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# Mould Growth in Residential Building in China: How Big Is the Problem?

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**Abstract**: In this paper, we explored the problems of dampness and mould growth in different climate regions of China. The prevalence of mould growth on the internal surface of external walls was found to be higher in regions with Severe Cold and Hot Summer and Cold Winter (HSCW) climates. For buildings located in the Severe Cold region, the mould problems often occur during winter seasons due to the large temperature difference between rooms and internal surfaces, causing surface condensation on walls. For buildings in the HSCW region, mould growth was often reported during the spring seasons as a result of humid and warm climate conditions. In Addition the factors influencing mould growth in a typical building were assessed using simulations and the moisture criteria proposed in Approved Document F. The results showed that floor difference, room orientation, indoor air temperature and occupancy behaviours influence mould growth.

**Keywords**: mould growth, residential buildings, factors, standards.

## Introduction

The indoor environment plays an important role in people's daily lives as people spend more than 80% of their time indoors (Klepeis *et al.*, 2001). Mould and dampness are common problems found in buildings, especially on the surface of internal walls, roofs and corners. Also, indoor mould growth can be a problem in different types of buildings and climate regions (Daquisto *et al.*, 2004). Mould growth is defined as the second risk category of domestic health and safety hazards by UK Communities and Local Government (2008). The World Health Organisation (WHO) has provided guidelines to help building owners to protect their living environment from the mould (2011). Therefore, the demand for a healthy indoor environment is becoming important for occupancy. Also, the problems of mould growth in residential buildings also have arisen and it is important to take the prevention of mould into consideration.

This paper aims to explore the condition of mould contamination on Chinese buildings and discuss the risk and factors influencing mould generation, based on UK moisture performance criteria. The detailed objectives are: (1) To review the conditions influencing mould growth in residential buildings in China; (2) To analyse the different conditions of mould growth on the internal wall surfaces of residential building located in different climate regions of China, such as external environmental conditions, living habits and building materials; (3) To evaluate the existing building regulations in relation to indoor humidity and mould growth prevention in residential buildings in China; (4) To analyse the risk of mould generation on the internal wall surfaces by computer modelling simulation and find the factors that have a higher influence on indoor mould growth in different climate region.

**Materials and methods**

- A literature review was carried out to explore the current situation of mould growth in residential buildings in China. Articles on indoor mould growth condition were reviewed and the keyword used were: mould growth, residential buildings, indoor environment and dampness.

- The risk of mould growth and the factors influencing its development in different climate regions of a typical residential apartment was simulated using DesignBuilder. The layout of the building simulated was based on a typical six stories residential building as shown in Fig 1 and Fig 2, which includes two bedrooms, one bathroom, one dining room/kitchen and one living room. The total area of the apartment is 80m$^2$.

