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## **Microbial assessment of the conservation status of the selected library collections from the Skałeczna Library in Kraków**

Mikrobiologiczna ocena stanu zachowania wybranych zbiorów  
bibliotecznych pochodzących z biblioteki  
Skałecznej w Krakowie

### **Abstract**

Microbes present in the indoor air of libraries and on the surfaces of books, map and cardboard packaging pose a threat to the health of workers and book users themselves. Therefore qualitative and quantitative analysis should be carried out to study microbial species and assess their cellulolytic activity to prevent the library resources from entomological disaster. Evaluation of the microbial hazards of the Skałka library was limited to 220 randomly selected volumes including 200 old prints and 20 incunabula. From all 220 objects samples were tested for the presence of filamentous fungi. Each volume was described by four microbiological samples, taken from the back and the front of the binding, front endpapers or the title card and a middle card from a pad of a book. After the incubation quantitative and qualitative analysis of a species of fungi was carried out. Appropriate methods and measures to combat microbes and insects in the records and books must be applied in order to protect the resources.

**Keywords:** *library collections, fungi, humidity*

### **Streszczenie**

Drobnoustroje obecne w powietrzu pomieszczeń bibliotecznych oraz na powierzchni książek, map i tektury opakowaniowej stanowią zagrożenie zdrowotne

dla pracowników oraz ich użytkowników. Stąd należy przeprowadzić analizę jakościową i ilościową obecności różnych gatunków drobnoustrojów oraz ocenić ich aktywność celulolityczną, aby nie doprowadzić do katastrofy entomologicznej i mikrobiologicznej zasobów bibliotecznych. Ocena stopnia zagrożenia mikrobiologicznego księgozbioru skałecznego, ograniczono do 220 losowo wybranych woluminów, w tym 200 starodruków i 20 inkunabułów. Z wszystkich 220 obiektów pobrano próbki, które badano na obecność grzybów pleśniowych. Każdy wolumin opisany został przez cztery próbki mikrobiologiczne, pobrane z grzbietu i przedniej okładziny oprawy, przedniej wyklejki lub karty tytułowej i środkowej karty z bloku książki. Po okresie inkubacji przeprowadzono ilościową i jakościową analizę gatunku grzybów. Dla ratowania zbiorów trzeba zatem zastosować odpowiednie metody i środki zwalczania drobnoustrojów w zbiorach bibliotecznych.

**Słowa kluczowe:** *zbiory biblioteczne, grzyby, wilgotność*

## 1. Introduction

Monastic libraries including the library of Skalka contained the collection of the most valuable historical works which through have been used forages thanks to the appropriate conditions of storage.

Many wonderful works survived there, because the Pauline monastery was not affected by major historical events which often resulted in the destruction or significant loss of library resources. Monastery underwent invasion of the Swedish army in 1655, and two years later the troops of Marshal of the Crown Jerzy Lubomirski. Then stolen library collections were characterized by a beautiful binding and were richly illustrated. However, the monastery did not experience larger fires and floods [1]. The condition is also affected how collections of books and archives have been stored for so long. Binding of books are heavily stained. The parchment and leather used in binding show visible signs of rot. Blocks books also show numerous damages in the form of stains, cavities and discoloration caused by the insect larvae in the block. Such a state indicates that it was stored in improper conditions. By the end of the sixteenth century the Library of Skalka was not a separate room, it occupied the treasury or the sacristy, in which liturgical collection a was stored. In the early seventeenth century the collection was located in the room between the sacristy and the monastery building. Around 1686 the construction of a new library building, located on the first floor, began which probably was supposed to eliminate the devastating effects of moisture and groundwater on the state of the harvest. After several years of operation, of the library there, it turned out that room is insufficient, hence in 1748 the construction of a new library started [2].

