The Journal of Social Sciences Research
ISSN(e): 2411-9458, ISSN(p): 2413-6670
Special Issue. 6, pp: 1180-1185, 2018
URL: https://arpgweb.com/journal/journal/7/special_issue
DOI: https://doi.org/10.32861/jssr.spi6.1180.1185

Academic Research Publishing Group

Original Research Open Access

Analysis of Mould Growth Causes in Higher Education Library Indoor Environment

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Abstract

This paper presents an analysis of mould growth causes that be found in an indoor library environment. The visual inspection had been conducted to identify visible mould in the indoor library environment. Three higher education institution libraries in Malaysia were selected as a case study. The identified mould species on the site were analysed using mould growth germination factors and possible causes that related to the growth. The result confirmed mould species such as *Aspergillus, Penicillium, Stachybotrys's* identified as a common mould growth found in the three library buildings. The analysis of mould growth causes is important for this study as is to confirm the relationship with the mould found in this building which may result in adverse health impact, environment, material and archive in the library. The result also can become guidelines and best practices for library management regarding good indoor environmental quality.

Keywords: Analysis; Higher education; Indoor environment; Moisture; Mould; Library.

1. Introduction

The World Health Organization (WHO) had developed internal air quality (IAQ) guidelines for dampness and management of mould in indoor building environment (WHO, 2009). The WHO guidelines highlight the need to prevent moisture, dampness and acceptable ventilation requirement. The water content and moisture in materials can support mould growth. Therefore it is important to eliminate the source of water in an indoor library environment. In addition, the remediation and action should be carried out immediately when the sign of dampness appear in the building. Failure to do this, it will cause mould growth and increased the risk of exposure to dampness appear in the building. Failure to do this, it will cause mould growth and increased the risk of exposure to the microbial flora, airborne spores and volatile toxin (Singh, 1999). The ongoing monitoring of the environmental conditions of buildings ensures the long-term health of building materials and structures. This paper focusing on the analysis of factors that contributes to the mould growth in an indoor library environment. The variable parameters of mould growth that had been discussed in the earlier research progress paper will be analysed further in this paper.

2. Literature Review

The majority of environmental problems in buildings are related with lack of maintenance, chronic neglect and building defects leading to water ingress, condensation and dampness in the building fabric (Singh *et al.*, 2010a). Previous research has shown it has become apparent that moisture and humidity control problem exists in library buildings. The cause of these problems can be complex and involve many aspects of library design, construction and maintenance (Wahab *et al.*, 2015).Therefore, the most important factor in the preservation of library collections is the maintenance of proper environmental conditions. In addition, research done by Maisarah (2010), found that various design and operations &maintenance problems have been identified as some of the casual factors to the infestation of mould in all the three hospitals that been selected as case studies in Peninsular Malaysia (Maisarah, 2010). Five main factors found that contributed to the causes of mould growth in the library building, such as indoor environment, poor maintenance, ventilation and air conditioning system, library indoor finishes and materials including library design and layout.

2.1. Indoor Environment

The five critical indoor environmental factors for the growth and development of mould in library collections determined as the presence of mould spores; source of nutrients; adequate moisture; temperature for a particular variety of mould; and limited air circulation. The existing of dampness in the building is one of the most damaging failures that really must be taken care of Sauni *et al.* (2013). Dampness can be a serious matter, particularly to the elements located near water sources. Dampness, which is noted only by minor moisture or condensate, is adequate

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for some mould, including species of Aspergillus and Penicillium. In addition, more hydrophilic, moulds such as Stachybotrys, Fusarium, and Acremonium grow in higher moisture content. Each fungal species has a minimum requirement for availability of water to grow, and the types of mould growth depending on the amount of moisture. This relationship is also related to the lower temperature reading in building (Johansson *et al.*, 2012).

