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Chapter

Considerations Regarding the Research for the Conservation of Heritage Textiles in Romania

Ilieș Dorina Camelia, Herman Grigore Vasile, Caciora Tudor, Ilieș Alexandru, Indrie Liliana, Wendt Jan, Axinte Anamaria, Diombera Mamadou, Lite Cristina, Berdenov Zharas and Albu Adina

Abstract

Textiles are valuable elements that make up Romania's cultural heritage, being unique through the production techniques, materials used and their significance for the Romanian population. Heritage textiles represent bridges between past and present, kept in collections from different types of buildings. Many of them are preserved and exposed in heritage buildings that are open for public viewing and do not benefit from internal microclimate monitoring systems. These things can have serious repercussions on the integrity and conservation status of these fragile materials. The chapter proposes to analyze the approaches used in different studies to evaluate the risks to which the historical textile collections from Romania are exposed, depending on the place and the way in which they are kept. All these approaches aim to determine the degree of conservation of the materials and their implications on the health of the people with whom they come into contact. Based on the methodology applied in the studies already published, examined in the first part of the chapter, in the second part, a case study was performed on a different sample of historical textiles from Romania. This comes to complete the sphere of knowledge in the field.

Keywords: textiles, heritage buildings, historical textiles, methodological approaches, microclimate, protection, conservation

1. Introduction

The textile materials represented a major coordinated on the evolution of human society both temporally and spatially. The objects made of textile materials have, over time, experienced a great typological, functional and structural diversity, in close relation with the needs of the human society at a certain stage regarding the technological progress achieved and means of processing the textile materials. Therefore, textile objects are part of the cultural heritage, with roles and functions in asserting the specific identity of the place [1–4]. The specificity and identity of the objects made out of textile are derived from the genetic, evolutionary and qualitative features that they incorporate (occupations, customs, technological level achieved, beliefs, superstitions, etc.) [5].

The mutations that have occurred lately against the backdrop of globalization call for sustained efforts to conserve these elements of cultural heritage and local identity. The necessity of their conservation has required the carrying out of numerous specialized studies that have highlighted the anthropogenic and environmental degradation factors [1, 6–8] and their effects on textile, yellowing, decreased elasticity and tear resistance, microflora development [9–15], as well as the necessary measures to prevent their degradation and to conserve them [16–19].

Considering that one of the most objective and important factors with direct effects on the degradation of textile is "time itself", a solution may represent digitization, constituting an informational bridge between past, present and future [20–23]. During the past decades, digitization has become one of the main concerns of cultural institutions and governments all over the world [22] as there is a constant need for preserving cultural heritage in a digital form as well. From a process that transforms a physical object into a digital one [21], digitization became an art itself involving various specialists from different domains having the same aim—preservation. But, still the final goal of digitization is not only to turn a material object into bytes, but making it accessible for everyone interested in it, in an online environment [24] as culture is considered a basic human right [25]. Thus, through digitization the past is connected to the future as the digital world may seem a better option for preserving and conservation of the cultural heritage resources. We are living in the "Digitization Age" and our society understood that cultural heritage belongs to the mass and plays an essential role not only for the social and economic development of the present society but for the future one as well.

From all the cultural resources, maybe the most sensitive in preserving are textile [3] as requires certain storage conditions. Temperature, humidity, light exposure and the mycological content in the composition of the materials are few parameters to be analyzed in order to assure proper storage conditions. In this context, digitization seems a better solution for preservation and promotion, their life span will be undeniable higher although it will be in the cyberspace not in the real world.

Among tests, an analysis that can be performed on textile materials for their digitization, the SEM analysis and digital radiography are highlighted practices whose results have a high degree of plausibility.

The scanning electron microscope (SEM) allows three-dimensional views of external morphology of the fibers, in order to determine their level of conservation [26]. SEM is used to identify fibers and to assess the level and type of fiber wear, degradation or structural alteration [27–29]. The environmental scanning electron microscope (ESEM) can be used to "characterise the surface, interface and dynamic properties of textile materials" [30].

X-radiography and digital radiography uses non-destructive techniques very useful in the study of textile materials, documentation and interpretation in order to conserve valuable objects from cultural heritage [31–33]. The limitation of this method is inaccessibility on a large scale due to the high costs. Another technique for studying old textile materials is the one proposed by Ahmed et al. [34]—laser induced breakdown spectroscopy (LIBS), which also provides chemical information; also for the determination of the chemical composition of the colors used, we mention the use of X-ray fluorescent spectrometry (Spectroscan Max G, Spectron), with the type of spectrometer being wavelength dispersive [35].

Mannes et al. [36] propose a non-invasive approach for the analysis of fragile materials of cultural heritage, neutron and X-ray imaging. Valuable information about the old manufacturing techniques used in the creation of textile but also about the possible treatments for cleaning and preserving them for a longer period of time can be obtained using all the techniques and X-ray spectroscopy methods: scanning electron microscopy with energy dispersive X-ray spectroscopy (SEMEDX), X-ray fluorescence spectroscopy (XRF), particle induced X-ray spectroscopy (PIXE) and also Rutherford backscattering spectroscopy (RBS) [37].

A simple technique that could be encountered for analyzing the colors of the cultural heritage objects is colorimetry (CIELab color system). This technique might be useful when a change in color is desired to be quantified when varying the parameters of the microclimate [38]. Moreover, colorimetry could be a suitable method to determine the change in color when a preservation treatment is tested on a heritage object [39], as the modification of its main features should be avoided.

The color of a cultural heritage object is given by pigments or dyes. These substances can be evaluated from the compositional point of view by using infrared spectroscopy (Fourier Transform infrared spectroscopy). Usually, this technique requires the use of a potassium bromide pellet, which is a time-consuming and destructive operation [40]. Fortunately, a new version of this technique, called attenuated total reflectance FT-IR, was developed, having the main advantage of its non-destructive fashion, as it allows the measurements to be performed without any previous preparation [41]. ATR-FTIR is a valuable technique when analyzing dyes and pigments because it can offer information about the molecular fragments of this substances [42, 43]. In this way, it is possible to determine what type of dye or pigment has been used in the original process of painting. This information could be very helpful when choosing the restoration materials.

But without a doubt, the best way to conserve historical textiles is to keep them in an interior environment that is less harmful for them. The great diversity of the buildings in which they are exposed (museums, traditional constructions, private collections, etc.) determines a great variety of indoor microclimate conditions, which could have repercussions on the degree of conservation of textile collections. Thus, of a major importance is both the determination of the state of conservation of the textiles, and the establishment of the influence that the microclimate from the different storage spaces exerts on them.

