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Indoor Mould Testing of a Historical University Building: UCL Chadwick Building

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Abstract: Indoor mould is one of the most important determinants of indoor air quality, with serious implications not only on human health, but also on the building envelope itself. This study is based on the Chadwick building, which is a late 19th century building, currently under the ownership of UCL as a workplace and school. Therefore it brings together different functions which are conventionally discussed separately in the relevant literature. This study aims to measure airborne and surface mould concentrations within the Chadwick Building, and to find out the correlations between these and the physical characteristics of the tested spaces. To this end, 3 classrooms, 3 offices, 3 laboratories, and 1 activity room were sampled to examine the airborne (active or aggressive) and surface mould concentrations. Samples were analysed for the β-N-acetylhexosaminidase (NAHA) activity to determine the fungal cell biomass at the laboratories of Mycometer in Denmark. The testing protocol also involved active particle counting, and temperature and relative humidity measurements. Offices were found to be the least mould intensive spaces, while laboratories were found to have the highest level of mould and particle intensity among all tested spaces. Based on the benchmarks previously established for residential indoor environments (currently in use by the Danish Building Institute), the results showed that most of the tested spaces did not have no mould and with a good/normal cleaning standard. Only one space and a few surfaces indicated either a minor (most likely non-building-related) mould, or a poor cleaning standard. The validity of these categories for a workplace/school should be further investigated by future research.

Keywords: mould testing, school, office, historical building

1. Introduction

Mould is a type of fungus. It grows in the form of multicellular filaments under a sufficiently long duration of favourable conditions, i.e. sufficient moisture, oxygen and nutrients (Sadovský and Koronthályová, 2017). According to the United States Environmental Protection Agency (2008) mould is ubiquitous, and they are able to grow on almost any substrate. If there are moisture problems within a building it can affect the building materials, where either discovered or undiscovered mould growth is more likely to occur with possible adverse health implications (Terr, 2009).

According to the National Human Activity Pattern Survey (1996) in America between 1992 and 1994, people spend about 5.4% of their time in an office/factory and about 11% of their time on average in other indoor environments including schools. Therefore, it is important to examine the workplaces and schools for mould presence. A number of earlier studies analysed the air quality in offices and schools by looking into different parameters with multiple sampling methods, while a direct quantification of indoor and surface mould within school and office spaces is scarce. The majority of these studies focused on the concentration of carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC) and room ventilation rates to identify the indoor air quality (e.g. Bluyssen *et al*., 1996; Apte, 2003; Chatzidiakou *et al*., 2012). Furthermore, Chatzidiakou et al. (2012) compiled findings from 312 classrooms in 80 schools to investigate the ventilation rates and

CO_2 concentrations. Bluyssen et al. (1996) indicated that in the UK around 30%-35% of offices were found to have an unacceptable air quality.

In the light of these, we report in this paper our findings from a rigorous testing scheme carried out in Chadwick Building, which is both a school building and workplace as UCL CEGE is based here with most of their teaching and research staff, and teaching facilities.

2. Methodology

With the aim of testing the mould levels in the late 19th century Chadwick Building, 10 rooms including office spaces, classrooms and laboratories shown in Figure 1, were chosen from different floors to take surface and air samples. None of the tested rooms had indication of visible mould, expect for part of a wall in B15 Concrete Lab, and all lab spaces showed some level of water damage (Table 1). First, the rooms were surveyed and their various physical characteristics, such as size, level of refurbishment, indoor plants, level of cleanliness and whether they had visible water damage, were reorded using a *Room Survey Sheet* developed for this aim. Then, 6 surface samples, and 2 parallel active[1] (aggressive) air samples were collected from each room, to then send to the Mycometer laboratories in Denmark to quantify the mould by the β-N-acetylhexosaminidase (NAHA) activity to determine the fungal cell biomass; this method was shown effective and verified by US Environmental Protection Agency in 2011. Finally, the number of particles and temperature and relative humidity values in each room were measured.

