

A survey to Diagnose the reason for Mould Growth in Buildings

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Abstract: Indoor mould growth is associated with lung diseases and fabric decay. The role that occupant's behaviours and house conditions play on the development of indoor mould was investigated through the application of a survey. The survey was developed considering four main areas linked to mould growth: moisture production, ventilation strategies, thermal properties of the building envelope, and heating regimes. 100 questionnaires were collected, with 25 from houses with visible mould. The results showed that the excess moisture production and the insufficient ventilation were the main reason for indoor mould in most of the houses. Participants were unaware of the thermal properties of their houses insulated or not

Keywords: Mould growth, buildings, diagnosis, behaviours

1. Introduction

People spend a large part of their time indoors (homes, schools, offices, some public buildings, etc.) Indoor moisture, dampness and mould are key aspects related to people's health and wellbeing (Norbäck & Cai, 2015). Inside the buildings, mould can be found growing on wood, fabric, wallpaper, carpeting, and easily be found in the bathroom, kitchen, or basements. According to the review of IOM (2004), at least 20% of the buildings in European countries, the US, and Canada have indoor moisture related issues.

Shorter et al. (2018) found a strong association between mould and the wheezing symptom of children. There is enough evidence showing that indoor mould exposure has an association with the development of asthma and allergic rhinitis, especially in children (Caillaud et al., 2018). In 2014, Hernberg et al. found that indoor mould exposure was related to groups of people who have a lower level of lung function. Mould growth also causes the deterioration of the building's fabric. Historic buildings may have a higher risk of mould growth and material damage. Poor maintenance, water leakage, rainwater intrusion, and other events would facilitate the development of mould growth (Aktas et al., 2018).

Existing monitoring methods to investigate the reason for indoor mould growth mainly focus on data collected after mould has been found growing in buildings. Data that is usually collected are external/internal temperature, internal surface temperature and internal relative humidity. However, measures of those parameters are limited and do not represent the real conditions when mould may have. This research aims to design a survey questionnaire which could help to diagnose the reason for mould growth.

The objectives of this research project were to:

- Review the literature to define main parameters for indoor mould growth
- Design a questionnaire which focuses on parameters linked to mould growth
- Apply the questionnaire in households and analyse the data collected to see if any of the parameters are linked to visible mould
- Compare the result from houses with and without mould to see if it is possible to

- identify the reason for the development of mould
- Discuss the strengths and weakness of the questionnaire

2. Methodology

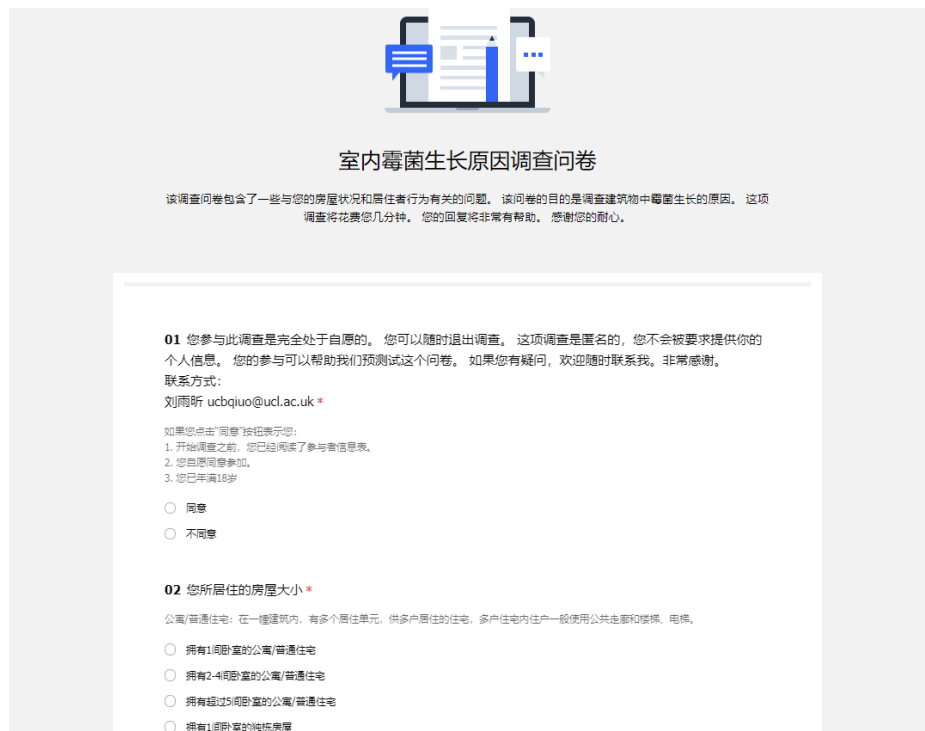
2.1 Search of literature and development of the questionnaire

