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# Risk of biodeterioration of cultural heritage objects, stored in the historical and modern repositories in the Regional Museum in Rzeszow (Poland). A case study

D. Grabek-Lejko [a], A. Tekiela [b], I. Kasprzyk [c, *]

[a] University of Rzeszow, Department of Biotechnology and Microbiology, 4 Zelwerowicza St., 35-601 Rzeszow, Poland
[b] University of Rzeszow, Department of Agroecology, 1A Cwiklinskiej St., 35-601 Rzeszow, Poland
[c] University of Rzeszow, Department of Ecology and Environmental Biology, 4 Zelwerowicza St., 35-601 Rzeszow, Poland

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ABSTRACT

Museum artefacts are generally stored for a long period in repositories and are prone to microbiological colonisation. The goal of this research was to assess the risk of biodeterioration of artefacts stored in the Regional Museum in Rzeszow, Poland. The museum building consists of the historic and newly built parts and the aim was to verify the hypothesis about higher airborne concentrations of microorganisms in the historic part. In all repositories, the number of bacterial colonies was higher than those of fungi. The most polluted depots were those where different types of artefacts were stored. There were no differences in the number of fungal colonies in the repositories located in the historic and modern parts of the museum. The differences concerned only bacteria. The most common fungi were *Penicillium expansum* and *Penicillium spp*., while among bacteria *Micrococcus luteus/lylae* and *Staphylococcus warneri*. The highest microorganism biodiversity was in the historical depots and the lowest in the room with a book collection in the modern part of the museum. Findings showed that the microbial biota is not specific for either building type or the kind of artefact. Regarding bacteria, we detected the effect of '*historical building air*'.



## 1. Introduction

A museum is an institution established to collect, study, and deal with the restoration of cultural heritage objects that have some historical or artistic value. The overarching issue is their protection from mechanical and biological damage (Czop, 2013; Fic-Lazar, 2013; Sterflinger and Pinar, 2013; Abe and Murata, 2014). There is a view that microbiological contamination of museums and objects of cultural heritage stored there is frequent. Most artefacts are of organic origin, which favours colonisation by bacteria and fungi. These organisms produce many types of exoenzymes decomposing organic matter (Pangallo et al., 2007, 2009; Sterflinger, 2010; Kavkler et al., 2015). They have a high tolerance for unfavourable conditions, such as extremal values of temperature, humidity or pH, and therefore they can survive for decades. To protect cultural heritage objects against biodeterioration, continuous monitoring of microclimate parameters and microbiological contamination of air and artefacts is necessary (Pasquarella et al., 2012; Sterflinger and Pinar, 2013; Abe and Murata, 2014). The most common methods that allow us to assess the risk of microbiological contamination of indoor air are volumetric viable and non-viable methods (Gallo et al., 2003; Fernández-Rodríguez et al., 2011; Pasquarella et al., 2011). Molecular detection has been recently used, but it is expensive and time consuming (Kraková et al., 2012, 2017; López-Miras et al., 2013). A good alternative, used in present study, is the automated system of microorganism identification - VITEK 2 based on biochemical tests (Książczyk et al., 2016). Vitek 2 gives over above 95% of compatibility with the genotyping (Nakasone et al., 2007; Monteiro et al., 2016). The risk of biodeterioration can be assessed by monitoring the concentration of ergosterol, which is an indicator of fungal contamination in indoor air (Skóra et al., 2015). The microbial biota of exhibits can be detected by enzymatic methods (activity of enzymes, e.g. esterase and lipase), and also by the spectroscopic method (López-Miras et al., 2013).

Most cultural heritage objects in museums are kept for a long time in depositories and are occasionally exhibited. The

* Corresponding author.
*E-mail address:* idalia@univ.rzeszow.pl (I. Kasprzyk).

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repositories should provide good quality and long-lasting protection for artefacts. The repositories have different fittings, configurations, size, kind of furniture, microclimate, and building materials (Gallo et al., 2003; Pasquariello and Maggi, 2003; Fic-Lazar, 2013). It is important that aerosanitary conditions in repository rooms meet required standards to protect exhibits against colonisation by bacteria and fungi and reduce as much as possible the risk of their colonisation by microorganisms. The depots should be adequately monitored in this respect (Abe, 2010; Czop, 2013; Abe and Murata, 2014). Air quality is also crucial for museum workers who spend a lot of time in storage rooms and could be exposed to dangerous airborne particles and bioaerosols such as toxins (Wiszniewska et al., 2009).