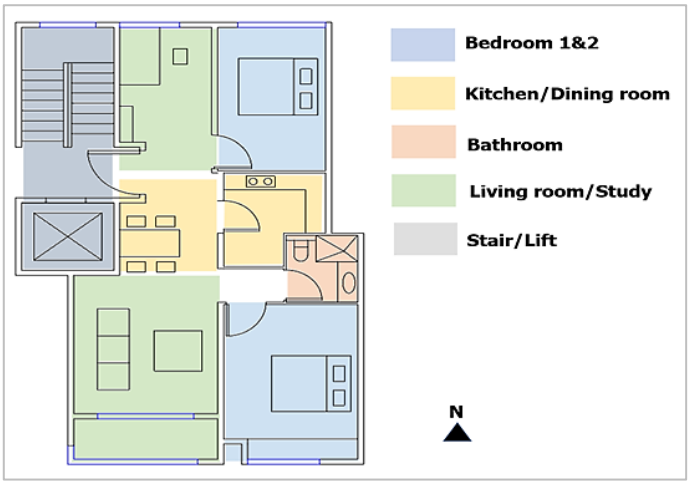



Figure 1 Layout

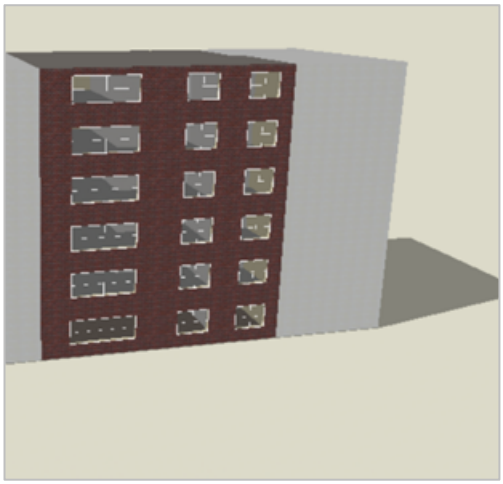


Figure 2 Building Model

- According to the GB 50716: Code for a thermal design for the civil building, there are five different climate regions in China, which should be used in the thermal design of residential buildings: Severe Cold, Cold, Hot Summer and Cold Winter (HSCW), Hot Summer and Warm Winter (HSWW) and Temperate regions. The building regulation for each region varies to achieve optimum indoor environment. For this study, four main climate regions (Severe cold, Cold, HSCW and HSWW) were selected to investigate the indoor RH and risk of mould growth. Three types of external walls were l considered in the model: (1)That used before any thermal regulation was available (no insulation in external walls + single glazing windows) (2) That used following the code for thermal design of the civil building (external insulation on walls + double glazing window), and (3) That type used following the standard for energy efficiency (external insulation on walls + double glazing window). The specific material properties of the walls (scenario 1, 2 and 3) tested are presented in Table 1

  Mould growth was assessed using the Approved Document F criteria shown in Table 2 (HM Government, 2010).

Table 1The parameters of the building envelop

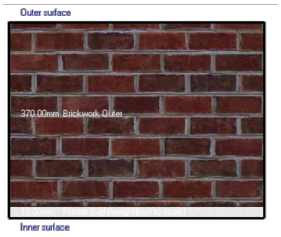
| Scenario | External wall type | Parameter | Severe cold | Cold | HSCW | HSWW |
|---|---|---|---|---|---|---|
| 1 |  | External wall U-value [W/m²·K] | 1.446 | 1.446 | 1.862 | 2.148 |
| | | Glazing U-value [W/m²·K] | 4.88 | 4.88 | 4.88 | 4.88 |
| 2 |  | External wall U-value [W/m²·K] | 0.616 | 0.891 | 1.608 | 1.608 |
| | | Glazing U-value [W/m²·K] | 1.960 | 3.094 | 3.094 | 3.094 |
| 3 | | External wall U-value [W/m²·K] | 0.471 | 0.534 | 1.147 | -- |
| | | Glazing U-value [W/m²·K] | 1.960 | 1.960 | 1.960 | -- |

Table 2 Moisture criteria

| Moving average period | Surface water activity | Room air relative humidity |
|---|---|---|
| One month | 0.75 | 65% |
| One week | 0.85 | 75% |
| One day | 0.95 | 85% |

Where surface water activity is numerically equal to the surface relative humidity. The surface relative humidity ($RH_S$) can be calculated by the following equation (1):

$$RH_S = \frac{\mathrm{p}}{p'_s} \times 100\% \quad (1)$$

P: Indoor vapour pressure [kPa] $p'_s$: Saturated vapour pressure for surface temperature [kPa]

The saturated vapour pressure (SVP) can be calculated by equation (2).

$$\mathrm{SVP} = 0.6105\exp\left(\frac{17.269\,T}{237.3+T}\right) \quad (2)$$

Vapour pressure (p) should be calculated priorly by equation (3).

$$\mathrm{p} = \mathrm{SVP}(T_s) \times \frac{\varphi}{100} \quad (3)$$

$\mathrm{SVP}(T_s)$: the saturated vapour pressure at an inside surface temperature [kPa]
$\varphi$: the relative humidity [%]

**Results**

Fig 3 shows the prevalence of visible mould spots in the bedroom for ten main cities in China as reported by the China Children Home Health (CCHH) programme (Hong, 2009; Zhang *et al.*, 2013). In this map, the prevalence of mould growth was categorised into different levels: red area (>10%), yellow area (5 to 10%) and green area (<5%). Among these ten cities, Harbin,

which is located in the severe cold climate region, had about 12% of homes affected by mould growth in bedrooms. Cities in the HSCW region also had high prevalence (5% to 10%) of visible indoor mould, specially on walls. Mould growth seems to be more serious on residential buildings located in severe cold regions. Moreover, residential buildings in the hot summer and cold region also suffer from mould growth.

