

Microbiology in the service of cultural heritage protection

Both the international law, including the Hague Convention of 1954, and the national regulations on the protection of historic monuments oblige



Poland to safeguard cultural property located within its territory from the effects of armed conflicts. The key to success lies in the measures taken in peacetime, including protecting these assets not only from fire, water or toxic chemical substances, but also harmful microorganisms.

How can museum, archival and library collections be effectively protected against fungi and bacteria without harming valuable exhibits? We are discussing this issue with **MAGDALENA DYDA, PhD**, a specialist with many years of experience who combines scientific research in the field of microbiology with its practical application for the protection of cultural heritage.

Daria Olender: Recently, much attention has been paid to issues related with civil protection and civil defence. This also encompasses the issue of protection of tangible assets, including cultural heritage. Let's talk about less obvious threats facing historical monuments and museum objects. Given your educational background and professional experience, I shall ask you: why do museums and archives need biologists?

Magdalena Dyda, PhD: Biologists and microbiologists support museums, archives and libraries in preventive conservation, which is mainly related to monitoring harmful biological agents. Among the most destructive living organisms – after humans – in the context of the conservation of cultural heritage held at buildings, we include rodents, insects and microorganisms. Support of biologists and microbiologists enables to carry out emergency response operations, e.g. following a flood, but also to plan a monitoring according to the Polish standard concerning the conservation of cultural heritage¹. Regular microbiological and entomological monitoring of exhibition and storage spaces makes it possible to detect a threat and determine the risk posed by the presence of a given insect or microorganism. Thanks to this, intervention measures, e.g. disinfection, which has an impact on historic materials, are carried out solely for those objects where it is justified. Here, we apply the principle of the lesser of two evils. We know that a disinfection is harmful, but if its microbiological activity is confirmed, we go ahead with it because the adverse effects caused by microbiological activity would be greater. Importantly, disinfection does not allow for the complete elimination of all microorganisms and their survival forms, because it is not a sterilisation. Often, a single treatment is not enough and needs to be repeated. Microbiological purity analyses are also helpful here, as they enable to verify the effectiveness of this procedure.

Microbiological analyses are also carried out when items are transferred to another institution, when they are returned from loan, or before they are relocated to a new building. By carrying out microbiological inspections of the museum, archival and library collections, we can assess which items are contaminated and require disinfection, which are contaminated with mould spores and need to be cleaned mechanically, and which can be safely transferred to a new location. Furthermore, due

¹ PN-EN 16790:2016-08 *Conservation of cultural heritage. Integrated pest management (IPM) for protection of cultural heritage.*

to the identification of isolated microorganisms we can assess employees' exposure to harmful biological agents at the workplace. We often conduct tests in rooms where a pungent, unpleasant and musty odour has been detected. Well planned tests make it possible to identify its cause. Most often, it is microbiological activity in areas with restricted circulation, e.g. behind furniture or near plumbing leaks.

Microbiologists also monitor the air quality, that is, the conditions under which collections are stored. The analysis of microorganisms and their airborne spores is the subject of a growing field of study – known as aeromicrobiology – which is dynamically developing, among other things, through the use of genetic methods. Air quality analyses make it possible to determine whether there is a problem with air pollution in a building, and if so, in which rooms and what the cause is. Allow me to make a digression here. The COVID-19 pandemic made people aware of the existence of the microbiological risk which is invisible. This has led to increased interest in air quality and a rise in the number of enquiries about such tests, particularly following the return to working in offices.

Measurements of the chemical composition of the air are also carried out indoors. These involve analysing the concentrations of selected chemical compounds using specialised devices. The presence in the air of highly oxidising and reactive compounds, such as sulphur oxides, nitrogen oxides, acetic acid and formaldehyde, significantly accelerates the aging of historic materials. For this reason, information on the maximum permissible concentrations of these substances in the air was included, for example, in ISO:11799 standard² or in the guidelines of the Canadian Conservation Institute³. Ensuring air quality in accordance with the guidelines has an impact on the safe long-term storage of collections.

Moreover, we carry out entomological inspections of collections. They allow to assess whether there are any arthropods, such as mole-like or skin beetles, in the rooms, the presence of which could pose a threat to the collections. Sticky traps, pheromone traps and direct specimen collection are useful for entomological monitoring.

² PN-ISO 11799:2024 *Information and documentation. Document storage requirements for archive and library materials*.

³ *Preventive conservation guidelines for collections*, Canadian Conservation Institute, <https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections.html> [accessed: 26 VIII 2026].

