WOODEN HOUSES INSULATION AND ITS PROTECTION AGAINST MOLD BY NANOPARTICLES

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Abstract

Wooden buildings are a traditional type of construction that has been gradually replaced by brick and monolithic technologies. The current trends lead up to use renewable materials even include different types of thermal insulations. The construction industry commonly use materials on a plant basis. If heat-humidity mode (in particular, increased humidity) is not balanced, suitable conditions for the growth of microorganisms are present. The common organisms occurring in/into natural based materials are mainly molds, bacteria, algae or wood decaying fungi. Biodegradability of plant based systems is a major drawback to using these materials in buildings. Given that condensation occurs in timber construction and materials from plant-based are susceptible to attacked by microorganisms, it is necessary to protect these materials. The paper deals with the possibility of protection of these insulation materials against mold using advanced nanotechnologies. The comparison of individual used measures is included.

Keywords: Thermal insulation, mold, material moisture, humidity

1. INTRODUCTION

Ecological buildings and all environmentally friendly practices are becoming more and more popular and, consequently, natural building materials are frequently applied [1]. It has to be stressed out, however, that it is necessary to use heat-insulating materials to reduce the energy consumption in these type constructions. Today, as in the past, it is possible to choose heat-insulating materials with a natural basis [2].

These materials behave environmentally friendly, but in practice their application exhibits some disadvantages. One of them is their lifespan and the requirement for proper adherence to technological procedures. The serious problem is also the moisture and its condensation within the construction layer [3,4,5].

Hemp may serve as a typical example of a natural-based material that is used as the thermal insulation of buildings [6]. The stems of cannabis plants are processed by various mechanical methods for fiber extraction [7]. The cutting process is controlled by the destruction of the stems of the plants so that the fiber can be separated from the wood core. This phase represents a barrier to wider use of flax and hemp fibers, both economically and in terms of fiber quality [8]. Problems caused by cutting include microbial contamination of the fiber, increased variability in fiber properties. The quality of the result of this activity depends on the actual weather at the time of processing. If fibers of useful quality could be obtained from raw cannabis, avoiding the problems caused by the need to tear stalks can be avoided. Additionally, young plants appear to be advantageous compared to the older ones. They achieve higher strengths and they are more durable overall [9]. The durability of hemp fibers against microorganism is related to their moisture. Excessive exposure to humidity may cause biological corrosion, i.e. degradation by bacteria, mold and wood decaying fungi acting on the surface of material. For this reason, the manufactured organic materials should be always separated from the sources of moisture, and/or a possibility of rapid drying must be ensured when materials get wet. Problems with moisture in walls should not occur if the building is properly designed [10, 11].

This paper is focused on hemp fibers using in wooden construction as a thermal insulation. The principal aim is to find the types of fungi most commonly attacking these materials and to verify the use of nanostructures (silver nanoparticles) as a preventative protection against them.

2. MATERIALS AND METHODS

Presented study was taken on plant based building material - hemp. Material was selected as one of the most frequent using material of thermal insulation in wooden building structures. The pH value was measured before experiment. This feature was measured by potentiometric device (pH meter, **Figure 1**, Monokrystaly, Czech Republic).

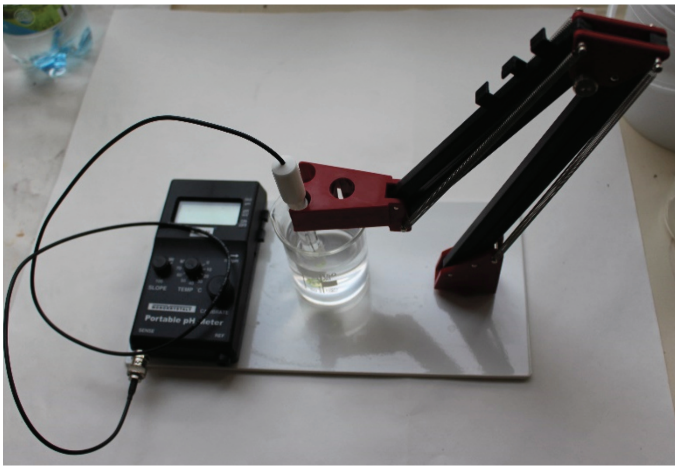

Figure 1 The used portable pH meter (Monokrystaly, Czech Republic)