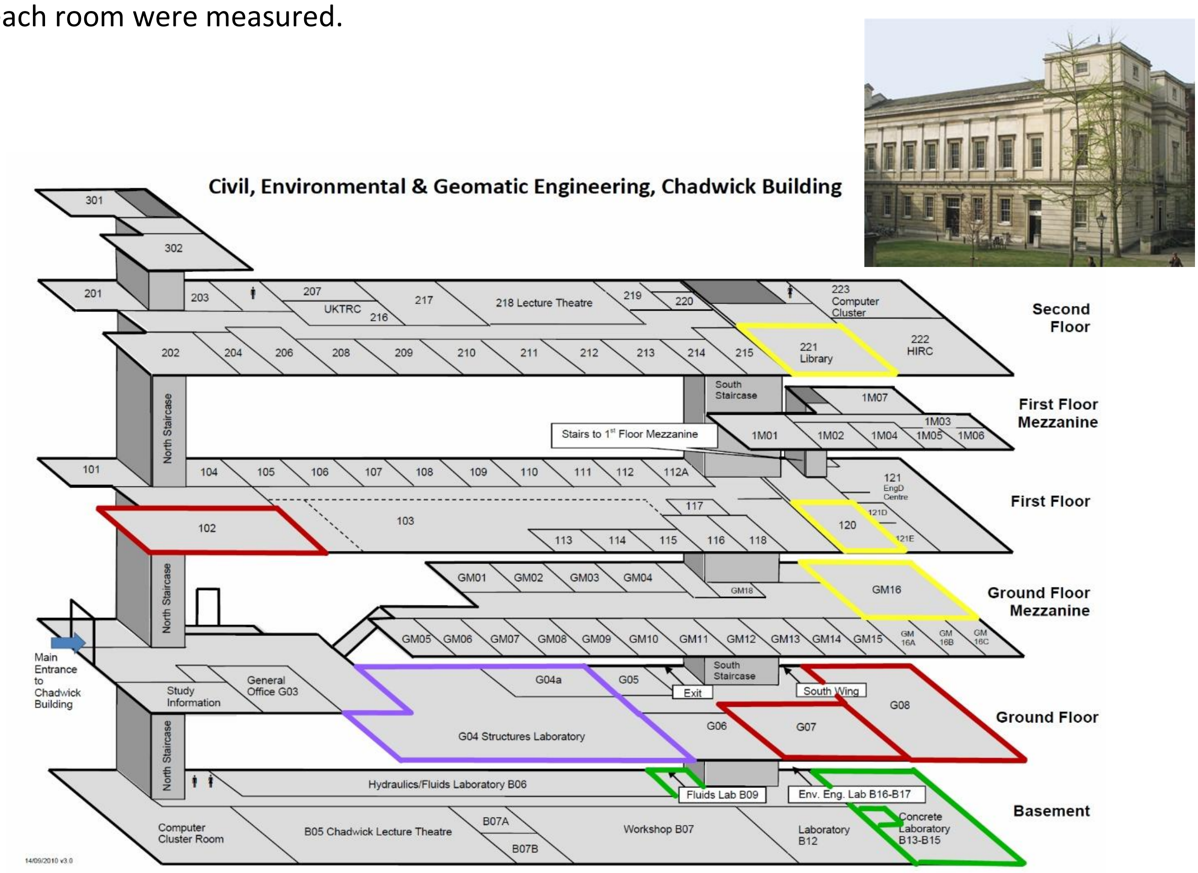

Figure 1: Chadwick Building photo and floor plan (from CEGE website) with tested rooms highlighted

(The rooms highlighted in RED are classrooms, YELLOW are offices, PURPLE is a multi-functional open area which is used as an activity room, GREEN are laboratories, B09 Fluids Lab cannot be seen fully in this diagram)

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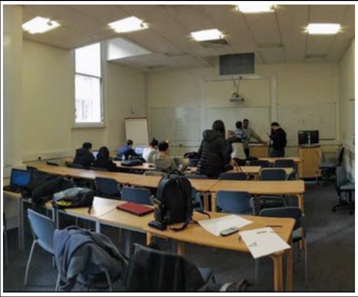
1 The terms "active" and "passive" sampling are occasionally used synonymously with impaction and sedimentation, respectively, however they are used here to mean aggressive sampling from mixed air and non-aggressive sampling from still air, respectively.

