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Vapour pressure excess as indicator of mould growth

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Abstract: Moisture is the key factor for mould growth. Previous research has focused on the relationship between relative humidity and mould development. However, this parameter is defined by temperature and water vapour content, so it cannot reflect in isolation the effect of moisture on mould growth. After analysing vapour pressure excess (VPX) calculated from apartments in a student accommodation, we found that: (1) VPX in warm months cannot be used as indicators for mould growth; (2) Although there was not too much difference between weekday and weekend VPX, higher VPX was calculated on weekends; (3) The lowest VPX usually occurred in the afternoons, while the highest at night before bedtime; (4) On the coldest weekend, VPX in rooms with visible mould was higher than on rooms without mould, indicating an excess of moisture in contaminated rooms. Opening windows for ventilation in winter could reduce the possibility of condensation and mould growth.

Keywords: mould growth, moisture, vapour pressure excess, relative humidity, ventilation

1. Introduction

Moisture and mould growth are common problems in both new and old residential and commercial buildings. WHO (2009) illustrates that moisture contributes to 75%-80% building envelop damages. Over 80 million European lived in damp buildings (Susanne Urlaub, 2016). One in six European dwellings had dampness and/or mould problems (Haverinen-Shaughnessy, 2012). 69% of people in South Carolina have admitted that their homes suffer from moisture problems (Gardner & Dewitt, 1992).

There are many studies about relative humidity and building mould development. However, relative humidity does not always have a strong correlation with mould development, because this parameter is a combination of dry bulb temperature and moisture content in the air. In order to find out how moisture affects mould growth only, this paper would analyse another moisture-related parameter, vapour pressure excess, which is defined as the vapour pressure difference between indoor air and outdoor air (Ridley, 2007). This parameter is only related to air moisture content and can be calculated using temperature and relative humidity.

This paper aims to present the analysis of the relationship between vapour pressure excess and mould growth and to explore whether it can be used as a better moisture-related indicator for mould growth. The objectives of the research work were:

- to analyse the difference between monthly, weekday, weekend, daytime and night-time vapour pressure excess and mould growth.

- to understand how occupant's living habits like ventilation and building indoor condition like condensation influence vapour pressure excess and mould growth as reported in a questionnaire.

2. Literature review

There are a vast literature and research on different moisture-related parameters and mould growth, being relative humidity the most popular one. For example, in Tsongas' study(2016), he concluded that the condition for visible mould growth was that average relative humidity of air in contact with sensitive building surfaces should be over 85% for more than 30 days. In Oreszczyn's (1999) study, he concluded that mould would grow if indoor air relative humidity were higher than 80% for one month or longer for most common construction materials. However, relative humidity relates to both dry bulb temperature and moisture content in the air. When the air moisture content is constant, the higher the temperature, the lower the relative humidity is. In the study of Altamirano-Medina's research (2006), mould was found in a room where the average surface relative humidity was 53.62% and air Rh was never above 70%. Hence, although RH could be used as an indicator for building mould growth, this could be not as accurate as required.

Moisture driving forces are air and vapour pressure excess (Gallo, 2000). Starakiewicz (2020) proved that mould would begin to grow when vapour pressure excess is higher than a threshold, but his conclusion was based on theoretical calculations. If there is vapour pressure excess or moisture excess, according to the principle of diffusion, more water vapour would be transferred from the higher concentration end to the lower concentration end, which is known as vapour diffusion. This effect is more common in wintertime because there is a larger temperature difference between the indoor and outdoor air, which results in a higher VPX.

In the research of Ridley(2007), he illustrated that there was a linear correlation between external temperature and vapour pressure excess. Standardized vapour pressure excess, which is defined as the vapour pressure excess when the outdoor temperature is 5 °C and outdoor relative humidity is 80% can be calculated based on a linear equation. Altamirano (2008) proved that SVPX had a stronger correlation with mould growth than other moisture-related parameters. Besides, in his study, 500kPa standardized vapour pressure excess was a threshold for visible mould in uninsulated rooms, while mould was not observed in rooms with insulation and high SVPX.

3. Methodology

The data used in this study were collected from 45 apartments located in London. These apartments form part of a student accommodation. Although these apartments almost share the same construction materials (cavity walls), five of them are part of a building built in 1992 with insulation, while the others were constructed in 1970 without insulation. Information on the presence of mould was collected and classified according to its severity.

