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## Establishment of regularities of the influence of polymeric shell on wood biodegradation

Yuriy Tsapko, Oleksandra Horbachova\*, Serhii Mazurchuk

National University of Life and Environmental Sciences of Ukraine  
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

**Abstract.** The analysis of the process of biological degradation of wood is carried out. It is established that neglect of environmentally friendly safe biosecurity products leads to the destruction of wood structures under the influence of microorganisms. The study of wood protection conditions allows creating new types of protective materials that help reduce water absorption and the amount of substances that are a medium for the development of wood-destroying fungi. In this regard, an analytical-experimental method for determining the proportion of destroyed material under the action of microorganisms using an antiseptic has been developed. Analysis of the results shows that the maximum mass loss in the case of biodegradation of untreated wood samples was from 7.6% to 16%, and the mass loss of samples of thermally modified wood did not exceed 3%, in those treated with an antiseptic water repellent – was less than 2%. It was determined that the protection in the case of treatment of thermally modified wood with wax oil and lasur increases in comparison with untreated wood by more than 4 times in terms of biodegradation, and in the case of treatment of non-thermally modified wood – by more than 8 times. Notably, the presence of wax oil and lasur leads to blockage of the wood surface, which prevents the penetration of moisture and microorganisms. Therefore, the intensity of development of wood-destroying fungi on the surface of different samples varies. Obviously, such a mechanism of influence of the protective coating is the factor in regulating the process, due to which the integrity of the object is preserved. Based on experimental data and modelling equations, the dynamics of the microbial population in the volume of material and the function of increasing the number of dead organisms are derived. In particular, a polymer shell was created on the surface of the sample, which significantly reduced the penetration of microorganisms into the wood, and the loss of wood mass during biodegradation did not exceed 2.5%. Additional application of protective substances on the surface increases the level of protection of untreated pine wood by 72%, thermally modified at 190°C – by 25%, at 220°C – by 37%. Similar results are obtained for hornbeam wood – 60%, 37%, and 28%, for oak – 50%, 37%, and 37%, respectively

**Keywords:** wood, efficiency of thermal modification, antiseptics, protective coatings, bio-degradation, wood stability

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\*Corresponding author

## Introduction

The search for highly effective means of protecting wood from degradation is a pressing issue in construction since outdoor operation makes wood vulnerable to environmental conditions, leads to a significant decrease in its natural durability and eventually destruction..

Thermal modification of wood causes chemical changes that significantly affect the physical, mechanical, and biological properties of wood (Tsapko *et al.*, 2021). Therefore, it is important to investigate these changes to make better use of the products. In particular, Kubovský *et al.* (2020) conducted thermal modification of wood using Thermowood technology at temperatures of 160°C, 180°C, and 210°C. Researchers claim that hemicelluloses are less heat-resistant than cellulose. Polysaccharide chains are split into shorter ones, which leads to a decrease in the degree of polymerisation and an increase in polydispersity. Crosslinking reactions also occur at the highest processing temperature (210°C). At lower temperatures, lignin degradation reactions predominate, while higher temperatures mainly cause condensation reactions and an increase in molecular weight. Chemical changes in the main components of thermally modified wood mainly affect its mechanical properties, which should be considered when designing a variety of wooden structures.

Thermal modification of wood is a promising alternative to chemical and biocidal modification processes, which increases the biological strength and dimensional stability of wood. The main purpose of the study, as reported by Candelier *et al.* (2020), was to determine the biological stability of ash wood treated with thermal modification and to evaluate the antifungal and antithermic activity of extractive compounds from heat-treated ash wood, depending on the intensity of the modification process (2 hours at 170°C, 200°C, 215°C, 228°C). Untreated and heat-treated wood samples were extracted with water or acetone. The extracts were then used to determine the effectiveness of inhibition against white rot (*Trametes versicolor*) and brown rot (*Rhodonia placenta*) fungi. It was found that the degree of

antifungal activity of these extracts depends on the solvent used during the extraction, and varies depending on the intensity of heat treatment. The extracts were more effective against brown rot than white rot fungi. However, the anti-termite activity of heat-treated ash wood extracts was not significant. In addition, new chemical elements are formed as a result of thermal decomposition of wood polymers (lignin and hemicellulose), in particular, aliphatic acids, monosaccharides, and other products obtained as a result of their dehydration reaction. The most common element was syringaldehyde from lignin-derived compounds, which may explain the antifungal effect of heat-treated ash wood extracts.

