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Saving the national heritage from harmful microbiological effects. Conditions and preventive measures

Introduction

Microbiological contamination in libraries and archives is a serious problem due to variable temperature and humidity conditions. Inadequate air humidity in library rooms results from poor insulation of the building from the ground or the cooling of the premises during the winter season, which creates condensation of water vapor on the walls in the collection areas. This favours the development of mycelium spores, which for a long period of time may be inactive, until the relative humidity falls below 60%, when the spores germinate.

Microorganisms develop on the different materials the book is made of. This process manifests itself first in staining the surface and then, depending on the species of fungus, with visible, deep, black, pink or brown spots and finally leads to the complete destruction of the collection (i.e., the scaling effect)[1]. The most intense growth of fungi takes place at 24–30°C and 65–80% relative humidity, whereas bacteria and radii grow optimally at 28–32°C and 80–95% humidity. Moreover, their growth depends on the chemical composition of the paper, bookbinding materials and auxiliaries used for paper production and their contact with infected collections. Apart from microorganisms, insects are also pests in library collections. In storerooms and libraries, there are beetles, marmots, insects, rodents, mites and others. They move into the rooms through contact with human clothes or openings in the windows, cracks in the floor, etc., and even along with food[2]. Insects thrive best at about 25°C and 75% relative humidity without decontamination, dust or room ventilation. Significant damage in warehouses is made by rats and mice, which feed on paper and other components

1 Z. Podbielkowski, I. Rejment-Grochowska, A. Skirgiełło, *Spore Plants*, Warsaw 1986, pp. 358–367.

2 A. Strzelczyk, *Microbiological destruction of library collections. Reasons and symptoms of destruction*, „Library Studies" 1997, t. 10, pp. 90–92.

of library collections. There are also dangerous birds and bats that carry insects and microbes contributing to collections' contamination[3].

Fig. 1. Destruction of books by the effects of damp. Photo A. Bangrowska

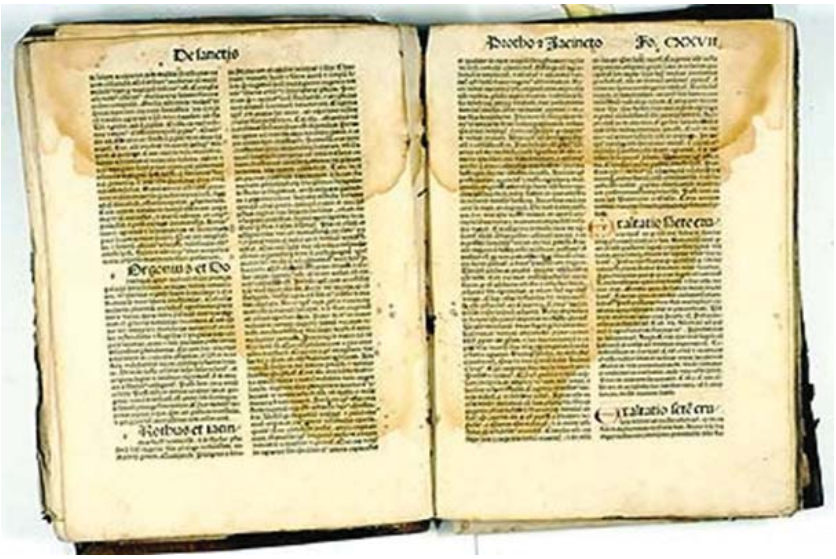
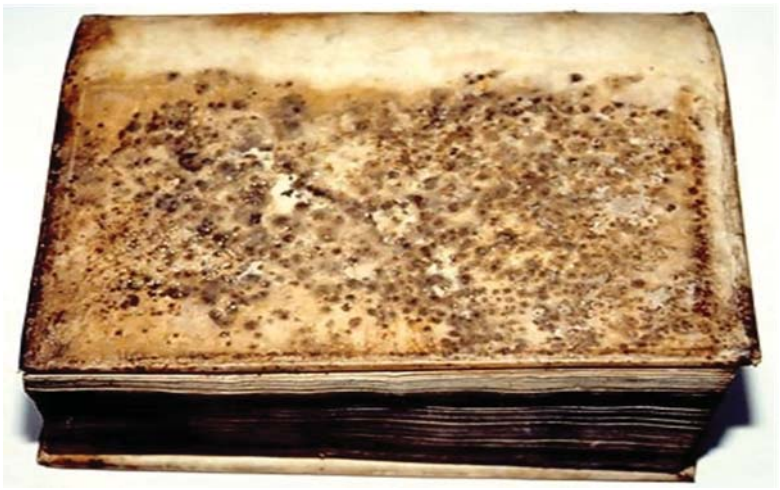


Fig. 2. Destruction of books by the effects of microorganisms. Photo A. Bangrowska

3 ISO Standard PN-ISO 11799: 2000, „Information and documentation – Requirements for storage conditions for archives and libraries".

