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Colonising organisms as a biodegradation factor affecting historical wood materials at the former concentration camp of Auschwitz II – Birkenau

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ABSTRACT

The former Auschwitz-Birkenau camp, which is under the care of the Auschwitz-Birkenau State Museum in Oświęcim, Poland, comprises historical edifices and objects commemorating the tragic events of the Second World War. These include wooden barracks as well as wooden elements of brick buildings – doors, floors, bunks, door and window frames, and structural walls and beams – which, when exposed to variable weather conditions, may undergo biodegradation. The aim of the present study was to determine the infestation of wooden surfaces infestation by various organisms and to identify the dominant species. The total bacteria counts on the wooden surfaces ranged 8–3.5 × 10^3 cfu 100 cm^{-2}, with *Bacillus* sp. being the dominant one, while the counts for fungi were in the range of 8–1.7 × 10^3 cfu 100 cm^{-2}, the main representatives being *Cladosporium* sp., *Alternaria* sp. and *Penicillium* sp. On the wooden parts of bunks and floorboards there were identified decay fungi such as *Poria vaporaria* and *Serpula lacrymans*. Cyanobacteria and algae of the *Bacillariophyta* and *Chlorophyta* groups, bryophytes *Ceratodon* sp. and *Bryum* sp., and lichens *Lecanora* sp., *Lepraria* sp. and *Protoparmeliopsis* sp. occurred mainly on the exterior of the doors of wooden barracks. Identification of the organisms will make it possible to select appropriate biocides and to protect the historical objects against the natural process of gradual biodegradation.

1. Introduction

Wood, as a raw material, is one of the oldest structural and decorative materials used in construction. In conditions which ensure a low level of its humidity, it is a highly durable material, lasting for even hundreds of years. Due to its chemical composition (66–88% polysaccharides, 19–25% lignin), wood is affected by numerous environmental agents, including the biotic ones. The process of biodeterioration of wood involves not only decay fungi and hyphal fungi, but also bacteria, algae, and higher organisms such as lichens, bryophytes and insects. These organisms may cause structural and chemical changes influencing the density and causing reduced durability of wood, as well as changes in its odour and colour (Blanchette, 2000; Fazio et al., 2010).

The most numerous, and at the same time the most harmful group of organisms causing degradation of wood are fungi belonging to the subdivision *Basidiomycota*, which cause brown and white rot. Some species of these fungi decompose lignin in the initial phase of colonisation, and only in the subsequent phases do they hydrolyse cellulose (e.g. *Polystictus versicolor*). Others cause the simultaneous decay of both these wood components (e.g. *Pleurotus ostreatus*) (Blanchette et al., 1991; Nilsson and Rowell, 2012). More than 60% of the investigated mycological infestations of historical buildings are caused by decay fungi of the species *Serpula lacrymans*, *Coniphora puteana* and *Poria vaporaria*, which cause brown rot in which cellulose and hemicellulose are destroyed

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already at the initial stage of fungal growth, leading to powdery and prismatic decay of wood and, consequently, a significant reduction in its strength (Ważny and Kurpik, 2004; Irbe et al., 2012).

Due to its hygroscopic properties, wood frequently suffers from infestation by moulds (Viitanen, 1994). Moulds from the genera *Chaetomium*, *Trichoderma* and *Penicillium* characterised by cellulolytic properties cause surface changes in the form of blue stains (grey decay). Their action results in depolymerisation of cellulose and hemicellulose, but this process is limited to the outer layer of wood that undergoes flaking following the chemical changes taking place (Witomski, 2001).

The role of bacteria in the decay of wood has not been fully explored yet, because it is only recently that they have been considered as an independent factor in the degradation of wood and wood-derived materials. It has been found that in the conditions of increased humidity and low availability of oxygen, where fungi are unable to develop, bacteria may cause structural changes such as erosion, tunnelling and cavitation. The greatest role in the decay of wood is played by aerobic cellulolytic bacteria (*Cytophaga*, *Cellvibrio*, *Cellfalcicula*) and anaerobic ones *(Plectridium*, *Clostridium)*. Also bacteria of the genera *Bacillus*, *Pseudomonas*, *Arthrobacter*, *Flavobacterium* and *Spirillum* (Kim and Singh, 2000; Gelbrich et al., 2008; Kretschmar et al., 2008) are significant in this context.

Photolithoautotrophic organisms, such as algae, usually develop on the exterior of wooden structures on the northern side, while inside they infest walls with a high level of damp and access to sunlight. These organisms form bright green or grey – green stains and streaks on construction materials. Their development also causes degradation of the material as a result of the production of organic acids, such as lactic, oxalic, succinic, acetic and pyruvic acids (Crispim and Gaylarde, 2005).

Exterior wooden constructions may also be infested by lichens and bryophytes. Lichens are the fourth most frequently occurring group of organisms, after bacteria, algae and fungi, colonising historical wooden objects, but their significance in the biodeterioration of wood is dependent on the presence of light, the humidity of the medium and the height above the ground.