The most common defects of structural elements are biological damage to the support zones of the coating and structures of the floor beam, and the use of impregnation with a polymer mixture in the destruction zones allows restoring the physical and mechanical properties of wood and preserving the appearance of the architectural structure. The paper by Gribanov *et al.* (2020) presents the results of X-ray tomography of reconstructed samples of destroyed wood, and a method for testing samples for crushing and cutting along fibres. It was found that the increase in the strength of reconstructed wood samples during crushing along the fibres was 77% compared to samples of destroyed wood and 83% during chipping.

The weather resistance of thermally modified wood was slightly better compared to untreated wood, but over time, the surface weathering occurred and additional processing became necessary. For this purpose, Miklečić *et al.* (2010) recommend the penetration treatment that oil-based coatings can provide.

To protect thermally modified wood, changes in some of its properties should be considered. Akyildiz & Kesik (2014) found that thermally modified wood has a more hydrophobic surface, absorbs little water, but still requires the use of elastic coatings, in particular, oil-based ones.

Features of the structure of wood as a material contribute to changes on a global scale in

construction. Wang *et al.* (2018) note that numerous multi-storey buildings made of solid wood are in the planning stage, under development, or have already been built. The effectiveness of their construction will change the way architects and engineers think of wood as a material. Although all materials can break down when wetted, the potential for wood biodegradation in a wooden building requires special study. Identifying and eliminating the conditions that can lead to this degradation will be crucial to ensure proper wood performance in such structures. This study examines and compares potential sources of biodegradation that exist for traditional wood construction with those used in mass construction, and identifies methods for limiting the risk of degradation.

Teacă *et al.* (2019) note that one of the most effective ways to prevent wood degradation is to apply protective coating layers by chemical modification of the surface. Recent trends in this area involve the use of natural products on a biological basis – extractives, oils, waxes, resins, biopolymers, biological control agents, for which the main classification criterion is represented by the type of protection. However, there are still unresolved issues related to the resistance of these coatings to atmospheric fluctuations when used in outdoor conditions.

Pavlič *et al.* (2021) studied the compatibility of various coatings with thermally modified Scots pine wood. Coatings applied to thermally modified wood showed better performance, including lower equilibrium moisture content, lower water permeability, increased dimensional stability, better UV resistance, and resistance to blue fungi compared to non-modified wood. Better penetration of the coating into modified wood and better wetting of thermally modified wood with protective coatings were also observed. In addition, oil-based paint and varnish materials showed better results after one year of external weathering compared to water-based coatings.

Oils provide the best protection for wood products, but their use is limited to their long-term

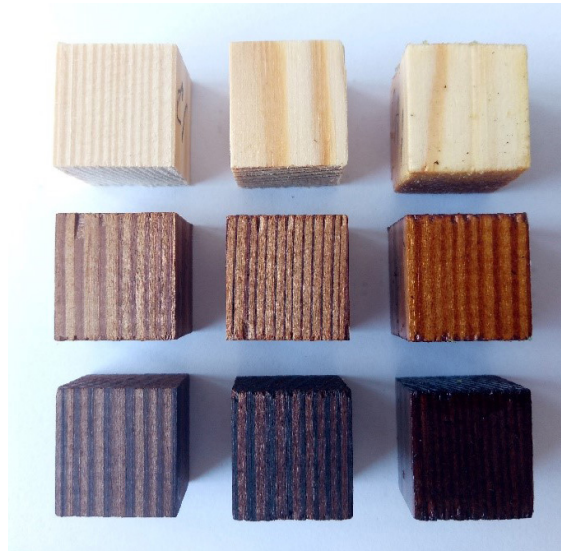
polymerisation, in addition, they guarantee protection for no more than 3 years. Arminger *et al.* (2020) investigated the behaviour of linseed and tung oil, in particular, tung oil gave hydrophobicity to all wood samples after application, even without drying. Linseed oil took longer to dry, and it was more susceptible to the effects of thermally modified wood.

Thus, from the literature sources it is established that during the use of wood, its components gradually degrade, which requires effective protection with environmentally friendly substances. The scarcity of data to explain and describe the process of wood biosecurity and neglect of the use of organic substances for elastic coatings leads to inefficient use of protective equipment. This indicates the expediency of conducting a study to determine the effectiveness of protecting wood products with protective coatings, which will increase the service life of building structures in environmental conditions.

The purpose of this study is to identify patterns of wood biodegradation when microbiological factors affect the protective coating.

