiency of buildings through retrofit, which can decrease unintended heat losses. Nevertheless, it can also bring side effects like the increase in the risk of airborne disease transmission. This paper aimed to understand how the refurbishment of the buildings can affect rhinovirus transmission. The five-stage refurbishment of the E. ON research house was selected and the Wells-Riley equation was used. Two more coefficients were added to the equation to detect the effects of indoor temperature and relative humidity. The main result was the improvement of the airtightness during the refurbishment process can increase the risk of infection. Secondly, higher occupancy caused little differences in the probability of transmission. If more than one occupant is infected, the probability of subsequent transmission could be higher. As a result of the refurbishments, changes on the indoor temperature and relative humidity could affect the rhinovirus transmission.

Keywords: Refurbishment, Airtightness, Airborne disease transmission, Rhinovirus, Wells-Riley equation on

1. Introduction

1.1 Background

In response to climate change, the UK government has set a target, which is to reduce Greenhouse Gas emissions and energy consumption by 80 % and 20 % by 2050, respectively (DECC, 2012). With the development of economy and society, the urban population is close to six billion (United Nations, 2008) and cities account for nearly two-thirds energy demand (McCarthy, 2012). Nevertheless, buildings consume an objective part of the energy in cities. According to IEA (2016), buildings are responsible for 32% of total energy consumption in the worldwide and thus generating a large percentage of greenhouse emission. Therefore, how to improve the energy performance of buildings is now more important than ever. For the current situation of buildings in the UK, Hewitt (2015) found that there are almost 26 million households in the UK and 60 % of them will still be in use in the next 30 years. To enhance the energy performance of the current buildings and to achieve the goals set, retrofitting can be regarded as one of the most effective methods. However, increasing the airtightness of the buildings through refurbishment may cause changes in parameters of the indoor environment like indoor temperature, relative humidity, and indoor air quality. Those changes may lead to consequences, such as the potential changes in the risk of airborne disease transmission.

1.2 Aims and objectives

This study was conducted to explore how the refurbishment of buildings for energy purpose can affect the probability of rhinovirus transmission. This paper's main objectives are:

1. Detecting the effects of energy refurbishment on rhinovirus transmission by using the Wells-Riley equation.
2. Detecting the effects of higher occupancy on rhinovirus transmission
3. Detecting the probability of rhinovirus transmission if more than one occupant got infected
4. Detecting the effects of indoor temperature and relative humidity on rhinoviruses transmission

2. Methodology

The Wells-Riley equation, which was modified by Rudnick and Milton (2002) was selected. The modified equation used carbon dioxide concentration as a marker to assess infectious risk (Sze To & Chao, 2009). A model of the E. ON research house was built in IES VE and used to simulate the indoor carbon dioxide concentration and to calculate the rebreathed fractions. Then the rebreathed fractions were used to calculate the risk of transmission with the modified equation. By changing the factors like higher occupancy and number of infected occupants, research questions 1, 2 ,3 were answered. Furthermore, two coefficients related to relative humidity and temperature were added to the equation to answer the research question 4.

2.1 IES VE simulation

In IES VE, the location data was selected as Nottingham Watnall, United Kingdom and simulations were run under a Typical Reference Year weather file for Nottingham (CIBSE, 2013). In the previous study of Altamirano-medina and Taylor (2014), nine hours from 22:00 to 7:00 were selected as simulation period, since occupants stay in their bedrooms for sleeping and might not leave during this period, which could minimize the errors that might be caused by human activities. The infiltration of the house was regarded as the only ventilation pathway. The E.ON house was previously retrofitted with four levels of energy refurbishment and the air permeability as a result measured (Table 1).

Table.1 Air permeability (infiltration rate) of the E. ON house at each stage

Stages	Air permeability at 50Pa (m^3/m^2h)
Baseline	15.57
2	14.31
3	9.84
4	8.60
5	5

Gillot et al. (2015) suggested that normal infiltration rate is equal to the air permeability divided by the value of 20, to convert the test result from air permeability (m^3/m^2h) at 50 Pa to air change per hour.

