THE BIOCIDAL PROTECTION OF TIMBER BY POLYVINYL ALCOHOL NANOFIBER TEXTILES DOPED BY SILVER IONS

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Abstract

The crawl space is a popular type of building foundations as in Europe as in Czech Republic. The bottom of building is the most predisposed space for biodeterioration and this space is often very difficult accessible for supplementary protection or for repairing. For that reason, there was studied the application of biocidal nanofiber textile on the material which is common used in this space - solid spruce wood. In the present paper there was evaluated the antifungal efficiency of polyvinyl alcohol nanofiber textiles doped by silver ions. The polyvinyl alcohol nanofiber textile doped by silver ions was fabricated by electrospinning on Nanospider LB 500. The final theoretical concentration of silver ions was 1 % in nanofibers. The nanofiber textiles were applied by enveloping of timber specimens and the samples were placed on inoculated agar plate. There were used two different ways of stabilization of nanofiber textile (glutaraldehyde vapor or leaching and heat treatment to get water insolubility) and the procedures sequence for specimens preparing (packing of specimens before and after stabilization). The efficiency of applied nanofiber textiles was measured as a percentage fungi coverage. The best protection was showed by used the nanotextile which was stabilized by glutaraldehyde vapor and the packing of sample was made before the stabilization process.

Keywords: Timber, nanofiber textile, silver ion, mold

1. INTRODUCTION

The current trend in the construction industry is produce eco-friendly building and it associated with timber using. The advantage of the wood is its natural base and its disadvantage is easy biodegradability. Wood is the source of nutrients and their shelter. The biodegradation process transfers this problem into the construction. So it is important to protect it against biodeteriogens.

One possibility is protection of the materials surface by paints, coatings, sprays etc. These treatments create barrier or add substances against organisms. The current biocide agents have different compounds basis. They have diverse efficiency against different microorganism a Directive of the European Parliament and Council Directive 98 / 8 / EC concerning the placing of biocidal products on the market of biocidal products are divided into four categories and 23 types:

- Disinfectants and general biocidal products preservatives
- Preservatives
- Pest control
- Other biocidal products [1]

The silver is one option to used as a biocidal agent for their human non-pathogenic properties. There have been published several studies focused on the topic and the effect of silver nanoparticles and ions was demonstrated. Silver has been practical used as a protection against bacteria and mold also used for example in the textile industry, medicine [2, 3, 4, 5]. The aim of the research is to find a suitable surface treatment of building materials as a prevention before the occurrence of mold. As one of the options there is possibility to use of nanofiber textiles doped with silver nanoparticles.

2. MATERIALS

There was used very popular building material - timber, specifically solid spruce wood. Squared wooden samples had dimension 40 x 40 x 10 mm.

There were also studied nanofiber textiles as a protection of wood against mold growth. Nanofiber textiles were prepared on device Nanospider LB 500 (Elmarco, Czech Republic) using electrospinning method [6]. The electrospinning solution consisted of 375 g Polyvinyl alcohol (PVA, Sloviol 16%), 4.4 g glyoxal and 3 g phosphoric acid as cross-linking agents, 117 g demineralized water and silver ions (included in silver nitrate $AgNO_3$, P-lab, Czech Republic). Device set up was: 78 kV, 0.100 mA and the distance between the electrodes was 130 mm, 600 mm long cylinder rotated electrode. Productions of the nanofiber textiles were carry out at common laboratory conditions at the temperature of 23 °C and relative humidity about 25 %. The nanofibers themselves were spun on a polymeric support textile substrate named spund bond, it is polypropylene (PP) base fabric with the width 500 mm, weight per unit area was 18 g/m^2 and an antistatic treatment was used.

The nanofiber textile was prepared as three-layered membrane. The diameter of fiber was in range from 50 to 200 nm. Silver ions accounted 1 percent from the final nanofiber textile weight. Silver ions were added into polymer solution because of their biocidal activity and human non-pathogenity There were use four different types preparation of samples. Nanofiber textiles had differed in a manner of stabilization and sequence of packing and stabilization.

Molds used for presented study are common contaminants of building structure and indoor environment in Central Europe. There was specifically used a mixture of following molds *Trichoderma, Penicillium, Alternaria, Paecilomyces* received from Czech Collection of Microorganisms (CCM).