## Materials and Methods

**Determination of the process of biological degradation of wood.** Studies were conducted on samples of pine and oak as structural materials and hornbeam wood as alternatives to expand the areas of use. In total, 9 groups (10 units each) of samples of each species were used, measuring 20×20×20 mm. Groups 1, 2, and 3 were untreated wood without and with additional surface protection with a water-repellent antiseptic, and groups 4-9 were thermally modified at 190°C and 220°C for 10 hours without and with additional treatment. Two types of materials were chosen as antiseptic water repellent – WAX OIL Bionic House and Lasur Colortex Komposit. The protective substances were applied by immersion with repeated treatment after the first layer dried in 24 hours. The average amount of coating applied corresponded to about 170 g/m<sup>2</sup> (Fig. 1).



**Figure 1.** Model sample of pine wood: 1 – unmodified; thermally modified: 2 – at a temperature of 190°C for 10 hours; 3 – at a temperature of 220°C for 10 hours

The determination of biological degradation of wood was carried out according to a working methodology, the essence of which was to experimentally determine the mass loss of protected wood under the influence of soil microflora under certain air and moisture conditions and for a certain time. Wood is considered bio-resistant if the average mass loss of samples is no more than 5%.

The proportion of destroyed wood was calculated using the equation:

$$X_e = \frac{m_1 - m_2}{m_2}, \quad (1)$$

where  $m_1$  – weight of the sample before the test, g;  $m_2$  – weight of the sample after testing, g.

**Modelling of parameters of microbial penetration into wood and its destruction.** It is assumed that the proportion of wood volume involved in the biochemical metabolic process and depending on the size of the microbial population can be determined from a system of differential equations:

$$\left. \begin{aligned} \frac{dN}{dt} &= (\alpha - \beta \cdot N) \\ \frac{dR}{dt} &= \gamma \cdot N \\ \frac{dX}{dt} &= k \cdot (a - X) \cdot N \end{aligned} \right\} \quad (2)$$

where  $N$  – the number (size) of the population of active (live) microorganisms in the volume of wood  $V$  ( $m^3$ );  $t$  – time of action of microorganisms on wood,

days;  $X$  – proportion of wood volume involved in the biochemical metabolic process;  $R$  – the function of reducing the number (bioprotective substances), the values of which are equal to the proportion of microorganisms that have stopped vital activity as a result of adverse conditions: accumulation of decomposition products of enzymatic activity; release of toxic substances during metabolic processes; increase in insulating ability;  $\alpha$  – maximum specific growth rate of microorganisms;  $\beta$  – specific rate of decrease in the number of microorganisms;  $\gamma$  – population reduction rate;  $k$  – coefficient of permeability of microorganisms to the material;  $a$  – total proportion of organic matter.

First, the independent system of the first two equations of system (1) is solved and the following is obtained (Tsapko, 2013):

$$N = \frac{N_m}{ch^2 \left[ \left(1 - \frac{t}{t_m}\right)^{\frac{\Delta}{2}} \right]}, \quad (3)$$

where  $N_m$  – maximum number of microorganisms in wood, %;  $t_m$  – time of development of the maximum number of microorganisms in wood, days;  $\Delta$  – parameter of microbial penetration; a solution for the function of reducing the number of active organisms in the form of:

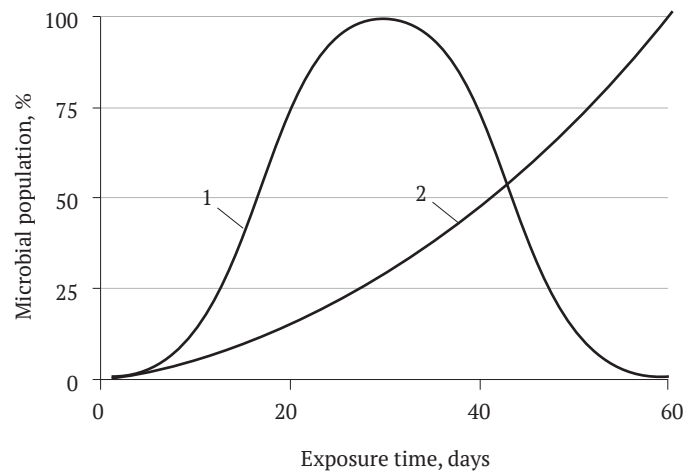
$$R = \frac{1}{2} \left\{ 1 - th \left[ \frac{1}{2} \left( 1 - \frac{t}{t_m} \right) \cdot \Delta \right] \right\}. \quad (4)$$

Based on experimental data (Tsapko, 2013) and modelling equations (3) and (4), the dynamics of the microbial population in the volume of material and the function of increasing the number of dead organisms are derived.

