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THE MICROBIOLOGICAL AIR QUALITY IN THE ST. BENEDICT CHURCH IN CRACOW

Abstract

The purpose of the study was to characterize the microbiological quality of air in the St. Benedict church in Cracow. The study was carried out during the spring season in 2016. Air samples were collected in triplicate at two points in the building (inside the church and the archaeological excavation) and at the one point outside the building. The air samples were collected using a 6-stage Andersen impactor. During sampling, the air temperature, relative humidity and dustiness were measured.

The results showed that the bacterial aerosol concentrations in the measuring points ranged from 455 cfu·m^{-3} to 1185 cfu·m^{-3} and the fungal aerosol concentrations in the measuring points ranged from 124 cfu·m^{-3} to 500 cfu·m^{-3}. The lowest concentrations of bacterial and fungal aerosol were observed in the outdoor air and the highest concentrations were observed in archaeological excavation point. There were no significant differences in the bacterial and fungal aerosol concentrations between the measuring points ($p>0.05$). There was no correlation between the concentration of bacterial aerosol and temperature, relative humidity and dust in the air ($p>0.05$) and there was no correlation between the concentration of fungal aerosol and ralative humidity and dust ($p>0.05$). The analysis showed a significant correlation between the concentration of fungal aerosol and temperature ($R=-0.84$, $p<0.05$). Bioaerosol concentrations obtained in this study are lower than reference values for bacteria and fungi in residential and public buildings (5000 cfu/m^3) recommended by the Panel of Experts of Biological Factors.
Keywords: *bacteria, fungi, bioaerosol, church.*

Introduction. Gothic church of St. Benedict is the smallest and one of the oldest churches in Cracow. The first archaeological research at St. Benedict on Lasota Hill were carried out in 1956. During these studies the walls of the pre-Romanesque rotunda were discovered, but archaeologists didn't know how to properly interpret that discovery or pair it with early period. The next research was carried out in 1962. The result of this work was the discovery of a Romanesque church and the pre-Romanesque rotunda under the church. The younger church was dated to the second half of the twelfth century (a single nave form, slightly trapezoidal; the presbytery with a shape similar to a square) and the older church was dated to the second half of the twentieth century or to the beginning of the eleventh century – it was building with a simple rotunda with a circular nave. Outside, on the western side, relics of the walls combined with the rotunda on the continuation in a westerly direction were discovered. The present research, begun in July 2014, made it possible to verify the earlier findings. The research confirmed the existence of pre-Romanesque building (but with a slightly revised plan and dimensions) built of sandstone blocks connected only with gypsum mortar and formed later the quadrangular church, slightly trapezoidal nave and presbytery with a shape similar to a square, but constructed of a different material and a different technique than proclaimed the study in 1962. Building material is not small cube limestone, but the tiles and blocks of sedimentary sandstone combined with lime mortar. During the archaeological research, many skeletal graves were discovered outside and inside the chuch [Skulski 1955, Żaki 1959, Zin i Grabski 1965, Zin i Grabski 1966].

The religious buildings of this type can be associated with microbial contamination of air [Żegota 1996, Zyska 1999, Papciak i Zamorska 2007]. Type of used building materials and specific climate conditions can affect the concentrations of microorganisms in the air [Rybczyńska i Miczyński 2008]. A major problem associated with health care are bacteria and fungi present in the air. These microorganisms can cause infections, immunotoxicity and allergy [2003 Karwowska, Jung et al. 2009]. The effect of the disease, created as a result of inhalation of different molecules in the air, depends on their size, chemical composition, microbiological properties and deposition in the respiratory tract [Frączek and Grzyb 2010]. The threat to human health from harmful microbiological agents is large and is not necessarily confined to pathogenic organisms [Górny 2010]. Considering this situation, the aim of this study was to characterize the microbiological quality of air in the St. Benedict church in Cracow.

Material and methods. The study was carried out during the spring season in 2016. Air samples were collected in triplicate at two points in the building (inside the church and the archaeological excavation) and at the one point outside the building, during archaeological work. The air samples were collected using a 6-stage Andersen impactor (model 10-710, Graseby-Andersen, Inc., Atlanta, GA, USA). The sampler was placed at a height of 1.5 m above the floor or ground (outdoor measurement) level to simulate aspiration from the human breathing zone. A 5-minute sampling period and the flow rate of 28.3 dm^3·min^{-1} were applied for the collection the air samples. The bacteria were collected on tryptic soy agar (TSA LAB-AGAR™, Biocorp) and the fungi were collected on malt agar (Malt Extract Agar, Biocorp). During sampling, the air temperature and relative humidity were measured using hygrometer Kestrel 4000 and dustiness was measured using dust analyzer DustTrak II (model 8530, TSI Inc., Shoreview, MN, USA).

The TSA plates were incubated for 1 hour at 37°C, then 3 days at 22°C and another 3 days at 4°C. The MEA plates were incubated for 4 days at 30°C, then 4 days at 22°C. After incubation, the colony of microorganisms were counted. The concentration of bioaerosol was calculated as the number of colony forming units per cubic meter of air (cfu·m^{-3}). The results were statistically analyzed using Statistica 12 (StatSoft, Inc., Tulsa, OK, USA). The analysis of variance (ANOVA) was calculated and the significance of differences between means was verified by Tukey's test (α=0.05). Results of the effect of microclimatic parameters (temperature and relative humidity) on the quantitative presence of microorganisms in the air were evaluated using the "r" coefficient of the Pearson's correlation.

