Preserving textile objects in Romanian wooden churches. Case study of the heritage wooden church form Oradea, Romania

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IOAN OANA
LILIANA INDRIE
AURELIA ONET
DORINA OANA
DORINA CAMELIA ILIEȘ
GRIGORE VASILE HERMAN
ALEXANDRU ILIEȘ
FLORIN MARCU

ABSTRACT – REZUMAT

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It is important to investigate the indoor air quality, the microbial concentration of indoor air and surfaces for preserving the cultural heritage. In what regards the microclimate inside the historic monument, the wooden church, the temperature and relative humidity were monitored using the thermo-hygrometer with data function logger "Klimalogg Pro" (eight sensors), October-December 2018, the thermos-camera "Thermal Imaging Camera FLIR I7" and "Digi-Sense Data Logging Luxmeter". Image analysis were also performed using digital image processing techniques (ARCGIS), mapping the areas damaged by temperature, humidity and also by rainwater infiltrated on canvas paintings, biodegradation, anthropically degraded areas etc. Isolation of microorganisms from the two canvas paintings and indoor air were taken though specific method, analyses showing the presence of microorganisms on the paintings, possible human pathogens especially for people with low immunity. A high fidelity database with the state of patrimony objects preserved in the Romanian wooden church and perspectives for their proper conservation could be created at a certain moment.

Keywords: *heritage wooden church, microbial, microclimate, preserve, canvas paintings, Romania*

Prezervarea obiectelor textile din bisericile de lemn românești. Studiu de caz biserica de lemn patrimoniu din Oradea, România

Pentru prezervarea patrimoniului cultural este important să se analizeze calitatea aerului din interiorul clădirilor și concentrația microbiană a aerului. În ceea ce privește microclimatul din biserica de lemn, monument istoric, temperatura și umiditatea relativă au fost monitorizate în perioada octombrie-decembrie 2018, folosind termo-higrometrul cu functie data logger "Klimalogg Pro" (opt senzori), camera de scanare termică "FLIR I7" și "Luxmetru Digi-Sense Data Logger". Analiza imaginilor a fost realizată folosind tehnici de prelucrare digitală a imaginilor (ARCGIS), cu cartografierea zonelor deteriorate de temperatură, umiditate și apa de ploaie infiltrată prin acoperiș și care afectează tablourile pictate pe pânză, biodegradarea, zone degradate din cauze antropice etc. Izolarea microorganismelor de pe cele două picturi pe pânză și din aerul interior a fost realizată prin metode specifice, analizele arătând prezența microorganismelor, care sunt posibili agenți patogeni umani, în special pentru persoanele cu imunitate scăzută. În viitor, ar putea fi creată o bază de date cu starea obiectelor de patrimoniu păstrate în bisericile de lemn din România și perspective pentru buna conservare a acestora.

Cuvinte-cheie: *biserica de lemn patrimoniu, microbian, microclimat, prezervare, pictura pe pânză, România*

INTRODUCTION

The old orthodox wooden church "Saint Martyrs Brâncoveanu and his sons", Oradea – Bihor county, is a historical monument built between 1760–1762 in Letca (Sălaj county, Romania), and relocated in 1990 in the campus of the University of Oradea (figure 1). The historic monument is built of wooden beams (durmast and hornbeam) [1–2], and is located on a river stone foundation. Since 2010, the wooden church is on the new list of historical monuments (BH-II-m-B-20958 m). The original decoration was made "in the early 19th century, with vivid colors and rich floral borders which were partly destroyed" [3]; the interior no longer retains its original aspect, being plated and repainted.

Among the textile objects preserved in the wooden church that we propose to analyze in the study are also paintings on canvas. At the entrance, in the narthex, the Virgin Mary with baby Jesus are painted on the ceiling. The painting is made on a blue background, and the Virgin Mary and baby Jesus are represented in warm and bright colors, being surrounded by Archangels Michael and Gabriel. The technique used is called "al secco", and the painting was performed in tempera with egg emulsion on dry plaster. On the opposite side of the altar, there is a canvas painting in oil, where the focus is on three Archangels painted in a circle, while on the sides two Archangels who protect them are represented.

