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ANNA LENART-BOROŃ[1], *MAGDALENA WIĘCKOWSKA*[1], *JOLANTA POLLESCH*[2]

[1] University of Agriculture, Department of Microbiology, Kraków
[2] Collegium Maius Jagiellonian University Museum, Department of Conservation, Kraków

Microbiological contamination in the selected premises of the Jagiellonian University Museum

ABSTRACT

This study was aimed to assess the seasonal variability of microbial aerosol concentrations in the Jagiellonian University Museum and the fungal contamination of the selected exhibits shown or stored in the JUM. The air contamination analysis was conducted four times per year by air collision method. The concentrations of mesophilic bacteria, mold fungi, actinomycetes and staphylococci were examined in the magazine of exhibits in the attic, at the Olszewski Hall (exposure), in the wooden frames magazine in the basement and the Museum cafe. External background was the Professors' Garden. In the study sites air temperature was measured during each sampling. The surface contamination of the Museum exhibits was examined by the collection of swabs. Seasonal differences in the concentration of the analyzed microorganisms were observed: the concentration of all microbial groups – except fungi – was the highest in summer, when the temperature in all tested sites was the highest. On the other hand, the highest concentrations of fungi in the tested premises were observed in autumn and spring. The smallest levels of mesophilic bacteria and staphylococci were observed in winter, while the smallest amounts of actinomycetes were found in spring and autumn. The smallest concentrations of fungi in all examined sites occurred in spring. The concentrations of the analyzed microorganisms did not exceed the limit values, except in one case – i.e. actinomycetes in the Museum cafe in summer. The surfaces of the exhibits were colonized by fungal strains that can be potentially dangerous to human health or cause biodeterioration, but only one object (the Wyspiański painting) was damaged by a harmful strain of *Penicillium italicum*. Other objects showed no losses due to microbial degradation, which proves effective conservation and lack of optimum conditions for fungal colonization. We also found a relationship between the concentration of microbial aerosol and the conditions in the studied sites, and therefore the season of the year. Also the type and utility character of the premises determined the bioaerosol concentrations. However,

the observed concentrations of airborne microorganisms do not pose a direct threat to the Museum employees or its visitors.

Keywords: microbiological aerosol, seasonal differences, bacteria, molds, actinomycetes, staphylococci

Introduction

Bioaerosol-forming microorganisms in museum premises are not only among the most important risk factors for health of the museum employees and tourists, but they can contribute to the biodeterioration of cultural heritage relics (Niesler et al. 2010; Zielińska-Jankiewicz et al. 2008). Biodeterioration is widely known as one of the major threats to the museum exhibits, since the combination of sufficient moisture and nutrient content in the art materials can provide conditions allowing microorganisms to damage the objects (Strzelczyk 2004). The decomposition mechanism and degree mainly depends on the object's material , so due to the fact that many museum exhibits or their elements are made of organic materials, they are particularly sensitive to the processes of biodeterioration (Niesler et al. 2010). Moreover, such collections are often located in old historical buildings, where the environmental conditions are appropriate for the growth of microorganisms (Valentin 2003). Also small nutritional requirements, as well as the ability to spread and reproduce easily are the most important characteristics of microorganisms that allow them to colonize almost all environments, including historical objects (Gutarowska et al. 2010).

It was shown that in non-industrial indoor environments humans are the major source of airborne bacteria (Stetzenbach 1997). In museum premises microorganisms can be introduced by both employees and visitors or with outdoor air through open doors and windows (Niesler et al. 2010). Another factor of microbial transmission in such types of rooms can be incorrectly operating air-conditioning systems (Camuffo et al. 2001).

It was shown in previous studies that museums, libraries and archives are characterized by high concentrations of microbial aerosol (Zielińska-Jankiewicz et al. 2008; Skóra et al. 2012). Studies on the exposure of the museum workers to biological agents show that this professional group can be at risk of allergies or respiratory tract diseases, among others due to the contact with organic dust containing toxigenic species of molds (Kolmodin-Hedman et al. 1986). Wiszniewska et al. (2009) found that 85% of art conservators reported allergic symptoms while 34.5% of them could link intensification of these symptoms with workplace exposure to filamentous fungi.

In view of the above, this study was undertaken to evaluate the seasonal differences in the concentration of microbial aerosol components in various premises of the Jagiellonian University Museum and the fungal contamination of the selected exhibits shown or stored in the Museum. The analyzed rooms are of different character, what affects the number of their visitors (tourists or only museum workers). The concentration of fungal aerosol and prevailing environmental conditions may also influence the level of fungal

contamination and/or biodeterioration of the exhibits which are shown or stored in the examined premises of the Museum.