2.2 Calculation of the rebreathed fraction and the probability of infection

After a series of simulations, an important factor in the modified Wells-Riley equation, the rebreathed fraction could be calculated: f= (C-Co)/Ca. In this equation, Ca means the volume fraction of CO_2 that would be added to the air space during exhaling. C and Co is the volume fraction of CO_2 in the indoor air and outdoor air, respectively. Then using the results of the rebreathed fraction in different situations, the risk of probability can be calculated.

2.3 The Wells-Riley equation that contains two more factors (T and RH)

Two coefficients are added to the Wells-Riley equation to solve the research question, the modified Wells- Riley equation is: P= 1- exp (-TH*fIqt/n).

Table.2 Indoor temperature and relative humidity coefficient

Low humidity level (30 ± 5%)	0.25	Low temperature level (<10°C)	1.8
Medium humidity level (50 ± 5%)	1	Medium temperature level (10°C-20°C)	1
High humidity level (70 ± 5%)	1.3	High temperature level (>25°C)	0.6

After the relative humidity and indoor temperature coefficients were added to the equation, the probability of rhinovirus transmission under nine different scenarios (combinations of different levels of relative humidity and indoor temperature) were calculated.

3. Results and Analysis

3.1 Effects of energy refurbishment on rhinovirus transmission

First, the indoor carbon dioxide concentration of the bedroom 1 was estimated and then the rebreathed fractions for the different stages of refurbishment were calculated.

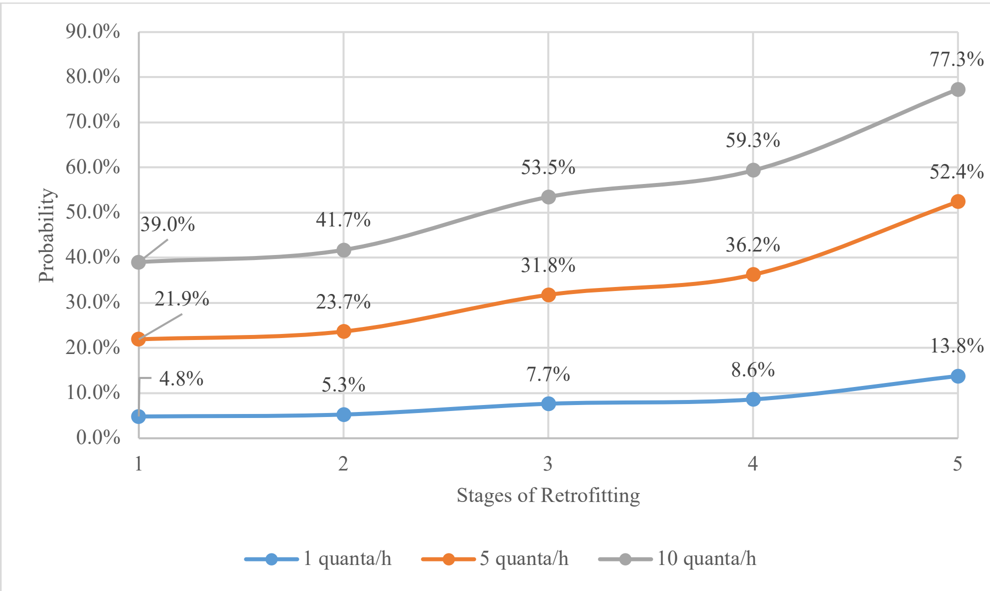

Figure 1 The probability of rhinovirus transmission at 5 stages of refurbishment (2 occupants)

The first finding is that the probability of rhinovirus transmission increases as the airtightness of the house increase. The risk of rhinovirus transmission had increased gradually when the house became more air-tight during the retrofitting process. From the baseline (stage 1) to the stage 5, the probability has increased for all quanta generation rates from 4.8% to 13.8%, 21.9% to 52.4%, and 39.0% to 77.3%, respectively.