In the context of the protection of collections, it is important that microbiological tests and entomological inspections are carried out on a regular basis. It is advisable to carry them out at different times of the year, with varying levels of tourist traffic, in rooms serving different purposes, with different types of ventilation and on different floors. A good example is the monitoring we carried out in Wawel Royal Castle, which results were published⁴. Unfortunately, not all cultural institutions are willing to share the results of such studies, which means we do not have a full picture of the scale of the problem.

It is a good practice to establish a separate department responsible for conservation prevention. Currently, such departments exist only in a few museum institutions.

And what do biologists take into account while assessing the condition of the building?

The assessment of building's condition is carried out by building mycologist. Comprehensive mycological analyses in a buildings include analyses of moisture vels in building components, the type of salt efflorescence (chlorides, nitrates, sulphates) including an analysis of salt concentration, an assessment of the degree of degradation of wooden elements and walls, as well as the extent of mould growth in building components, including identification of microbiological agents and insects. We pay attention to the presence of thermal bridges as well as the causes of biological corrosion and contamination affecting building components. We know from experience that the greatest risks associated with water damage affect the top and bottom floors. This is confirmed by, among others, the National Library – 90% of the paper-

⁴ *Prewencja jako niezbędny element opieki nad zbiorami Zamku Królewskiego na Wawelu. Konserwacja prewencyjna kolekcji Lanckorońskich* (Eng. Prevention as a necessary element of care for the collection of Wawel Royal Castle in Kraków. Preventive conservation of the Lanckoroński collection), E. Wiłkojć, J. Winiewicz (eds.), Kraków 2019; *Konserwacja i prewencja jako niezbędny element opieki nad zbiorami w Zamku Pieskowa Skała* (Eng. Conservation and prevention as a necessary element of care for the collection at the Pieskowa Skała Castle), E. Wiłkojć (ed.), Kraków 2023; M. Dyda, A. Pyzik, P. Drabik, Ł. Istel, E. Wiłkojć, O. Buchwald-Zięcina, A. Bogdanowicz-Prus, A. Skłodowska, *Monitoring of Bio-Aerosols, Gaseous and Particulate Matter (PM) Pollution of Wawel Royal Castle in Krakow, Poland*, "CEST2019 Proceedings" 2019. <https://doi.org/10.30955/gnc2019.00887>; A. Pyzik, M. Dyda, E. Wiłkojć, J. Winiewicz-Wolska, *Microbiological Diversity and Microbial Related Risks at Wawel Royal Castle in Krakow, Poland*, "CEST2019 Proceedings" 2019. <https://doi.org/10.30955/gnc2019.00339>.

-based collections sent to them for drying after water damage were stored in either basements or attics. The main causes of water activity in materials and the resulting growth of microorganisms are leaks from the roof and plumbing systems, as well as capillary action from groundwater or flooding from microclimate control systems, such as humidifiers and dehumidifiers.

It is worth noting that a mycological and structural survey is a requirement for both modern and historic buildings, particularly prior to planned reconstruction, expansion, modernisation or a change in the building use, as well as when dampness or signs of biological corrosion are detected. This follows from the *Regulation of the Minister of Infrastructure* on the technical specifications for buildings⁵.

| What do preventive measures look like in archives?

The State Archives may follow the ISO 11799 standard, I have already mentioned. It sets out the principles for the safe long-term preservation of archival and library collections, which consist mainly of paper-based materials. However, this is a standard that – like most – is not obligatory. Some archives have introduced a rule stipulating that any item which, by virtue of the Act, is transferred to them for permanent storage must be accompanied by microbiological test results confirming that it is free from contamination. This requirement stems from the ISO standard in question⁶. Depending on the volume of files submitted, the archive determines the number of microbiological tests required.

When it comes to storing archive collections, the main microbiological contaminants are spores, which settle on surfaces through sedimentation. To minimise this process, it is recommended to use air purifiers with filters that are regularly replaced, as well as to ensure adequate ventilation and frequent cleaning of living areas and furniture – wiping them down with paper-safe disinfectants, and mechanically cleaning packaging for archival items. It is the foundation. Let us bear in mind, however, that even

⁵ *Regulation of the Minister of Infrastructure of 12 April 2002 on the technical specifications to be met by buildings and their location* (consolidated text, Journal of Laws of 2022, item 1225, as amended).