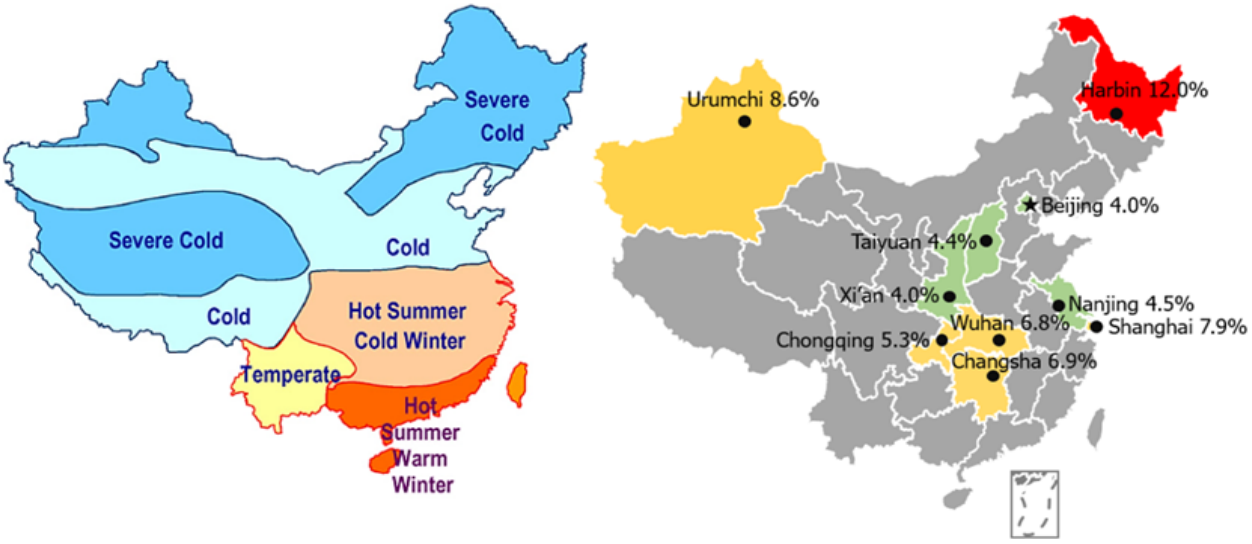



Figure 3 Typical climate regions and the prevalence of mould growth

According to the literature, mould growth on the internal surface of external walls is an important problem in Chinese residential buildings, especially in severe cold climate regions. The difference between the surface temperature of the wall and room air temperature of the three types of walls assessed (scenarios 1 to 3) and located in the severe cold regions are shown in Fig 4. It can be observed that the thermal insulation can reduce the temperature difference between room air and internal surface significantly, especially in winter. According to the ADF moisture criteria assessment, thermal insulation in the building envelop reduce considerably the risk of mould growth (Fig 5). Hence the provision of external insulation for existing buildings when undergoing refurbishing can help reduce the risk of mould problems.

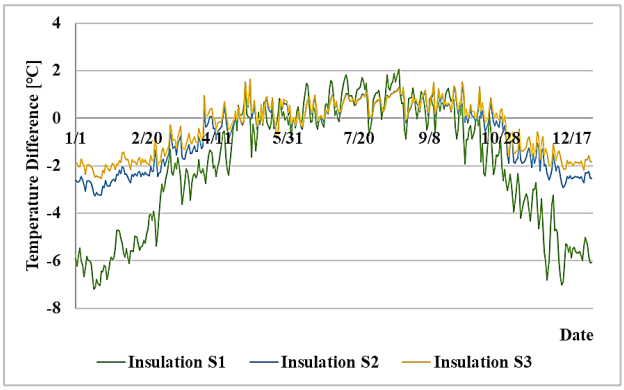



Figure 4 The temperature difference between the internal surface and room air (Severe cold region)

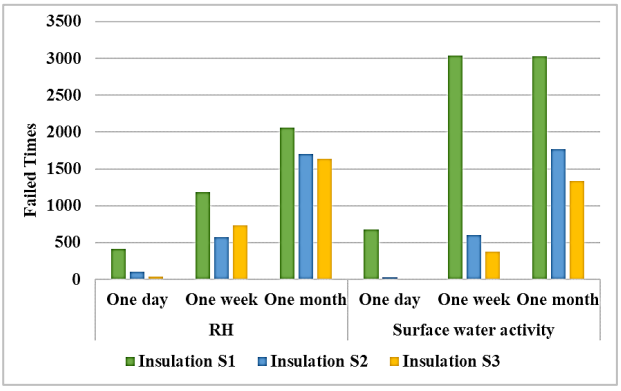



Figure 5 The failed times of scenario 1-3 of ADF moisture criterions (Severe cold region)

The factors that seem to have a major influence on indoor mould growth such as characters of building construction, season difference and occupancy behaviours were simulated in DesignBuilde and are summarized and discussed in Table 3.