In this context, the present study aims to highlight some methodological aspects and the results obtained following their implementation in a series of researches carried out on three structural elements defining for the Romanian society, in which different collections of textiles are kept: wooden church "Saint Martyrs Constantin Brancoveanu and his sons", The Museum House from Sălacea and National Archives of Romania—Bihor County Service from Oradea Municipality (**Table 1**). About the three locations where the research was carried out, we can say that they are representative regarding the Romanian rural communities, offering different environment conditions, including the anthropic impact with implications in manifesting in a form or another the negative effects of the textile objects hosted. Nevertheless, in order to diversify and deepening the obtained results by the research team from University of Oradea and collaborators, in the last part of this chapter a new case study regarding a traditional women's shirt over 100 years old from a private collection, has been conducted.

2. Case studies

This paper aims to analyze from the point of view of approach, methodology and research object, three case studies already carries out regarding the current state and the conservation conditions of some textile collections from three buildings in Bihor County, Romania (**Figure 1**) serving different purposes. These three collections have been extensively examined in numerous specialized papers, some being already published and some being in print.

No.	Location of study	*Title of the studies*—Status (journal, volume, issue, page)—Year
1	Wooden church *"Saint Martyrs Constantin Brancoveanu and his sons"*	*Investigations on air quality in the historic wooden church in Oradea city, Romania*—Published (Environmental Engineering and Management Journal, 17, 11, 2731–2739)—2018
2		*Study on microbial and fungal contamination of air and wooden surfaces inside of a historical Church from Romania*—Published (Journal of Environmental Biology, 39, 6, 980–984)—2018
3		*Indoor air quality assessment and its perception. Case study—historic wooden church, Romania*—In print (Romanian Biotechnological Letters)—2020
4		*Exploring the Indoor Environment of Heritage Buildings and its Role in the Conservation of Valuable Objects*—Published (Environmental Engineering and Management Journal, 18, 12, 2579–2586)—2019
5		*Preserving textile objects in Romanian Wooden Churches. Case study of the heritage wooden church from Oradea*—In print (Industria Textila Journal, 2)—2020
6		*Spectrometry Study of Heritage Objects for the Digitisation of Cultural Heritage—In print (Environmental Engineering and Management Journal)—2020*
7	Sălacea Museum House	*Indoor air quality of museums and conservation of textiles art works. Case study: Salacea Museum House, Romania*—Published (Industria Textila Journal, 70, 1, 88–93)—2019
8		*Analyzing indoor museum air quality implications: Case study of Salacea Museum House in Romania*—Conference paper (Global and Regional in Environmental Protection GLOREP, Ed. Politehnica, 89–91)—2018
9		*Microbial and fungal contamination of air and wooden surfaces inside of Museum House Salacea, Romania*—Under evaluation—2020
10	National Archives of Romania—Bihor County Service	*Microclimatic characteristics and air quality inside of the National Archives of the Bihor County (Romania) for the long-term preservation of the documents and the health of the employees*—Under evaluation—2020
11		*SEM investigations on old maps with canvas support*—Conference paper (International Conference TexTeh IX. Advances textiles for a better world, Proceedings, 9, 153–157)—2019

Table 1.
Details of the studies already carried out by the research team from the University of Oradea and collaborators, on the three buildings in which textile collections are kept.

In the first case, it is a wooden church located in the University of Oradea Campus, built in the second half of the eighteenth century and currently considered a historical monument, being registered in the list of historical monuments with the code BH-II-m-B-20958. It houses numerous paintings, some of which are made on textile material (**Figures 2** and **3**). These are very valuable in terms of the techniques used for painting (al secco), the colors used (some with gold composition), the dimensions and materials on which they are made. The studies envisaged for the methodological and result analysis are focused on determining the interior microclimate of the monument [7, 44, 45] as well as the preservation of the valuable objects inside [35, 46, 47].

The second case study is represented by a former nineteenth century peasant household from the village of Sălacea, which was later refurbished and is currently functioning as a village museum. Numerous ethnographic items are exposed inside such as: furniture, traditional fabrics and other household items (**Figure 4**);

precious due to the prominent place formerly occupied in the life of the Romanian village, especially in the villages from Bihor County. The museum house has been the object of study for three scientific works, one focused on the determination and analysis of the internal microclimate [48], and the second on its influence on the conservation of the exposed textile materials [2].

Figure 1.
The location of the three case studies at the Bihor County level.

Figure 2.
Painting on canvas inside the wooden church historical monument depicting The Holy Trinity.

Figure 3.
Painting on canvas from the ceiling of pronaos inside the wooden church depicting the Virgin Mary with Baby Jesus.

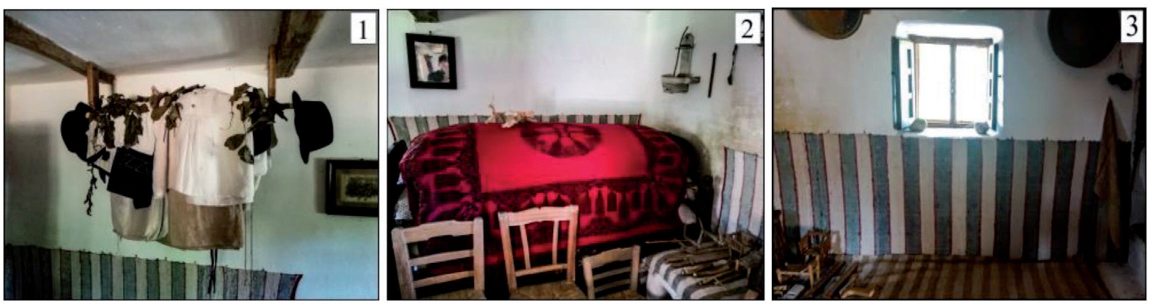

Figure 4.
Traditional port and household items from Sălacea Museum House made of textile materials: (1) elements of the traditional port from the Ier Valley; (2) and (3) items for daily use made from different textile materials.

In the last case study, the conditions and the degree of conservation of the documents and textile materials deposited in the National Archives of Romania—Bihor County Service, based in Oradea Municipality—were examined. The researches focused on a thorough analysis of both the main parameters of the internal microclimate from several deposits [49] and of old maps dated between 1895 and 1910 with the support of textile materials (especially cloth) [50].

Due to the different age of the three buildings, the different construction materials and the purpose they serve, the collections of textiles inside them are subjected to various anthropogenic and environmental pressures. If the building of the National Archives of Romania—Bihor County Service is recently built, using modern building materials and access is restricted, so the textiles inside are subject to minimal external influences in order to conserve them for as long as possible; at the opposite pole is the wooden church from the University of Oradea Campus. It is about 260 years old, built mostly of organic material (wood) and is a "living" monument (it still serves the purpose for which it was built) that houses an average of 60 parishioners at each religious service [7], the paintings on the canvas inside are exposed to much amplified pressures. As for the Museum House in Sălacea, it was built in the last century, made of beaten clay and covered with reed; functioning as a village museum, it is occasionally visited by tourist groups, the textiles not being exposed to a very high stress (at least anthropic).