⁶ ‘The items stored in the warehouse should be biologically clean. It is recommended to disinfect all items suspected of being contaminated with microorganisms or harbouring insects. Similarly, disinfection of the racks and shelves where the presence of microorganisms was detected is recommended’.

the most advanced devices designed to ensure the security of documents will not fulfil their purpose unless they are constantly monitored. This year, we experienced a water leak from the climate-controlled cabinet installed in the storeroom housing our most valuable and sensitive collections, namely paintings, paper artefacts and photographs. As a result of the leak, mold developed on the walls and objects. This example demonstrates that the installation of advanced technical solutions will not replace periodic checks of the premises' condition by staff.

It is worth mentioning the aspect of disinfection again here. In the case of collections on paper, the safest and most commonly used method in libraries and archives is disinfection using ethylene oxide⁷ by fumigation in specialised chambers. For collections affected by flooding, I suggest carrying out this disinfection, with an extended fumigation time, in order to INCREASE the effect of the biocidal compound on microorganisms. This approach helps to keep costs down – we avoid another fumigation, which involves a repeat transport of collections.

In June 2026, a fire caused by a Russian attack destroyed the historic complex of the Kyiv – Pechersk Lavra, a UNESCO World Heritage Site. This is just one of many examples of the enormous losses caused by the war in Ukraine. Do you think that, influenced by experiences from across the eastern border, organisations in our country have started to take better care of the preservation of historic monuments? What I mean is mainly thinking about looking for places that could serve as a shelter in the event of a crisis situation.

The premises in museum institutions are designed primarily with the evacuation of collections in mind, not people. The structural engineers must have the final say. They are the ones who identify the safest location in a given building, assess whether it can withstand an impact, and determine whether the ceiling can support any debris that might fall on it. The collections must be secured well in advance, as this is essentially impossible during hostilities. Explosions need not necessarily cause the building to collapse, but they may damage the windows. This exposes the exhibits to environmental factors such as rain, temperature and, as a result, to moisture in the materials, which encourages the growth of fungi – not only mould but also large-fruited

⁷ Trade name – Rotanox.

fungi. This is where unconventional solutions come into their own, such as products containing silver nanoparticles, which remain effective for much longer than traditional alcohol-based biocides. They are not approved for use in historic buildings, but war is an exceptional situation. Poland provided Ukraine with preparations based on silver nanoparticles. They were sprayed onto the book collections in rooms without windows to protect them, until evacuation, from the growth of mould that could completely destroy paper. A good practice for protecting collections in the event of hostilities is to keep them away from windows.

In Poland, we faced a similar situation following a fire in the Archive of the City hall in Cracow⁸. It took place in February, but due to the risk of structural collapse and the work of the investigators, the documents could not be recovered until April. Two months after the fire had been extinguished – a process which involved pumping 60 000 m³ of water into the building – the documents were so badly infested and overgrown with fungal mycelium that most of the collection could not be saved. In the case of Cracow, the losses are comparable to those associated with the burning down of the Library of the Krasinski Family Entail⁹. Situations like these lead us to reflect that we should invest in the creation of digital twins of the objects held in cultural institutions. A similar approach should be taken to safeguard historic buildings. A high-resolution 3D survey, featuring detailed photogrammetry and capturing architectural details, will enable these to be reconstructed if necessary. I know that such actions are being taken in our country. A mobile laboratory was established in the National Institute of Cultural Heritage to inventory historic buildings.

| What else can we do to act more effectively in crisis situations?

I consider practical training sessions to be invaluable – though, I regret to say – we organise far too few of them. Over a dozen years ago, the State Archives network conducted training sessions in which participants entered the flooded storage area and had to evacuate the collections. The groups were

⁸ The fire broke out in February 2021 and completely consumed the archive. Approx. 150–200 mln of documents were destroyed. Out of 20 km of files, less than 1 km was saved, and the files were in very poor condition.

⁹ The Library of the Krasinski Family Entail was burned down in September 1944 due to the bombing carried out by Germans.

international, therefore the language barrier was an additional challenge. This experience fostered sensitivity to many aspects and taught humility. In my opinion we should return to such practices. I am pleased that this proposal is being raised more and more often at meetings relating to the preservation of historic monuments. It was heard, for example, during the last conference of the Polish Association of Museum Registrars, where it was highlighted that simple training in the use of a fire extinguisher is more effective than a fire safety instruction or procedure. And it is the staff who will be the first to respond in the event of a real threat.