3.2 Effects of higher occupancy (4 and 6 occupants)

When the number of occupants was four, two bedrooms (bedroom 1, 2) on the first floor of the E. ON research house were occupied and two bedrooms in the IES model were connected. When the number of occupants was six, three bedrooms (bedroom 1, 2, and 3) were occupied connected in the IES model. The results are shown in Figures 2 and 3.

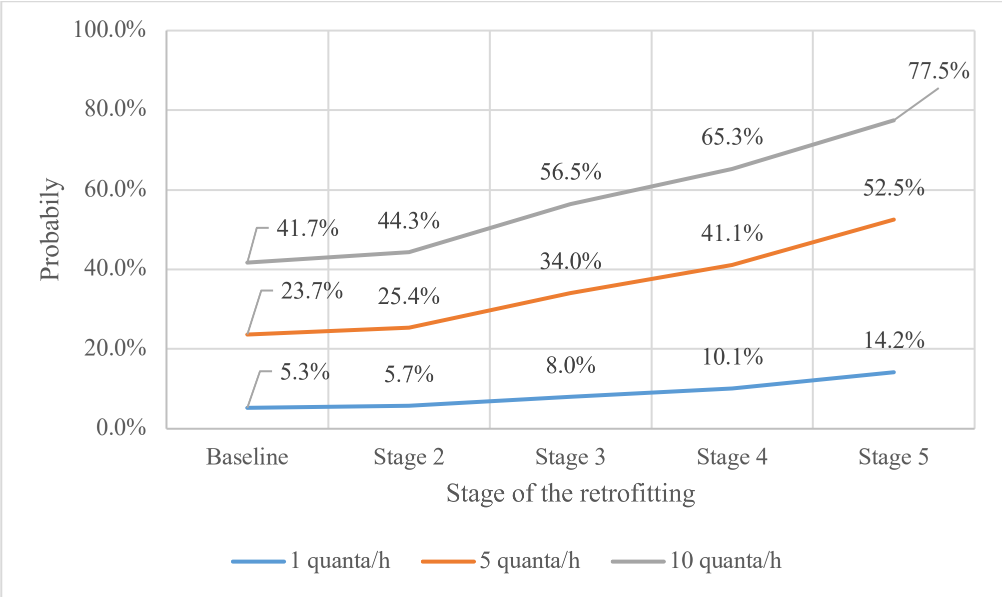

Figure 2 Rhinoviruses transmission probability at 5 stages of retrofitting (4 occupants)

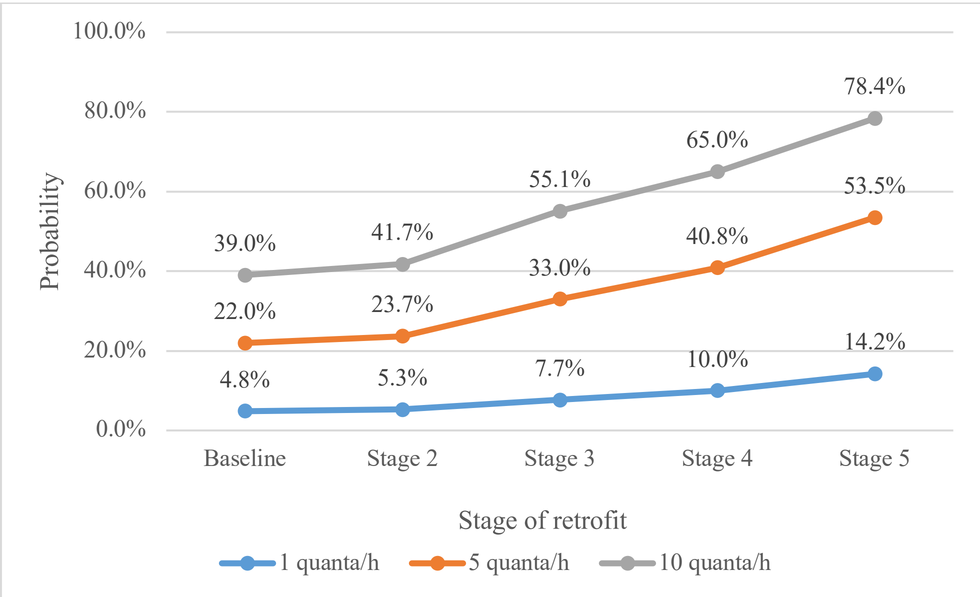

Figure 3 Rhinoviruses transmission probability at 5 stages of retrofitting (6 occupants)