Moving exposes books to mechanical damage, contact with moisture, with fungal copies or dust, containing countless numbers of fungal spores and (to a lesser extent) different forms of bacterial infections. Microorganisms in a short

time can destroy the material inhabited by itself (destruction caused by floods prove it) if they find suitable living conditions, such as adequate humidity, access to food and the right temperature. Bacteria invade libraries collections usually after flooding at a relative humidity of 95-100%, Actinomycetes require relative humidity of 65-80%, fungi need a relative humidity of 65-85%, hence both these groups play a major role in the destruction of library collections. Apart from humidity, it is temperature and paper pH (that is an indicator of the concentration of hydrogen ions in the environment) which are very important for the development of microbes. Bacteria and Actinomycetes grow in a neutral or slightly alkaline (6.8-8pH) environment, however fungi in the an environment of weak acid (pH of 4 to 6) [3]. Most actively, a large number of forms of microorganisms grows in the temperatures range from 10 to 37°C. Bacteria and fungi break down lignin, hemicelluloses, cellulose aromatic compounds, aliphatic hydrocarbons. The building material for the microbes are glues of animal origin (skin, bone structure, parchment, fishy) and plant (starch adhesive), then the skin, paper, cardboard, and canvas. Traces of micro-organisms are visible indifferent kinds of hyperpigmentation, taints, water stains or dirt. The biggest threat are filamentous fungi spores, their sizes are that of a few microns and their light weight makes it very easy to spread in the air, accumulate in dust.

After falling on the base they begin to germinate under the influence of humidity. One may include sclerotia, chlamydospores to the survival structures of fungi. They are very drought- and environmental- resistant. Spores, while germinating, produce mycelium, which is built of thread-like cells called hyphae. The mycelium, when growing, creates colonies with a diameter of several millimeters to several centimeters. It feeds on the skin nutrients, paper and adhesives production processes. Fungi and other microorganisms cannot obtain food in the form of macromolecular compounds (they need to decompose it by using enzymes) which include fats (leather), protein (collagen the main skin building component, parchment), poly-sugars (cellulose, starch-mucilage glue component). Growing fungus colony begins to produce spores, which, by dispersing around the colony, may germinate and create the next colonies, damaging the book even further. In these places there are difficult to remove colored spots on paper. Most often we find the spores and thus staining in white, cream, green, gray, black. This type of colors is described as mechanical. Discoloration may also be of chemical origin [4]. Fungi produce a very wide range of colors, which can be excreted outside cells causing the occurrence of different colored stains. Strong yellowing of paper is associated with the decomposition of cellulose. The paper in the place in which the mycelium develops, becomes brittle, thin, porous, and finally as a result of depolymerization of cellulose molecule it disintegrates and losses arise. Microbes first attack these places in books which is easily accessible by moisture and the nutrition is present: back of the book, the inner side of the cover, endpapers, the edges of the book. Ridge books and endpapers are saturated with glue – either vegetal or animal. These natural adhesives are an excellent medium for micro-organisms [5].

The distribution of the glue on the back of the book leads to relaxation of the book's sides and after the destruction of twines and sewing, to spillage of papers. Backs of the books are also places through which water and fungus spores easily penetrate. With strong humidity micro-organisms grow into the backs reaching the depths the level of oxygen allows them. In its absence, the slowing down of paper degradation may be observed, stains are formed and the drying book becomes distorted. Cardboard or canvas binding are attacked by cellulolytic microbes. Leather and parchment paper contain collagen which is decomposed by anaerobic bacteria. In addition to collagen in both materials we may observe proteins, fats, carbohydrates, mineral salts. These substances are an excellent source of nutrition for thermophilic Actinomycetes [6].

## **2. The microbiological evaluation of library material**

Evaluation of the microbial hazards of the Skalka library was limited to 220 randomly selected volumes including 200 old prints and 20 incunabula. The books published after 1800 were not examined. After analyzing them, traces of microorganisms were observed and proved by various kinds of stains, discolorations, soiling, damp patches, deformations or cavities. From all 220 objects samples were tested for the presence of filamentous fungi.

Each volume was described by four microbiological samples, taken from the back and the front of the binding, front endpapers or the title card and a middle card from a pad of a book. The examination of the pad of a book or a title card was conveyed by imprinting a moist, sterile paper disc with a 6cm<sup>3</sup> diameter in places with visible micro-organisms' activities.