As can be seen from Figure 2, at the initial time point, the population of active microorganisms in the material is low:  $N(0)=N_0$ , but increases over time, and this function necessarily has a global maximum point (the maximum possible number

of microorganisms) at a certain time  $t=t_m$ , in which  $N(t_m)=N_m$ . Over time, the amount of nutrients decreases and the population of microorganisms die off.

These results give an idea of the reproduction of microbacteria in the material and their death, and, accordingly, show changes in the metabolic processes of microorganisms. Protective substances in the material increase the suspended animation of microbacteria and allow controlling the process of countering biodegradation.

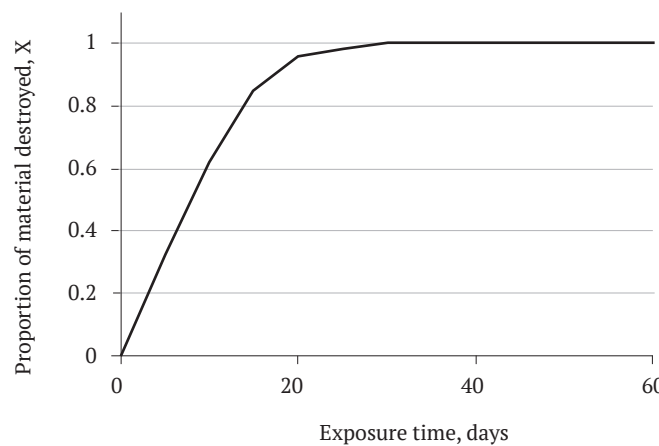


**Figure 2.** Dynamics of the microbial population in the volume of material: 1 – spread of microorganisms, 2 – increase in the number of dead organisms

After integrating the third equation of system (2), given that the proportion of destroyed material cannot exceed 1 or take negative values, and after substituting in its right-hand side instead of  $N$  for equation (3), the following equation is obtained:

$$X = 1 - e^{-2kN_m \frac{t_m}{\Delta} \left\{ th \frac{\Delta}{2} - th \left[ \left( 1 - \frac{t}{t_m} \right) \cdot \frac{\Delta}{2} \right] \right\}}. \quad (5)$$

Figure 3 shows the calculation of the proportion of material that is destroyed by microorganisms.



**Figure 3.** Proportion of material destroyed by microorganisms

## Results and Discussion

The process of biological degradation of wood has an incubation period – a period of time after which intensive destruction begins. It is assumed that the duration of this period coincides with the time interval  $t_m$  at which the microbial population will reach a critical size. In addition, it is necessary to find the parameter value of biodegradation process  $\Delta$ , permeability coefficient  $k$  and determine the maximum number of microorganisms in the wood  $N_m$ .

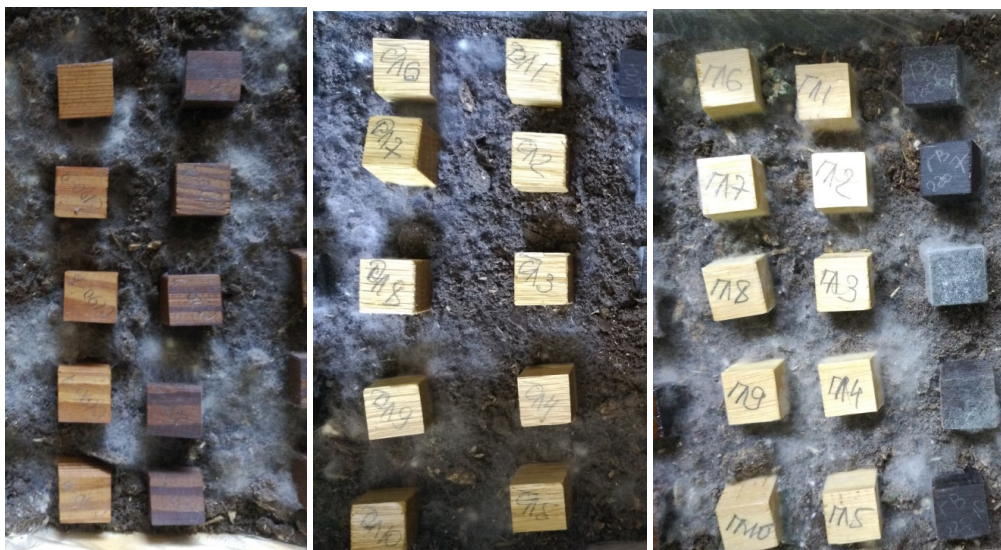
Experimental samples were kept for two calendar months in laboratory conditions at the Department of Technology and Design of Wood Products of the NUBIP of Ukraine. A culture of the wood-destroying fungus *Hericium erinaccus* was planted in the soil (Fig. 4). This type of fungus has the same effect on both coniferous and deciduous wood species. The medium parameters were also monitored and maintained at the required level: medium temperature –  $25 \pm 2^\circ\text{C}$ , soil moisture – 75-80%.



