EVALUATION BIOCIDAL EFFECT OF NANOFIBER TEXTILES PREPARED BASED ON PVA AND BIOCIDAL COMPOUNDS AGAINST MOLD AND WOOD DECAYING FUNGI

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Abstract

We prepared nanofiber textiles doped Preventol A8, boric acid, Wocosen 50 TK and other by electrospinning on device Nanospiser LB 500 at Nanocenter of civil engineering at CTU. The textiles are stabilized by thermal treatment at 140°C and by chemical method by methanol. As a model organism was used Aspergillus niger, Serpula lacrymans, Coniophora puteana and Gloeophyllum sepiarium. The experiment was made on the agar plate under suitable condition for microorganism. The effect was evaluated as a halo distance around samples. The results show strong dependence on type additional biocidal compounds and their concentration and it is different between model organisms. The positive biocidal effect was evinced Preventol A8, Wocosen 50 TK and their combination, no effect had boric acid. The strong biocide properties was shown against Coniophora puteana and weak effect against Serpula lacrymans.

Key words:

Nanofiber textile, Aspergillus niger, Coniophora puteana, Serpula lacrymans, Gloeophyllum sepiarium

1. INTRODUCTION

Nowdays construction practice works primarily "under the direction" of developers and their pressure on the speed of construction. Currently, there is almost impossible to find new construction or restoration object (and not only these types of buildings) without problems with high humidity and the associated incidence of molds and fungi [1]. Molds apart from a significant effect on the human body also represent a risk to the building structure. They cause degradation of building materials by their metabolites, but also cause more moisture retention and allow for the presence of other microorganisms.

Infestation of structures wood decaying fungi is one of the major issues in the construction industry. Since the redevelopment of the contested elements is very difficult and often the only solution to remove the contested elements and replace them by a new element of healthy wood. It is important to focus on preventive protection against attack by wood-decaying fungi and molds.

Currently it is available a range of biocidal coatings for wood with high efficiency, but often with a high efficiency of these products goes hand in hand with wholesomeness. Durability of this protection is also limited, and therefore there is a need for such protection to be regularly repeated, but it is not possible with covered parts of construction e. g. gridiron beams [2].

Nanotechnology and nanomaterials are young branch of science that is developing and still evolving. As the tested material were used nanofiber textiles dopped by biocides. Their advantage is the use of very small amounts of biocide compared to conventional paints and longer lasting protection compared to conventional coatings. But the question still remains practical application of nanofiber textiles on site. Tested nanofiber textiles were manufactured based on polyvinyl alcohol [3, 4].

This paper is focused on the possibility of applying preventive measures in the form of nanofiber textiles against molds and wood-decaying fungi.

2. MATERIALS AND ORGANISMS

2.1 Nanofiber textile

The used production method was electrospinning, which was performed on a Nanospider Elmarco NS Lab 500 S. PVA polymer solution for spinning was prepared in a volume of 500 ml and contained: 375 g 16% PVA (Sloviol), 117 g of distilled water, 4.4 g glyoxal and 3 g of phosphoric acid (75%). Stabilization was performed using methanol [5]. Stabilized nanofiber textiles are mechanically more durable and more resistant to moisture damage [6, 7].

The biocide was added to the PVA in the form of a liquid substance into the electrospinning solution. The used biocidal active ingredients (boric acid, Wocosen, Preventol, IPBC, Acticide 45) are components of commercial product Lignofix E-Profi [8]. The quantity of the active substance is shown in **Table1**.

2.2 Organisms

A model organism of mold was used **Aspergillus niger**. This microscopic filamentous fungus is widespread worldwide, produces black coat and is toxigenic. It is often isolated from foodstuffs, both plant and animal origin, but also from the surface of various materials, including the construction. In this experiment, was used the culture of the Czech Collection of Microorganisms CCM no. 8189.