Fig. 3. Book damaged by moulds (fungi). Photo A. Bangrowska

Fig.4. Mouldy leather cover. Photo A. Bangrowska



Selected species of fungi found in libraries and archive collections

Alternaria alternata Nees ex Fr.

A. alternata is a species with a very wide geographical range. It is characterised by a wadded olive-brown or black-grey mycelium. It is an allergenic, toxic and pathogenic species. The optimum temperature for growth is 22–25°C (min. 2–6°C, max. 31–31°C) with a pH range of 2.7–8.0. The water activity value is Aw 0.85–0.88. The spores are very resistant to drought because they contain 86% water; therefore, they remain

viable for several years. *A. alternata* develops in soils and in wood, rubber, artificial materials, paper, parchment and food items[4].

Cladosporium herbarum (Persoon) Link ex S. F. Gray

C. herbarum occurs in all climatic zones on Earth and, most importantly, its spores are most abundant in the air. It can develop in soil (wheat, oats, tobacco, potatoes, onions, clover, nut plants, coffee), wood, leather, artificial materials, paper and wet plaster. The skin and parchments appear dark green in colour. The optimal temperature for its growth is 18–28°C (also at -6°C). Water activity values needed for growth are Aw 0.85–0.88. Development pH range is 4.4 to alkaline; optimal growth at pH 6.0[5].

Geotrichum candidum Link ex Leman

G. candidum is the most common fungus worldwide (found in air, soil, water, sewage, cereals, dairy products, citrus fruits, tomatoes, cucumbers). Its presence is also seen in the skin, sputum and human faeces. It develops in the temperature range of 25–27°C, and the maximum temperature is 35–38°C[6].

Aspergillus niger van Tieghem

A. niger is the most common cosmopolitan (widely distributed geographically) species in the world. It occurs in soil, fruit, vegetables, dates (fresh and dried), wood, rubber, wax, water (clean and polluted, rivers), textiles (cotton, jute, wool), audiovisual substrates (photos, microfilms), synthetic materials (plastics, plasticisers), paper, parchment, leather and metals. The minimum, optimal and maximum temperatures for mycelium growth are, respectively, 11–13°C, 17–42°C and 47–48°C. It is classified as a mesophile. The value of water activity needed for growth is Aw 0.77[7].

Aspergillus fumigatus Fres.

A. fumigatus is also a cosmopolitan fungus. It develops in the atmosphere and on moist organic materials (e.g., compost heaps, causing rapid decomposition with the release of a large amount of energy), synthetic materials, rubber, paper, food products, (e.g., milk, fruit, vegetables, nuts, spices), cereals, soil and meat products The value of water activity needed for growth is Aw 0.85–0.94. The fungus is a thermotolerant species and can grow in the temperature range of 12–57°C, with optimal growth at 37–43°C. The ideal growth is at pH 3.0–8.0[8].

Penicillium funiculosum Link ex Fr.

P. funiculosum is widespread in temperate soils. It uses various nutrients for its development. It is a polyphage and a saprophyte. It is found on the skin and in food

4 O. Fassatiová, *Grzyby mikroskopowe w mikrobiologii technicznej*, Warszawa 1983; A. Grabińska, A. Łoniewska, Z. Kańska, *Atlas grzybów mikroskopowych*, Warszawa 1990.

5 Ibidem.

6 Ibidem.

7 Ibidem.

8 Ibidem.

products (fruits, legumes, grains, nuts). In addition, it develops on filter paper and cotton fabrics. It grows in the temperature range of 8–42°C and reaches optimum development at 25–28°C. The value of water activity needed for growth is Aw 0.9. It is resistant to acids, and therefore, it can develop on acidic soils with a pH of 2.0. It is characterised by high cellulolytic activity and synthesises a set of cellulases: endo-β-1,4-glucanase, exo-β-1,4-glucanase and β-glycosidases[9].