2.2. Poor Maintenance

Poor maintenance practices had been identified as most significant causes for mould growth in an indoor environment that related to Sick Building Syndrome (SBS) and related illness to the occupant (Crook and Burton, 2010; Fingerman, 2011; Maisarah, 2010). Poor operation and maintenance in library building are one of the most reason for mould growth. Previous research shows that 95 percent of Texas A&M University (TAMU) campus buildings with humidity problem were categorised as having a maintenance problem (Chen and Garcia, 2004). Supported by Singh *et al.* (2010b) which found that lack of maintenance, chronic neglect, and building defects leading to water ingress, condensation, and dampness in the building fabrics would lead to a proliferation of toxic moulds (Singh *et al.*, 2010b). In the example, a library with poorly maintained air conditioning systems, insufficient ventilation, and bad maintenance practices lead to microbial proliferation. Wahab *et al.* (2015), confirmed that from the walkthrough on the selected library, found that the roof was not maintained properly, and unwanted plant and debris not been cleared by the maintenance contractor. As a result, the rainwater outlet and drainage was a blockage (Wahab *et al.*, 2015). It was concluded that in the large institutions where there is a large number of buildings to maintain, regularly scheduled maintenance is often delayed. The cost has become a major issue in any upgrading and maintenance work. As a result, problems that could have been prevented begin to accumulate and created deferred maintenance.

2.3. Ventilation and Air Conditioning System

The design of an HVAC system that provides a good indoor climate which, at the same time, guarantees the preservation of hygroscopic books and ensures the occupant's thermal comfort, is challenging (Steeman *et al.*, 2010). Domestic humidifiers and air-conditioning systems in library buildings can be important sources of mould growth.

According to Wu et al., the ventilation system would be an important factor affecting microbiological contamination of indoor environments (Wu *et al.*, 2005). The way air moves in the library and the condition of the ventilating and air-conditioning system are critical aspects of bioaerosol exposure (Storey *et al.*, 2004). Large concentrations of biological agents are mostly resulting from bad management of the ventilation and air conditioning systems. The insufficient fresh air intake is allowing for the built up of indoor air contaminants, condensation or water accumulation in pans under cooling coils, humidifiers, and dust accumulation in air filters (Hess-Kosa, 2011). Ducts with internal lining or duct board can become microbial reservoirs and amplifiers if they become humid and dirty (Storey *et al.*, 2004). Therefore, the mechanical ventilation system should be properly maintained to optimise the volume of dilution air and to minimise the accumulation of contaminants that are microbial growth (Wang *et al.*, 2010).

Research by Adriana found that although there was no difference in the number of genera found in the samples collected from the libraries with natural ventilation and air conditioning, there were significant differences in the proportion of genera found in each group, suggesting that air conditioning matters (Araujo Reis-Menezes *et al.*, 2011). The maintenance of the ventilation and air conditioning system would be of key importance to establish a proper balance between humidity and temperature inside library buildings. An air-conditioning system that does not receive proper maintenance can be more harmful to book collections. Also, research done by Wahab *et al.* (2015), found that improper maintenance of filters and diffusers have been identified as causal factors to the infestation of mould in all the three libraries that been selected as case studies (Wahab *et al.*, 2015). The way to deal with the mould problem is to prevent it by having a properly building ventilation and air conditioning designed system and to keep it performing adequately with proper maintenance (Chen and Garcia, 2004).

2.4. Library Indoor Finishes and Materials

The materials found in libraries and archives, such as a book, paper, starch-based glue, leather and cloth, are ideal substrates for fungal growth. The propagules present inside libraries and archives frequently originate from the outside building. The internal causes of the deterioration of papers in books are due to its acidity and biological factors (Pinzari *et al.*, 2004; Zyska, 1997). Material that is neglected, exposed to the poor environment or stored in unsuitable conditions led to attack by mould, bacteria and insects and causes irreversible physical and chemical damage to collections (Child, 2011). In addition, the indoor environment can also be a source, from humidifiers and the presence of food, plants and other substrates (Singh *et al.*, 2010b). Mould growth on library building materials and components may range from small areas covering a few centimetres to a very large extent. Also, moulds have the potential to cause degradation in virtually all building materials they colonies (Hoang *et al.*, 2010; Nielsen *et al.*, 2004). Preservation Advisory Centre, United Kingdom had produced a guideline for mould outbreak in the library and archive collections.