Environmental data were collected using HOBO data loggers. A data logger was installed in each tested room. Recorded indoor and outdoor environmental parameters were dry bulb temperature and relative humidity. Occupants in these recording rooms were also asked to complete a questionnaire. The main content of the questionnaire included questions regarding the general household habits on bathing, cooking, ventilating and cleaning. There was also information on the location of mould, room dryness, and the effects of mould on participant's life.

Based on the recorded temperature and relative humidity, vapour pressure excess of every room was calculated. Then the analysis considered monthly, weekday, weekend, daytime and night-time vapour pressure excess. The correlation between vapour pressure excess during different periods of time and mould growth was assessed to see whether VPX could be used as indicators for mould growth.

4. Results

4.1 Monthly vapour pressure excess

November, a warmer month, was compared with other cold months in this section. Average vapour pressure excess during November in most rooms was much lower than that during other colder months. The possible reasons for this could be: (1) temperature and relative humidity in November were higher than other months, (2) occupants usually opened windows more frequently in warmer months, therefore better ventilation could have helped remove excess vapour from the interior.

As for standardized vapour pressure excess (SVPX), it was also lower in November than that of other months. SVPX in December, January, February and March were closer to the value calculated for the whole monitoring period. In colder months, r^2 (the square of the correlation coefficient) of external temperatures and vapour pressure excesses for most rooms were between 0.1 and 0.5, but most r^2 in November were less than 0.1, which meant that there was a weak correlation between these two parameters for November in most rooms. During colder months, occupants preferred to close windows, so vapour pressure excess did not fluctuate greatly due to lack of ventilation. Hence, the correlation between external temperature and vapour pressure excess would be stronger in colder months.

4.2 Weekday and weekend vapour pressure excess

There were 26 rooms whose weekends' average vapour pressure excesses were higher than that of weekdays among these 45 rooms. But most rooms had very little difference during these two periods. According to occupants' living habits, most people had the same activities in both weekdays and weekends, although the duration of activities were different. For example, people slept more on weekends, especially in the morning, and their meals were later but for longer times in some houses. Besides, almost all occupants spent more time indoors on weekends due to pause in their work and/or studies. Some people also preferred to go out on weekends more.

SVPX during these two periods were much closer than their average vapour pressure excess. But in a few rooms, the calculated SVPX was still very different between weekdays and weekends, which showed that people's lifestyle was very different in those rooms. However, there was not too much difference in standardized vapour pressure excess overall.

4.3 Daytime and night-time vapour pressure excess

Night-time vapour pressure excesses were higher for most rooms. Higher vapour pressure excess appeared between 18:00pm and 24:00pm in 23 rooms, and the lower calculated between 13:00pm and 18:00pm. On the one hand, daytime temperature was higher, which resulted in higher outdoor water vapour content or vapour pressure. On the other hand, most occupants would go out in the afternoon for hours on both weekdays and weekends, so very little or even no water vapour was produced at that time indoors. Vapour pressure excesses during bedtime between 1:00am and 7:00am were also low, since human had a greater metabolism and produced more water vapour when they were awake, even just seating. When sleeping, only 40g vapour can be produced per hour per person. However, there would be 70g/h water vapour produced when seated, and it reached 90g/h for people standing (ISSE, no date).

As for SVPX, there was little difference in the number of rooms that met the 500kPa for them. 27 rooms passed this rule for daytime, while 28 for night-time, which was very similar to the results based on the whole data. Therefore, for most rooms, there is little difference between the vapour pressure excess by day or by night alone and the vapour pressure excess throughout the whole day in this study. And it is feasible to study the data during these three periods, daytime, night-time and the whole day in this study.

4.4 The coldest weekend

The coldest weekend was on the 16th and 17th of February in 2008 throughout the monitoring period, with an average outdoor temperature of 2.86°C. As for contaminated rooms, their vapour pressure excesses were much higher than that of other time. By comparing the vapour pressure excess in rooms with mould and without mould, we could see that most of these contaminated rooms had an average vapour pressure excess higher than the 500kPa during this weekend and previously defined as the threshold. The reasons for this are: (1) lower outdoor temperature resulted in lower outdoor vapour pressure, hence higher internal vapour pressure excess; (2) people in these rooms might be less willing to open the windows, so more moisture indoor. As for rooms without mould, half of them had the average vapour pressure excesses lower than 400Kpa, with values in most rooms lower or equal than 200Kpa.