According to Figure 2 and 3, compared with two occupants living in the house, the risk of infection was similar when the number of occupants was four and six. The maximum probability when four people occupied the house is 77.5%, and when occupied by six people is 78.4%.

3.3 Effects of more than one occupant infected

The purpose of this section is to check the risk of infection if there is more than one individual with the rhinovirus. For example, the results of 5 of 6 occupants get infected are shown in Figure 4.

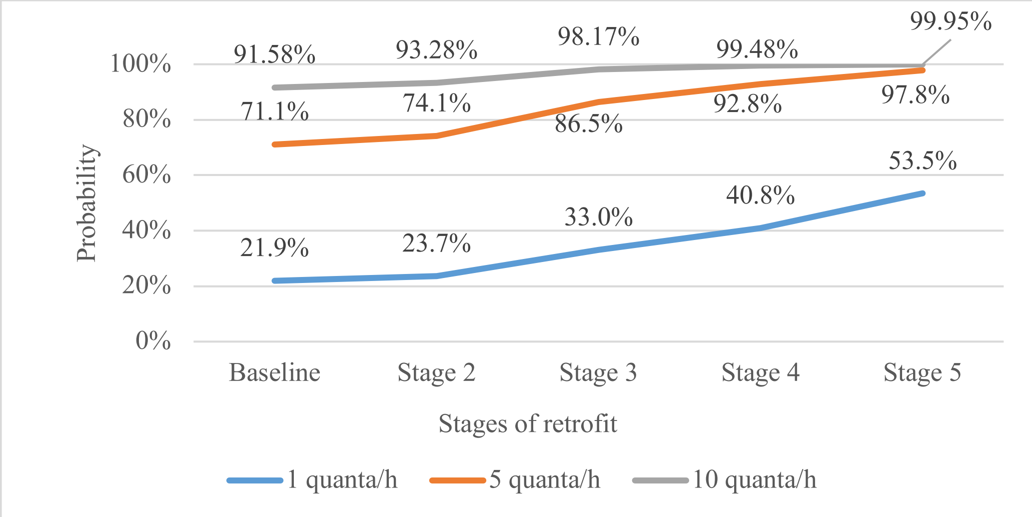

Figure 4 When 5 of 6 occupants get infected

The results showed that if more than one occupant infected by rhinovirus, the probability of infection will increase. Especially at 5 and 10 quanta/h generation rate, the probability can reach nearly 100% when 5 of 6 occupants were infected. The probability can be even higher if reinfection can be considered.

3.4 Effects of indoor temperature and relative humidity on transmission

The indoor temperature and relative humidity were added to the Wells-Riley equation to illustrate how these two factors might influence the risk of rhinoviruses transmission. The number of occupants remained as two. Nine scenarios of different levels of indoor temperature and relative humidity were considered. The box plot below shows the influences of relative humidity and indoor temperature level on the risk of rhinovirus infection. They can illustrate the estimated mean (x), median (-), quartile range, minimum, and maximum rhinovirus infection probability under nine different situations of relative humidity and indoor temperature level at 10 quanta/h generation rate.