The spectrum of microorganisms and their concentrations differ in repositories and exhibition areas as well as outdoor. The most dominant outdoor airborne fungal spores are *Cladosporium, Penicilium, Aspergillus*, and yeasts (Stępalska et al., 1999). Their concentrations are characterised by seasonality with a maximum during the peak growing season and a minimum or the lack of spores in the air in winter (Kasprzyk et al., 2004). Indoor air only partially reflects airborne outdoor microorganisms and seasonality is less pronounced (Kruczek, 2014). Among fungi, the most dominant are *Penicilium* and *Aspergillus* conidia, whereas ascospores and basidiospores rarely occur. Indoor air also contains Gram-positive cocci like different species of *Staphylococcus, Micrococcus* as well as Gram-negative *Pseudomonas* (Harkawy et al., 2011; Skóra et al., 2015). In *'unhealthy'* rooms, the qualitative and quantitative spectrum of microorganisms is quite different (Cabral, 2010). Museum objects kept in repositories are especially prone to colonisation by microorganisms. Materials of organic origin, which they are usually made of, are a good medium for fungal and bacterial growth (Harkawy et al., 2011; Hempel et al., 2014; Scarlat et al., 2015). Textiles of plant and animal origin (e.g. flax and wool, respectively), organic glues, paint, wood, parchment, paper and ceramics, are destroyed by enzymes produced by them. The results are loss of material, discolouration, spots, changes or loss of strength, smell, crushing, and cracking (Sterflinger, 2010; Kavkler et al., 2015). The most common causes of biodeterioration are fungi such as *Stachybotris chartarum, Penicillium chrysogenum, Alternaria alternata, Aspergillus versicolour, Penicillium aurantiogriseum, P. expansum, Trichoderma viride, Chaetomium* spp., *Ulocladiu.* spp., *Aureobasidium* spp., as well as bacteria: *Micrococcus, Bacillus, Clostridium, Streptomyces, Staphylococcus, Aerobacter*, Actinomyces (Harkawy et al., 2011; Gutarowska et al., 2015).

The goal of this research was to assess the risk of microbiological colonisation of cultural heritage objects stored in the Regional Museum in Rzeszow. To realise this aim, the bacterial and fungal contamination of indoor air was monitored in the depositories with various kinds of artefacts. We considered whether the older building has its own *'historic climate'* that influences the concentration of airborne microorganisms. The research was planned in such a way that the same type of exhibit (e.g. paintings, books) was warehoused in the repositories located both in the historic and modern parts of the museum under the study. It allowed us to verify the working hypothesis of the diverse composition of bacteria and fungi depending on the age of the depots, with the higher concentrations and biotic diversity in the older one.

## 2. Materials and methods

### 2.1. Characteristics of the study site

The research was carried out in the Regional Museum in Rzeszow, SE Poland in January 2016 during a working day. Winter is a suitable season to investigate indoor air because the influence of outdoor microorganism contamination is reduced. The museum is located in the centre of the old town (50°03′N; 22°00′E). Its main part (exhibition areas, several repositories) is housed in a 17 th century monastery complex. In the early 1950s, the monastery was intended for the museum. In the 1960's, the museum was enlarged and in the new building there are administration offices, several repositories and the conservation laboratory specialising in the conservation of paintings, furniture, leather and paper. Both parts do not have a central air conditioning system. Museum rooms as well as most of the artefacts were never disinfected. In the book collection, there are about 1800 pieces, including 700 old prints. Paintings are from the seventeenth century to the present. The museum objects are stored regardless of the age of origin. Microbiological contamination was examined in the repositories located in two parts of the building: the historic and modern buildings indicated later as H and M, respectively. The investigations were carried out in the depots with different types of exhibits: books (B), paintings (Pa, Pb), weapons (W), graphics (G), and historical artefacts (H). The office room (O) was analysed as the internal control and outside air as the external control. In total, the study was conducted in 11 rooms and outdoors, close to the museum.

### 2.2. Sampling of air

To realise the aims of the study, a non-destructive method was applied. 50 l and 100 l samples of air were collected using portable equipment - AESAP 1075 Saimpl'air Lite. The air was sucked onto Petri dishes with a diameter of 90 mm containing appropriate media. Fungi were incubated on PDA medium. It is a good medium to culture conidial fungi. To determine the total bacterial number two media were used: TSA medium (Tryptic Soy Agar, Biocorp, Poland) with nystatin to avoid fungal growth and also Mannitol Salt Agar (BTL, Poland) for determining *Staphylococcus* strains. Air sampling was done at a height of 1 m above floor level in the central place of the rooms in three replications on each medium. All samples were incubated at the following temperature: bacteria – 1 day at 37 °C, followed by 2 day at 22 °C, and fungi – 5 days at 30 °C. After the incubation, the viable microbial concentrations in the air were calculated as colony forming units per 1 $m^3$ ($CFU/m^3$). The final results are presented as the arithmetic mean of all replications.

### 2.3. Identification of microorganisms

Isolated fungi were serially diluted to achieve homogeneous colonies under laminar chamber. Fungal isolates were identified on the base macro- and micro-morphological features. Colonies were compared with reference materials, photos and taxonomical keys (e.g. Barnett and Hunter, 1998; Macura, 2008). All isolated bacterial colonies were macroscopically and microscopically characterised using Gram-staining, catalase and oxidase tests. All isolates were identified using the automated system of microorganism identification - VITEK 2 Compact system (Biomerieux, Germany) based on analysis of a panel of biochemical tests (64). Its accuracy of identification is comparable with molecular detection (Monteiro et al., 2016). For this purpose, bacteria were cultured on TSA agar medium (Biocorp, Poland) and incubated for 18–24 h at 37 °C. Subsequently, a bacterial suspension was adjusted to a McFarland standard of 0.50 in a solution of 0.45% sodium chloride using DensiChek Plus Meter (Biomerieux). The time interval between preparation of the solution and filling of the card was always less than 1hr. Taxonomical identification was done using appropriate cards for Gram-positive and Gram-negative bacteria. Cards were automatically read every 15 min. Data were analysed using the VITEK 2 software in accordance with the manufacturer's instructions (bioMerieux, 2016 February 01).