As part of the 3rd Congress on Heritage Security KOBED in 2025, I had the opportunity to observe rescue and firefighting exercises for a fire that ‘broke out’ in the forest next to the Pieskowa Skała Castle. The first fire trucks arrived about 30 minutes after the report was made. I do not mention this to point out the fire fighters’ sluggishness. Absolutely not! I just want to remind that the access for emergency services depends on the specific characteristics of the terrain. This illustrates the challenges faced by museums and other cultural institutions located far from city centres. I therefore believe that, when it comes to protecting cultural heritage in the event of disasters and acts of war, we should place great emphasis on practical training that takes into account various threat scenarios. Firefighting trainings are conducted by, for example, the Heritage Security Institute. I would like to add that it is the organiser of the above-mentioned KOBED Congress, during which issues related to the protection of cultural assets in the face of contemporary crises are discussed¹⁰.

Let us touch upon another aspect of your work. The microbiological research also serves to protect the health of museum and archives workers.

The case I am about to describe does not, in fact, concern museum buildings, but it illustrates the problem well. This year, we conducted analyses of the microbiological purity of the air in premises located in a 10-year-old office building in Gdańsk. The results proved

¹⁰ The fourth edition of this event took place in 2026. See: *IV Kongres Bezpieczeństwa Dziedzictwa Kobed’26. Zabezpieczenie i Ochrona Dóbr Kultury* (Eng. The 4th Congress on Heritage Security KOBED’26. Safeguarding and Protection of Cultural Heritage), <https://ibid.org.pl/kobed26/> [accessed: 26 VIII 2026].

catastrophic. The level of mold spores in the air was comparable to that found in the dump crypts of the cathedral. We enter the crypts wearing masks and protective suits, yet in these offices people were working for eight hours without any protective equipment. It turned out that flooding had occurred in the second part of the building, and the raised floor structure had allowed water to spread to other rooms, causing damp throughout the entire storey in the plasterboard partition walls and the growth of mould on their surfaces. Mould spores were floating in the air, although there was no visible microbiological activity on the floor. The main reason for conducting air quality analyses was an unpleasant odour and allergic symptoms among workers. On that note, I would like to emphasise that the microbiological infection is often not visible, yet it has serious health consequences. As they grow, mould fungi release several dozen different chemical compounds, including harmful mycotoxins, some of which are carcinogenic. It is worth bearing in mind that such incidents are increasingly affecting new buildings. This is not only a matter of the poorer quality of the materials used in plumbing and drainage installations, but also the result of inadequate maintenance of the ventilation and air-conditioning systems in the building. We are also observing dangerous practices where building administrators reduce the rate of air exchange in order to cut operating costs. This results in concentrations of harmful substances in the air that are hazardous to health – carbon dioxide, formaldehyde and bioaerosols. This leads to reduced concentration and work efficiency in people, and in the case of long-term exposure, it can cause allergies and respiratory diseases.

I would like to take this opportunity to point out that the popular practice of ozonation is often ineffective when dealing with mold fungi. Ozone has a biocidal effect on viruses and bacteria, however, mould spores often remain completely resistant to its effects, as confirmed by one of the Provincial Sanitary-Epidemiological Stations. Furthermore, in order to achieve a biocidal concentration of ozone and ensure safety of this procedure, it is essential to maintain a very airtight environment. Ozone is dangerous gas because it binds to our blood cells more rapidly than oxygen. During ozonation, the concentration of formaldehyde released when plastics – such as adhesives, varnishes and paints, for example from the surfaces of furniture – are oxidised by ozone also increases dramatically. I am aware of cases of formaldehyde poisoning among people who were in a room adjacent to the one being treated with ozone.

So how can we check whether the air where we work is clear?

Unfortunately, it is not easy. Building administrators conduct inspections, but the problem is that there is no requirement to carry out microbiological air research. If such an inspection is carried out at the request of the office space lessor, but the client is a building administrator, then ensures impeccable conditions on the day it is due to take place. I remember an incident when, while carrying out measurements on behalf of an institution, who was renting office space, I was escorted out of the building by security on the pretext that the administration had not been informed of the survey in advance. I am in favour of encouraging administrators to ensure good indoor air quality rather than punishing them. We are spending more and more time indoors, so the importance of indoor air quality is also increasing. And here is an interesting fact. In Japan, during the recruitment process, it is emphasised that the air quality in the office is monitored on an ongoing basis and that the results are publicly available. This is seen as an incentive and a benefit for the employee.