Table 1: Some of the tested rooms

CLASSROOMS	102		LABORATORIES	Water damage on the ceiling of B09	
	G08			Water damage and mould growth in B15 Concrete Lab	
	G07			Rusty water pipes in B15 Curing Room	

The testing and sampling protocol that was used for this study was previously developed as part of a research project titled "Indoor Mould Growth Testing and Benchmarking" carried out by UCL CEGE in collaboration with UCL IEDE, UK Centre for Moisture in Buildings, Polygon UK and Mycometer. Different steps of the testing protocol are explained below more in detail.

2.1 Surface sampling

In this study, six surface samples (three from visually clean surfaces and three from visually dirty/dusty) were taken by using moistened sterile cotton swabs, for an appraisal of distribution of table-top mould within the room, and to detect localised mould problems, if any. An adhesive template was used to limit the area of sampling to 3 cm x 3 cm (Figure 2.2).

Figure 2: Surface sampling

2.2 Active air sampling

The active (aggressive) sampling includes mixing of the air within the test area to mimic a high activity level in order to measure maximum airborne exposure level, hence the test results are reproducible, and not activity level dependent, as passive (non-aggressive) sampling (cf. Maunsell, 1952). In this study, a Makita blower was used to mix the air within the room, by blowing air on horizontal and vertical surfaces from approximately 2 m distance. The blowing duration was determined based on the size of the room (1 min for rooms up to 10 m^2, 2 min for rooms up to 20 m^2, 3 min for rooms up to 30 m^2, and 4 min for larger rooms). One minute was allowed before starting to sampling to allow very large particles to settle. The air pressure was adjusted by screwing the cap as shown in Figure 3 to 15 L/min by one sampler, and the sampling lasted 15 minutes.

Figure 3: Detail of air pressure gauge

2.3 Passive and active particle counting

As part of this study, active particle counts were measured in parallel to active air sampling to determine how particle intensive the tested indoor environments were. This was done by a CEM Particle Counter (Model DT-9880; flow rate 2.83 L/min with 6 channels: 0.3, 0.5, 1.0, 2.5, 5.0 and 10μm), logging also T and RH values (T ranging between 0-50°C, ±0.5°C at 10-40°C; RH ranging between 0-100%, ±3% at 40-60%, ±3.5% at 60-80%, and ±5% at 80-100%).

3. Findings and discussion

The obtained results indicate that none of the rooms suffers heavily from mould attack. The obtained airborne mould concentration values are all below 300 MMA (Mycometer Air Value measured in Relative Fluorescence Units (RFU), which is the measure of the β-N-acethylhexosaminidase, or NAHA, activity obtained when following the Mycometer protocol for sampling and analysis), except for the classroom G07, where we obtained 730 MMA. According to the benchmark values developed previously for residential properties using this technique and currently in use by the Danish Building Institute (DBI), this indicates either an old/minor mould problem, or relatively poor cleaning standards. The high surface values and comparatively very high particle counts we obtained from the same room suggests that the latter is more likely, given also that the thorough physical survey of the room did not reveal any indication of previous water damage, or old mould growth – however this does not rule out the possibility of a hidden source of mould. Surface mould concentrations suggest poor cleaning standards also in B15 Concrete Lab, and in the G08 and GM16.

The results also showed that the lowest airborne mould concentration values were obtained from offices, while classrooms had the highest range (Figure 4(a)). 3 of a total of 10 rooms had visible old or fresh mould or water damage in them, but we failed to find a strong correlation between this and the obtained airborne or surface mould concentrations.

Similarly the presence of carpets, orientation or the level of cleanliness assigned to each room by the surveyor did not seem to influence much the mould concentration values, except for dirty surface mould concentration values, which seem to be related (yet with high level of uncertainty) to the cleanliness level assigned to each room. Laboratories, the only spaces classified as dirty or very dirty, have, unsurprisingly, the highest dirty surface mould concentrations and particle counts (Figure 4(b&c)). Importantly all of the laboratory spaces tested as part of this study had some past or fresh water induced damage on its walls, and the B15 Concrete Lab had mould on one of the partition walls as well. Laboratories were the most humid among the tested spaces with 25-30% higher RH values on an average. While the role that high humidity values in a given indoor environment is known to increase the susceptibility to mould growth (Sedlbauer, 2001; Abuku et al., 2009; D'Ayala and Aktas, 2016; Aktas et al., 2017), this particular conclusion should be approached with care as the measured RH values may not be representative of the long-term moisture conditions within the laboratories.