**Figure 4.** Determination of wood resistance to biological pests: *a* – cultures of fungi *Hericium erinaccus*; *b* – experimental samples of wood in laboratory conditions

During the test, the development of fungal lesions on the surface of the samples was monitored.

After six days, white fluffy mycelium of the fungus was observed in all the boxes on the soil surface (Fig. 5).



**Figure 5.** Appearance of mycelium on the soil surface in boxes with wood samples in the first week of the study: *a* – pine; *b* – oak; *c* – hornbeam

The mycelium of the wood-destroying fungus partially spread on the surface of samples of all the studied wood species with additional treatment with

lasur. A cotton-like mycelium of green colour can be observed on samples of pine wood untreated and treated with wax oil (Fig. 6).



**Figure 6.** View of pine wood samples on Day 6 of the exposure in a box with soil: *a* – untreated; *b* – surface is treated with wax oil

On Day 8, a similar mycelium appeared on samples of pine wood thermally modified at 190°C and 220°C with wax oil treatment. Brown spots were

observed on samples of untreated hornbeam wood (Fig. 7). Over time, the number of damaged samples and the area of damage increased.



**Figure 7.** Changing the appearance of hornbeam wood samples after a week of exposure in a soil box

On samples of oak wood modified at a temperature of 220°C with a surface treated with wax oil, fluffy green mycelium began to appear on Day 16, but it was different in appearance from what was found on pine. At this time, powdery grey mycelium was found on hornbeam wood thermally modified

at 190°C without surface treatment. On hornbeam wood without thermal modification with a surface treated with lasur, a fluffy mycelium of grey-green colour was found.

At this stage, the untreated oak wood began to turn yellow (Fig. 8).



**Figure 8.** View of untreated oak wood after two weeks of research

On Day 20, pine wood was covered with dirty green mycelium over a larger area. Hornbeam wood, thermally modified at 190°C and with additional treatment with wax oil, began to become

covered with a grey coating. After another four days, black spots began to appear on the ends of pine wood samples with surface treatment with wax oil (Fig. 9).



**Figure 9.** Appearance of black spots on oil-waxed pine wood samples on Day 24

Samples of oak wood, thermally modified at 190°C and treated with lasur, were partially covered with green powdery mycelium at this time.

The prototypes continued to be kept in

conditions favourable for the development of wood-destroying fungi. A week later, the appearance of green and red fungi on untreated pine wood was observed. Samples of untreated oak actively

collected moisture during this period and were coloured yellow. Moreover, at the ends, a cotton-like mycelium of green colour was visible in some places. A similar phenomenon occurred on samples of oak wood modified at a temperature of 220°C. The hornbeam wood remained unchanged.

On Day 38 of exposure in laboratory boxes, pine wood actively collected moisture from the soil

and acquired a yellow colour. The same situation was with samples of oak wood treated with wax oil, on some surfaces a red colour was noticeable. White mycelium appeared on the ends of samples of oak wood, thermally modified at 190°C and treated with lasur. A very small proportion of yellow mycelium was visible on samples of untreated hornbeam wood (Fig. 10).



**Figure 10.** Appearance of untreated hornbeam samples on Day 38 of exposure under aggressive conditions

After another 10 days of the experiment, samples of pine treated with wax oil accumulated moisture and turned yellow. Samples of pine thermally modified at 220°C showed white mycelium on a significant surface. The end surface of pine wood, modified at 220°C with additional application of lasur,

was covered with light green mycelium. The appearance of the hornbeam treated with wax oil has also changed: yellow mycelium was visible on the end surfaces, and a reticulated web of hyphae was visible on the upper part (opposite from the point of contact with the soil) (Fig. 11).



**Figure 11.** Appearance of hornbeam wood samples treated with wax oil

On samples of untreated hornbeam, brown spots changed to black in some places. After two months of exposure of the samples in aggressive conditions, darkening of the lower part, which was directly in contact with the soil, was noticeable.

After the experimental study was completed, the samples were cleaned of soil, weighed after drying, and the effect of wax oil and lasur coating on the resistance of wood to biodegradation was determined (Table 1).