Correct identification of aetiological factors in the degradation of wood is the first and key element in developing a strategy for saving buildings, particularly those of historical importance, from progressive destruction.

The former Nazi German concentration camp of Auschwitz-Birkenau (1940–1945), where more than a million people lost their lives, is a world-famous Memorial Site, visited by almost 1.5 million people annually. Structures that have been preserved up to the present time at the former KL Auschwitz II – Birkenau camp include 45 brick barracks and 22 wooden barracks. They lack heating, and often also damp insulation and effective ventilation (Kościelniak et al., 2012). These conditions, in addition to the climatic factors such as changeable temperature and humidity and constant exposure to sunlight, cause that the wooden structural elements and fittings of these historical structures are exposed to biocorrosion. The high standard of care applied in the preservation of this site requires monitoring the degree of biological contamination, as well as seeking appropriate methods to protect and conserve this historical landmark. Taking into account the type of surfaces of the investigated objects, natural progressive biodegradation and the need to preserve the authenticity of the site, designing effective methods of protection is a significant challenge for the researchers and conservators.

The aim of the research was to estimate the degree of infestation of wooden elements and structures in the historical wooden and brick barracks, and to identify the dominant species of bacteria, fungi (decay fungi and moulds), algae, lichens and bryophytes.

2. Materials and methods

2.1. Analysis of biological contamination of the wooden surfaces

2.1.1. The investigated surfaces

The tests were carried out on the surfaces with visible symptoms of biological deterioration in 8 brick barracks and 2 wooden barracks at the former Auschwitz II – Birkenau camp (Fig. 1). The samples were taken from the wooden structural elements as well as the fittings and equipment contained inside the buildings. These were, in the wooden barracks: structural walls (number of samples $N = 8$), structural beams ($N = 10$), doors ($N = 2$) and bunks ($N = 5$); and in the brick barracks: doors ($N = 8$), doorsills ($N = 8$), bunks ($N = 7$), floors ($N = 16$), window frames ($N = 12$) and door frames ($N = 20$). The tests were repeated in the spring, summer, autumn and winter.

2.1.2. Bacteriological and mycological analysis

The samples were taken by swabbing from a surface area of 25 cm^2. The total bacteria counts were determined on a Tryptic Soy Agar medium with added Nystatin (0.06%) (TSA, Merck, Germany), and the mould counts were determined on a Sabouraud Agar medium with Chloramphenicol (Merck, Germany) (Gutarowska et al., 2012). The plates were incubated at $25 \pm 0.5\,^{\circ}C$ for up to 7 days. The results were presented in cfu 100 cm^{-2} of surface.

The isolated pure cultures of bacteria and moulds were transferred accordingly onto TSA and Czapek-Dox media (Merck, Germany). Identification of bacteria was carried out using standard methods, based on their macroscopic and microscopic morphological features, Gram staining, and biochemical tests with the application of API strips (bioMerieux, France). Identification of moulds was performed based on their macroscopic and microscopic morphological features according to the diagnostic keys (Domsch et al., 1993; Samson, 2006). Decay fungi were identified on the basis of the macroscopic features of their growth, namely the presence of superficial mycelium, mycelial strings and fruiting bodies, as well as the decay symptoms shown by the wood tissue (Ważny, 2001).

The taxonomic position of all the isolated bacteria was confirmed with the use of molecular methods based on the 16S rRNA gene sequencing, and in case of selected hyphal fungi it was confirmed based on the sequence of the ITS1 region (internal transcribed spacer). The nucleotide sequences obtained for gene 16S rRNA and the ITS1 region were compared, using the BLAST 2.2.27+ program, with the sequences available in the National Centre for Biotechnology Information.

2.1.3. Algological analysis

Macroscopically differing biofilms and thalli of algae were sampled from the wooden surfaces and preserved in a 4% solution of formaldehyde. The qualitative analysis of the diatoms was carried out following maceration of the preparations preserved using a mixture of concentrated sulphuric (VI) and chromic (VI) acids in the ratio of 1:3 for 3 days. After maceration, the deposit was rinsed several times with distilled water, centrifuged (3500 $\times g$, 3 min), and suspended in Naphrax® resin (Brunel Microscopes Ltd, England), after which it underwent microscopic observation. Individual algae taxa were identified based on the morphological features of the cells, colonies and thalli, according to Starmach (1966, 1968), Krammer and Lange-Bertalot, 1986, 1988, 1991a,b), Komárek and Anagnostidis (1999, 2007), Lange-Bertalot (2001), Wołowski and Hindák (2005), Hindák (2008), Samad and Adhikary (2008), Pliński and Hindák (2010). The frequency of occurrence of individual species of algae was determined on the basis of microscopic observations, with determination of the proportional