3. METHODS

The studied samples of wood were covered by nanofiber textile and put on glass rods. Two samples were covered before the process of stabilization and two remaining were covered after this process. There were used two different ways of stabilization. One of them was stabilization by heat (exposition 140 °C for 10 minutes) and the second one was exposure to glutaraldehyde vapors (24 hours, RT). We prepared these samples the same way in five repetitions. Labeling of samples is shown in **Table 1**.

At the beginning it was necessary to expose the wood to higher relative humidity to get samples with higher moisture content. The condition of exposition was around 100 % relative humidity for 1 day.

Table 1 Labeling of samples

Labeling of sample	Description of samples
A	Stabilization by glutaraldehyde vapors exposition, covered before the process of stabilization
B	Stabilization by glutaraldehyde vapors exposition, covered after the process of stabilization
C	Stabilization by heat, covered before the process of stabilization
D	Stabilization by heat, covered after the process of stabilization
K	Control sample without any surface treatment

The inoculum solution was prepared as physiological saline solution with added mold mentioned above. The plates (Czapeck Dox, OXOID LTD, England) were inoculated with 600 µl inoculum solution and it was preincubated for 3 days. The samples were placed on rods. The glass U-shape rods were used to separate wooden samples from agar surface and to eliminated nutrient transfer from the agar broth. We prepared this plate the same way in five repetitions. The incubation conditions were around 23 °C. The mold growth on samples was observed for 5 weeks. The observation consisted of mapping the growth of mold on the surface of the sample and eventually the zone around the sample without mold, named halo effect. The scale for the evaluation of growth is given in **Table 2**.

Table 2 Evaluation of mold growth on the surface of wooden sample

Scale	Description of the relevant stage of mold growth
1	Zone around the sample without mold greater than 10 mm
2	Zone around the sample without mold less than 10 mm
3	Surface of sample without any visible mold growth
4	Weak mold growth on sides of sample
5	Strong mold growth on sides of sample
6	Weak mold growth on top surface of sample
7	Strong mold growth on top surface of sample

4. RESULTS

Mold growth on the surface and around the wood samples was monitored and noted. In **Table 3** there are shown results of the selected time intervals as an average value.

The results did not show significant difference between kind of protection during the first four days. At seventh day they observed first variation in mold growth by kind of protection. Only sample A (Stabilization by glutaraldehyde vapors exposition, covered before the process of stabilization) was 100 % protected, there was visible mold growth on remaining samples at 4th day. The situation, which was at the end of experiment, showed that the best wood protection was packing samples by nanofiber textiles before stabilization by glutaraldehyde vapor.

Similar results were achieved by packing samples before heat stabilization. The samples, which were packed into the previously stabilized nanofiber textile, had higher occurrence of mold on the surface than using stabilization of packed samples and better results were achieved in case using heat stabilization. The most massive and the fastest mold growth was observed, as expected, on the control sample without any treatment. An illustrative example of mold growth is shown in **Figures 1 and 2**.

Table 3 Evaluation of mold growth on the surface and around the wood samples

Labeling of sample	Mold growth description in selected time interval (day of cultivation)					
	1st	4th	7th	11th	13th	31st
A	1	1	1	1	1	1
B	1	2	4	6	6	7
C	1	2	3	3	3	4
D	1	2	4	4	5	6
K	1	2	4	7	7	7