**Table 1.** Results of the study of the effect of wax oil and lasur on the resistance of wood to biodegradation

Test object	Sample weight, g		Mass loss of wood, %	Proportion of destroyed wood
	before testing	after testing		
1	2	3	4	5
Untreated pine	4.9	4.1	16.330000	0.195122
Untreated pine+wax oil	4.33	4.12	4.850000	0.053528
Untreated pine+lasur	4.7	4.5	4.250000	0.044444
Pine T.M.* at 190°C	4.86	4.7	3.290000	0.034043
Pine T.M. at 190°C+wax oil	5.65	5.51	2.480000	0.025408
Pine T.M. at 190°C+lasur	4.46	4.36	2.240000	0.022936
Pine T.M. at 220°C	4.49	4.36	2.890000	0.029817
Pine T.M. at 220°C+wax oil	5.45	5.35	1.830000	0.018692
Pine T.M. at 220°C+lasur	3.87	3.8	1.810000	0.018421
Untreated hornbeam	6.89	6.32	8.272859	0.090190
Untreated hornbeam +wax oil	7.24	6.99	3.453039	0.035765
Untreated hornbeam+lasur	6.99	6.77	3.147353	0.032496
Hornbeam T.M. at 190°C	6.7	6.54	2.38806	0.024465
Hornbeam T.M. at 190°C +wax oil	7.31	7.2	1.504788	0.015278
Hornbeam T.M. at 190°C+lasur	7.13	7.03	1.402525	0.014225
Hornbeam T.M. at 220°C	6.48	6.36	1.851852	0.018868
Hornbeam T.M. at 220°C+wax oil	6.9	6.81	1.304348	0.013216
Hornbeam T.M. at 220°C+lasur	6.8	6.71	1.323529	0.013413
Untreated oak	5.44	4.98	8.455882	0.092369
Untreated oak+wax oil	4.98	4.76	4.417671	0.046218
Untreated oak+lasur	4.75	4.55	4.210526	0.043956
Oak T.M. at 190°C	4.14	4.02	2.898551	0.029851
Oak T.M. at 190°C+wax oil	5.29	5.19	1.890359	0.019268
Oak T.M. at 190°C+lasur	5.14	5.05	1.750973	0.017822
Oak T.M. at 220°C	4.43	4.31	2.708804	0.027842
Oak T.M. at 220°C+wax oil	4.3	4.22	1.860465	0.018957
Oak T.M. at 220°C+lasur	4.29	4.22	1.631702	0.016588

\* T.M. – thermally modified

Thus, thermal modification increases the resistance of wood to biological pests. In particular, the mass loss of thermally-modified samples at 190°C during exposure in contaminated soil decreased by 5 times for pine wood, by 3.5 times for hornbeam, and by 3 times for oak. Exposure to a temperature of 220°C helps reduce the indicator by 5.6, 4.5, and 3.1 times, respectively. Additional application of protective substances on the surface increases the level of protection of untreated pine wood by 72%, thermally modified at 190°C – by 25 %, at 220°C – by 37%. Similar results are obtained for hornbeam wood – 60%,

37%, and 28%, for oak – 50%, 37%, and 37%, respectively.

Considering the presented results for determining the proportion of destroyed wood, such as pine, using a three-factor simplex – the central method of planning an experiment in the mathematical environment Statistica 12, statistical processing of the results was carried out.

The following factors were chosen as variation factors: thermal modification temperature, °C (factor  $X_1$ ); amount of coating, g/m<sup>2</sup> (factor  $X_2$ ), the changes of which are shown in Table. 2.

**Table 2.** Variation factors

Factors	Code	Variation levels			Variation interval
		-1	0	+1	
Temperature of thermal modification, °C	$X_1$	100	190	220	30
Amount of coating, g/m <sup>2</sup>	$X_2$	160	170	180	10

The proportion of destroyed material was chosen as the initial parameter (response function), the values of which were recorded on samples exposed