2.1 The methodology used and its relevance

The three case studies already conducted are based on a common principle regarding methodology; namely the monitoring of the internal microclimate of the spaces where the textiles are stored in order to determine the characteristics of its main elements (temperature, humidity, luminosity, CO_2, contamination with bacteriological microflora and fungi). This has been achieved because it is known that historical textiles are highly susceptible to being damaged by the action of these environmental factors [51]. Theoretically, for textiles to be stored in an environment that is most suitable for storage, the indoor temperature should not exceed 22°C, with a relative humidity between 50 and 65% and a brightness between 50 and 80 luces [52]. To determine the temperature, humidity, brightness and CO_2 concentration, a large number of electronic devices were used in the research, most of them being data loggers for the simultaneous monitoring and storage of the values. The values of the temperature and the relative humidity were determined using Klimalogg Pro, Thermal Imaging Camera FLIR I7 and Delta Ohm HD 32.3, brightness with the help of Digi-Sense Data Logging Luxmeter and Luxmeter data logger Extexh SDL400, and the amount of carbon dioxide with Nova 5000.

Regardless of whether the textiles are made from fibers of plant or animal origin, too high temperature can determine tissue weakening and discoloration. The increased relative humidity of the environment can cause its absorption to the textile fibers and as a result of the humidothermal treatments contractions can occur. Mechanical technological processes can result in a loss of elasticity, flexibility and tensile strength [53]. Furthermore, excess natural light can cause the oxidation of polymers from the composition of natural textile fibers, leading, in time, to the breaking of the intermolecular bonds, yellowing of the material, facilitating the breakdown and penetration of microbial enzymes [13], especially in the case of wool.

The pressure that the characteristics of the main parameters of the microclimate exert on the textile materials in general and the historical ones in particular, should not be considered as an intrinsic relation. These factors are interconditioning and acting simultaneously in the process of material degradation. Thus, there is a directly proportional relationship between the amount of natural light and the interior temperature, as well as inversely proportional between the temperature and relative humidity variations. Further, all these environmental factors contribute to the emergence and spread of microorganisms (such as bacteria and fungi), which present an increased risk of deterioration for materials of organic origin, such as textiles. The most favorable conditions for the colonies of fungi and bacteria are high temperatures (between 24 and 30°C) and very high relative humidity [51]. As a consequence of the activity of certain groups of microorganisms on textiles, we can mention: fiber degradation, discoloration, loss of structural resistance, shading of the affected areas in red, brown, orange or black, cracking and fragmentation areas [1]. For the determination of microbial contamination, for all three case studies the method of Koch sedimentation of the conventional techniques of open plates was used, the samples being collected both from the air and from the surfaces of the textiles. The sampling of the types of fungi and bacteria was done by microscope analysis, and the calculation of the average value of the number of colonies of fungi was materialized by applying Omeliansky's method [54].

If all these methods presented above were of a general nature, being used to establish the influence that the internal microclimate exerts on the textile collections of each of the three analyzed buildings, further on an individual investigation of the fabric samples was carried out. In the wooden church, it was analyzed and represented in cartographic form, with the help of GIS techniques [55, 56], the areas of paintings on canvas anthropic degraded, as well as the distribution of temperatures and brightness within the frescoes. Finally, the colors used for painting inside were examined from the point of view of the internal composition, by digital techniques (X-ray fluorescent spectrometry) [35]. A digital technique was also used to examine two samples collected from old maps with textile support deposited in the

National Archives of Romania—Bihor County Service. Namely scanning electron microscope (SEM); a technique often used in studies targeting textiles, but with a high efficiency in determining their degree of conservation. The use of SEM aimed to identify morphological aspects and irregularities of the fibers that make up the fabrics, as well as the presence of microorganisms and dust [47].

For centuries, the purpose of textiles has been to serve man. Offering protection against the glazes of nature through clothing and material or building houses (tents of nomadic populations), means of purchasing food (fishing nets and various traps), mobility in the territory (sails of ships), and many other practical uses. This has not changed until today, fabrics still occupying a central place in the everyday life of modern society. The relationship of interdependence created along the time between man and textile makes it impossible to analyze the latter separately from the creative element. Therefore, in the accomplishment of the three case studies, the influence of the internal microclimate on the conservation of textiles, as well as their integrated action (internal microclimate + textiles) on human health, was considered.

Furthermore, it is worth mentioning that all the interventions for determining and monitoring the degree of conservation of textiles have been chosen so that they are non-invasive for materials; ensuring that they are kept in the best conditions.

2.2 Results obtained

2.2.1 Wooden church "Saint Martyrs Constantin Brancoveanu and his sons"

Following the microclimate measurements carried out in two periods, March-April (2016) and October-December (2018) respectively, a fluctuating evolution of the main parameters was found. Between March and April 2016, the average temperature inside was 25.8°C, with an average relative humidity of 38% [7]; none of these indicators are complying with the rules in force. The situation is improving, and the values approach the ideal parameters (according to the GD no. 1546/18.12.2003, see [52]), at the level of 2018, when between October and December, the temperature has an average value of 21.1°C, and the relative humidity of 44.3% [46]. Oscillating quantities have also been recorded in terms of carbon dioxide. During the religious services it exceeds in multiple times the value of 2000 ppm, so that during the periods without human activity it is constantly maintained between 400 and 500 ppm.

Following analyses with X-ray fluorescent spectrometry, it was determined that these oscillations are responsible for modifying several properties of the pigments that make up the paintings, eventually leading to their degradation [35].

In order to establish the damaged areas of the paintings on the canvas, the mapping of the areas in which they were degraded by temperature, humidity and rainwater infiltrated in the painted canvas was performed. Also in this sense, the distribution and influence of heat and light on the painted canvas were analyzed (**Figure 5**), at different times of the day and in different seasons [47].

