kompleksu [The influence of the bryophytes on the content of macroelements and organic carbon in technozems of the dumps of the Chervonohrad mining industrial complex]. Bulletin of Kharkiv National Agricultural University, Biological Series, 33, 52–59 (in Ukrainian). http://nbuv.gov.ua/UJRN/Vkhnau_biol_2014_3_9
5. Karpinets, L. I., Lobachevska, O. V., & Yavorska, H. V. (2025). Vplyv mokhovoho pokryvu na vmist mineralnykh spoluk nitrohenu zalezhno vid mikroklimatychnykh ta edafichnykh chynnykiv seredovyshcha u lisovykh ekosystemakh Ukrains'koho Roztochchya [Influence of moss cover on the nitrogen mineral compounds content depending on microclimatic and edaphic factors of the environment in forest ecosystems of the Ukrainian Roztochchya]. Chornomorski Botanical journal, 21(4), 354–364 (in Ukrainian). https://doi.org/10.32999/ksu1990-553X/2025-21-4-4
6. Nikolaichuk, V. I., & Bilyk, P. P. (1997). Laboratorni ta praktychni roboty z hruntoznavstva: navchalnyi posibnyk [Laboratory and practical work on soil science: a textbook]. Uzhhorod: Patent. 112 p. (in Ukrainian)
7. Siwach, A., Zhuang, Q., & Baishya, R. (2024). Impact of seasonality, moss cover, and forest types on soil microbial biomass and enzymatic activity: an environmental prospective from the Himalaya. Catena, 244, 108269. https://doi.org/10.1016/j.catena.2024.108269
8. Wei, M., Sun, Q., Liu, D. (2025). Moss cover modulates soil fungal functional communities and nutrient cycling in alpine forests. Forests, 16(1), 138. https://doi.org/10.3390/f16010138

https://doi.org/10.30970/apmicro.2026.5

Kravchuk A.[1,2], Hryshchenko N.[1,3], Fomina M.[1]

CHALLENGES AT SIMULATION OF FUNGAL BIODETERIORATION OF MEDIEVAL FRESCOES IN EXPERIMENTAL LABORATORY MODELS

[1]D. K. Zabolotny Institute of Microbiology and Virology of the National Academy of Sciences of Ukraine, 154 Akademika Zabolotnoho St., Kyiv, 03143, Ukraine
[2]Educational and Scientific Centre "Institute of Biology and Medicine" of Taras Shevchenko National University of Kyiv, 2, Hlushkova Ave., Kyiv, 03127, Ukraine
[3]Institute of Molecular Biology and Genetics of the National Academy of Sciences of Ukraine, 150 Zabolotny St., Kyiv, 03680, Ukraine
e-mail: kravchuk.alona1@gmail.com

Abstract. The unique medieval frescoes in Saint Sophia cathedral in Kyiv have suffered from dark-spotted biodeterioration caused by xerophilic aspergilli. This work is aimed at the development of experimental models adequately simulating this type of biodeterioration under laboratory conditions to be able to test antifungal treatments prior to their application *in situ*. A microcosm was developed based on ground medieval plaster (2000 g/L), which reproduced calcite-rich mineral matrix, extreme low-water activity required for xerophilic aspergilli, and the original dark-spotted biodeterioration along with general properties of authentic plaster. The developed model advantages, emerged challenges and mitigation measures for future research were identified.
Keywords: fungi, cultural heritage, frescoes biodeterioration, xerophilic aspergilli, experimental modelling.

It is well known that fungi are major contributors to the biodeterioration of cultural heritage, displaying remarkable adaptability and the capacity to thrive under unfavourable conditions, including extreme xerophilic behaviour within indoor heritage environments. Cultural heritage materials vary widely in composition and structure, and fungi are able to adapt successfully to each substrate, often in unpredictable ways, exhibiting puzzling patterns of material colonisation. This is particularly true of xerophilic aspergilli, which are

typical biodeteriogens of museum environments. Combating fungal colonisation effectively demands a thorough understanding of the multiple factors influencing this process, along with the design of tailored experimental strategies suited to each individual case, with special emphasis on the creation of suitable controlled laboratory systems that accurately replicate cultural heritage microenvironments.

The current work was dedicated to the development of adequate experimental laboratory models which can correctly simulate the process of dark-spotted biodeterioration of medieval mineral frescoes of Saint Sophia cathedral (Kyiv, Ukraine) in order to develop specific antifungal treatment against xerophilic aspergilli causing this biodeterioration.

The experimental system was based on a microcosm of sterile plastic 6-well cell culture plates. *Aspergillus vitricola* strain, isolated from biodeteriorated frescoes of Saint Sophia cathedral, was used as a model deteriogenic microorganism. Fungi were cultivated on PDA +15 % NaCl medium mixed with ground medieval plaster. Light microscopy, scanning electron microscopy (SEM), image analysis (ImageJ/Fiji), spectrometry for analysis of phenolic compounds, and one-way ANOVA (MINITAB) were used. Also, total DNA was extracted from the samples of microcosm plaster using a QIAamp DNA Mini Kit (QIAGEN) (Fomina et al., 2022).