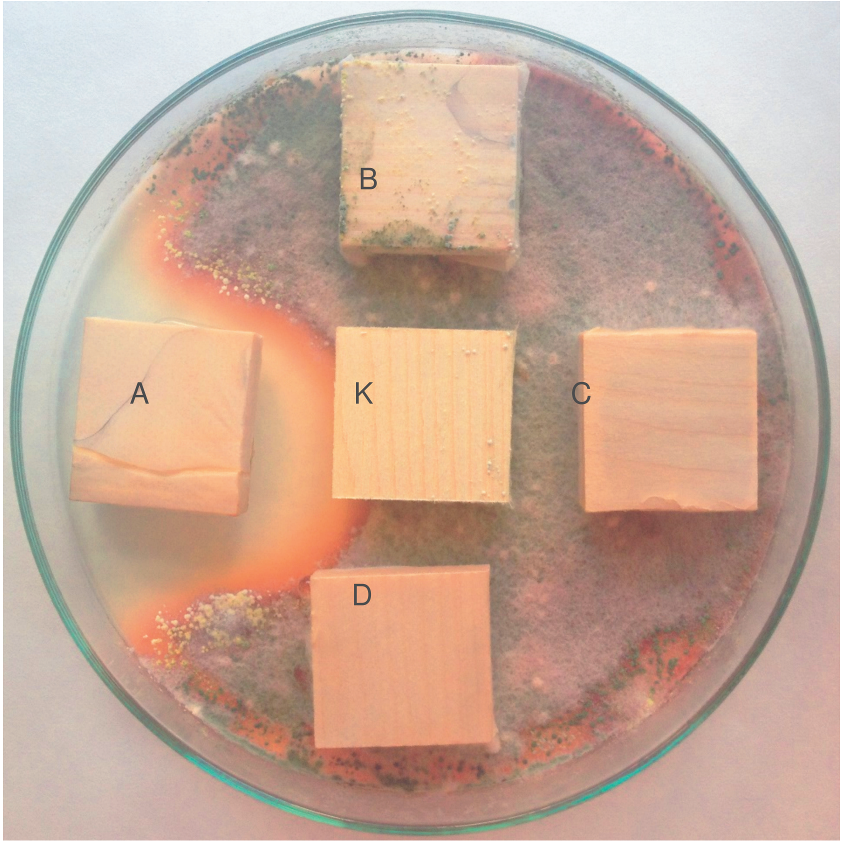

Figure 1 Plate with wooden samples at 7th day of experiment

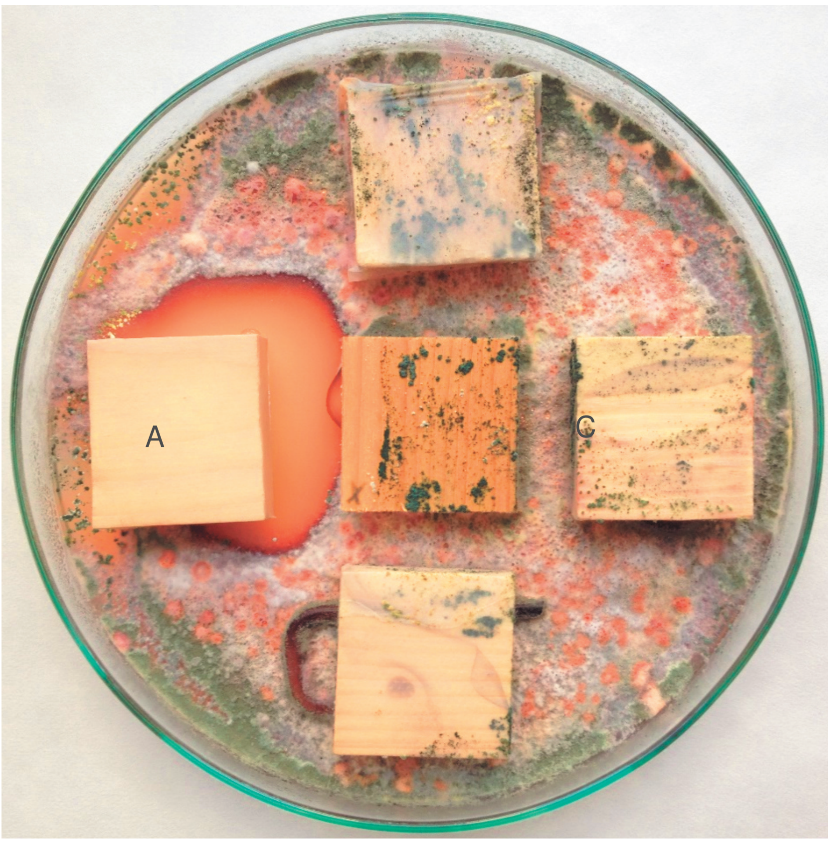

Figure 2 Plate with wooden samples at 11th day of experiment

5. CONCLUSION

Presented study was focused on fungicidal effect of four samples covered by nanofiber textiles doped by silver ions. The effect of silver ions in PVA based nanofiber textile against mold growth has been demonstrated in our previous studies [7, 8, 9]. Nanofiber textiles were used as a packet of samples from spruce wood. The best results were achieved in the case wooden samples which were packed into nanofiber textile before stabilization by glutaraldehyde vapors. It cannot be excluded that the vapors aldehyde had affected only nanofiber textiles. On the thus prepared samples the growth of mold was not observed for one month.

ACKNOWLEDGEMENTS

This work was supported by the Technical University in Prague, grant No. SGS 14/175/OHK1/3T/11 GACR project No.14-04431P and TACR grant No. TA04010837. Special thanks belong to Ivana Loušová - technical worker.

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