Serpula lacrymans is one of the biggest pests of wood. It is occured in dark unventilated areas with high relative humidity and temperature lower than 30 °C. It is occured only in buildings, mostly located in the floor, in the deckings and in the ceiling beams. It occurs most often compares to the other wood-destroying fungi because it needs up to 20% moisture by weight for the growth. The wood consists of gray-white films, or reddish brown fruiting body with a white border [2].

Coniophora puteana lives mainly in wood, which is in contact with wet objects (with the ground, with a wet masonry, steam). Well it thrives in areas with relative humidity above 40%. If the humidity falls, the development is stopped. Is a "gateway" for Serpula lacrymans and its direct predecessor. It causes brown rot, wood decay into small cubes and then to powder. Fruiting bodies are 1 mm thick, having ocher or ocher-green colour [2].

Gloeophyllum sepiarium occurs primarily on wood exposed to the weather. It does not mind alternating dry and wet or high temperature, so it can also occur in the attic. It causes brown rot inside the wood, the wood surface is nothing to know, so Gloeophyllum sepiarium occurrence is found after a longer period [2].

3. METHODOLOGY

The based samples were prepared with a broth layer into Petri dishes from commercially made mixture - maltose agar from Merck company in a volume of about 20 ml per dish. There is a difference between samples with molds (Aspergillus niger) and wood-decaying fungi (Coniophora puteana, Serpula lacrymans, Gloeophyllum sepiarium).

3.1 Molds

The subject of investigation of the presented experiment with Aspergillus niger was to compare the effects of nanofiber textile based PVA with and without components of the biocidal product against mold growth. This experiment was carried out in Petri dishes with solidified malt agar plate with a volume of 20 ml and 100 ml of an aqueous solution of Aspergillus niger. There were prepared circular samples of 10 mm diameter of nanofiber textiles. Three samples from each species were made. These samples were placed in the center of Petri dishes including supporting nonwoven polypropylene fabric and are kept in optimal conditions for growth of the fungus and 25 °C. The growth of molds with different types of nanofiber textile samples was monitored for 14 days after application.

3.2 Wood-decaying fungi

The subject of investigation of the presented experiment with wood decaying fungi was to monitore and compare the effects of nanofiber textile based PVA with and without components of the biocidal product against growth of Coniophora puteana, Serpula lacrymans and Gloeophyllum sepiarium. The circle samples of nanofiber textiles with a diameter of 30 mm were placed into the middle of each dish. There were used ingredients of a commercial preparation Lignofix E-Profi (each substance separately). Four samples (size 2x2 mm) of each of wood decaying fungi (Coniophora puteana, Serpula lacrymans and Gloeophyllum sepiarium) were placed into each dish around the circle sample. Three samples from each species were made. Samples were placed into the optimal condition; temperature 22 ± 2 °C and humidity 98 %.

Table 1 The growth of model organisms 14 days after application

Active substance	Quantity of active substance [g/m^2]	Serpula lacrymans			Coniofora puteana			Gloeophyllum sepiarium			Aspergillus niger		
		A	B	C	A	B	C	A	B	C	A	B	C
Without any treatment	0.0	5	5	5	5	5	5	5	5	5	5	5	5
H_3BO_3	6.1	3	3	3	1	1	1						
H_3BO_3	3.1	2	1	4	1	1	1						
Preventol A8 + Wocosen 50 TK	18.0 + 59.0				1	1	1				2	2	3
Preventol A8 + Wocosen 50 TK	9.0 + 30.0				2	2	2	4	4	4	4	4	4
Wocosen 50 TK PPC	17.3	4	4	4	2	2	2	3	4	3	3	3	3
Wocosen 50 TK	8.2	3	4	5	3	3	3	3	3	3	3	3	4
Wocosen 20 TK PPC+IPBC	31.1	1	2	1	1	1	1	3	3	3			
Acticide 45 (OIT)	3.1	1	1	2	1	1	1	4	4	4			
Polyvinylalcohol	0.0	5	5	5	5	4	4	5	5	5	5	5	5

1	killing effect
2	biocidal effect with diffusion
3	biocidal effect with low diffusion
4	biocidal effect without diffusion
5	without any effect