Human-contact symptoms

The first symptom of the harmful effects of mould fungi may be respiratory tract diseases, conjunctivitis, joint pain, weakened immunity and chronic fatigue. Later, more serious diseases called mycoses may appear. However, mycotoxins are not the only harmful substances. A large group of substances dangerous to humans, produced by mould fungi, are the so-called volatile organic compounds, which include aldehydes, alcohols and ketones. Many of these compounds, like mycotoxins, are irritating, toxic and carcinogenic[10]. These substances impart an unpleasant odour to mould-infested rooms and are also considered (along with mycotoxins and glucans) to be causative factors in "chronic fatigue syndrome" and "sick house syndrome". Patients chronically ill with diabetes, renal failure and cardiovascular and respiratory diseases also have weakened immunity and may develop severe mycoses of organs. On the other hand, for a healthy person, fungi can be a threat when they occur in large numbers in the environment, as can be the case in neglected library collections. They can then cause mycoses of the skin, hair, and nails and conjunctivitis. Fungi are also strong allergens and can cause allergic conjunctivitis, nose and throat inflammation, bronchial asthma and skin allergic diseases in people with atopy. In high concentrations, some species of fungi produce aflatoxins with a potential carcinogenic effect. Pulmonary mycosis has also been reported in people taking immunosuppressive or anti-cancer drugs who are exposed to airborne fungi[11].

Selected species of fungi – their impact on the human body and cellulose material

A. alternata Nees ex Fr. can cause serious respiratory diseases (asthma, rhinitis, chronic sinusitis). It can also cause mycoses of the skin. Its mycotoxins are responsible for leukopenia (reduction of white blood cells or leukocytes). In Poland, the genus *Alternari*a is responsible for the severe course of allergic rhinitis and bronchial asthma.

9 Ibidem.

10 A. Bangrowska (Bakalarz), *Microbial assessment of the conservation status of the selected library collections from the Skałeczna Library in Kraków*, "Zesz. Nauk. Wyż. Szk. Zarz. Ochr. Pr. Katowice" 2015, nr 1, pp. 30–37.

11 A. Bangrowska (Bakalarz), *Zagrożenia mikrobiologiczne zbiorów bibliotecznych*, "Nowa Biblioteka" 2014 nr 1(14), pp. 165–170.

A. niger is toxic and pathogenic; it causes mycoses of various organs: kidneys, lungs, bronchi, brain, ears, paranasal sinuses, eyes, etc.

A. fumigatus Fres. causes some diseases (aspergillosis, mycoses of the skin, bronchi, lungs, ears, paranasal sinuses, brain, etc.). It also produces mycotoxins: tryptoquivalenes, fumitremorgens, verruculogen and gliotoxin with an immunosuppressive effect.

G. candidum can cause gastrointestinal mycosis (geotrichosis - a rare mycosis caused by *G. candidum*).

C. herbarum produces ochratoxin with an action similar to very dangerous mycotoxins. It is pathogenic for humans and highly allergenic.

P. funiculosum is one of four species (the others are *Botryotrichum piluliferum*, *Trichoderma viride*, *Scopulariopsis brevicaulis*) that have cellulolytic enzymes that allow the decomposition of cellulose material.

Control of climatic conditions in library rooms. Physicochemical methods for destroying microbes

Disinfestation and disinfection of infected objects is a kind of treatment that aims to combat the microorganisms that attacked the affected objects and stop the infection from spreading to neighbouring collections. Before deciding whether to disinfect a collection of books or archives, it is necessary to assess whether there is a microbiological infection or whether the objects are only dusty and soiled. A better and more effective way of protecting collections is to clean objects of dust rather than using fungicides. An important task for conservators is to keep constant control of the microclimate in the rooms where the library collections are located. Conducting appropriate controls, analysing the temperature results and relative humidity and proper preventive measures can prevent the attack of microorganisms[12].

Constant control of humidity changes will help to determine the impact of the external environment on the microclimate of the library or the storage space. This will be possible by the use of a suitable ventilation system (i.e., air conditioning with activated rather than electrostatic charcoal) to avoid the production of ozone in rooms, which acidifies the environment. To prevent the spread of and to eliminate the numerous spores contained in dust, humidifiers can be used. Another method might be the sterilisation of dust suspended in the air or the fumigation of objects against bacteria and fungi. For the removal of microorganisms from rooms with low levels of dust in the air, photocatalytic ionisation can be used. It can work in a continuous and safe way for workers. Disinfection is carried out in storage rooms with the use of a device based on photocatalytic ionisation, which does not produce ozone in the air during the process. The maximum reduction degree of microorganisms after