Regarding the contamination with bacteriological microflora and fungi, following the laboratory analyses and sampling of results, 47 colonies of bacteria and 31 of fungi colonies were identified in the air [45]. Fungi belong to a number of 18 species, the most common being *Aspergillus sp., Alternaria sp., Absidia sp., Penicillium sp.*, as well as *Rhodotorula* and *Candida*; and four types of bacteria were identified (*Staphylococcus, Micrococcus, Bacillus,* and *Actinomyces*) [44]. The large number of microorganisms identified in the air inside the wooden church can represent a potential danger to the health of the parishioners, but at the same time they can colonize the textile materials [47]. The organic components that characterize

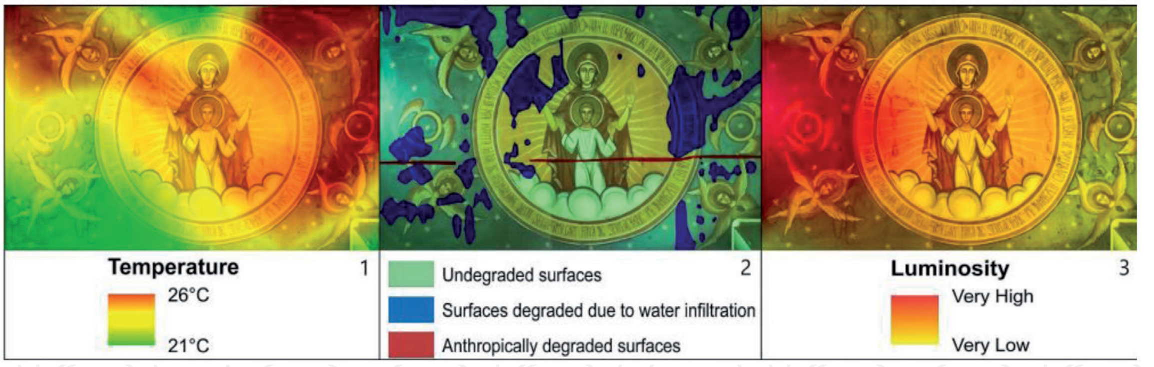

Figure 5.
Distribution of temperature, luminosity and degraded areas on the painting on canvas "Virgin Mary with the Baby Jesus" (after Oana et al., see [42]): (1). Temperature distribution at the canvas level; (2). Distribution of degraded areas at the canvas level; (3). Distribution of natural light at the canvas level.

the paintings on canvas [35] represent a nutritional source for a wide range of microorganisms [45], proving the large number of identified colonies. The samples collected from the paintings on canvas revealed the presence of no less than seven fungi and one type of bacteria [45, 47]. The integrated action of these microbes, both from the air and from the surfaces, can, in time, lead to the decomposition of textile materials, damage that is practically irreversible.

2.2.2 Sălacea Museum House

The measurements made between 03.06.2018–2102.07.2018 in the Museum House in Sălacea Village indicated that the values of temperature, humidity and brightness comply, with small exceptions, the norms set in GD no. 1546/18.12.2003 [2]. Only the temperature recorded an average value higher by 1.3°C than the optimal one (22°C); while humidity, with an average of 65%, is at the upper limit of the ideal. The brightness, having values between 10 and 20 luces, does not influence textiles in any way.

However, these environmental conditions cause the development of microorganisms, which attack the tissues and endanger the health of the visitors. A number of 73 colonies were identified in the center of the main room, 63 colonies in the corners and 39 in the ceiling [2]. Due to the fact that the museum is visited only periodically by tourists, the number of fungal species was obviously smaller than in the wooden church, only three being observed (*Alternaria*, *Geotrichum* and *Cladosporium*) [48]. However, the action of the bacteriological microflora present inside can cause degradation of textile fibers, as well as health problems (allergies) in humans [6].

2.2.3 National Archives of Romania: Bihor County Service

According to the order No. 235/05.07.1996, supplemented by the Daily Provision of the General Director of the National Archives No. 92/14.05.2009 [57], for the optimum preservation of the documents (including those of textile materials) the microclimate of the interior should be kept between 15 and 25°C regarding the average air temperature, between 40 and 65% the average relative humidity and below 0.3 m/s the speed of air currents [49]. Excluding the relative humidity, which registered a value with 2% (38%) lower than the limit, the other elements are included in these norms (average air temperature of 23.3°C; air currents speed of 0 m/s). The amount of CO_2 recorded an average of 570 ppm, a value considered to be within normal parameters [58].

Aeromicroflora was determined to be composed of fungi species: *Alternaria, Botrytis, Cladosporium, Penicillium, Scopulariopsis* and various subspecies of

Aspergillus [49]. These microorganisms affect human health and integrity of textile fibers; the second case being detected after the SEM analysis of the samples of old maps with textile support. These revealed that the fibers are strongly damaged due to the presence of fungi and dust. Among the microorganisms identified on the maps, there are different subspecies of *Penicillium* and *Fusarium* [50].

3. A new case study

In order to diversify the study objects, a new research on a textile material with historical implications was conducted. It is about a traditional women's shirt called "ie" (**Figure 6**), specific to Alba County, Romania. The value of this fabric lies in its very old age (over 100 years), due to the fact that it is handmade from natural cotton fibers, but also due to the special significance it has in the life of local communities.

Like the other collections of textiles presented above, which are stored in buildings with different environmental conditions, the present study comes to complete the way historical textiles are preserved in Romania. The traditional shirt, being part of a private collection, to which only the owner has access, its preservation conditions are different from all the other samples. It is stored in household microclimate, which commonly consists of an average temperature in the range of 20–24°C (during wintertime) and 23–26°C (during summertime). Also, the humidity level range between 30 and 60% [59]. Moreover, due to the fact that the piece still serves the purpose for which it was achieved, being occasionally worn, it is necessary to determine the bilateral implications of this action; both on the degree of conservation of the shirt and on the health of the wearer.

3.1 Methodology

Based on the methodology applied in previous studies, for the traditional shirt it was decided to evaluate the state of the material, its physical characteristics, the