A part of the experiment was focused on the study of molds present in natural-based material used as thermal insulation. Square shaped samples (dimension 40 x 40 x 20 mm) were placed on nutrient agar (Czapek-dox agar, Oxoid, Czech Republic) and were cultivated under conditions suitable for mold growth (23 ± 3 °C) in dark for ten days. The natural grown mold on agar plate and inside materials samples were identified by methods hanging drop or native preparation by typical microscopic characters on optical microscope (Olympus BX41, 160 - 400x magnification) to used identification keys [12].

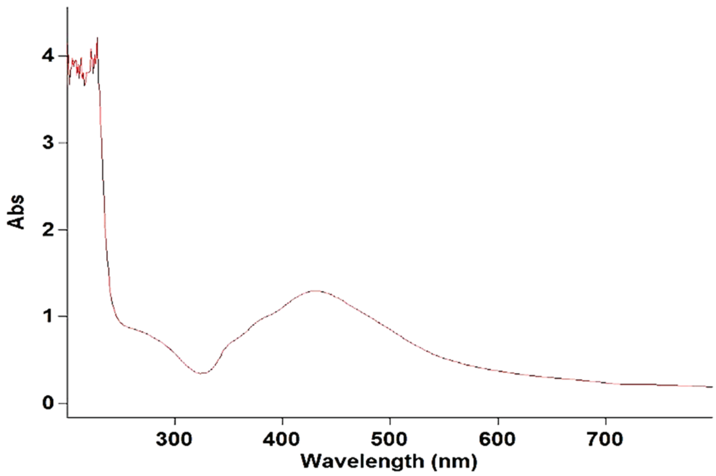

Figure 2 Spectrum of a liquid solution with the silver nanoparticles (measured by Diomid Revenco, UCT)

Potential biocidal protection of thermal insulation was prepared in the form of silver nanoparticles. Those nanoparticles were prepared according to Turkevich Method for Ag Nanoparticles Synthesis [13, 14] by the following procedure. A solution of 1 ml of $AgNO_3$ solution (approximately 250 g / l) was used after dilution to approximately 600 ml. A solution of 0.01 M sodium citrate (2.94 g / l) was also added in 10-fold quantity, ie. 60 ml. The spectrum (Spectroquant Pharo 300, Merck) of a liquid solution with the nanoparticles is shown in **Figure 2**. The size of the obtained nanoparticles was about 50 nm. This solution was used as a biocidal protection for thermal insulation.

The biocidal protection study was taken on square shaped samples of hemp fibers (see **Figure 3**) of sizes 40 x 40 x 10 mm. One set of samples were dipped into above mentioned solution with silver nanoparticles and the second one was submerged in distilled water for one hour. Then the sample of thermal insulation together with 5 ml of suspension containing physiological saline solution and mold (Aspergillus niger as model organism) were placed into a bottle. The bottle has a magnetic stirrer and it is closed by BOD sensor (VELP Scientifica, Italy). Biochemical Oxygen Demand analysis is a chemical procedure for determining the amount of dissolved oxygen consumed by aerobic biological microorganisms in water. It is carried out on a given water sample at certain temperature over a specific period. The results are most commonly expressed in milligrams of oxygen consumed per liter of sample at a constant temperature of 20 °C for incubation period (BOD_5), or during complete oxidation obtained after a maximum period of 30 days ($BOD_{ultimate}$) Measurements were performed for 5 days. Device for BOD analysis is depicted in **Figure 4**.