These guidelines are useful for librarians in term of providing mould information and its lifecycle, requirement of good indoor environment and material storage guidelines (Child, 2011). In practice, fumigation has become the regular cure for books assumed to control insects or fungi or books in which an insect or fungus has been observed (Jan, 2006), but not recommended because of human health concerns (Weaver-meyers *et al.*, 1998).

2.5. Library Design and Layout

The physical conditions of the library building, including building design, age, location, floors level and occupation density affect the indoor environment quality and its performance. Libraries have been storing and collecting depiction obtains more thousands of books and documents. The situation of such conserved books collection is under the stable control of different environmental factors. The library buildings and individual rooms also promote micro-climates and ecosystem niches that favour the establishment, growth and proliferation of a great diversity of fungi that can cause damage to build structures, decorations and other materials and degrade the internal air quality (Singh *et al.*, 2010b). The library building required watertight and should not allow damp to penetrate through the fabric from blocked drains, faulty roofs or other building defects (Child, 2011). Steeman *et al.* (2010), had developed a building simulation model that can be used to improve the indoor climate with respect to the preservation of valuable books. A plan and section of the library building design and air handling unit (AHU) system been analysed to measure the comfort criteria (Steeman *et al.*, 2010). ASHRAE classification for the preservation of books in the indoor climate had been applied. The research found the presence of occupants and hygroscopic books interact on the moisture balance of the library and that a larger exposed hygroscopic surface enables to significantly damp temperature and humidity variations in the library (Steeman *et al.*, 2010).

Furthermore, in Preservation Advisory Centre booklet (Child, 2011) listed several precautions and guides for preventing mould in the indoor libraries such as materials place, storage, protection from water, dirt and dust and regular inspection material on lower shelves. Therefore, library design and layout play important roles in minimising mould growth and its effect no the users.

3. Material and Methods

This research adopted a qualitative-dominant design with the inductive procedure. The data gathered in the natural and real situation of three selected case studies. The sites were surveyed with the following criteria:

(a) The collection of library building characterization data based on direct inspection and interviews with library officers;

(b) The library characterization including measurement of temperature and humidity, lighting and air conditioning systems;

(c) Physical examination of the building and inspection of sites that has been wetted or showed mould growth; and

(d) Mould sampling and analysis.

Data collection was only conducted in an indoor environment of selected libraries with visible mould growth. Visible mould growth has been identified early during the visual inspection. It appears in forms of stains on the wall, ceiling and floor, discoloration and rust on metal materials. Some of the mould also visible on the carpet and have a mouldy odour. In this research, semi-structured interviews and open-ended interviews have been adopted. An interview schedule was set up, and questions were designed before the interviews were conducted. The interviews were conducted with two different personnel of University management: the chief librarian and the maintenance personnel involved in maintaining the library building.

During the three case studies investigation, interviews with the librarian of selected libraries were conducted. The question-answer session was held formally before the researcher did the measurements. The questions started with general matters, then moved to a particular issue regarding mould growth. The question aims to get feedback about the libraries environments, problems and experience. The information from them may help the researcher to know the scenario happen to the libraries about the condition of building physical and mechanical and ventilation condition. The questions are focusing on ventilation system review, the HVAC system in libraries and maintenance aspects. There searcher gathers data and confirmation of possible causes of mould growth. In addition, information on the water or moisture symptoms from past and present leaks, spills and condensation; review ventilation and note apparent mould, and area with mouldy and musty odours been reviewed during the session.

4. Results and Findings

The analysis result data for Library A, B and C are shown in Table 1. All libraries experienced with mould growth especially on the books, air conditions outlet and ceiling. The type of mould found are Aspergillus sp., Penicillium sp. and Stachybotrys sp. However, only Rhizoctonia Solani sp. found in library B due to the existence of soil inside the building.

