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Correlation analysis of health and mould in buildings: based on the Health Survey for England

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Abstract: Mould in buildings is a significant public health issue in England. It affects the living environment of residents and may also have some negative health effects. This study uses the Health Survey for England (HSE) 2010 dataset to explore the correlation between building mould and health data, and the relationship between mould and building conditions, socio-economics, and lifestyle habits. This paper summarises 23 potentially mould-relevant features based on the literature review and database. It also redefines some features, such as the housing overcrowding criterion. The study used multiple logistic regression to explore the correlations between these key characteristics. The study results show significant correlations between housing crowding, resident education levels, income levels, pet ownership, housing tenure and regional differences and building mould. There were also correlations between mould and respiratory health conditions and mental health issues such as sleep difficulties. Research into the relationship between mould and health in dwellings could be improved by adding more mould-related questions to future HSE surveys.
Keywords: Mould growth; Health; Mould in buildings; Building feature; Moisture

Introduction

The relationship between the built environment and the health status is not monolithic and needs to be accounted for by many characteristics at the same time. In particular, significant factors include indoor air quality, temperature and humidity, ventilation rate, and housing characteristics (Wai & Willem, 2011; Turunen et al., 2014; Brambilla & Sangiorgio, 2020). Some evidence suggests significant inconsistency in psychological stress and health levels among residents across housing types and living conditions (McCarthy et al., 1985; Ellaway & Macintyre, 1998; Dunn, 2002; Ward et al., 2021). Many researchers consider the degree of overcrowding in a home to be critical when discussing the impact of housing characteristics on health(Nkosi et al., 2019; Dong et al., 2008; Lorentzen et al., 2023).

Mould in buildings in the UK is becoming a public health hotspot. Mould growth process can be divided into three distinct stages: germination, growth, and sporulation (Grimbley-Smith, 2023; ToxicBlackMould, 2024). Numerous factors contribute to mould growth in buildings, which can be summarized into three main points: socio-economic conditions, the housing environment, and the behaviour and habits of the inhabitants. These factors, such as income levels, housing airtightness (ventilation rate), the organic content of the house, humidity, temperature, exposure time, building materials, age of the house, and daily habits of the inhabitants (Coulburn and Miller, 2022; Brambilla and Sangiorgio, 2020), are interconnected and contribute to mould growth simultaneously.

Mould presence negatively impacts residents' health, causing respiratory issues like coughing, asthma, allergies, and infections (Peat et al., 1998; Coulburn & Miller, 2022;

Mendell et al., 2009). It also increases stress and anxiety regarding health (Liddell & Guiney, 2015).

Based on data from the 2010 HSE survey provided by the NHS, this study aims to explore whether there is a significant correlation between mould and health in buildings. This study will answer the following questions: 1)What factors in the built environment significantly influence mould growth? 2)Is there a correlation between mould growth in buildings and the health of the residents (both physical and mental health)? 3)What questions can be added to the subsequent HSE to better understand the correlation between mould and health?

Methodology

To help the NHS better understand the impact of mould on public health and improve its prevention and intervention strategies, this project uses quantitative research based on the Health Survey for England (HSE) 2010. The HSE is used by the NHS to better monitor national health and care trends. The survey has been implemented annually in England since 1993 by the National Centre for Social Research (NatCen) and the UCL Department of Epidemiology and Public Health. The dataset used in this study, includes 8,420 adults and 5,692 children, covering 1,607 variables. Missing values were handled during data cleaning, and irrelevant variables were excluded, retaining only valid data. Based on the literature review, the following relevant characteristics were selected for analysis (Table 1):

Table 1. Key features linked to mould growth filtered from the HSE database based on literature review.

Mould	● Fungus ● Damp
Building conditions	● Number of bedrooms ● Type of heating or cooking appliances used
Socio-economic factors	● Age ● Household type ● Number of adults, children and infants ● Person number ● Marital status, including cohabitees ● Highest Educational Qualification ● Economic status ● Total household income ● Tenure ● Government Office Region ● Degree of urbanisation ● Quintile of IMD SCORE ● PCTspearhead indicator for new PCTs
Living habits (moisture production)	● Pets ownership ● Cigarette smoking status
Health conditions	● Respiratory condition ● Asthma ● Anxiety/depression ● Sleep quality

New variable added	• Regional weather condition • Overcrowding

The main method of analysis in this study was the construction of multiple logistic regression models. Firstly, the chi-square test was used to review the independence between the mould-related variables in Table 1 one-by-one, e.g. moulds and tenure, moulds and asthma. The results were then used to construct a logistic regression model. R was then used to construct a logistic regression model for the resulting significant variables to explore the extent to which the different variables specifically affect mould growth. In addition, to explore the potential health effects of mould exposure in different age groups, this study incorporates household-type data to screen and group the samples according to age.