UCL Explore was used to search for literature on mould and the parameter that could be linked with its development in buildings. The keywords used in the search were: (1) Mould, mold, fungi, bacteria, microorganisms, dampness, damp; (2) Indoor, building, dwelling, home, school, room, offices; (3) why, reason, cause, influence factors. After the identification of a parameters, a set questions were designed based on four main aspects: moisture production, ventilation, thermal properties of the building envelope, and heating regimes.

Most of the questions were designed as closed-ended questions, with answer choices kept between four or five at most. Answers were presented as excellent, good, only fair, poor, or from a shorter time period to a longer time period. Some open questions were also used to let respondents express their views. E.g. "Why do you usually ventilate your home

2.2 Testing the questionnaire

The survey questionnaire was designed in English and translated into a Chinese version before given out to Chinese participants. 'Tencent Questionnaire', a completely free online questionnaire survey platform was used for the release and collecting of information, as seen in Fig 1.



室内霉菌生长原因调查问卷

该调查问卷包含了一些与您的房屋状况和居住者行为有关的问题。该问卷的目的是调查建筑物中霉菌生长的原因。这项调查将花费您几分钟。您的回复将非常有帮助。感谢您的耐心。

01 您参与此调查是完全处于自愿的。您可以随时退出调查。这项调查是匿名的，您不会被要求提供您的个人信息。您的参与可以帮助我们预测试这个问卷。如果您有疑问，欢迎随时联系我。非常感谢。

联系方式：
刘雨昕 ucqiuo@ucl.ac.uk *

如果您点击“同意”按钮表示您：
1. 开始调查之前，您已经阅读了参与者信息表。
2. 您自愿同意参加。
3. 您已年满18岁

同意
 不同意

02 您所居住的房屋大小 *

公寓/普通住宅：在一栋建筑内，有多个居住单元，供多户居住的住宅，多户住宅内住户一般使用公共走廊和楼梯、电梯。

拥有1间卧室的公寓/普通住宅
 拥有2-4间卧室的公寓/普通住宅
 拥有超过5间卧室的公寓/普通住宅
 拥有1间卧室的独栋房屋

Figure 1. The online questionnaire

2.3 Analysis of data

First, the questions designed for all the participants were analysed. The percentage of houses with mould and those without mould were identified. At the same time, some common

answers were extracted from the results to see the participant's common life habits in mainland China. Second, the questions for houses with mould were analysed according to the type of room with mould and the activities carried out on those rooms. Third, houses without mould were analysed, with a focus on occupant's behaviours at home. The results from houses with mould and without mould were compared to see if there was any commonalities or differences.