Table-1. Analysis of Mould Growth in the Library

No	Item	Library A	Library B	Library C
1	Location of Mould growth	• Books • Air conditioning outlet • Book Shelf	• Ceiling • Wall • Books • Air conditioning outlet • Window • Carpet	• Ceiling • Wall • Books • Air conditioning outlet
2	Mould Species	• Fungal sp. • Aspergillus sp. • Penicillium sp. • Stachybotrys	• Fungal sp. • Aspergillus sp. • Penicillium sp. • Stachybotrys • Rhizoctonia Solani	• Fungal sp. • Aspergillus sp. • Penicillium sp. • Stachybotrys
3	Temperature	20°C - 23°C	20°C - 27°C	23°C - 26°C
4	Relative Humidity	61% - 76%	62% - 75%	67% - 83%
5	Material moisture reading	➢ 8 %	➢ 8 %	➢ 8 %

Table 2 shows the analysis of the five factors that caus the mould growth in the indoor library environment. The result confirmed all three case studies had related to the five main factors that contributed to the mould growth.

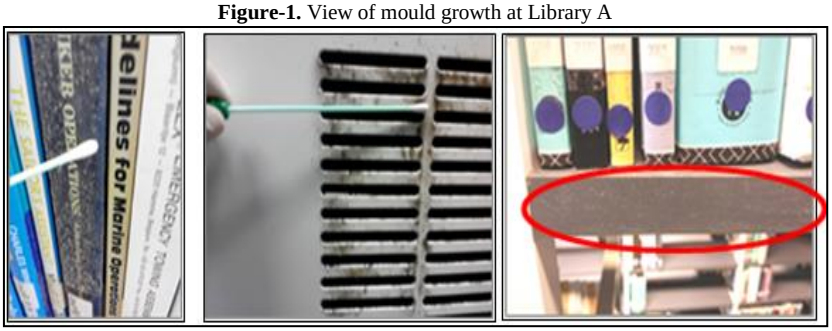
Table-2. Analysis of Possible Causes of Mould Growth in the Library

No	Factors	Library A	Library B	Library C
1	**Indoor Environment** - presence of mould spores - source of nutrients - adequate moisture - temperature - air circulation	√	√	√
2	**Poor Maintenance**	√	√	√
3	**Heat and Ventilation Air-conditioning System (HVAC)**	√	√	√
4	**Library indoor and material finishes**	√	√	√
5	**Library Design and Layout**	√	√	√

4.1. Library A

The result that causes to mould growth is indicated in Table 2. In library A, visible mould and fungi appear mostly on the ground floor and open reading area at Level 1, 2 and 3. Since this building was built in 2004, most of the fixtures, fitting and building component were in good and acceptable condition. High relative humidity of 61% to 76% was one of the factors that contributed to the mould growth in Library A. The moisture exists on the books due to high relative humidity result. As shown in figure 1 below a stain such as mould growth on the surfaces of the book cover found. The mould also occurs on the air condition outlet at each level of Library A due to high humidity and lack of maintenance. The mould also found on the book shelf level 2 due to the shelf itself made from timber and it supports the growth due to the presence of high humidity.

Figure-1. View of mould growth at Library A



4.2. Library B

The result that causes to mould growth for Library B is indicated in Table 2. In library B, visible mould and fungi appear mostly at Level 3 and Level 4. The analysis shows that causes of mould growth came from ageing material and high moisture on the surface due to leakage and excessive of water in the particular area.The problems with leaking flat roofs are usually as a consequence of either poor workmanship installing the roof membrane, poor maintenance by the building owner or as a cause of age. A well designed and waterproofed flat roof should not cause

problems or leak. All flat roofs should be regularly inspected to prevent from blockage occurring and leaf guards should be well secured.In this case, leaves building up and start to block the drain. These should be cleared out during a regular maintenance schedule. The failure of rainwater down pipe (RWDP) in the timber column contribute to the rain penetration inside this library. Water ponding on a flat roof is a prime cause of weakening because variants in temperature between wet and dry areas of the roof can cause differential thermal movement. Together with the accumulation of acids left by evaporating rain, this would reason a failure on the roof surface. Figure 2 below shows the picture that causes and effects of mould growth in library B.