Material and Methods

The air sampling was conducted in 5 sites of the Jagiellonian University Museum (Tab.1, Fig. I). The samples were collected four times per year, once in each season, i.e. March (spring), August (summer), November (autumn) and December (winter) 2015.

Table 1. Study sites and the recorded temperatures during sampling

Season / Site	Spring (March)	Summer (August)	Autumn (November)	Winter (December)
Magazine of exhibits in the attic	19.2	22.3	10.3	7.0
Exposition – Olszewski Hall	22.5	23.3	16.0	17.3
Magazine of wooden frames in the basement	21.7	23.2	26.0	22.0
Cafe of the Jagiellonian University Museum	21.8	21.0	19.5	19.0
Professors' Garden (background)	21.8	25.0	10.0	3.0

The samples were collected using a MAS-100 air sampler (Merck, Switzerland) and the volume of collected air was 100 L. During measurements the air sampler was placed at a height of c.a. 1.5 m above the ground to simulate the aspiration from the human breathing zone and the samples were collected on Petri dishes with proper media to enumerate mesophilic bacteria (Trypticase Soy Agar – Biocorp, Poland; culture at 36±1°C for 48 h), mold fungi (Malt Extract Agar – Biocorp 24°C for 3–5 days), actinomycetes (Gauze medium, 24°C for 7 days) and staphylococci (Chapman agar – Biocorp, 36±1°C for 48 h). All measurements were conducted in triplicates and the data are presented as means from the replicates. After incubation, the number of colonies characteristic for different microbial groups were counted and expressed as colony forming units per cubic meter of air (CFU/m^3). The actual colony count per each culture plate was corrected according to the positive hole correction table (Operator's manual MAS-100).

Objects which are exhibited or stored in the analyzed premises were selected for the analysis of their colonization of potentially harmful fungi. Swabs were collected from the surface of 27 objects located in the magazine of exhibits in the attic, magazine of the wooden frames in the basement, conservation workshop, Olszewski Hall exhibition and in the Professors' Garden (Fig. II). The swabs were inoculated on the surface of malt agar and after c.a. 5 days of culture at 24°C the grown fugal colonies were counted, subcultured and their species were identified after comparing the microscopic preparations and

culture characteristics with diagnostic manuals (Krzyściak et al. 2011; Samson, Frisvad 2004; Klich 2002).

Statistical analysis of data was performed using Statistica v. 12 (StatSoft, USA). Basic descriptive statistics were calculated and a one-way ANOVA test was conducted to verify the significance of differences in the microbial concentrations between the analyzed study sites and seasons of the year.

Results and discussion

The mean concentrations of the analyzed microorganisms in different seasons and premises are shown in Table 2. The number of mesophilic bacteria ranges between 0 and 210 CFU/m^3, depending on the sampling site and season of the year. The highest concentration of these microorganisms was observed in the Professors' garden in summer, when generally the bacterial levels were the highest. In the winter in the attic magazine and the Professors' garden the air was the cleanest, i.e. no bacteria were isolated. The highest concentration of staphylococci – 180 CFU/m^3 was detected in summer in the Museum cafe. Bacteria from this group were not isolated in autumn and winter in the attic and in the Professors' garden. The concentration of mold fungi in the air of the examined sites ranged from 50 CFU/m^3 in the Olszewski Hall in spring to 1,250 in summer in the Professors' garden. The obtained values were compared to the limits given in Polish Standards PN-89/Z-04/04111/02 and PN-89/Z-04/04111/03 and to the proposed limit values given by the Team of Experts on the Biological Factors on the acceptable concentrations of microbiological factors in atmospheric air, working areas contaminated with organic dust and in living spaces and public premises (Gąska-Jędruch, Dudzińska 2009). It was shown that the value of the concentration of actinomycetes (Jagiellonian University cafe in summer) exceeded the acceptable concentration (bolded value in Table 2). The remaining values allowed to classify the air in the studied premises as clean or moderately clean. The proposition of the Team of Experts (2009) does not specify the limit value for the concentration of airborne staphylococci. Therefore, it can be stated that the single value obtained in the Professor's garden in spring (i.e. 80 CFU/m^3) exceeded the limit given in the Polish Standard.

The results obtained for different seasons of the year were averaged and shown in Figure III. The highest concentration of all airborne microorganisms occurred in summer. This was probably due to atmospheric conditions prevailing at the day of the measurement – sunny and dry weather, as well as high air temperature in the period before the measurement. This is because during rain the microorganisms fall to the ground with the rain drops, therefore long-lasting lack of precipitation may increase the concentration of microorganisms in the atmospheric air. Also high temperatures, typical of the summer season, create favorable conditions for the growth and proliferation of microorganisms (Paluch 1972).