We monitored the microclimate (temperature, humidity, luminosity) inside the wooden church between

Fig. 1. The historic monument wooden church, University of Oradea, Campus, photo December 2018

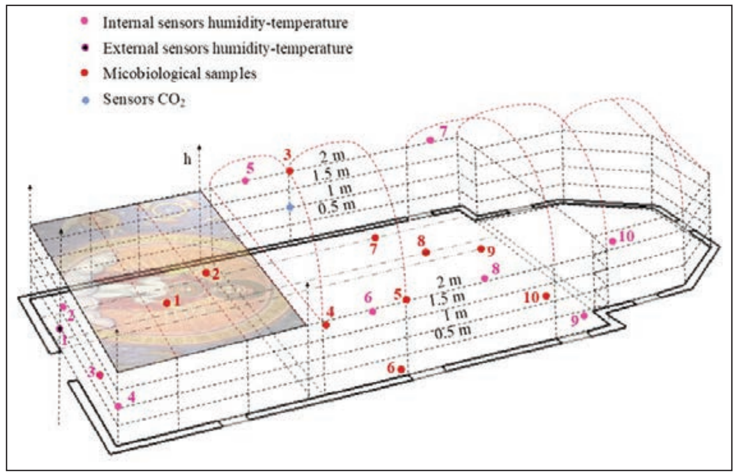

Fig. 2. The location of the sensors for microclimate monitoring, microbiological sampling points, wooden church “St. Martyrs Constantin Brancoveanu and his sons“ – “Archangels Michael and Gabriel”

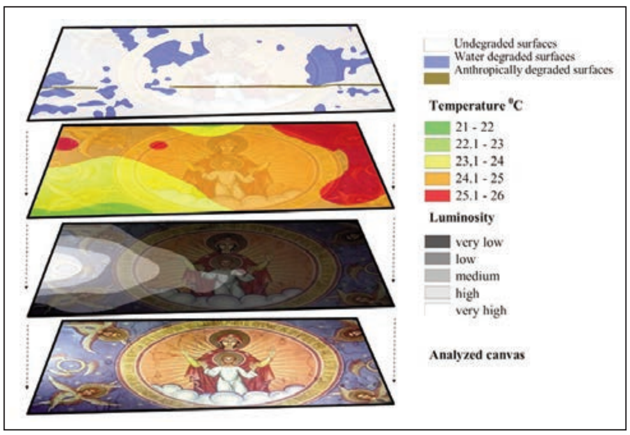

Fig. 3. The distribution of light and heat: *a* – canvas painting; *b* – luminosity; *c* – thermal map applied to the painting; *d* – surfaces degraded by pluviality, biodegradation and anthropic elements

October and December 2018 (figure 2), and microbiological samples from air and paintings were collected and analyzed [4].

We performed the mapping of areas degraded by temperature, humidity and rainwater infiltrated on painted canvas prior to the change of the shingle roof before 2016, biodegradation and anthropic deterioration in order to establish the damaged or vulnerable areas. The distribution of light and heat on the painted canvas at different moments of the day and season and their possible influence on the canvas paintings were also analyzed (figure 3).

CASE STUDY

Literature review

In Romania few researches are approaching the biodeterioration of textiles support for painting in religious places: was analysed the biodeterioration inside of some Romanian wooden churches [4–5]; the development of micro-fungi on the surface of paintings induces aesthetical, mechanical and biochemical decay [6] investigates the preservation state of the painting inside the wooden church [7–11] focused on biodegradation problems. In international scientific literature, studies on the biodeterioration of textiles support for painting in religious places do not lack: Merritt 1993, wrote about causes, detection, prevention of mould and mildew on textiles [12]; the most frequent biodeteriogens of textiles [13]. Jain P., 2008, has a special chapter dedicated on microbial degradation of textiles [14]. Abdel-Kareem, O., 2010 refers to the monitoring, controlling and preventing the fungal deterioration of textiles in the museum of Jordanian heritage, especially to the disinfection of fungal deteriorated textiles with some fungicides that are safe for both textile objects and conservators [15]. The same author studied also fungal microflora deteriorating historical textiles in the Egyptian and Coptic Museums, Cairo. The investigation including the canvases of easel paintings stored religious institutions in Slovenia, initially indicated relatively widespread fungal contamination [16]. Some paper presents the method of treatment of tapestry textile, linen which was stretched on wooden frame treated by anti-fungal substance [17]. Other authors presented a microscopy study with focus on the cellulolytic fungi action on cotton fiber’s physical aspect [18], or analyses fungi and bacteria on artworks in different environments, considering the human/artefact/environment system as being very dynamic [19].