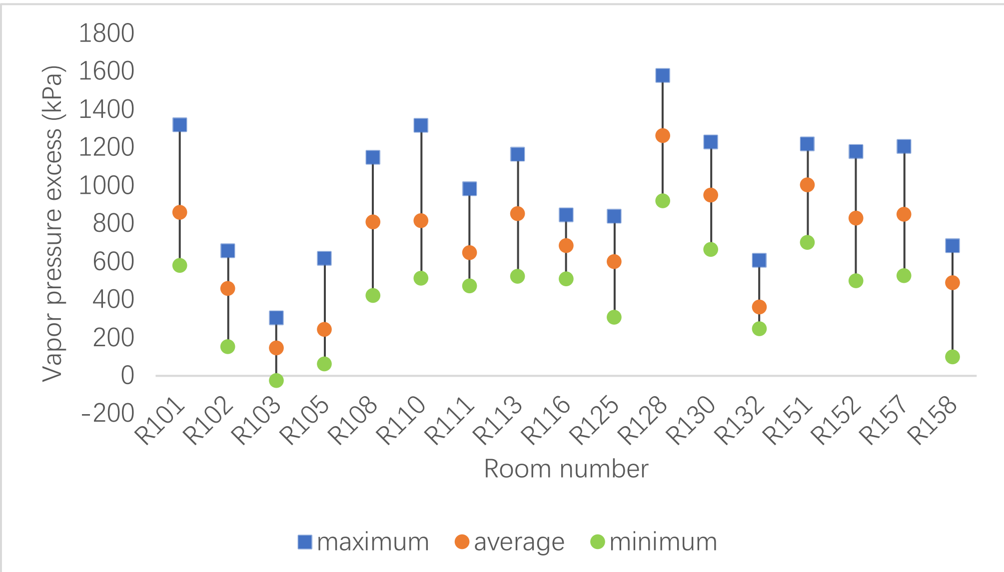

Figure 1 Vapour pressure excess of the contaminated rooms on the coldest weekend

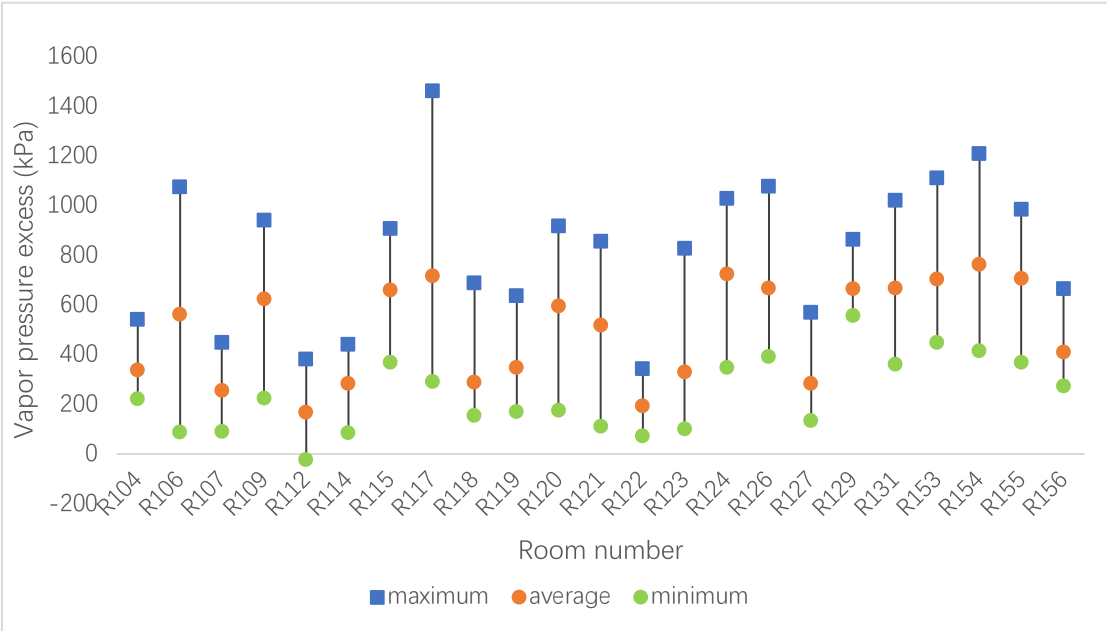

Figure 2 Vapour pressure excess of the clean rooms on the coldest weekend

5. Conclusion

According to the analysis conducted in this study regarding the vapour pressure excess during different periods, it can be concluded that (1): vapour pressure excess in warm months cannot be used as indicators for mould growth, because people tend to open windows during warm months; (2) The calculated vapour pressure excess during weekends was higher than that on weekdays for most rooms in this study; people stayed indoors more on weekends, (3) there was not too much difference between average daytime and night-time vapour pressure excess based on the whole database, and the calculated SVPX during these two periods was also found to have minimum difference (4) vapour pressure excess in most rooms was higher between 19:00 pm and 24:00 pm, and the lowest between 13:00 pm and 18:00 pm, (5) on the coldest weekend, people in the rooms with mould preferred to close the windows, which would contribute to moisture excess, risk of condensation and increasing chance of mould development.

In the process of data analysis and collation, we find out some unignorable deficiencies and problems in the methodology applied in this study, so these uncertainties, limitation and errors are briefly described below:

1. This paper only considered data collected during the one heating season. It is not known the condition of these apartments before the data was collected. Therefore, the mould reported could have growth before the monitoring exercise.
2. The number of recording houses is not large enough, so the conditions in some rooms might be accidental and not representative.
3. Only one HOBO data logger was used in every room. However, the humidity and temperature of air varied from place to place. Besides, accuracy errors of data loggers were unavoidable in the experiment, which could have resulted in variable values.

Based on the limitation and conclusion of this study, there are also some suggestions for improvement of this study.

1. Data loggers should be placed in more and different areas of the studied buildings.
