What defines "*Moisture in Buildings*"? The growth of xerophilic fungi in museum repositories challenges the perception of humid buildings and the preservation of cultural heritage

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Abstract

In the last decade, fungal infestations have emerged in Danish museum repositories challenging cultural heritage preservation. The growth is unexpected as the relative humidity in most repositories is controlled according to the international guidelines for heritage collections. This pilot study examined three museum repositories with the aim to enlighten inexplicable fungal infestations. The study showed growth of *A. halophilicus*, *A. domesticus*, *A. vitricola* and *A. magnivesiculatus*; four xerophilic fungi which are able to grow on substrates with low water activity and may be associated with a revision of the environmental guidelines for heritage collections. Larger studies of the prevalence of xerophilic fungi can give a more comprehensive understanding of the causative factors and improve preventive conservation of heritage collections.

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Introduction/Background

Within the last decade, fungal infestations have emerged in Danish museum repositories challenging museum staff's health and heritage preservation [1]. The growth is unexpected since the relative humidity (RH) in most repositories is controlled according to environmental guidelines for preserving cultural heritage [2]. When fungal growth occurs inexplicably, it challenges our perception of "moisture in buildings" and questions the guidelines for environmental conditions in heritage collections.

Specifications for the environmental conditions preserving heritage collections for posterity have been discussed among conservation scientist for more than 30 years. The consensus has been to keep RH and temperature (T) within strictly controlled setpoint values 20-21±2°C and 50±5% RH [3]. In the last decade, the increasing awareness of the global climate changes and human contribution to CO₂ emissions have led to initiatives to revise the strict setpoint values. An agreement has been reached on 15-25°C and 40-60% RH [2-3]. The revised environmental guidelines provide more sustainable storage of heritage collections by reducing energy consumption and the carbon footprint. The revision should, in theory, not increase the risk of fungal growth in heritage collections, as the borderline for growth is defined to 70% RH [4]. However, it is not well researched whether the revision increases the risk of fungal growth in heritage collections.

This pilot study examined indoor fungal occurrence in three Danish museum repositories to determine the fungal species growing on museum artefacts and the species presented in the dust on surfaces. The three repositories were located in heavily insulated buildings. The museums controlled the environmental conditions with HVAC systems keeping RH fluctuating within 51-64% and T 12-19°C on an annual basis. Surface temperature and material moisture content were monitored as a part of the preventive conservation strategies showing no microclimate evidence. The fungal growth was solely on the heritage artefacts located on shelvings at a distance of outer walls and other cold surfaces. There was no fungal growth on the interior and building structures. The pilot study aimed to enlighten inexplicable fungal growth in apparently healthy museum repositories climate-controlled according to the international environmental guidelines for heritage collections.

Materials and methods

The indoor fungal composition was examined with air and surface sampling followed by incubation and morphological identification in addition to DNA sequencing of fungal isolates. The air sampling was conducted by MAS 100 ECO on V8-agar, DG18-agar and MY50G-agar after air circulation making the deposited dust on surfaces airborne [5]. In parallel, outdoor air samples were taken as reference. The V8 and DG18 agars were incubated for seven days at 25°C in darkness. The MY50G agars were incubated 14 days at 25°C in darkness. The appearing colonies were streak inoculated and incubated for isolation with three-point inoculation. The fungal species were identified visually at 40 and 400x magnification. The surface sampling was conducted from fungal colonies on nine heritage artefacts manufactured in wood, leather and cast iron with sterile rayon swabs (Sarstedt tube applicator) and inoculated on V8-agar, DG18-agar, and MY50G-agar, incubated, streak-inoculated, three-point inoculated for isolation and identified with the same methods as the air samples. The morphological ID of the fungal isolates was confirmed by DNA sequencing. DNA from isolates were purified (Fast DNA Spin Kit for Soil). PCR amplification of fungal DNA regions was conducted with a Taq DNA Polymerase Kit according to the manufacturer's manual calmodulin primers (cdm5/cdm6) to obtain a good separation of xerophilic species (Sklenář et al., 2017). DNA fragments were sequenced using a BigDye Terminator v.1.1 Cycle Sequencing Kit and by the use of a SeqStudio Genetic Analyser from Applied Biosystems. The sequences obtained were analysed using the EMBL-EBI homepage BLAST service (ebi.ac.uk).

Results

The DNA sequencing of isolates from fungal growth on museum artefacts showed 100 % identity with *A. halophilicus*, *A. domesticus*, *A. vitricola* and *A. magnivesiculatus*. *A. halophilicus* gave rise to growth at all examined museums, while *A. domesticus*, *A. vitricola* and *A. magnivesiculatus* gave rise to growth in one museum. Figure 1 shows the fungal species in air samples by the number of museums positive for the species. The xerophilic species were both present in the air and on surfaces (orange bars). Expect for xerophilic fungi, none of the species present in the air gave rise to growth. The outdoor samples showed outdoor fungal species; the only overlap with the indoor species was *Cladosporium sp.* and *Alternaria sp.*

Fig. 1. Fungal species in air-samples by number of museums positive for the species. The species marked with orange were both present in air and growing on artefacts.

Discussion

This study showed growth of *A. halophilicus*, *A. domesticus*, *A. magnivesiculatus*, and *A. vitricola* on artefacts in three climate-controlled museum repositories. It also showed an overlap of species in the three museums and that air samples detected more species than surface samples from artefacts. The airborne fungi were primarily species commonly found indoor [6], however, the fungi growing on the artefacts were also found in air-samples. It was remarkable that the species growing on the artefacts were all xerophilic fungi from *Aspergillus* section *Restricti* preferring substrates with a low water activity (a_w) [7]. When fungi can grow at low a_w , it is equivalent to growth at low RH, and climate-controlled museum repositories may provide this environment.

An ever-present joker, when working with fungi, is that you find what you are looking for. When fungal infested museums are examined, the dominating methods used are the same as in domestic environments [8]. In housing, fungal growth is primarily caused by damp environments or water damages, which is a very different premise than climate-controlled museum repositories. In this study, an agar with a low a_w (MY50G) was included, making it possible to isolate and identify the xerophilic fungi. If this agar was not included, the results would be different, and the xerophilic fungi would have been non-detected.

The study documented the growth of xerophilic fungi but did not clarify the cause. The three museums were striving to comply with the international environmental guidelines for heritage collections and have been storing museum artefacts for more than a decade without fungal growth in the repositories. Based on monitoring the environmental conditions, it was not surprising that solely xerophilic fungi were causing the growth. The conditions were not lucrative for the growth of common indoor fungi.

Fungal infestations in Danish museum repositories have increased during the last decade. In the same period, global climate changes have caused more and heavier precipitation in Denmark. Besides, a revision of the environmental guidelines for heritage collections has been implemented with an increased acceptable level with up to RH 60%. The fungal infestations in Danish museum repositories could indicate that these circumstances increase the risk of fungal growth in heritage collections.

Conclusion

The study revealing the growth of xerophilic fungi on the museum artefacts in three climate-controlled museum repositories, indicating that the environmental guidelines for heritage collections do not adequately address the risk of fungal growth. There is a need for larger studies examining the prevalence of xerophilic fungi in Danish museum repositories and the local conditions within each museum repository regarding RH, T, MC and a_w . A more comprehensive understanding of the causative factors may enable a more targeted climate-control in the preventive conservation strategies ensuring the cultural heritage preservation.

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