Plaster concentration was found to strongly affect fungal colonisation of the microcosm: colony area increased sharply at 15–120 g/L (due to sparse marginal mycelium and guerrilla-type growth (Fomina et al., 2024)), then declined at 250–2000 g/L. SEM showed endolithic growth within mineral matrix, biogeochemical activity, and versatile morphology of *A vitricola*. Colonies darkened with increasing plaster content (1.3-fold lower brightness at 2000 g/L vs control), and content of total phenolic compounds decreased. The 2000 g/L plaster medium was the best to reproduce the dark-spotted biodeterioration on cathedral walls and it was chosen for further studies where the effect of ethanol treatment on fungi was tested. Ethanol treatment was observed to cause increased conidiogenesis and hyphal aggregation during fungal recovery in the affected areas.

Advantages of the developed model:

The microcosm was established as a scaled-down model of a painted wall, using ground medieval plaster to reproduce a calcium-rich mineral matrix dominated by calcite, together with extreme low-water-activity conditions (achieved via 15 % NaCl) required for xerophilic aspergilli.

The 2000 g/L plaster variant successfully reproduces both the original dark-spot damage on the cathedral walls and the general characteristics of authentic plaster.

The model is well suited to microscopic examination by both stereomicroscopy and SEM, allowing colonisation of the internal plaster space to be observed and endolithic mycelial behaviour to be documented.

This variant was successfully applied in preliminary antifungal treatment trials using ethanol, validating the model as a platform for testing antimicrobial agents in vitro prior to their application on actual heritage surfaces.

Challenges and mitigation measures for future research:

The nutrient-rich conditions used to accelerate colonisation in this model were highly exaggerated compared with the oligotrophic conditions found on the actual cathedral walls. The next step would be experiments with reduced nutrient content.

The dense mineral matrix formed at high plaster concentrations protects fungal biomass so effectively that it hinders homogenisation and the extraction of nucleic acids and other metabolites using standard methods. The next step would be to explore alternative homogenisation approaches (e.g., a bead-mill homogeniser with glass-bead lysis tubes) or develop an alternative model based on a different substrate, such as glass.

The optimal time frame for treating biodeteriorated plaster remains unclear. The next step would be further experiments focused on antifungal treatment trials.

References

1. Fomina, M., Cuadros, J., Pinzari, F., Hryshchenko, N., Najorka, J., Gavrilenko, M., Hong, J. W. & Gadd, G. M. (2022). Fungal transformation of mineral substrata of biodeteriorated medieval murals in Saint Sophia's cathedral, Kyiv, Ukraine. *International Biodeterioration & Biodegradation*, *175*, 105486.
2. Fomina, M., Gromozova, O., & Gadd, G. M. (2024). Morphological responses of filamentous fungi to stressful environmental conditions. *Advances in applied microbiology*, *129*, 115–169.
3. Gadd, G. M., Fomina, M., & Pinzari, F. (2024). Fungal biodeterioration and preservation of cultural heritage, artwork, and historical artifacts: extremophily and adaptation. *Microbiology and Molecular Biology Reviews*, *88*(1), e00200-22.

https://doi.org/10.30970/apmicro.2026.54

Leonova N., Fomenko S., Kyrylov V.

MICROBIAL DYNAMICS AND BIOLOGICAL ACTIVITY IN SHELL-EXPLOSION-DAMAGED SOILS

D. K. Zabolotny Institute of Microbiology and Virology of the National Academy of Science of Ukraine, 154 Akademika Zabolotnoho St., Kyiv, 03143, Ukraine
e-mail: natali_leonova@ukr.net

Abstract. The full-scale Russian invasion of Ukraine has severely disrupted soil ecosystems and microbial communities. This study evaluated phytobacterial remediation of shell-explosion-damaged soil near Bakhmut using microbial bioformulations, white clover (*Trifolium repens*), and *Rhizobium leguminosarum* bv. *trifolii* 320b. After 60 days, nitrogen-fixing, phosphate-mobilising, amylolytic, ammonifying, and pedotrophic microorganisms increased, whereas oligotrophic and cellulolytic populations declined. The strongest increases were observed for phosphate-mobilising microorganisms (2.2–5.2-fold). Overall, remediation promoted functional restructuring of the soil microbiome and recovery of nutrient cycling and biological soil fertility.
Keywords: soil microbiota, military impact, microbial abundance, bioformulations.

The full-scale Russian invasion of Ukraine has resulted in substantial degradation of soil ecosystems through mechanical disturbance, chemical contamination, and disruption of microbial communities (Solokha et al., 2024). Explosive residues, including TNT, RDX, and HMX, may persist in soils, exert toxic effects, and alter the structure and functional activity of soil microbial communities (Corredor et al., 2024). While the physicochemical impacts of warfare are increasingly recognised, alterations in soil microbiome structure and function remain insufficiently understood. Given the essential role of microorganisms in nutrient cycling, soil organic matter turnover, fertility, and ecosystem functioning (Sokol et al., 2022), restoration of microbial communities represents an important component of post-war soil rehabilitation. Therefore, this study aimed to assess microbial dynamics and biological activity in soils affected by shell explosions and to evaluate microbial bioformulations as a biotechnological approach for accelerating their ecological recovery.

The study was conducted under vegetation conditions using soil collected from an artillery shell crater near Bakhmut (Donetsk region, Ukraine); unaffected soil sampled 50 m