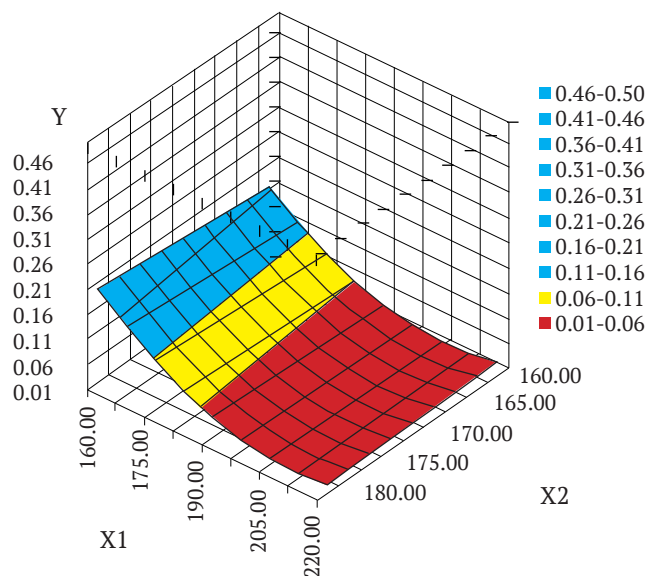
to microbacteria. The experiment planning matrix and its mathematical implementation are shown in Table. 3.

**Table 3.** Experiment matrix and its implementation

No.	Factors, type		Planning matrix		Response function	
	$X_1$	$X_2$	Temperature of thermal modification, °C	Amount of coating, g/m <sup>2</sup>	Y fact.	Y calc.
1	1	1	220	180	0.029	0.03
2	1	-1	220	160	0.034	0.04
3	-1	1	100	180	0.2	0.20
4	-1	-1	100	160	0.16	0.16
5	1	0	220	170	0.031	0.03
6	-1	0	100	170	0.18	0.18
7	0	1	190	180	0.042	0.05
8	0	-1	190	160	0.048	0.04
9	0	0	190	170	0.044	0.04
10	0	0	190	170	0.043	0.04
11	0	0	190	170	0.045	0.04

As a result of modelling, regression equations are obtained and ternary surfaces of changes in the

initial parameter are constructed depending on changes in variation factors (Fig. 12).



**Figure 12.** Ternary surfaces of changes in the output parameter depending on changes in the factors of variation of wax oil

Regression equation:

$$Y_{calc} = 0.044 - 0.074X_1 + 0.005X_2 + 0.061X_{11} + 0.0001X_{22} - 0.011X_1X_2.$$

Similarly, for hornbeam and oak wood:

$$Y_{calc} = 0.036 - 0.051X_1 + 0.006X_2 + 0.035X_{11} - 0.0001X_{22} + 0.003X_1X_2,$$

$$Y_{calc} = 0.042 - 0.081X_1 - 0.002X_2 + 0.066X_{11} - 0.0004X_{22} - 0.006X_1X_2.$$

Based on the computer modelling performed, the best value of the modification temperature and the amount of protective coating that ensures the fulfilment of the task was determined, namely, the lowest value of the proportion of destroyed material.

## Conclusions

The positive effect of creating a protective coating film on the wood surface on increasing resistance to biological pests was revealed. Analysis of the results shows that the maximum mass loss in the case of biodegradation of untreated wood samples was from 7.6% to 16%, and the mass loss of samples of thermally modified

wood did not exceed 3%, treated with wax oil and lasur – less than 2%. The idea of reproduction of microbacteria in the material and their death is revealed, which accordingly show changes in the metabolic processes of the vital activity of microorganisms.

It was found that the use of surfaces treated with wax oil and lasur reduces the biodegradation process by more than 8 times for untreated samples. This coating significantly increases the service life of wood. The findings also allow purposefully solving further problems of creating new means and methods of wood protection in accordance with the conditions of wood operation at various facilities.