From the book's back a sample was taken by moving a sterile wad from inside of the book's back where, below the headband, adhesive binding is found. The paper disc and a sample wad were transferred onto a Petri dish with a 12 cm<sup>3</sup> diameter containing the medium of 10 cm<sup>3</sup>, that was prepared according to the recipe of Czapek-Doxa. The evaporating dishes were incubated at 30°C, which is considered an optimal temperature for the development of fungal pathogens, that develop on a historic library material. In order to assess the microbiological risks it was assumed, that optimal time interval after which the mycelium covers the entire dish is 21 days. It was also assumed that if within 7 days of incubation a mycelium with a 3 cm<sup>3</sup> diameter should appear the highest level of hazard will emerge suggesting the presence of live mycelium in the examined material. The growth of mycelium to a diameter of 6 cm<sup>3</sup>, after 14 days of incubation, was qualified as an average hazard which means that preventive measures such as disinfectant treatment should be undertaken. Incomplete and uneven covering of the dish by small-sized colonies (a few millimeters) after 21 days of incubation will prove the presence of inactive spore forms.

Table 1. The number of infected evaporating dishes  
Tabela 1. Liczba zainfekowanych szalek

Place of extracting the sample Miejsce pobrania próbki	The number of evaporating dishes that had colonies developed on them Liczba szalek, na których wyrosły kolonie	The percentage of infected dishes in the entire test Procentowy udział szalek zainfekowanych w odniesieniu do całej próby
Endpaper or title card wyklejka lub karta tytułowa	65	29,5
binding grzbiet	63	28,6
Front cover lining przednia okładzina oprawy	58	26,4
Book's pad Blok książki	49	22,27

The microbiological inspection revealed that from the number of objects of 220, 151 in at least one of the four test points showed a fungal infection. Copies, in which at only one point the colony emerged was 97, at two points 48, 16 at three, with four 1.

Having considered to the construction of the book, it was found that microbial infection is not evenly located. The greatest threat is created by a lining connecting the pad of books with the inner surface of the lining and the outer surface of the binding. Microbial infection located on endpaper is transferred onto title cards and further pages of book's pad deep enough to have a free access to light and air. Binding, especially covering material was infected in 58 cases and the paper of the book's pad in 49 case (Table 2). Generally, a good evaluation of the collection's condition was caused by the fact that out of 220 infected volumes there were only 12 in which a fungal growth zone reached 3cm<sup>3</sup> in diameter after seven days of incubation and in the other 16 objects it reached such a diameter after fourteen days. In the endpapers such an elevated level of infection was observed in 19 cases; in the back of the books in 16 cases and in the lining, also in 16 cases. The number of objects with advanced forms of fungi diseases not exceeding 25% proves that the mycelium development in the storage conditions was limited.

Table 2. Qualitative and quantitative microbiological assessment of the tested set  
Tabela 2. Jakościowa i ilościowa ocena stanu mikrobiologicznego badanego zbioru

Time interval Przedział czasowy	The back of the book Grzbiet			Lining Okładzina			Endpaper Wyklejka			Printing paper Papier drukowy		
	***	**	•	***	**	•	***	**	•	***	**	•
1498–1500	5	7	30	3	2	35	7	10	24	4	6	28
1501–1550	2	3	7	4	2	10	3	4	6	3	3	10
1551–1600	2	6	6	3	3	10	3	3	10	2	3	10
1601–1650	4	8	8	3	1	15	3	2	12	1	2	15
1651–1700	3	6	12	3	2	16	3	5	13	2	2	16
<b>Sum Suma</b>	<b>16</b>	<b>30</b>	<b>63</b>	<b>16</b>	<b>10</b>	<b>86</b>	<b>19</b>	<b>24</b>	<b>65</b>	<b>12</b>	<b>16</b>	<b>79</b>

\*\*\* the fungal surface with a diameter of 3 cm<sup>3</sup> after 7 days of incubation

powierzchnia grzybni o średnicy 3 cm po 7 dniach inkubacji

\*\* the fungal surface with a diameter of 6 cm<sup>3</sup> after 14 days of incubation

powierzchnia grzybni o średnicy 6 cm po 14 dniach inkubacji

• the fungal surface did not reach 12 cm<sup>3</sup> diameter after 21 days of incubation

powierzchnia grzybni nie uzyskała średnicy 12 cm po 21 dniach inkubacji

Microbiological risk assessment has been completed with a qualitative analysis of the micro-organisms. The isolated fungi were assigned to the species (Table 3).