You work at the Research and Development for Life Sciences – the first spin-off company established at the University of Warsaw offering, among others, microbiological research for museums and archives. What were the beginnings of this initiative and how has it evolved?

The venture originated in Professor Aleksandra Skłodowska's¹¹ academic work who, among other things, supervised doctoral proceedings in the field of art conservation. The RDLS Company was set up in 2014 on her initiative, and that of Łukasz Drewniak, PhD, now the Professor at the University of Warsaw, as well as Łukasz Rodek, currently serving as its president. Our head office is located at the Faculty of Biology at the University of Warsaw and we deal with activities related to microbiology. During our conversation, we focused on the microbiological threats to museums and archives, but let us not forget that microorganisms also have an impact on the environment

¹¹ Professor Aleksandra Danuta Skłodowska (1953–2024) – a distinguished specialist in microbiology and environmental biotechnology, the initiator of the Environmental Contamination Analysis Laboratory at the Faculty of Biology of the University of Warsaw, which she led for 16 years.

around us. The second ‘pillar’ of the activities of the RDLS is the design and construction of natural wastewater treatment systems, which are easy and inexpensive to maintain. Due to their relatively large size, they are best suited to rural areas. In 2025, we were awarded the title of ‘Innovator of Mazowsze’ for implementing this technology. To date, we have built five such treatment plants.

As regards our cooperation in the field of microbiological and mycological research, over the past 12 years we have carried out thousands of analyses for national research centres, archives, museums, libraries and state administration. For example, we examined such valuable exhibits as Wawel arrases, Łaski’s Statutes and the Constitution of the 3rd May from the collections of the Central Archives of Historical Records and the Gutenberg Bible in the Diocesan Museum in Pelplin.

We have also been conducting training and workshops in cultural institutions, including in cooperation with the National Institute of Museums. The result of many years of cooperation with the NIM is the practical guide, which concerns the microbiological safety of the collection. It is available free of charge in electronic form on the Institute’s website¹².

In our activities we focus on research performed for national institutions, but they also have a cross-border dimension. We have implemented projects, among others, together with the National Library in Prague, the State Archives in Budapest and the Slovak National Library. We produced a practical guide for those involved in collections,



Image 1. Science in the service of cultural heritage – Magdalena Dyda, PhD, during testing Wawel arrases.

Source: M. Dyda’s archive.

¹² M. Dyda, *Zagrożenia mikrobiologiczne zbiorów muzealnych* (Eng. Microbiological threats of museum collections), Warszawa 2020, <https://nim.gov.pl/wydawnictwa/abc-zagrozenia-mikrobiologiczne-zbiorow-muzealnych> [accessed: 25 VIII 2026].

to help them deal with unforeseen incidents¹³. In it, we set out the basic range of measures that the institution can implement to prepare for such situations. Unfortunately, we did not take into account the war conditions, because the publication was written before Russia's full-scale invasion of Ukraine.

Interviewed by: Daria Olender

Magdalena Dyda, PhD

PhD in biological sciences, she specialises in conservation microbiology and the preservation of museum, archive and library collections. She works at the RDLS, a spin-off company of the University of Warsaw.

The author of scientific and outreach publications. She is a co-organiser of conferences as well as workshops and lectures focused on practical methods of biological prevention and security of collections. She conducts research, provides consulting and delivers training in the field of biological threats, security of collections and conservation prevention for institutions responsible for collections. He specialises in analysing the diversity and activity of microorganisms inhabiting buildings and movable heritage objects made from various materials, as well as monitoring of physico-chemical factors and microbiological contamination of indoor air.

She has been working with cultural institutions for over 10 years, including Wawel Royal Castle in Kraków, the Royal Łazienki Museum, the State Archives, the National Institute of Museums. She conducted research within the framework of projects including 'Wawel – heritage for the future' ('Wawel-dziedzictwo dla przyszłości'), 'Multicultural Republic of Poland – the Pieskowa Skała Castle' ('Wielokulturowa Rzeczpospolita, Zamek Pieskowa Skała') and 'We are saving the Pelplin Gutenberg Bible' ('Ratujemy Pelplińską Biblię Gutenberga'). Since 2017, she has been conducting microbiological trainings and workshops as part of the cooperation with the NIM.

¹³ B.F. Zerek, *Guidelines for preparing an emergency protocol for libraries and archives*, https://bparchiv.hu/wp-content/uploads/2024/02/v4_emergency_protocol_guidelines_0.pdf [accessed: 25 VIII 2026].