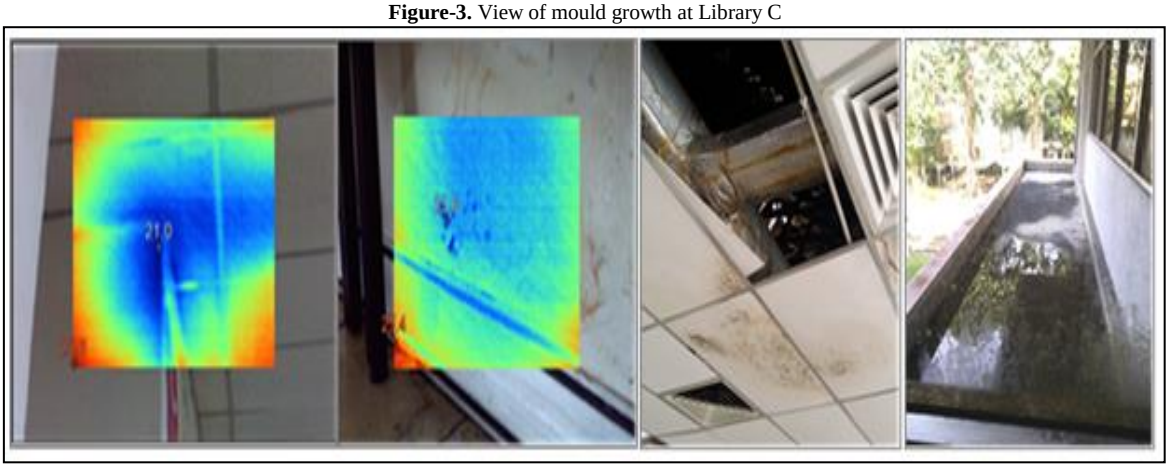
Figer-2. View of mould growth at Library B

4.3. Library C

The result that causes the mould growth for Library C is indicated in Table 2 above. In library C, visible mould and fungi appear mostly at Level 2 and Level 5. These situations were common in the damp area where high moisture that found at air conditioner outlet contributed to these mould species growth. Some book on the book shelf at Level 2 also indicated the appearance of these two fungal species. The high relative humidity of 67% to 83% was one of the factors that contributed to these mould species growth in Library C. However at level 5 the moisture exist due to the failure of the roof system. The roof leaking impact will cause during the

heavy runoff, water may start seeping through a hole that has been there for a while and drip onto the ceiling. Also due to little or ageing insulator of air conditioning ducting. Insulation is the key to avoiding air conditioning leaks from arising. If the insulation has torn away or there is no insulation, then the condensate from the pipes that run through the roof will leak directly onto the ceiling. If there is no insulation on the ceiling (in the roof cavity) than the water marks will affect the ceiling. This is one of the most common causes of water leaks. Figure 3 below shows the picture that related to the causes and effects of mould growth in library C.

Figure-3. View of mould growth at Library C



5. Conclusion

This study has justified the importance of indoor air quality by dragging together issues that are relevant to the sick building syndrome situation. Data analysis and findings that have been discussed matched with the staff opinions on mould presence. Thisis based on what they have experienced and perceived while working in the indoor environment of the library. It has been specified temperature and moisture causes such as water leaks incidents occurred within the past year such as roof leaks, plumbing leaks, flooding due to water penetration in the building, and window leaks contribute to the mould growth. Besides that, the symptoms that they experienced also has been evaluated and related to mould identification and quantification.

Acknowledgements

Ministry of Education and University Teknologi Mara sponsored the corresponding author and this paper. We greatly appreciate the assistance and useful discussion support from the Chief Librarians and Maintenance Personnel of Library TP, SA and TH.

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