Table 3. Isolated fungi from a historic library collection's sample  
Tabela 3. Wyizolowane grzyby z badanej próby zabytkowego zbioru bibliotecznego

Kind of funguj Rodzaj grzyba	Material Materiał	Paper Papier	Leather Skóra	Parchment Pergamin	Animals and plant glues Kleje zwierzęce i roślinne
Penicilliumchrysogenum		x	x	x	
Penicillium funiculosum		x	x		
Aspergillus niger		x	x		
Aspergillus flavus		x	x	x	x
Aspergillusversicolor		x	x	x	x
Aspergillus fumigatus		x	x		
Botritiscinerea		x	x		x
Cladosporiumherbarum		x	x		x
Mucorracemosus		x	x		x
Fusariumsolani		x	x		
Trichoderma viride		x	x	x	

Kind of funguj Rodzaj grzyba	Material Materiał	Paper Papier	Leather Skóra	Parchment Pergamin	Animals and plant glues Kleje zwierzęce i roślinne
Scopulariopsisbrevicaulis		x	x	x	
Chaetomiumglobosum		x			
Geotrichumcandidum		x			
Trichotheciumroseum		x			
Rhizopusstolonifer		x	x		

Among the species marked on all kinds of materials there were two species of *Aspergillus flavus* and *Aspergillus versicolor*. On three of the materials six species appeared. The others on two or one material. All fungi dwelling on the library material are typical pathogens that in favorable conditions of relative humidity and ambient temperature can pose a threat to the harvest. *Aspergillus* is one of the most toxin-producing fungi. The symptoms of its presence are characterized by black stains on paper cards that is difficult to remove. On the other hand, *Botritis* in low level of concentration is treated as harmless in the air, a library space included. *Penicillium*, being filamentous fungus is a natural material with antibiotic-like qualities. Molds, especially with the types of *Penicillium*, *Cladosporium*, *Aspergillus* and *Alternaria*, develop, among other things in coverings, carpets, the cracked walls, crevices, plumbing installations. Some of them produce mycotoxins penetrating into the human body through the skin food passage and through inhalation which could cause a number of diseases in humans. The symptom of harmful effects of molds can be conjunctivitis, respiratory diseases, joint pain, weakened immunity and chronic tiredness. More serious disease can appear which bear the name of fungal infections. A large group of substances dangerous for people produced by molds are volatile organic compounds which include eg.: aldehydes, alcohols and ketones. They have irritant, toxic and carcinogenic effect. People with diabetes, renal failure, cardiovascular and respiratory systems problem have also lowered immunity and serious organ mycosis may develop in them. And for a healthy man fungi can be hazardous when present in large quantities in the environment, as this can take place in neglected library collections. They can then be the cause superficial fungal infections: skin, hair, nails, conjunctivitis. Fungi are also strong allergens and among those people with atopic they can cause allergic pharyngitis, conjunctivitis and nasal, bronchial asthma, allergic skin diseases and cancers.

### 3. Conclusions

Of 220 of studied objects 20.5% consisted of objects on which alive and, active spores and spore of fungi were observed. This shows that the development of the

mycelium in the conditions of collection storage, was limited. This result implies the need of preventive disinfectant treatments. The Skalka collection is stored in wooden cases. One may assume, therefore that the form of storing books limits access to the air, light, and above all, dust (which is the main medium for fungal spores) creates a specific microclimate, constraining hazards or stimulating disease development on the stable and safe for the collection level. After their search and analysis of the results, all of the objects have been fumigated in the vacuum chamber which is installed in the Silesian Library. The applied Fumigants were ethylene oxide with strong properties of fungicides and insecticides. Microbes can be hazardous to the health of the library staff and readers. To limit the growth of fungi in rooms that hold paper products, follow the instructions laid down by the IFLA, namely:

- check whether there is mold on new acquisitions and shipments,
- keep moderate temperature and relative humidity (less than 20 degrees Celsius and 65% RH),
- provide good air circulation,
- regularly vacuum documents,
- do not place bookcases next to external walls,
- do not grow plants in the building,
- provide waterproof basements and foundations,
- regularly check the collections for the possible occurrence of efflorescence [7].

## LITERATURE

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