4. RESULTS

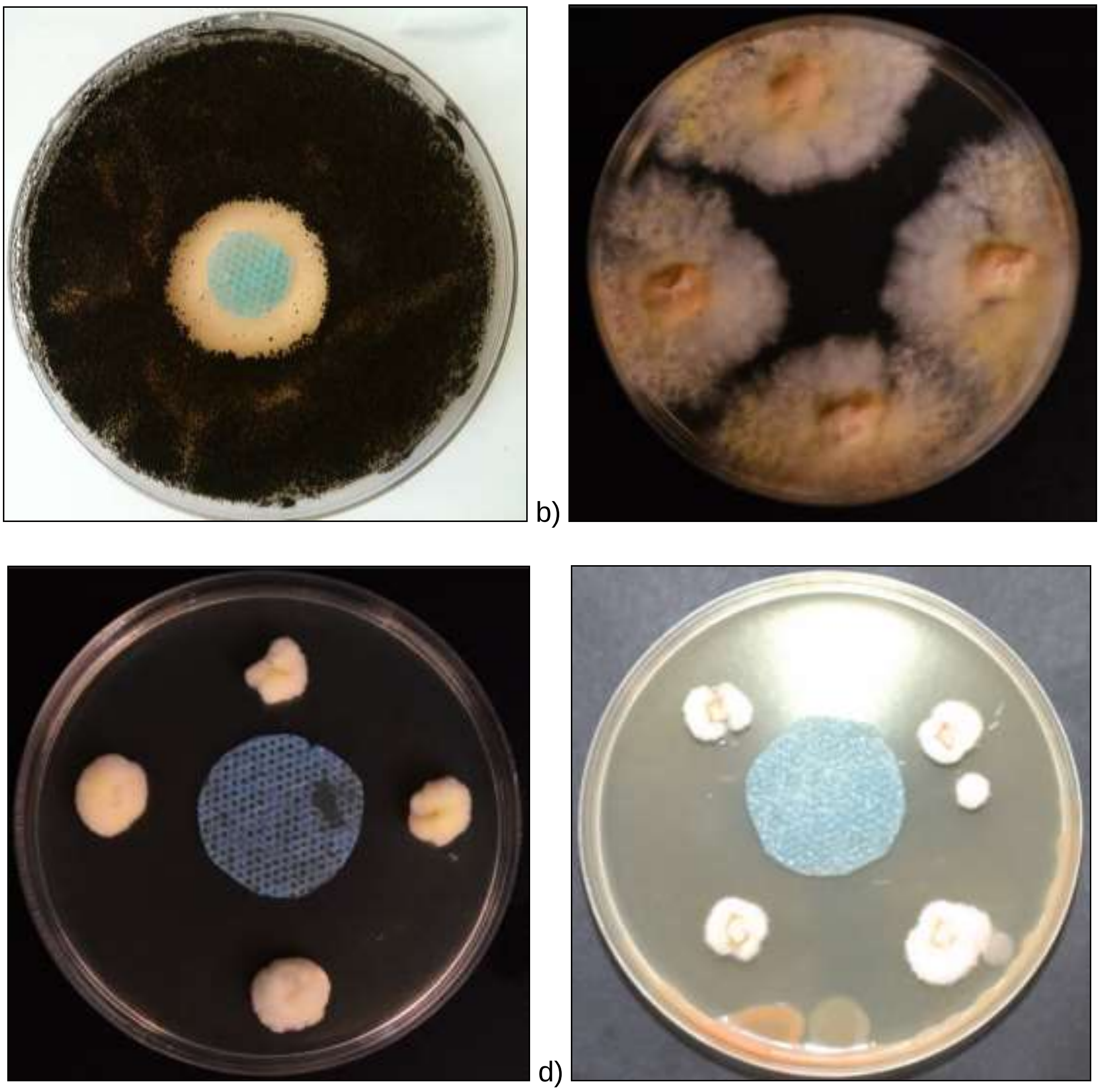
The biocidal properties of nanofiber textile was evaluated as a change microorganism growth. There was measured the size of area without the growth of mold or fungi. The size of it was evaluated by comparison of the area with and without organism using image analysis. The results are shown in Table 1.