2. If possible, the number of samples should be larger to improve the reliability of the study.
3. For the content of questionnaires, mould growth of every room before respondents' occupation should also be recorded.

6. References

Altamirano-medina, H., Davies, M., Ridley, I., Mumovic, D., & Oreszczyn, T. (2008). *Vapour pressure excess as an indicator to predict mould growth ; a case study of UK apartments with fungal problems*.

Altamirano-Medina, H., Davies, M., Ridley, I., Mumovic, D., & Oreszczyn, T. (2006). *An initial evaluation of a biohygrothermal model for the purpose of assessing the risk mould growth in UK dwellings. In: (Proceedings) European Modelling Symposium 2006, University College London, London,* 166-175.

Gallo, F. M. (2000). Mold damage due to moisture intrusion. *Forensic Engineering, Proceedings of the Congress*.

Gardner, L. L., & Dewitt, C. A. (1992). Moisture damage in South Carolina housing: Excess moisture of increasing frequency in buildings is causing concern in the united states costing over $2BN in 1978–1980 rising to an estimated $15.6BN by the year 2000. *Building Research & Information*.

Haverinen-Shaughnessy, U. (2012). Prevalence of dampness and mold in European housing stock. *Journal of Exposure Science and Environmental Epidemiology*.

ISSE. (n.d.). *Specific average moisture generation rates.*

Oreszczyn, T., & Pretlove, S. E. C. (1999). Condensation Targeter II: Modelling surface relative humidity to predict mould growth in dwellings. *Building Services Engineering Research and Technology*.

Ridley, I., Davies, M., Hong, S., & Oreszczyn, T. (2007). *Vapour pressure excess in living rooms and bedrooms of English dwellings: Analysis of the Warm Front dataset*.

Starakiewicz, A., Miasik, P., Krasoń, J., & Lichołai, L. (2020). Methods for determining mold development and condensation on the surface of building barriers. *Buildings*.

Susanne Urlaub, G. G. (2016). *Mould and dampness in European homes and their impact on health*. *49*(0), 64.

Tsongas, G. A., & Rioroan, F. (2016). Minimum conditions for visible mold growth. *ASHRAE Journal*.

WHO. (2009). GUIDELINES FOR INDOOR AIR QUALITY-DAMPNESS AND MOULD. *Journal of Biomedical Semantics*.