Method

Image analysis [20] were used in order to extract information from one or more images; digital image processing techniques were used [21]. The ArcGIS system has been used to highlight spatial trends, because it easier to visualize, analyse and interpret available data in order to understand the trends of evolution [22–29]. Isolation of microorganisms from paintings were done through specific means, samples of 1 cm^2 from the surface of two canvas paintings were taken using sterile cotton swabs [4, 30–31].

Cotton swabs were submerged in 1 mL of sterile distilled water and decimal dilutions were performed. Suitable dilutions of each sample were inoculated into nutrient agar on petri dishes to identify bacteria and on Sabouraud agar with chloramphenicol for isolation of fungi. They were incubated at 37°C for 72 h (isolation of bacteria) and at 25°C for 5–7 days (isolation of fungi). After this period, the colonies were counted with the colony counter. Cultural and morphological characteristics of fungal colonies were observed and the identification was performed according to different manuals [32]. Regarding the microclimate inside the historic monument wooden church the temperature and relative humidity of the air was monitored using the thermo-hygrometer with data function logger „Klimalogg Pro", which allowed detailed records of temperature and humidity values as well as their active monitoring in the months of October-December 2018 (eight sensors). Luminosity analysis was performed with "Digi-Sense Data Logging Luxmeter", while the temperature was scanned with "Thermal Imaging Camera FLIR I7" thermo-camera.

Discussions

At the suitable temperature and relative humidity, the air microbiota can coexist together with the collections and people in a specific ecosystem without causing significant damages. The oil painting in the church museum is made on cotton canvas also due to its quality to be easily painted. Cotton is a natural cellulosic fiber unicellular [33–34], characterized by a very high stability of the fiber in textile structures (fabrics) due to the twist of its fibers and surface structure (a good fixation of the fiber in the products provide them a longer use, stability in different loads and a pleasant aspect). The temperature is an important factor contributing to the deterioration of the paintings: high temperature values (figure 3, *c*) lead to an accelerated degradation of unstable materials. In addition, low temperatures make organic materials more perishable. Also, big temperature differences in the room can contribute in time to damage, cracks or support detachments. The thermal degradation of cellulose fibers is also accompanied by hydrolysis and oxidation. The resistance of a cotton fabric, heated in the presence of air, decreases as the temperature rises. In the case of low temperature, the organic components became more friable. In the absence of air and humidity, the heated cellulosic fibers suffer lower changes than in their presence.

In terms of humidity, (relative humidity) U.R. variations create tensions between the components of a painting, as well as between the painting and its support. The hygroscopicity of cotton is medium, but in standard conditions (temperature between 20 °C ± 2 °C and 65% ± 5% relative air humidity) absorbs between 7–8% water [35–36]. However, if the humidity exceeds 68–70% it favours not only the development of microorganisms on organic materials, but also the destruction of the internal structure of cellulosic fibers [37]. Depending on the moisture persistence, isolated or extended stains may appear on the surface (figure 3). Pigments can suffer a physical alteration, which does not involve switching to another chemical compound, but there is a phenomenon of colour "darkening" due to a high degree of hydration (figure 3). The phenomenon can definitely influence the condition of the textile fiber, the preparation, the colours and the vernil [38]. Increased humidity can accelerate chemical and photochemical processes that result in colour change, material fragility, decreased mechanical strength of textile fibers etc., and it can lead to increased volume, swelling, wrinkling and softening of natural adhesives (figure 4). In time, a decreased moisture affects the state of health of organic objects: furniture, wooden objects, paintings etc. If humidity decreases below 50%, but especially below 40%, it first dehydrates the materials and decreases the mechanical strength of the parts, causes the volume to decrease, scorching, loss of elasticity, appearance of micro fissures, exfoliation, removal of natural adhesives (figures 3, *d* and 4) [38]. Following the exposure of the painting to the natural light radiation and the different intensity of the solar radiation throughout the day, by overlapping the images one can see in the figure (figure 3, *b*) oxidative degraded areas due to the impact of these radiation on the painting, both from the point of view of colour intensity and resistance of the exposed fabric structure. Thus, it can be noticed that in places where the natural luminous intensity was higher, discoloration areas of the painted canvas appeared (figure 3, *b*). The resistance of a cotton fabric decreases after 6–7 days of exposure to ultraviolet rays [35–36].