This study examined many household characteristics, but the main focus of this paper is on the results of the overcrowding problem. In order to discuss the potential effects of overcrowding on mould and health in the built environment, the following assumptions were made in this study:
1. it is assumed that the higher the level of overcrowding and the higher the air humidity, the more prone a dwelling is to dampness and mould.
2. due to the lack of data on the exact size of each room, the definition of overcrowding here could follow one of the UK statutory room standards (Table 2).
3. As the counting of numbers in this dataset does not follow the relevant statutory age categorisation, for this study, the number of infants under two years of age is recorded as 0 per person, the number of children aged 2-15 years of age is recorded as 0.5 per person, and the number of people aged 16 years and over is recorded as 1 per person.

Table 2. Relationship between the number of rooms and the number of people (SHELTER, 2023)

Number of rooms	1	2	3	4	5+
Number of people	2	3	5	7 1/2	2 per room

Results and discussion

Regarding building conditions, different households have different heating methods and number of bedrooms. In terms of heating methods, the questionnaire counted a total of 11 different heating methods in households in England. Some dominant heating methods, such as gas-fired boilers for central heating or hot water (85.79% of the total sample) and gas hobs or cooking rings (58.45% of the total sample), were confirmed to be statistically insignificant in correlation with mould and dampness. However, in other households that used a heating method, such as a paraffin heater, it was found that dampness and mould problems were present in more than half (65.3%) of the households. This may be because when paraffin is being burned, it produces large amounts of water vapour and carbon dioxide, increasing the room's humidity(Fylde Council, 2019).

The ratio of the number of bedrooms to the number of people in a home determines overcrowding. Based on the definition of overcrowding in this paper, 208 households were overcrowded, representing 1.47% of the total sample size. In this result, the number of children between the ages of 2 and 15 years old was credited as 0.5 per person. However, the degree of overcrowding derived from such a calculation of the number of people is not a good predictor of the correlation with mould due to the varying humidity produced by

different ages. Therefore, counting the number of people needs to be adjusted to incorporate changes in humidity. Combining data on humidity generated by individual adults and individual children in passenger carriages measured by Gładyszewska-Fiedoruk and Teleszewski and taking the average of each humidity range, the average humidity generated by children aged 6-15 years was estimated to be approximately 56.75 g/hr (2020). However, since separate age data for all children in each household were not captured in the questionnaire data, the model's accuracy was improved in this study by noting the number of children between the ages of 2 and 15 as 0.7. The result was that 631 families had overcrowding conditions, nearly three times larger than the previous overcrowding data. Further analysis of these 631 homes observed that 383 homes (approximately 61%) had damp or mould. Thus, there may be some correlation between overcrowded homes and mould.

The health status of these 383 overcrowded homes with damp or mould was reviewed. The results were that about one in five homes (76 homes) had residents with asthma or other respiratory symptoms; 23% had mental health problems, such as feeling anxious or depressed, and even 54 of the sample reported losing sleep due to excessive worry.

In addition, a simple logistic regression analysis of the variables initially screened for significant correlation by the chi-square test yielded 13 variables such as number of bedrooms, household type, number of inhabitants, education, income level, tenure, region, urbanisation, regional deprivation, pet ownership, respiratory status, asthma, and sleep difficulties, which were all significantly correlated with building mould, with their p-values were all less than 0.05. In general, better economic conditions and household education levels mean a lower risk of mould. For example, the probability of mould being present decreases when household income increases. Furthermore, an interesting point is that households with pets seem to have a lower probability of mould being present than households that do not own pets. Although no research previously confirmed this idea, regression analyses of household income and pet ownership yielded a positive correlation between higher-income households and pet ownership.