3. Results

3.1 Questionnaire structure

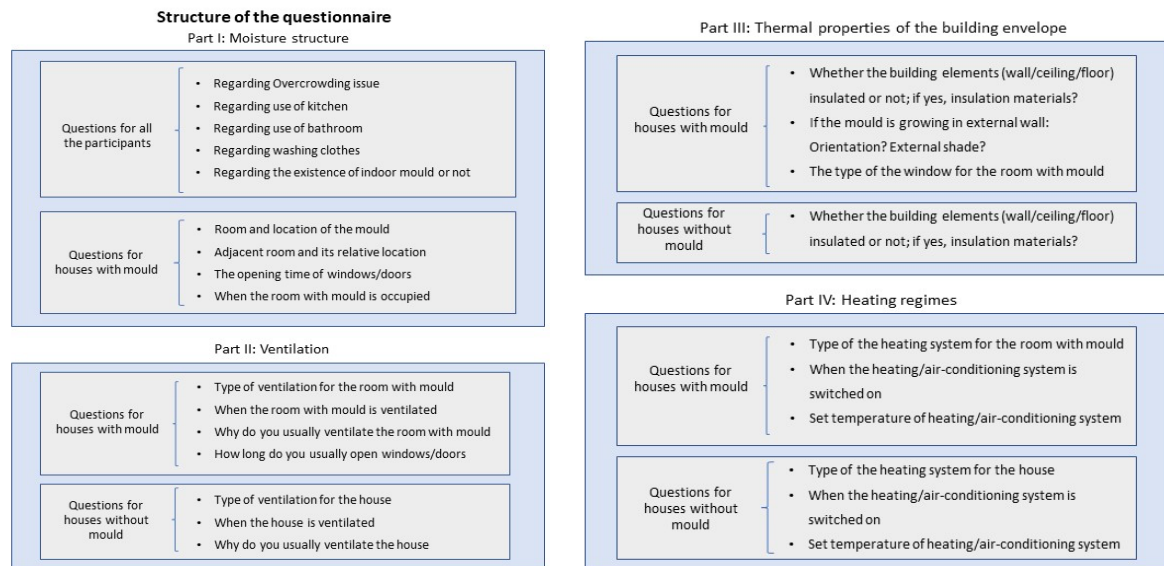


Figure 2. The structure of the questionnaire

As seen in Fig 2., the questionnaire has four sections, corresponding to the four main aspects: moisture production, ventilation strategies, thermal properties of the building envelope, and heating regimes. Each section contains questions designed for houses with visible mould and houses without mould.

3.2 General results

A total of 100 questionnaires were responded. Most participants live in mainland china, and some of the participants live outside China, as seen in Fig 3. Hunan, Yunnan, and Guangdong are provinces in humid and subtropical regions. From the 100 questionnaires completed, 25 correspond to residents living in houses with mould. Most of the houses with mould are located in Hunan and Yunan provinces which have wet weather and could have contributed to indoor conditions favourable for the development of mould.

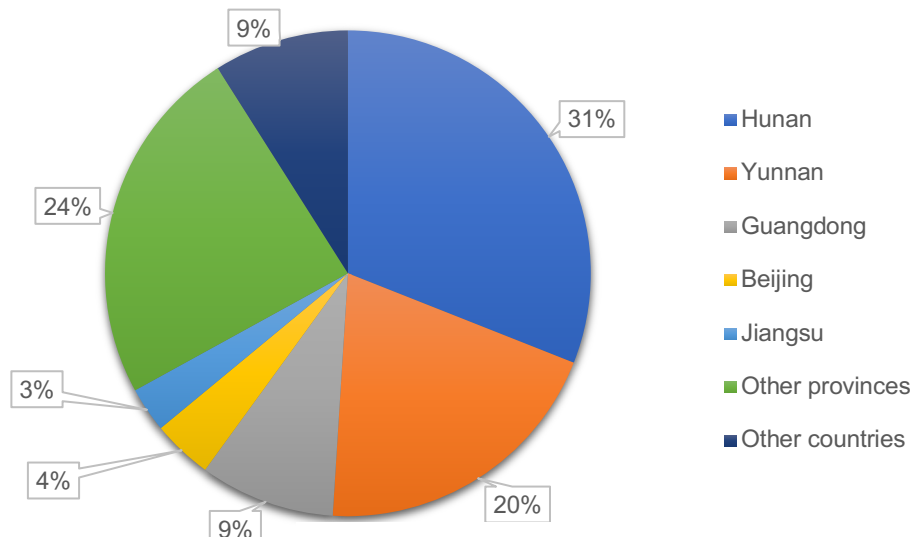


Figure 3. The distribution of participants locations

In general, only 2% of houses have problems with overcrowding. 57% of households use gas for cooking, 19% use electricity, and 23% use both fuels. One household mentioned the use of coal for cooking. In terms of cooking behaviour, 72% use lids when cooking, which helps reduce the moisture in the air. Most participants wash dishes by hand, and only 5 participants use dish-washing machines in their daily life. As for clothes-washing, most participants wash their clothes in washing machines, and only 16% of participants wash by hand. Most people dry clothes in open spaces such as balconies (50%) as in some provinces located in the northern part of China, the climate is dry. The rest of the participants dry their clothes indoor, laundry rooms, bedrooms, livings, and bathrooms.