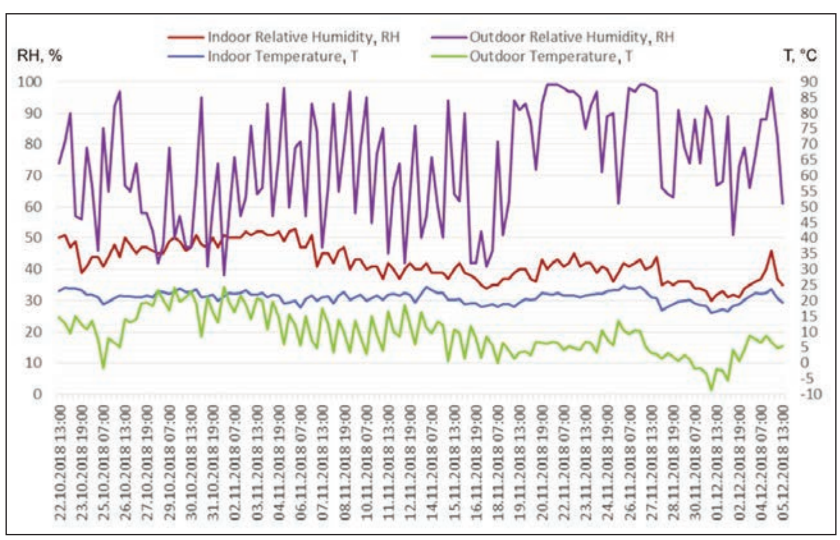

Fig. 4. Variation of the air temperature and the relative humidity indoor and outdoor of the heritage wooden church, in the monitoring period 22/10/2018 – 05/12/2018

Ultraviolet rays can also cause yellowing of exposed materials, discoloration, and loss of mechanical resistance in the case of wall paintings. In addition, hydrogen peroxide molecules have been identified both on the surface and in the capillaries of a fabric exposed to light. Under the action of light and atmospheric agents (temperature and humidity), the resistance of fabrics decreases as follows: with 26.5% after one month, with 45.3% after two months and with 60.7% after 3 months [35–36].

The biochemical degradation of cellulosic fibers occurs due to the action of microorganisms, and the attack of cotton can be recognized by the appearance of some yellow, brown or black stains, where the local resistance is diminished and the dyeing is uneven. This can be freely noticed on the paintings exhibited in the church, especially in the joining areas, where the variations in humidity and temperature are higher (figure 4). Increasing thermohygrometric values at the repository, microorganisms can accelerate biodeterioration [39]. Microorganisms participate in the mineralization of paints through biofilm formations on the surfaces causing aesthetic and structural damage. Various types of organisms are involved in paint spoilage and they include bacteria, fungi, algae, and protozoa. The interactions between these organisms can enhance or retard the overall rate of paint biodegradation [40]. Different fungal genera were isolated from the two paintings choose to be investigated for biodeterioration. On the painting on canvas inside of the heritage wooden church were isolated: *Streptomyces sp.*, *Arthrographis sp.*, *Beauveria sp.* concerning the bacteria presence on the painting canvas, Bacillus sp. has been isolated and filamentous bacteria from genera *Streptomyces*. The actinomycetes, in particular *Streptomyces*, are capable of decomposing relatively complex organic substances such as cellulose, pectin, chitin, proteins, and humic substances [4, 40].

Also, based on microscopic techniques were identified unknown bacteria strains with the shape cocci and bacilli. Paint spoilage by bacteria in addition to fungi and algae, bacteria are also involved in the biofilm formation followed by reduced durability of structures. While fungal and algal growths are often visible to the naked eye, bacteria can be present on an apparently clean surface in sufficient numbers to exert adverse effects. This situation conditions the surfaces to absorb humidity that helps the microbial adherence and the subsequent biofilm formation [30, 41]. The organic components in paintings represent a good source of nutrition for a wide range of heterotrophic microorganisms. However, biological attack occurs only when there are favourable environmental conditions, and such conditions are often found in old churches without any control of the humidity and temperature [4, 42].