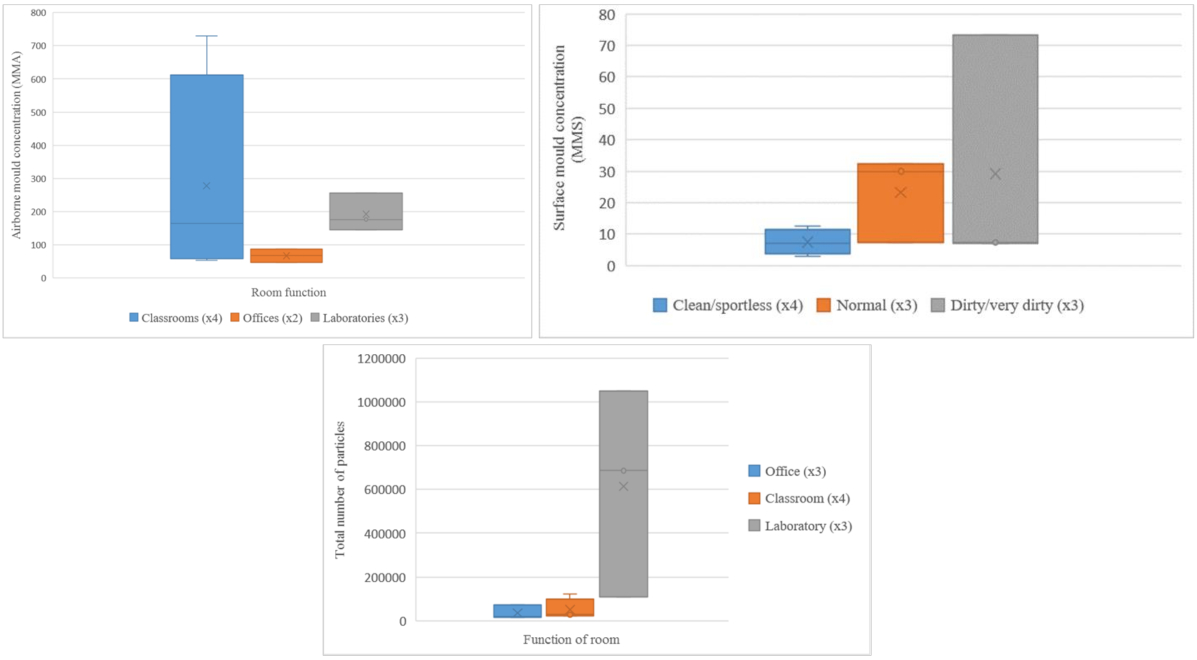


Figure 4: (a) airborne mould concentration vs. room function, (b) average dirty surface mould concentration vs level of cleanliness, (c) particle counts vs room function

In order to better evaluate the obtained results, UCL Estates was contacted to take information about their cleaning and maintenance programme. We learnt that the Chadwick Building and other UCL buildings were cleaned "as required", and did not have a regular cleaning schedule. This explains the high surface values obtained from skirting boards, cable trays and windows, which are often ignored during cleaning.

4. Conclusions

The testing results show that none of the tested rooms in the Chadwick building is under heavy mould attack. However, G07 requires attention due to its high airborne mould concentration and dirty surface mould concentrations, and it requires improvements in its cleaning. The tested laboratories may need refurbishment on some parts of their walls, and the fresh water damage needs to be remediated. Furthermore, the B15 Concrete Lab was detected to have mould existence on the water damaged wall corner, which needs to be examined.

Our study shows that air testing and surface testing should be combined for a robust methodology that is able to detect localised problems.

In this study, we were unable to find clear and strong correlations between the measured NAHA activity and the physical characteristics of the tested spaces, due to limited data. More similar testing activities in the future should increase the amount of data to study such correlations. Further, future research should focus on benchmarking problematic mould levels for historic and modern schools and workplaces for a better understanding of the background mould levels, as the benchmark values that we currently have were developed for residential properties.

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