Biocidal properties of thermal insulation materials was evaluated as a respiration activity of microorganism in tested materials treated by solution with silver nanoparticles and distilled water. It was measured as a biochemical oxygen demand value.

Figure 3 Detail of structure - hemp fibers

Figure 4 Device for Biochemical Oxygen Demand analysis

3. RESULTS

The water leachate of materials was close to pH value 6. This value is suitable for growth of microorganism.

Molds and microorganism covered the materials samples placed on Czapek Dox agar, they grew also inside materials. The most commonly identified molds from the surface of hemp thermal insulation samples were Alternaria sp., Aspergillus niger, Mucor sp. and Stachybotrys sp. Molds were identical on the surface and inside of the samples.

Results of BOD analysis are represented in **Figure 5**. It is clearly seen that the samples treated with the nanoparticle solution had a lower biochemical oxygen demand throughout the experiment and that the increase was not as steep as in the case of physiological saline samples. The insulation was exposed to high humidity nevertheless the silver solution has antifungal properties for first two days of experiment. Then its activity was changed to biocidal (**Figure 5**). Despite the fact that it should be 5 day incubation period (BOD5), the experiment was completed after the fourth day of measurement. All oxygen has been consumed.

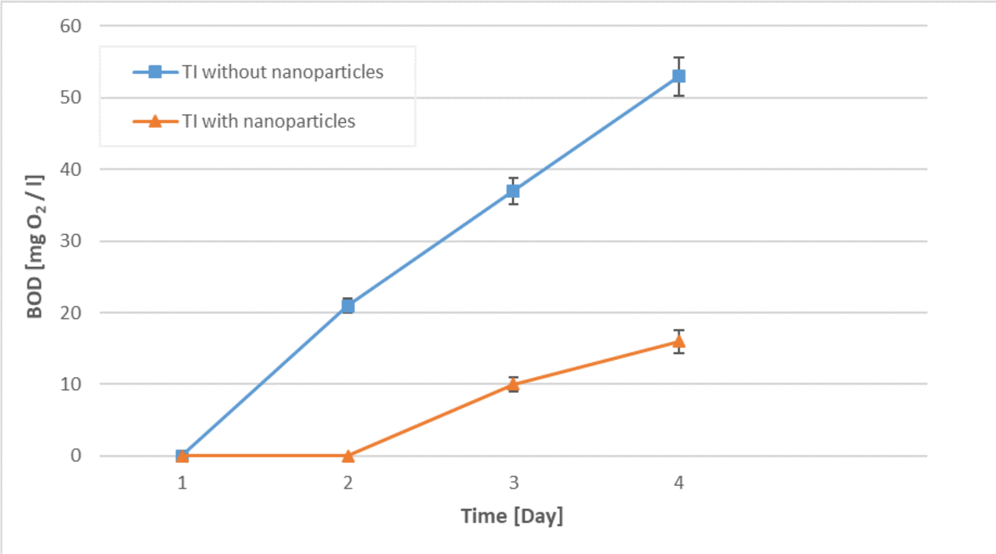

Figure 5 BOD value as a function of time during the thermal insulation test with and without treatment by the silver nanoparticles

4. CONCLUSION

Presented assay confirmed natural thermal insulation materials contain germs of mold and there is a possibility mold will be occurred and grown in the event of a disruption of the thermal moisture balance. For that reason, it is necessary to use natural materials properly, protect them against moisture, and thereby mold growth. The paper presented protection of hemp thermal insulation material by solution with silver nanoparticles. The results show that even in the presence of increased moisture there was a reduction of mold growth. The insulation was in the conditions that are not common in construction, nevertheless the silver solution has antifungal properties for first two days and after that, its activity was changed to biocidal. The reason for this is probably the creation of biofilm on the surface of nanoparticles during the second day of experiment.

It should be pointed out, however, that the application of the solution to isolation in a larger amount of material will be probably not possible in practice due to financial reasons. This practical aspect will be solved in our future studies.

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