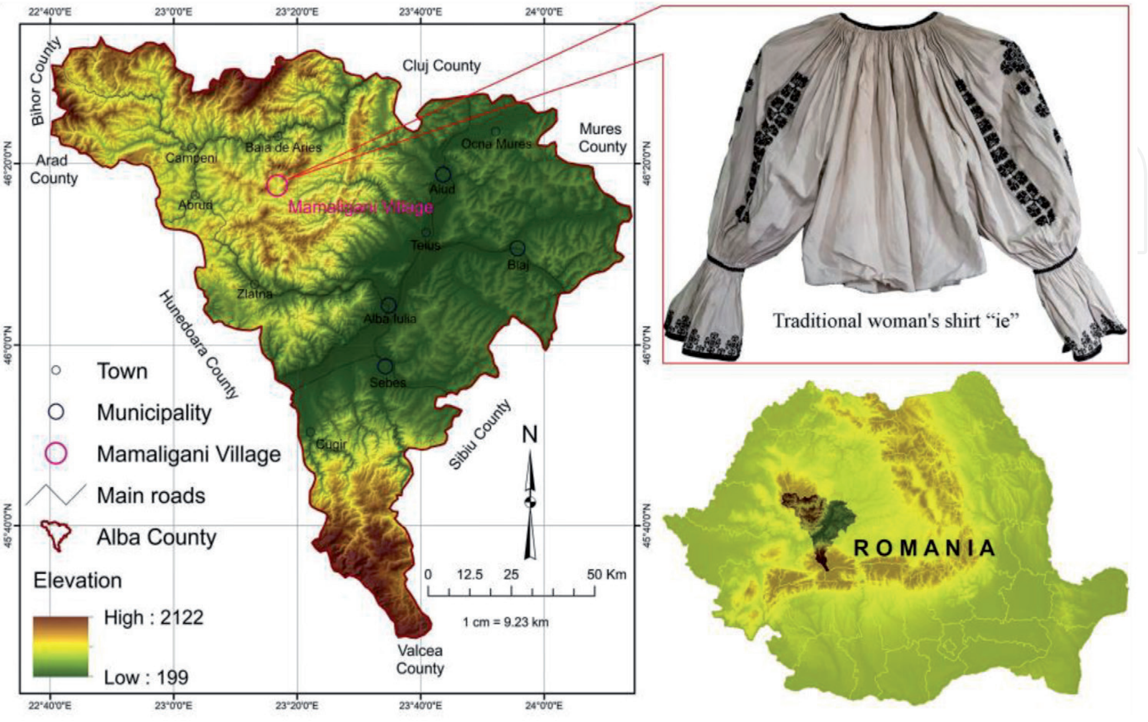

Figure 6.
The geographical location of the area of origin of the traditional women's shirt "ie".

degree of mechanical destruction and the possible influence of atmospheric factors. The samples collected from the textile material were examined using the scanning electron microscope (SEM), to determine the current state of the fibers. The morphology of the fiber system was determined in order to identify visible damage under the microscope and verify the occurrence of dust on the tested impurities. An attempt was made to determine the fungi and other microorganisms potentially occurring on the tested material [60, 61]. The test samples were presented in successively increased magnifications, from 178× to 2.31K× at EHT 20.00 kV. Using the FEI Quanta 200 microscope, a comparative examination was performed between a white and a black thread from the shirt's composition, in order to determine any differences in terms of material or degree of preservation. The whiteness index was determined with the Datacolor Spectrophotometer with a D65/10 lamp, by measuring the X, Y and Z chromatic components from three areas (**Figure 7**) with different bleaching levels.

To identify the microorganisms that are currently colonizing the material, Dichloran culture medium 18% glycerol agar with chloramphenicol (DG 18) was used; the diluent used being peptonated water. Further, petri plates were seeded, and the samples were incubated under aerobic conditions, at 25 ± 1°C, for 5–7 days. Macroscopic and microscopic examination of fungal colonies [62, 63] highlighted the following types of fungi: *Aspergillus niger, Penicillium spp., Cladosporium spp., Alternaria spp. and Candida spp*. After dishes incubation, fungal and bacterial colonies were counted. Colony forming units per cubic meter (CFU • m^{-3}) were determined, following the Omeliansky's equation [64, 65]:

$$N = 5a \times 10^4 \, (bt)^{-1}, \quad (1)$$

where N = microbial CFU • m^{-3} of indoor air, a = number of colonies per Petri dish, b = dish surface (cm^2), t = exposure time (min). Determination of the number of fungi (NTF) per gram of product ufc/g showed NTG/ml or /g = greater than 300 at both 22°C and 37°C, NTF/ml or /g = 2.1×10^3.

3.2 Results and discussions

The first pair of images at 178× magnification (**Figure 8**) and 270× (**Figure 9**) allowed the determination of the tested fiber's condition, as good. The first image

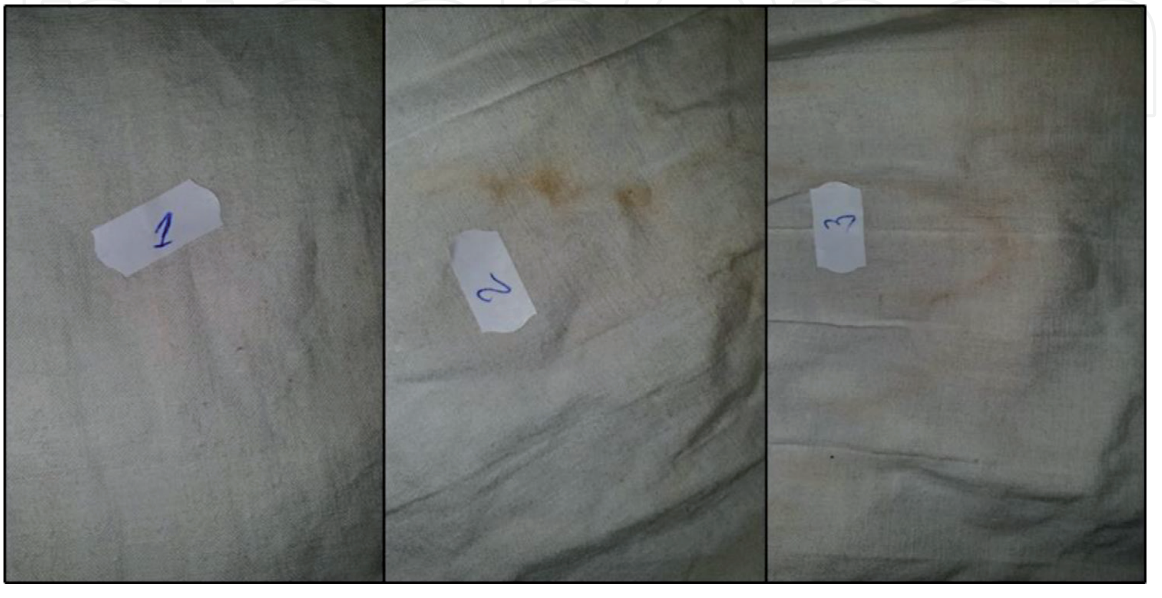

Figure 7.
The three points in which the whiteness index was measured.

clearly shows the weave of threads constituting the basic fiber of the material of the costume under examination. Its good condition may indicate that the folk costume ("ie") is not used very often (within the scope of the test sample), as well as it is kept in good storage conditions. This is confirmed by another image (**Figure 9**), which shows only slight mechanical damage to the fibers. The entire fiber bundle tested is in good condition. However, even at this low magnification, enhanced by image enlargement using computer tools, we can see atmospheric dust covering the fibers.