Results and discussion. The concentration of bacterial and fungal aerosol are presented in table 1. The results showed that the highest concentration of bacterial and fungal aerosol occurs in archaeological excavation measuring point (1185 cfu·m^{-3} and 500 cfu·m^{-3}) and the lowest concentration of bacteria and fungi occurs in outdoor air (455 cfu·m^{-3} and 124 cfu·m^{-3}). The analysis showed non-significant differences in the concentrations of bacterial and fungal aerosols between the measuring points (p>0.05). Bioaerosol concentrations obtained in this study were lower than reference values for bacteria and fungi in residential and public buildings (5000 cfu·m^{-3}) recommended by the Panel of Experts of Biological Factors [Górny 2010].

Table 1

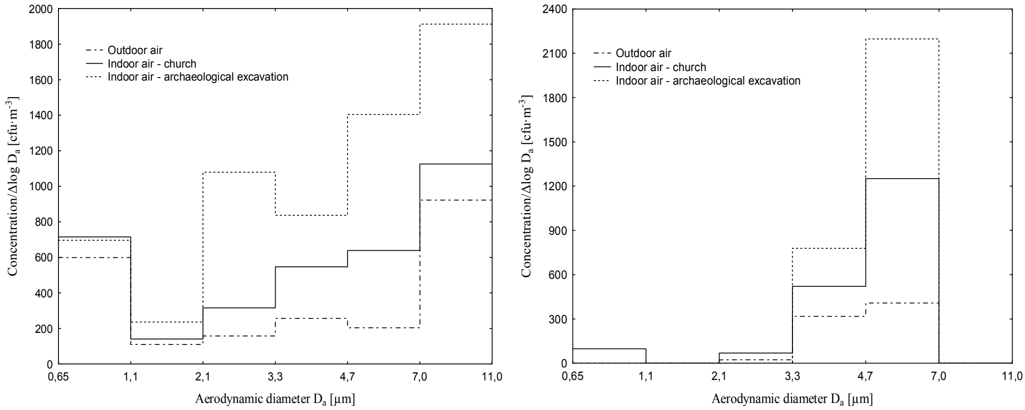
Concentration of bacterial and fungal aerosol (cfu·m^{-3}) inside and outside the St. Benedict church in Cracow

Measuring point		Bacteria [cfu·m^{-3}]	Fungi [cfu·m^{-3}]
Indoor air	Inside the church	681 a*	333 a
	Archaeological excavation	1185 a	500 a
Outdoor air		455 a	124 a

** averages marked with the same letters are not significantly different by Tukey's test (α = 0.05)*

By using a 6-stage Andersen's air sampler, it was possibile to get information about the size distribution of air microflora in the investigated measuring points (Figure 1 a-b). Based on the analysis of bioaerosol particle size distribution it was observed that the bacteria concentration had a maximum value in a range of diameters 7.0-11.0 µm and the concentration of fungi had a maximum value in the diameter range of 4.7-7.0 µm. It shows that these microorganisms can be deposited in the human respiratory tract in mouth, nose and throat [Wlazło et al. 2008].

Microclimate conditions may affect the number of microorganisms in the air [Katial et al. 1997]. Microclimate parameters and dustiness are presented in the table 2. Analysis of the impact of the temperature, relative humidity and dustiness on the observed bacterial aerosol showed that these factors had no significant effect on the concentration of the total number of bacteria in the air (p>0.05). Analysis of the impact of the relative humidity and dustiness on the observed fungal aerosol showed that these factors had no significant effect on the concentration of the fungi in the air (p>0.05).



a) b)

Fig. 1. The size distribution of bacterial and fungal aerosol inside and outside the church: (a) bacteria, (b) fungi

However, the analysis showed a significant correlation between the concentration of fungal aerosol and temperature (R=-0.84, p<0.05). It proves that the decrease in temperature affects the increase in concentrations of fungi in tested air [Klimek et al. 2011].

Table 2

The values of microclimatic parameters and concentration of dust in the indoor and outdoor air in the St. Benedict church in Cracow

Measuring point		Temperature [^{o}C]	Relative humidity [%]	Concentration of dust – fraction 10.0 μm [mg·m^{-3}]	Concentration of dust – fraction 4.0 μm [mg·m^{-3}]
Indoor air	Inside the church	13.5	53.8	0.062	0.061
	Archaeological excavation	11.8	75.6	0.075	0.070
Outdoor air		22.0	74.0	0.061	0.061

Summary. The results showed that the concentrations of bacterial and fungal aerosols were higher inside the St. Benedict church than outside. However, statistical analysis didn't show significant differences in concentration of bacteria and fungi between measuring points. Basing on the research, higher levels of bacteria than fungi were observed, but the concentration of the tested microorganisms didn't exceed the values recommended by the Panel of Experts of Biological Factors.

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