12 A.B. Strzelczyk, J. Karbowska-Berent, *Microorganisms and insects destroying monuments and their combat*, [w:] *North European Symposium for Archaeological Textiles X*, Toruń 2004, pp. 105–116.

disinfection is 41.7–99.6% in the air and 23.3–76.1% on the tested surfaces. Microorganisms resistant to photocatalytic ionisation of fungi are *Penicillium*, *Aspergillus*, *Cladosporium*, *Rhodotorula*, *Brevundimonas vesicularis* and Radiobacteria. However, fungi of the genera *Botrytis*, *Mucor*, *Alternaria* and *Acremonium*, *Sphingomonas paucimobilis*, , *Stenotrophomonas maltophilia*, *Bacillus megaterium* and *Bacillus sp*[13] are microorganisms sensitive to the photocatalytic ionization process and are destroyed. It should be remarked that the disinfection process is not preventive; the decision to undertake it must be made with great caution and consideration and only when it is necessary. For insects, the chemicals used should be toxic to all stages of the insect's development (i.e., they should destroy the mature form, larva, chrysalis and egg), but at the same time, they should not be harmful to humans or documents. In the case of microorganisms that are actively decomposing historic material, the infection should be fought with the use of chemical or physical methods. There are two forms of historical object disinfection: mass disinfection and individual item disinfection. Mass disinfection procedures can be divided into, firstly, disinfection of the collection at the place of its storage in the library stores, and secondly, disinfection outside of the collection storage, which is the case with UV irradiation:

- erosion of the microorganism by etching;
- erosion of the microorganism by internal photodesorption.

Studies have confirmed the effectiveness of biocidal action and the absence of unwanted changes in tested paper samples and writing media.

In conclusion, it is important to point out that dust and dirt are the main sources of infection in library collections with insects and microorganisms, so it is the job of the library staff to maintain adequate cleanliness in the storerooms. The floor should be washed with a damp cloth immersed in water with the addition of disinfectant at least once a week, and then the floor should be dried and pasteurised. Shelves should be systematically wiped with a damp cloth in book-free places and vacuumed. Library collections should be subjected to disinfestation and disinfection. For disinfection, a 40% solution of formaldehyde should be placed in a wide flat dish over which a document should be hanged on a wire mesh and then covered with a tightly fitting box for 12 h. This treatment should be carried out at temperatures above 18°C and relative humidity above 65%. By this method, the bacteria, moulds and fungi are killed; unfortunately, it does not immunise the document for a longer period of time before re-attack by the microorganisms.

The best methods of individual disinfection are as follows[14]:

P-chlorine-m-cresol is a white powder and readily soluble in ethanol, acetone or turpentine but not in water. It is used as a 10% solution in ethanol in the form of interleaves. The whole book is packed in a plastic bag and kept in a warm place for about 7 days. P-chlorine-m-cresol can also be used as a 0.3% solution in the form of

13 A. Fulishima, *Titanium dioxide photocatalysis: present situation and future approaches*, „Chimie" 2006, No. 9, pp. 750–760.

14 J. Karbowska-Berent, T. Kozielec, J. Jarmiłko, B. Brycki, *Attempts to use new biocides to disinfect historic pape*, [in:] *Library and archival collections – research and maintenance*, Toruń 2010, pp. 183–197.

tamponings; however, this agent has rarely been used recently because many species of fungi have become resistant to it. After this period of time, the object should be ventilated until the decay of the disinfectant[15].

Sterinol is used in the form of a 10% solution with the addition of a pH stabilizer, which is used to clean old, moldy books. The agent is not toxic to humans. It is also used in a bath in the form of a 7.5% solution at a temperature above 50 ° C for 15 minutes. It is used to decontaminate library shelves, floors and walls during renovations.[16].

Aseptines. We distinguish between Aseptina M, Aseptina A and Aseptina P. All show strong fungicidal and bactericidal properties and are not toxic to humans. They are mainly used for the protection of starch adhesives. Moreover, when applied to paper, they delay the process of aging[17].

It is not recommended to disinfect with the following chemicals:

Sodium fluoride protects the paper inefficiently, darkens it and acidifies it to pH 5.5.

Tymol. This is a fungicide at high temperature. At low temperatures, it stimulates the growth of mycelia, and it is not toxic to insects. Steams of the compound are harmful this pastels and cause darkening of the paper during its aging.

Sublimate (mercury chloride) darkens paper very much and acidifies it to pH 3.0. While aging, it loses its endurance[18]. In Western European countries, ultraviolet rays are used for general disinfection, whereas in Poland, due to different climatic conditions, the results are inadequate[19].