Table 2. Mean concentration of airborne microorganisms (CFU/m^3)

Sampling site / Season	1	2	3	4	5
Mesophilic bacteria					
Spring	90	70	90	110	80
Summer	90	100	120	200	210
Autumn	10	100	40	140	10
Winter	0	20	10	30	0
Staphylococcus spp.					
Spring	40	20	20	10	**80**
Summer	50	100	50	180	40
Autumn	20	40	40	70	0
Winter	0	10	10	30	0
Mold fungi					
Spring	110	50	90	80	55
Summer	140	120	190	240	1250
Autumn	470	60	180	400	540
Winter	310	210	210	170	290
Actinomycetes					
Spring	25	20	80	15	15
Summer	80	80	160	**230**	140
Autumn	6	25	0	30	15
Winter	20	65	20	15	25

Mean concentrations of airborne microorganisms, shown in Figure IV, demonstrate that the highest concentrations of mesophilic bacteria and staphylococci were observed in the Museum cafe. This might be the result of the character of this site, which is most probably the most frequently visited by both the Collegium Maius employees and the Museum tourists. On the other hand, small levels of airborne microorganisms were observed in the two rarely visited sites, i.e. the attic and the basement. Issues related to microbiological contamination of air in public premises and workplaces are of great interest, mostly because of the related threats. Contact with air containing fungal spores or bacterial cells and toxins might cause allergies as well as infections of upper and lower respiratory tract or asthma (Grinshpun et al. 1997).

Analysis of variance showed that the differences in the microbial concentrations between the seasons of the year are statistically significant (p<0.05) for staphylococci (F= 4.74) and mold fungi (F=5.99). The differences are not significant for mesophilic bacteria (F=2.39) and actinomycetes (F=0.24). In the case of the test conducted for the locations, the differences were significant (p<0.05) for mesophilic bacteria (F=4.17) and staphylococci (F=6.34) and not significant for actinomycetes (F=0.35) and molds (F=1.12).

Table 3. Fungal species isolated from the surfaces of the Museum exhibits

No.	Object description	Location	CFU	Identified fungus
1	Wyspiański painting – wooden frame	Olszaewski Hall, exhibition	1	*Penicillium italicum*
2	Stained glass painting (19th century)	Magazine in the attic	1	*Penicillium melanoconidium*
6	Picture frame – wood	Magazine in the basement	1	*Penicillium italicum*
7	Sculpture – stone	Professors' garden	24	*Alternaria* spp.; *Cladosporium cladosporioides*; *Verticillium* spp.
8	Gypsum cast	Conservation workshop	8	*Penicillium paneum*
9	Piece of Coptic fabric	Conservation workshop		*Ulocladium* spp.
10	Negative picture	Conservation workshop	3	*Penicillium paneum*
11	Negative picture	Conservation workshop	2	*Penicillium italicum*
12	Telescope enclosure – leather	Exhibition	6	*Penicillium italicum*; *Cladosporium cladosporioides*
13	Sculpture – wood	Ehxibition	4	*Trichophyton* spp.; *Cladosporium herbarum*

Twenty-seven objects were analyzed in this study, but only 13 (Tab. 3) were colonized by filamentous fungi and one (Wyspiański painting) was visibly damaged by a fungus from the *Penicillium italicum* species (Tab. 3, Fig. V). *Penicillium* and *Cladosporium* were the most frequently isolated fungal genera. According to Gutarowska et al. (2010), species from these genera are among the indicator microorganisms for the workplace exposure in museums, as e.g. *P. italicum* or *P. paneum* (or other species such as *P. digitatum*, *P. polonicum*) can produce mycotoxins, while *C. herbarum* cause different types of inhalant allergies. One of the pieces of Coptic fabrics was colonized by the fungus *Ulocladium* spp., whose growth is characteristic of textiles, paper and wood. It is also recognized as one of the contaminants of clinical materials and can very rarely be the cause of human diseases (Krzyściak et al. 2011).

Conclusions

The concentration of airborne microflora was significantly related to the season of the year and the prevailing atmospheric conditions. Also the type of the room and its utility character (and therefore the frequency of visits to the studied rooms) affected the bioaerosol concentration. The observed concentrations of microbial aerosol components did not exceed the Polish limit values, suggesting that the quality of air in the analyzed sites does not pose a threat either to the museum employees, or its visitors.

The surface of some of the examined museum exhibits was colonized by mold fungi, which however in many cases was not related to the degradation of the material. On the other hand, many of the isolated fungal species can be harmful to the human health, as they can cause respiratory tract infections or allergies. Lack of visible signs of deterioration of the Museum exhibits indicate the proper conservation of the objects and lack of optimal conditions for the growth of harmful microorganisms.

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