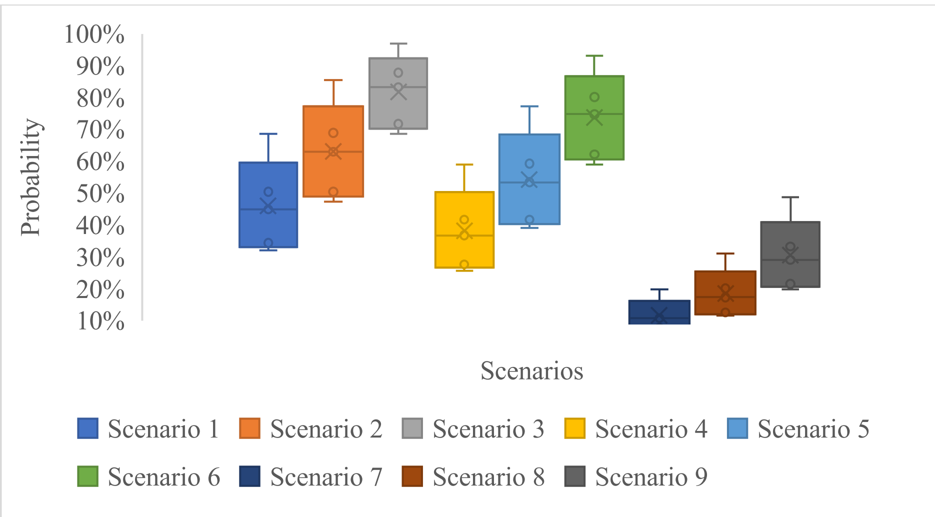

Figure 5 Risk of rhinovirus infection under nine scenarios (10 quanta/h)

The results show that when the indoor temperature level is low, and the relative humidity level is high, the risk of rhinovirus transmission can reach to the maximum value, which is around 99% when the quanta generation rate is 10 quanta/h. As a contract, when the relative humidity level is low, and the indoor temperature level is high, the probability of infection is the decreased to the minimum value, which is under 10% when the quanta generation rate is 10 quanta/h.

4. Discussion and Conclusion

4.1 Limitations

1) Residents who share the room with someone who is already infected might have a higher chance of being infected due to the short contact distance and long exposure time. Those factors were not be considered in this study and may have caused the overestimation of the probability of infection.
2) The chance of reinfection was not considered, which might cause an underestimate of the risk of infection.

4.2 Recommendations for future study

The main conclusions are as follows.

- The probability of rhinovirus transmission increases as the airtightness of the house increases. Especially when the quanta generation rate was high (10 quanta/h in this case).
- Higher occupancy caused little differences in the probability of transmission.
- If more occupants were infected, the higher the chance of subsequent transmission. However, reinfection was not considered in this study, which might lead to an underestimation of the probability of infection.
- Changes on indoor temperature and relative humidity as a result of the refurbishments can affect the transmission. With the low indoor temperature and the high relative humidity level, the risk of transmission can reach to 99% at 10 quanta/h generation rate. As a comparison, under the situation of low relative humidity and high indoor temperature level, the probability of infection decreased to 10%.

Reference

Li et al., 2007. Role of ventilation in airborne transmission of infectious agents in the built environment – a multidisciplinary systematic review. Indoor Air, 17(1), pp.2–18.

Riley EC, Murphy G, and Riley RL (1978) Airborne spread of measles in a suburban elementary school. American Journal of Epidemiology, 107(5), 421–32.

Rudnick, S.N. & Milton, D.K., 2003. Risk of indoor airborne infection transmission estimated from carbon dioxide concentration. Indoor Air, 13(3), pp.237–245.

ROBERTS, B.M. ... et al, 2017. The effect of refurbishment and trickle vents on airtightness: the case of a 1930s semi-detached house. Presented at the 38th AIVC - 6th TightVent - 4th venticool Conference, Nottingham, UK, 13-14 September 2017, pp.369-380.

Wood, R. et al., 2014. Quantification of Shared Air: A Social and Environmental Determinant of Airborne Disease Transmission. PLoS ONE, 9(9), p.e106622.

Sze To, G. and Chao, C., 2010. Review and comparison between the Wells-Riley and dose-response approaches to risk assessment of infectious respiratory diseases. *Indoor Air*, 20(1), pp.2-16.

Shrubsole, C. et al., 2014. 100 Unintended consequences of policies to improve the energy efficiency of the UK housing stock. Indoor and Built Environment, 23(3), pp.340–352.