Regionality can also be used to generalise the influence of mould and factors. The generalised results showed that most areas of England have a 50-60% proportion of mould or dampness in their homes. However South West has a higher percentage of homes with mould or damp problems at 71.3%. The relatively low average regional income (£29,623) and higher proportion of the most deprived sample (29.5%) may be contributing to the high level of mould problems in buildings in the area. In addition, climatic conditions determine the hygrothermal performance of buildings under different regions, while the degree of exposure of buildings to moisture determines the durability of building materials. Based on the classification of the four wind-driven rain exposure zones in the UK Building Regulations Approved Document C, it can be concluded that wind-driven rain greater than 100 litres/m^2 per spell exists in Southwest, West Midlands and the North West. High-intensity precipitation may be one of the reasons for the growth of mould in these areas. However, this alone does not prove that there is a significant correlation between climatic conditions and mould growth in different regions. This is due to the fact that indoor temperature and humidity can be influenced by a variety of factors, such as how often residents open windows and the climate changes that occur during different seasons.

From a health perspective, the presence of mould in the home is also associated with several physical or mental health conditions. This study shows a significant relationship between residents having respiratory diseases and mould in the home. Fungus was present in 1481 of all samples, of which respiratory symptoms were present in 166 samples, occupying 11.2%. When also considering dampness, the total number of samples noted to have either dampness or fungus or both was 3193, of which 327 had respiratory disease, also occupying about one-tenth. However, changes in asthma status did not significantly affect the probability of mould presence, perhaps because the sample size was not large enough to monitor this effect. In addition, there is not much evidence that the presence of mould affects the mental health of residents, except for some data suggesting that the probability of residents having trouble with sleep due to excessive worry increases with the presence of mould.

In considering the relationship between different household structures (different age group memberships) and mould and health, this study compared households with and without children and with and without elderly people. The results yielded that families with children were more likely to have mould or dampness than families without children, particularly mould, which was twice as likely to be present in families with children than in families without children (Figure 1a). When discussing health, health is better in families with children compared to families without children, both in terms of physical and mental health. This may be because families with children have higher levels of satisfaction and responsibility (Angeles, 2009). In addition, damp and mould were less prevalent in households with over 60 year olds in childless households (Figure 1b), and when combined with the relative sample sizes, the risk of mould was lower in households with elderly people than in households without elderly people.

(a) (b)

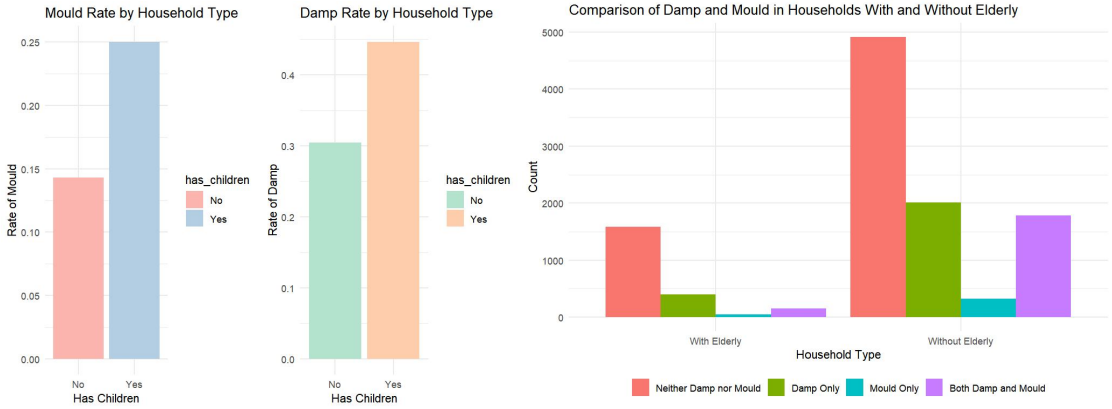

Figure 1. a) Relationship between the presence of children in the household and mould and dampness. b)Comparison of damp and mould in households with and without elderly

Conclusion

Overall, this study investigated the correlation between mould growth in buildings and the health of the inhabitants through logistic regression, taking into account socio-economic factors, housing conditions, living habits and weather factors. Key findings indicate mould growth is linked to household overcrowding, type, education, income, tenure, region, urbanisation, and pet ownership. Overcrowding, in particular, increases moisture, heightening mould risk. The study's limitations suggest that future research include age-specific data, individual behaviours impacting moisture (like window opening habits), and

integrating additional databases to enhance the analysis of building mould and health correlations.

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