The samples without any treatment and pure polyvinyl alcohol did not have any biocidal effect against the mold and fungi. The highest biocidal effect against the growth of Aspergillus niger had nanofiber textile with Wocosen 50 TK (concentration 17.3 g/m^2).

The highest biocidal effect against the growth of Serpula lacrymans had nanofiber textile with Wocosen 20 TK PPC + IPBC (concentration 31.1 g/m^2) and Acticide 45 (OIT) (concentration 3.1 g/m^2).

The biocidal effect against the growth of Coniophora puteana had nanofiber textile with boric acid (concentration 6.2 and 3.2 g/m^2), Preventol A8 + Wocosen 50 TK (concentration 18.0 + 59.0 g/m^2), Wocosen 20 TK PPC + IPBC (concentration 31.1 g/m^2) and Acticide 45 (OIT) (concentration 3.1 g/m^2). The pure PVA nanofiber textile had only barrier effect.

The highest biocidal effect against the growth of Gloeophyllum sepiarium had nanofiber textile with Wocosen 50 TK (concentration 8.2 g/m^2) and Wocosen 20 TK PPC + IPBC (concentration 31.1 g/m^2).



a) b) c) d)

Fig. 1. Samples with nanofiber textile with PVA+ Wocosen 50 TK (concentration 17.3 g/m2) after 14 days since application. a) Aspergillus niger, b) Serpula lacrymans, c) Coniophora puteana, d) Gloeophyllum sepiarium

5. CONCLUSION AND DISCUSION

Nanofiber textile based PVA solution with the addition of a suitable biocidal efficiently substances have antimicrobial properties (Rácová, Wasserbauer et al. 2013, Ryparová, Wasserbauer et al. 2013). The biocidal effect of nanofiber textiles have had dependent on type of added substances and their concentration. Biocidal effect of the sample with substances Woconen 50 TK (concentration 17.3 g/m2) was higher in comparison with the other samples with added substances against whole used model microorganism. The present experiment demonstrates that the composition of the dope can affect the properties of nanofiber textiles especially the properties against molds and wood decaying fungi. This is consistent with other results [9, 10, 11].

The growth of molds and fungi in Petri dishes with applied nanotextiles was compared with the growth without any further action. The experiment confirmed that the PVA itself without the addition of biocidal efficiency substances have no characteristics that would be useful as preventive or remedial measures against mold growth specifically Aspergillus niger. Unless enriched the spinning solution is a substance having a biocidal effect is achieved of certain biocidal effect which inhibits the growth of microscopic fungi. Even if they are used as active substance targeted primarily to prevent fungi and wood-decaying, in the experiment was achieved similar effects against the growth of microscopic fungi. The resulting "halo" effect (**Fig. 1a**) was more pronounced in samples with a higher concentration of active substances and biocidal effect reached the highest specimens of which used a combination of biocides (**Fig. 1b, 1c, 1d**). This effect also points to the fact that the active substance is discharged into the environment through free agar diffusion. It heralds a problem for the future use of these textiles in practice, where it could be washed improvement agents of nanofiber textiles.

The efficiency of nanofiber textile doped biocide is depending on a type of stabilization. The thermal stabilization of PVA nanofiber kept nanostructure of textiles, but the insoluble properties are not 100 %. The other problem is a stability of added substance at higher temperature. The each substances of biocide have stability only up to 30 °C. The chemical treatment by methanol is gently for added substance but on the other hand the nanofiber textiles lost their fine nanostructure. The advantage of stabilization by thermal treatment is in successively leaching of biocide.

The comparison with our unpublished data showed the similar biocidal effect of nanofiber textiles doped complete solution of commercial biocide Lignofix E-Profi against the growth of molds. The effect with combination of biocide is better because they target to more kind protection how they can influence organism cells.

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