3.2.1 Houses with mould

The main findings from houses with mould are:

- (1) Bathroom and kitchen are the most common room where mould was found. Few mentioned mould growth in bedrooms, living rooms, and laundry room. In most cases, mould was reported in surfaces of external walls at the intersection of wall and floor.
- (2) The frequency of showering/bathing in bathrooms with mould contamination was more than once per day. Half of the residents indicated that in average the length of showering/bathing was between 6 and 15 minutes, while 38% of participants indicated between 16 and 30 minutes. In most cases, the residents reported opening doors and windows after showering or bathing. Several residents indicated that they ventilate either in the morning or afternoon, while showering/bathing at night. Bad ventilation combined with too much moisture production could be one of the reasons for mould growth in most bathrooms.
- (3) Eleven participants reported mould in kitchens, and half of these participants cook 1 to 3 times per day. 45% of participants cook for more than 30 mins, with some almost an hour. The others reported cooking between 10 to 30 minutes.
- (4) There is only one participant indicating the presences of mould in the laundry room. The possible reason could be that this participant indicating washing clothes 4 to 6 times per week.
- (5) There are three main reasons for excess moisture production and mould growth in the

bedroom and living room. First, some participants reported that kitchen or bathroom is adjacent to the bedroom or living room, which could be the sources of excess moisture. Second, several participants reported that they usually air-dry their clothes in those rooms.

(6) Most participants do not know their rooms are insulated or not.

3.2.2 Houses without mould

The main findings from houses without mould are:

- (1) Most residents ventilate their homes, either through natural ventilation (73%), mix-mode ventilation (25%).
- (2) They all reported the use of ventilation for fresh air; they get used to open windows and doors; for cooling purposes as they feel hot at home; because of bad smell, or to remove the kitchen fumes.
- (3) Most participants reported that they do not know if their buildings are insulated or not.
- (4) 38% of participants reported there is no heating system in their home. Due to the cold weather in the northern part of mainland China, most of the families have the central heating system, which is operating by the local government or the local organization. While the central heating was not applied in the southern part of China, families in southern china usually use air conditioning system to warm their house, and some of them would install heaters by themselves.
- (5) 55% of participants switch on the heating system for the entire night, while 19% sometimes during the night.

4. Discussion and Conclusion

Even though the reason for mould growing in some properties could be related to some parameters and people behaviours, there are still some properties where the causes of the indoor mould cannot be explained. In some cases, it is difficult to understand why similar behaviour do not have similar outcomes. This could indicate that the designed questionnaire may have some limitation:

- (1) Apart from bathing/cooking/cloth-washing, other activities no asked in this questionnaire could have a greater effect on moisture production.
- (2) Questions on ventilation strategies and the regimes should have also been asked on houses with mould
- (3) More information on local climate and specific location (e.g. cities) where residents live should have been considered. This is a piece of key information, which could have helped explain some occupant's behaviours. For example, why and when they use the heating system or air conditioning system? Why they don't use the dryer? Why they switch on the heating during the night? Etc.
- (4) The connections between questions should be improved. Question 18 ask participants to select the room with mould. However, if participants choose more than one room,

they have also to answer question on ventilation, thermal properties of walls, and heating regimes for each room twice, three or more times.

- (5) Another factor which could influence the questionnaire result is the participant's bias. The result of the questionnaire is subjective. It can reflect the participant's living habits and daily behaviours at a certain time during the year, which may not be representative of the time when mould starts to growth.

The limitation mentioned above indicates that the questionnaire could help identify only, in some cases, the cause of mould. However, there are too many uncertainties. To investigate the causes of indoor mould more clearly, complementing the questionnaire with field-work survey would be ideal. The existing monitoring method, where surface temperature, indoor humidity, internal temperature, and outdoor temperature are monitored during a two-weeks period, seems to be an adequate complement of the use of questionnaires. Future research to diagnose the reason for mould growth should consider both qualitative and quantitative methods. What is more, except for diagnosing the reason for mould growth and identify the sources of moisture, it is equally important to perform a series of diagnostic tests to determine whether the building poses a potential health hazard due to mould.

5. References

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