Successive image magnifications, 818× (**Figure 10**) and 877× (**Figure 11**) confirm previous observation. At this magnification, dust and dirt are clearly visible on individual fibers. Also, it can be observed in **Figure 10**, the structure of a single fiber of natural origin. In the case of natural fibers, with a lose arrangement, the rough, lamellar surface structure means that they are able to transport significant amounts of material, including microbial origin [66]. Computer enlargement of the image of the same fragment of the sample, showing the tested fibers, allows to detect the presence of dust particles and microbiological contamination.

The images of the next sample at 1.31× magnification (**Figure 12**) with clear contamination and at 2.31× magnification with single fiber (**Figure 13**) confirm this observation. The first of them clearly shows mechanical impurities, although the individual fiber in the next image is free of impurities.

Using a datacolor instrument, the whiteness indices of the shirt was measured on three portions, from the portion where the textile is clean to the portions where yellow spots are observed (**Figure 7**). Berger and CIE whiteness indices are presented in **Table 2**. When comparing to literature, the indices for the traditional shirt are significantly lower [67, 68]. This is a proof of the shirt age, even if it has been kept in better conditions. Due to the variations of humidity and temperature, over time the cotton fibers have oxidative reactions, in fact an aging of the cellulose fibers of cotton occurs, thus causing the yellowing of the material.

The SEM images (**Figure 14**) resulting from the analyzes on the two different color yarns (black and white) collected from the shirt, confirm the similarities regarding the cellulose nature of the fibers, both being made of cotton [69]. At the same time, there are no noticeable differences in the state of conservation between the white and black fibers (from the manually embroidered model), both of which are in very good state of conservation.

Figure 8.
SEM image of the fibers from traditional shirt at magnification 178×.

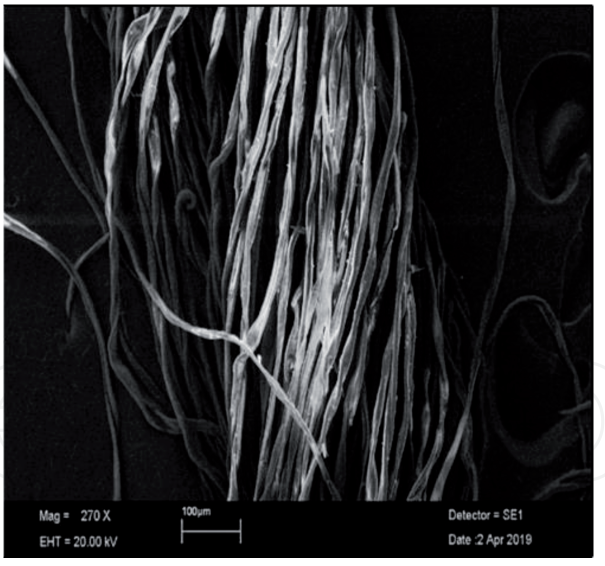

Figure 9.
SEM image of the fibers from traditional shirt at magnification 270×.

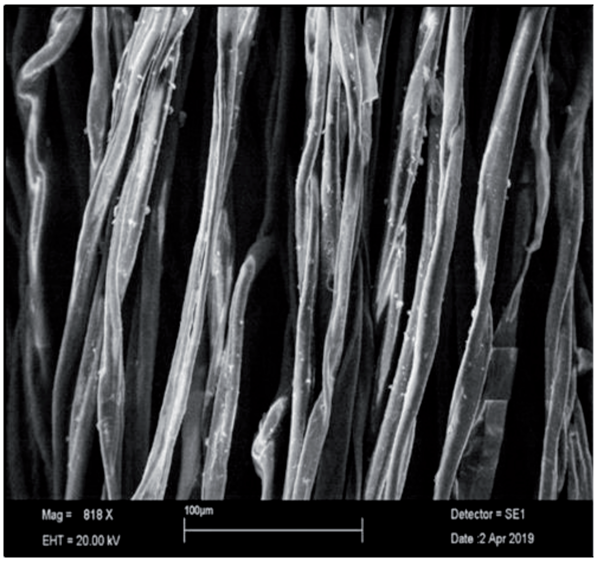

Figure 10.
SEM image of the fibers from traditional shirt at magnification 818×.

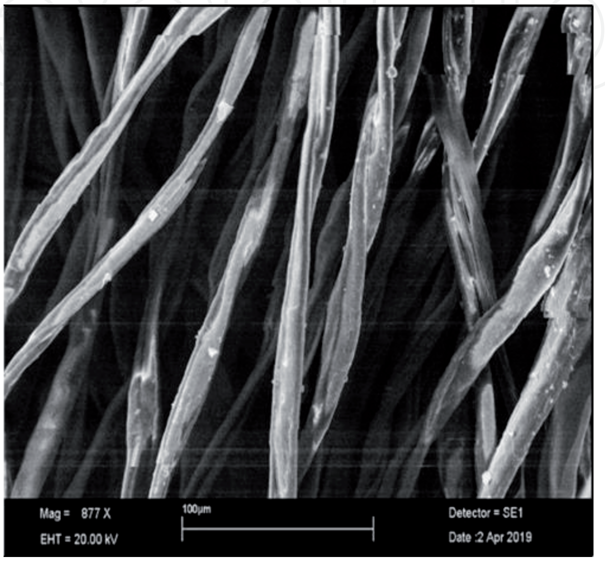

Figure 11.
SEM image of the fibers from traditional shirt at magnification 877×.

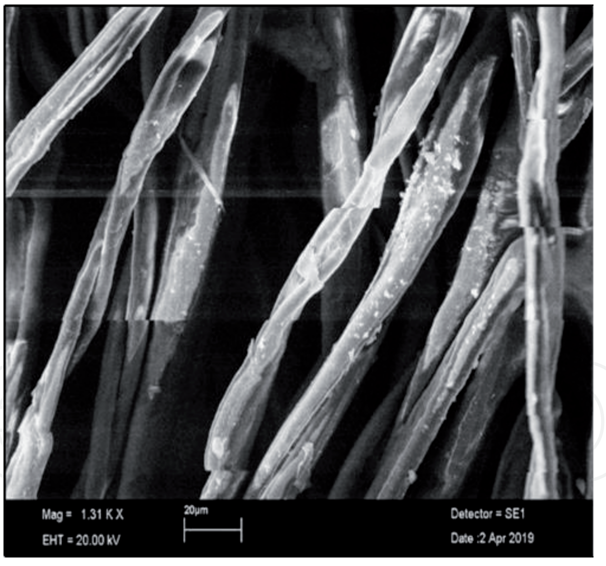

Figure 12.
SEM image of the fibers from traditional shirt at magnification 1.31×.