The micro flora attacking paintings include virtually all species of micro-fungi because the variety of organic components of these works of art can represent a carbon source for practically all species. In addition, they show a great tolerance for environmental conditions and can use condensation moisture [43]. In fact, in paintings on canvas, the microbial attack usually starts from the reverse side, because the glue sizing increases the natural susceptibility of textiles. Then the biodeteriogens "penetrate inside canvas reaching the backside of the paint layer, causing cracks and detachment, while the cellulose hydrolysis creates differences of adhesion between the paint layer and the canvas itself" [4, 44]. Biological attack on the paint layer is less frequent than on the support and depends on the nature of pigments. "The most susceptible to biological attack are casein and egg distemper, emulsion distemper and linseed oil in this order" [4].

Watercolours contain only a small amount of organic binder and are, therefore, susceptible to microbial deterioration as pastels [45]. The growth of a micro fungal mycelium by a microscopical germinating spora is quite rapid, with radial development, and it became macroscopically visible in few days. The development of micro fungi on the surface of paintings induces aesthetical, mechanical and biochemical decay. In fact, the growing mycelium spread over the paints, masking design and colour, while the growth of hyphae and fruiting bodies inside the support can cause friability and loss of the paint layer.

As environmental microorganisms can deteriorate the different supports of heritage significance [31, 41] as well as affect human health as allergies and skin affections [39]. *Streptomyces spp.*, commonly widespread bacteria that is usually saprophytic for humans and which can usually cause localized fistulized cutaneous nodules and rarely cause severe invasive infections. Most of these cases may occur in patients with low immunity. Such invasive infections have also been reported in the presence of pre-existing conditions associated with low immunity: AIDS infection, oral corticosteroid treatment, the presence of a central venous catheter or of an aortic heart valve prosthesis [4, 46]. *Arthrographis Genus-Arthrographis kalrae*, one of the five existing species, is a saprophytic medium fungus found mainly in soil and in fertilizer, and which has rarely been identified as a possible human pathogen. According to specialist research, few cases of opportunistic infections attributed to this pathogen have been described: pulmonary infection, endocarditis, sinusitis, meningitis, keratitis, and onychomycosis affecting both immunocompromised and immunocompromised patients [4, 47]. *Beauveria* sp. is a widely spread fungus but is rarely reported as a human pathogen. Although a rare event, studies show that systemic infection with Beauveria is possible for patients undergoing immunosuppressive treatment [4, 48].

CONCLUSIONS

For a better preservation of textile objects inside the heritage wooden church, it is necessary [49] to continuously monitor the interior microclimate, compressive the microbial concentration of the air, because the presence of these fungal genera and bacteria on paintings results to be highly risky both for their preservation and for the human health. It is necessary to better isolate the rooms where the paintings are exposed, a better ventilation, as well as maintaining the standard conditions of relative air humidity between 65% ± 5% and of temperature between 20°C ± 2°C. A high fidelity database regarding the state of patrimony objects preserved in Romanian wooden churches and the perspectives for their proper preservation can be created. It is recommended to change the air conditioner filters, carpets, and to sanitize the interior of the wooden church and of paintings etc.

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Authors:

IOAN OANA[1], LILIANA INDRIE[1], AURELIA ONET[2], DORINA OANA[1], DORINA CAMELIA ILIEȘ[3], GRIGORE VASILE HERMAN[3], ALEXANDRU ILIEȘ[3], FLORIN MARCU[4]

[1]University of Oradea, Faculty of Energy Engineering and Industrial Management, Department of Textile, Leather and Industrial Management, 4, B.St. Delavrancea Street., 410058, Oradea, Romania
e-mail: oanaioanpavel@yahoo.com, liliindrie@yahoo.com

[2]University of Oradea, Faculty of Environmental Protection, 26, Gen. Magheru Street, Oradea, Romania
e-mail: aurelia_onet@yahoo.com,

[3]University of Oradea, Faculty of Geography, Tourism and Sport, 1st University Street, 410087, Oradea, Romania
e-mail: iliesdorina@yahoo.com, grigoreherman@yahoo.com, ilies@uoradea.ro

[4]University of Oradea, Faculty of Medicine and Pharmacy, Oradea, Romania
e-mail: mfmihai27@yahoo.com

Corresponding author:

OANA IOAN
e-mail: oanaioanpavel@yahoo.com