Currently, the mass protection of library collections against microorganisms is achieved with the use of so-called passive disinfection. Mass disinfection of stored collections is combined with disinfection of shelves, walls, ventilation ducts and other components of the room. After removing the whole collection, the entire storeroom with all equipment is disinfected. Then, antique books are returned to the disinfected room. Such a project is not only time-consuming but also requires a lot of financial expense. The most commonly used method in the process of mass disinfection of historic objects outside the place of storage is ethylene oxide disinfection in a vacuum chamber with the use of a mixture ethylene oxide and carbon dioxide in a 1:9 ratio[20].

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15 M. Froehlich*, Attempts to use p-chloro-m-cresol and zinc pentachlorophenolate to protect eggshell paints from microbiological deterioration*, Acta Universitatis Nicolai Copernici. "Humanistic and Social Sciences. History of Science and Conservation" 1974, z. 5 (52), pp. 111–116.

16 W. Sobucki, *Maintenance of the support*, "Chemical issues" 2013, p. 129.

17 Ibidem, pp. 129–130.

18 W. Sobucki, *Paper maintenance*, „Chemical issues" 2013, p. 131.

19 J. Perkowski, *Radiation technology in restoration and renovation works*, Perkowski Renovations" 2000, No. 3 (14), pp. 12–17.

20 A.B. Strzelczyk, J. Karbowska-Berent, *Microorganisms and insects destroying monuments and their combat,* [w:] *North European Symposium for Archaeological Textiles X*, Toruń 2004, pp. 186–200.

Most of the antiques can be subjected to gasification, although it is not recommended for photographs and parchments Ethylene oxide is carcinogenic; it causes genetic changes, damage the neuro-endocrine system and in low concentrations it is a potential allergen for many humans. After the treatment, these gases are released into the atmosphere, which gets contaminated. The method is very dangerous for the people carrying out the gasification and for bystanders[21].

As well as chemical methods, physical procedures can be used, including gamma-ray disinfection. This radiation is characterized by high penetration, which allows for disinfection of the entire collection. However, the permeability of gamma rays through the book layer strongly decreases with an increase in the pack thickness. This method is safe for the environment and for human health. However, the use of gamma rays for antique books raises serious concerns. The mechanism and effects of gamma radiation are different in the case of antique papers and contemporary ones. Gamma rays have a lesser impact on paper that contains lignin, a compound that is more resistant to radiation. As a result of the irradiation, the degree of polymerisation of the paper is reduced, but the whiteness and acidity are not significantly altered . A second physical method is the use of high energy electrons and, recently introduced, a non-thermal plasma (low temperature).

Summary

The fundamental task of libraries and archives is to collect national heritage, preserve it for the next generations and make the resources available to the widest possible extent, which are exposed to various dangers both during their use and storage. The collections consist of a significant part of organic substances that are not only subject to the natural aging process, but are also biologically endangered by microorganisms, mainly mold fungi, and less often by bacteria. Fungal activity can lead to complete destruction of paper, leather and parchment. Mold fungi also pose a significant threat to human health. The purpose of disinfection is to eliminate microorganisms that have attacked the historic object and to stop the spread of infection to neighboring collections. In conservation practice, chemical and physical agents and methods are used to combat fungal infections.

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21 Disinfection chamber, [on-line:] http: //www.bu.kul.pl/files/072/gfx/act/diagnostic_acne – 14.11.2021.

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Abstract

This article aims to present the physicochemical methods and chemical agents used to combat microorganisms in library collections as well as in library rooms. Based on an analysis of documentation available at various library centres, the methods and chemicals used to destroy fungi and moulds were compared. The standard storage conditions of library collections were used. Library collections from different sources can be attacked by microorganisms because they are almost entirely composed of organic materials, forming nutritional matter for those organisms. Environmental supervision is only one of many ways to prevent and ensure proper book storage conditions, but it is not a suitable method for fighting bacteria, fungi, mould, etc. The ways and methods of library collections' disinfection should be considered very broadly. Disinfection of the collection itself is not enough; this must be combined with

disinfection of the storerooms and additionally the removal of all potential sources of infestation. Emphasis should be placed on the implementation of modern methods of destroying microorganisms which, of course, will not harm humans but will prolong the life of library collections. Moreover, libraries and warehouses should be equipped with appropriate equipment to maintain suitable climatic conditions.

Keywords: national heritage, library collections, library climate, chemicals, disinfection.