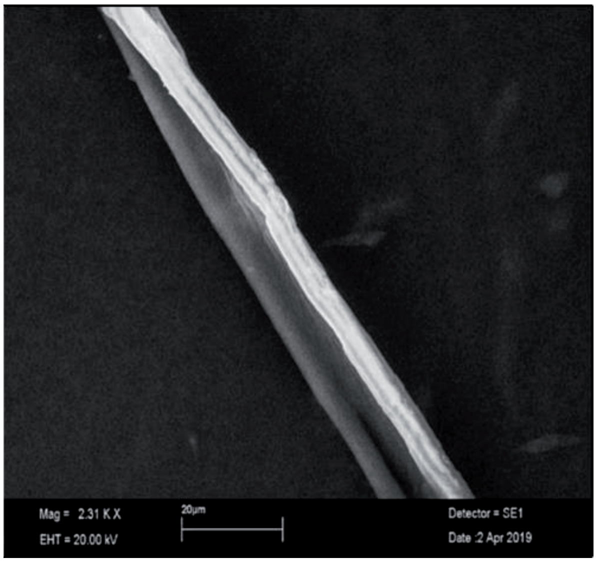

Figure 13.
SEM image of the fibers from traditional shirt at magnification 2.31×.

According to the literature on the subject [66, 70, 71] and the conducted research, it can be stated that the most common fungi found on the tested material (folk costume) and cellulose textiles (cotton, linen) include different species of *Aspergillus, Penicillium, Alternaria, Botrytis, Chaetomium*, etc. [70].

Portion	X	Y	Z	W (Berger)	W (CIE)	T	Obs.
1	65.64	68.92	67.68	46.07	43.86	−3.16	Ref.
2	63.15	66.73	62.74	36.24	30.44	−3.57	Darker More saturated More green
3	63.51	66.69	64.5	41.18	37.34	−3.48	Darker More saturated More green

Table 2.
The whiteness index of the traditional shirt measured in three different portions.

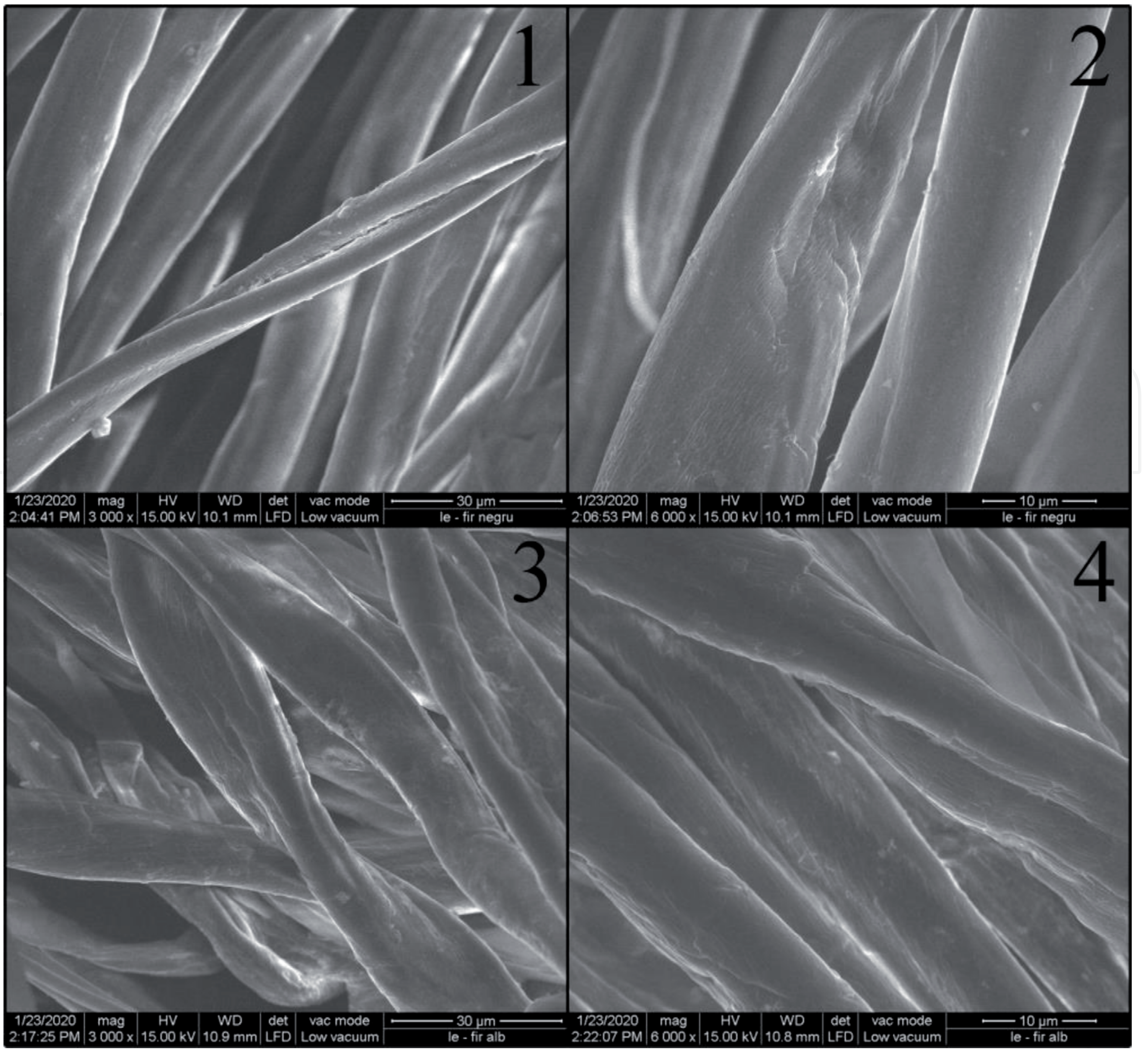

Figure 14.
SEM images of the two white and black wires from the traditional shirt: (1) SEM image of the black wire at 3000× magnification; (2) SEM image of the black wire at 6000× magnification; (3) SEM image of the white wire at 3000× magnification; (4) SEM image of the white wire at 6000× magnification.

The conducted tests of the described fiber samples confirmed the presence of *Aspergillus niger, Penicillium spp., Cladosporium spp. Alternaria spp.* and *Candida spp*. The penultimate enlargement of the tested fabric (**Figure 10**) clearly shows microbiological contamination and the process of fiber development and possible colonization by *Aspergillus* and *Penicillium.*

People are frequently exposed to spores and vegetative forms of *Aspergillus niger*, present on various textile objects. *Aspergillus niger* can cause allergic symptoms and produce certain mycotoxins that can especially affect people with a weak immune system, respiratory, renal, immune system or hearing aids; they can also cause local lesions in both the internal and external ears, postoperative cavities, etc. [72].