Table 3 Summary table of simulation results

| | | **Severe cold (Harbin)** | **Cold (Beijing)** | **HSCW (Shanghai)** | **HSWW (Guangdong)** |
|---|---|---|---|---|---|
| **Characteristics of building** | Building construction insulation | ● The thermal insulation of external can reduce the potential of having mould problems<br>● However, the problems still exist with standard insulation<br>● Other measures | ● The thermal insulation of external can reduce the potential of having mould problems significantly<br>● The standard for energy efficiency can work efficiently on mould growth control | ● The thermal insulation of external can reduce the potential of having mould problems<br>● The problems still exist because of the humid outside weather | ● Thermal insulation of the wall cannot reduce the risk of having mould problems efficiently |
| | Floor difference | ● Lower floors usually have more serious problems with indoor mould growth<br>● Preventive measures should be taken for lower floors | | | ● All the floors had a similar potential of mould growth |
| | Orientation difference | ● North-facing rooms have a higher potential for indoor mould growth than south-facing rooms<br>● The reasons are probably due to lack of sunlight and ventilation | | | |
| | Heating setpoint temperature | ● The increasing heating temperature can increase the failed times of moisture criteria guideline<br>● The standard indoor design temperature may lead to the undervaluation | | --- | --- |
| **Season differences** | | ● Indoor mould growth is likely in winter seasons | | ● Indoor mould growth is likely in both spring and winter seasons | ● Indoor mould growth is likely in spring seasons |
| **Occupancy behaviour** | Occupancy density | ● The increasing of dweller number can raise the indoor relative humidity and surface water activity | | | |
| | Frequency of opening windows | ● Increase the frequency of opening windows can significantly reduce the potential of having mould problems.<br>● However, adequate ventilation may not be achieved in practice because the outside air temperature is quite low in winter seasons. | | ● Adequate ventilation can reduce the mould growth risk<br>● However, increasing the ventilation in spring seasons cannot reduce the potential of mould growth effectively because of the humid outdoor environment | |

## Conclusion

In this study, the risk of indoor mould growth was assessed for residential buildings in China. The problem of indoor mould growth in China was investigated by literature review. From north to south, China can be divided into five climate regions. The problems of mould growth were found to be more serious in Severe Cold and Hot Summer and Cold Winter climate regions compared to other climate regions. However, the reasons for indoor mould growth are different for these regions. For buildings located in severe cold regions, indoor mould is mainly caused by the high-temperature difference between indoor and outdoor in winter seasons. For buildings located in the Hot Summer and Cold Winter region, the problem of indoor mould growth is caused by the high relative humidity outside. A residential building was simulated and its indoor environment conditions assessed. The results show that improving the thermal performance of external walls can reduce the risk of mould growth, especially in buildings located in Severe cold and Cold regions. As shown in Table 3, other factors such as orientation, season difference and the frequency of opening windows should be considered in the prevention of mould growth.

## References


Daquisto, D., Crandell, J. and Lyons, J., 2004. *Building Moisture and Durability Past, Present and Future Work*. US Department of Housing and Urban Development.

Department for Communities and Local Government, 2008. *BD2518 Review of Health and Safety Risk Drivers*. p. 365.

Hänninen, O. O., 2011. *WHO guidelines for indoor air quality: dampness and mold*. Fundamentals of mold growth in indoor environments and strategies for healthy living, pp. 277–302. doi: 10.3920/978-90-8686-722-6_10.

HM Government, 2010. *The Building Regulations 2010: Approved Document F*.

Hong, T., 2009. *A close look at the China Design Standard for Energy Efficiency of Public Buildings*. Energy and Buildings, 41(4), pp. 426–435. doi: 10.1016/j.enbuild.2008.11.003.

Klepeis, N. E. *et al.*, 2001. *The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants*. Journal of Exposure Analysis and Environmental Epidemiology, 11(3), pp. 231–252. doi: 10.1038/sj.jea.7500165.

Zhang, Y. P. *et al.*, 2013. *Ten cities cross-sectional questionnaire survey of children asthma and other allergies in China.* Chinese Science Bulletin, 58(34), pp. 4182–4189. doi: 10.1007/s11434-013-5914-z.