## References

- [1] Akyildiz, M. H., & Kesik, H. I. (2014). Effect of heat treatment on the adhesion strength of water based wood varnishes. In L. Nunes, D. Jones, H. Callum, et al. (Eds.), *Proceedings of the Seventh European Conference on Wood Modification*. Lisbon, Portugal, March 2014.
- [2] Arminger, B., Jaxel, J., Bacher, M., Gindl-Altmutter, W., & Hansmann, C. (2020). On the drying behavior of natural oils used for solid wood finishing. *Progress in Organic Coatings*, 148. <https://doi.org/10.1016/j.porgcoat.2020.105831>
- [3] Candelier, K., Thévenon, M.-F., Collet, R., Gérardin, P., & Dumarçay, S. (2020). Anti-fungal and anti-termite activity of extractives compounds from thermally modified ash woods. *Maderas: Ciencia y Tecnologia*, 22 (2), 223–240. <http://doi.org/10.4067/S0718-221X2020005000209>
- [4] Griбанov, A., Glebova, T., & Roschina, S. (2020). Restoration of Destructive Wood in Supporting Zones of Wooden Beams. *Lecture Notes in Civil Engineering*, 70, 157–166.
- [5] Kubovský, I., Kačíková, D., & Kačík, F. (2020). Structural changes of oak wood main components caused by thermal modification. *Polymers*, 12 (2), 485. <https://doi.org/10.3390/polym12020485>
- [6] Miklečić, J., Jirouš-Rajković, V., Pervan, S., & Grujić, S. (2010). Oils usage in finishing of thermally modified wood in outdoor applications. In D. Radovan (Ed.), *Conference: Wood is Good-Transfer of Knowledge in Practice as a Way Out of the Crisis*. University of Zagreb, Faculty of Forestry, Zagreb, Croatia.
- [7] Pavlič, M., Petrič, M., & Zigon, J. (2021). Interactions of Coating and Wood Flooring Surface System Properties. *Coatings*, 11 (1), 91. <https://doi.org/10.3390/coatings11010091>
- [8] Teacă, C.-A., Roșu, D., Mustață, F., Roșca, I., & Varganici, C.-D. (2019). Natural bio-based products for wood coating and protection against degradation: A review. *BioResources*, 14 (2), 4873–4901.
- [9] Tsapko, Yu. V. (2013). Study of modified wood resistance to microbiological destruction. *Eastern-European Journal of Enterprise Technologies*, 6/10 (66), 52–55.
- [10] Tsapko, Yu., Horbachova, O., Mazurchuk, S., & Bondarenko, O. (2021). Study of resistance of thermomodified wood to the influence of natural conditions. *IOP Conference Series: Materials Science and Engineering*, 1164, 012080. <https://doi:10.1088/1757-899X/1164/1/012080>
- [11] Wang, J. Y., Stirling, R., Morris, P. I., Barnes, H. M., & Morrell, J. (2018). Durability of mass timber structures: A review of the biological risks. *Wood and Fiber Science*, 50, 110–127.

## Встановлення закономірностей впливу полімерної оболонки на біоруйнування деревини

Юрій Володимирович Цапко, Олександра Юріївна Горбачова,  
Сергій Миколайович Мазурчук

Національний університет біоресурсів і природокористування України  
03041, вул. Героїв Оборони, 15, м. Київ, Україна

**Анотація.** Проведено аналіз процесу біологічного руйнування деревини. Встановлено, що нехтування екологічно безпечними засобами біозахисту призводить до руйнування конструкцій із деревини під дією мікроорганізмів. Дослідження умов захисту деревини допомагає створити нові типи захисних матеріалів, які сприяють зниженню водопоглинання, а також зменшенню кількості речовин, які є середовищем для розвитку дереворуйнівних грибів. У зв'язку з цим розроблено розрахунково-експериментальний метод визначення частки зруйнованого матеріалу під дією мікроорганізмів із застосуванням антисептика. Аналіз результатів показує, що максимальна втрата маси в разі біоруйнування необроблених зразків деревини склала від 7,6 % до 16 %, а втрата маси зразків термічно модифікованої деревини не перевищила 3 %, в оброблених антисептиком-гідрофобізатором – була менше ніж 2 %. Визначено, що захист у разі оброблення термічно модифікованої деревини масловоском і лазур'ю збільшується порівняно з необробленими у понад 4 рази за показником біоруйнування, а оброблення нетермомодифікованої – у понад 8 разів. Слід зазначити, що наявність масловоску та лазури призводить до закупорки поверхні деревини, що перешкоджає проникненню вологи і мікроорганізмів. Тому інтенсивність розвитку дереворуйнівного гриба на поверхні різних зразків різниться. Вочевидь такий механізм впливу захисного покриття є тим фактором регулювання процесу, завдяки якому зберігається цілісність об'єкту. На основі експериментальних даних і шляхом моделювання рівнянь виведено динаміку популяції мікроорганізмів в об'ємі матеріалу та функції підвищення чисельності загиблених організмів. Зокрема, на поверхні зразка було створено полімерну оболонку, що значно знизила проникнення мікроорганізмів до деревини, а втрата маси деревини при біодеструкції не перевищила 2,5 %. Додаткове нанесення захисних речовин на поверхню посилює рівень захисту деревини сосни необробленої на 72 %, термомодифікованої за 190 °С – на 25 %, за 220 °С – на 37 %. Схожі результати для деревини граба – 60 %, 37 % і 28 %, для дуба – 50 %, 37 % і 37 % відповідно

**Ключові слова:** деревина, ефективність термічної модифікації, антисептики, захисні покриття, біоруйнування, стійкість деревини