Aspergillus and *Candida* cause deaths due to invasive infections. The fungal species in the *Candida* family are the most common etiologic fungal agent of invasive infections that can endanger life in patients: immunocompromised; they have undergone invasive clinical procedures or major trauma and require long-term hospital care [73]. *Cladosporium spp.* can cause allergic reactions in humans, which sometimes results in asthma. Rarely, it can cause opportunistic infections, mainly located in the skin and subcutaneous cellular tissue [74]. Exposure to fungi of the *Alternaria* has been recognized as a risk factor for the development, persistence and severity of asthma and allergic respiratory diseases. They can cause rhinosinusitis, onychomycosis, and skin and subcutaneous infections, generally in immunocompromised patients. Infections with *Penicillium* can be mainly by inhalation and sometimes by ingestion. Pathologies that are the result of infection with *Penicillium spp*. are generally referred to as penicilliosis. Prolonged exposure to fungi from the *Penicillium* family which typically produce mycotoxins ochratoxin A and citrinin, has been reported in combination with opportunistic infections such as keratitis, otomycosis and urinary tract infections [75, 76].

4. Conclusions

In all four case studies, it was proved that the values of the main elements of the microclimate play a decisive role both in the degradation of the textile materials and development in the air and on the surfaces of the bacteriological microflora. In time, its leads to the deterioration of the historical fabrics exposed inside, at the same time endangering human health. The degree of accessibility of the public and the age of the building, is directly proportional to the quality of the elements of the microclimate. Thus, in the wooden church (the oldest building among those analyzed, where human activity is the most intense), textiles are exposed to the highest risk of being degraded due to poor environmental conditions. At the opposite pole, in the Museum House and National Archives of Bihor County, due to the more recent dating of buildings, the nature of the materials and largely limited human activity, the fabrics find better conditions of conservation, and people are exposed to much reduced risks.

By far, in the best state of conservation is the traditional Romanian shirt ("ie"), which due to the fact that it is part of a private collection, is exposed to anthropogenic and lower environmental pressure. It is stored in good conditions, the fibers are very little affected, they do not show discoloration or breakage as a consequence of the action of the microflora.

The analyzes carried out in this study show that some of the historical textiles are in a poor state of conservation, or are threatened to be degraded by human action or environmental factors. In order to conserve the materials for a longer period of time, it is necessary first of all a careful and continuous monitoring of the internal microclimate. The values of its main parameters should be kept as far as possible within the allowed limits, and the impact of the bacteriological microflora and the anthropic factor must be limited. Furthermore, where appropriate, exhibits are preferably to be protected by their installation in special glass boxes to reduce mechanical and chemical damage. All these interventions have both the role of creating a favorable environment for the conservation of textile materials, as well as of minimizing the implications on human health.

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Author details

Ilieș Dorina Camelia[1], Herman Grigore Vasile[1], Caciora Tudor[2]*, Ilieș Alexandru[1], Indrie Liliana[7], Wendt Jan[3], Axinte Anamaria[2], Diombera Mamadou[4], Lite Cristina[5], Berdenov Zharas[6] and Albu Adina[7]

1 Department of Geography, Tourism and Territorial Planning, University of Oradea, Oradea, Romania

2 Doctoral School in Geography, University of Oradea, Oradea, Romania

3 Faculty of Oceanography and Geography, Institute of Geography, University of Gdansk, Gdansk, Poland

4 Training and Research Unit of Economic and Social Science, Department of Tourism, University of Ziguinchor Assane Seck, Ziguinchor, Senegal

5 National Research and Development Institute for Textiles and Leather, Bucharest, Romania

6 Department of Physical and Economic Geography, Faculty of Science, Gumilyov Eurasian National University, Nur-Sultan, Republic of Kazakhstan

7 Department of Textiles, Leather and Industrial Management, Faculty of Energy Engineering and Industrial Management, University of Oradea, Oradea, Romania

*Address all correspondence to: tudor.caciora@yahoo.com

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References

[1] Gutarowska B, Pietrzak K, Machnowski W, Milczarek JM. Historical textiles—A review of microbial deterioration analysis and disinfection methods. Textile Research Journal. 2016;**87**(19):2388-2406. DOI: 10.1177/0040517516669076

[2] Indrie L, Oana D, Ilieș M, Ilieș DC, Lincu A, Ilieș A, et al. Indoor air quality of museums and conservation of textiles art works. Case study: Salacea Museum House, Romania. Industria Textilă. 2019;**70**(1):88-93. DOI: 10.35530/TT.2019.32

[3] Kumar RA, Sathya RI. Importance of digitization process in textiles. International Journal of Innovative Research in Computer and Communication Engineering. 2015;**3**(7):7011-7015

[4] Petroviciu I, Van den Berghe I, Cretu I, Albu F, Medvedovici A. Identification of natural dyes in historical textiles from Romanian collections by LC-DAD and LC-MS (single stage and tandem MS). Journal of Cultural Heritage. 2012;**13**(1):89-97. DOI: 10.1016/j.culher.2011.05.004

[5] Buchczyk M. To weave or not to weave: Vernacular textiles and historical change in Romania. Textile The Journal of Cloth and Culture. 2014;**12**(3):328-345. DOI: 10.2752/175183514x141563595 36980

[6] Di Carlo E, Chisesi R, Barresi G, Barbaro S, Lombardo G, Rotolo V, et al. Fungi and bacteria in indoor cultural heritage environments: Microbial-related risks for artworks and human health. Environment and Ecology Research. 2016;**4**(5):257-264. DOI: 10.13189/eer.2016.040504

[7] Ilieș DC, Onet A, Marcu F, Gaceu O, Timar A, Baias S, et al. Investigations on air quality in the historic wooden church in Oradea city, Romania. Environmental Engineering and Management Journal. 2018;**17**:2731-2739. DOI: 10.30638/eemj.2018.272

[8] Zavrl SM, Zarnic R. Indoor climate control in building heritage in Slovenia by low temperature wall heating. In: OPET WorkshopLow Exx, Maastricht. Ljubljana, Slovenia: Technological Building and Civil Enginering Institute; 2002

[9] Eryuruk SH, Kalaoğlu F. The effect of weave construction on tear strength of woven fabrics. Autex Research Journal. 2015;**15**(3):207-214. DOI: 10.1515/aut-2015-0004

[10] Gargano M, Rosina E, Monticelli C, Zanelli A, Ludwig N. Characterization of aged textile for archeological shelters through thermal, optical and mechanical tests. Journal of Cultural Heritage. 2017;**26**:36-43. DOI: 10.1016/j.culher.2017.01.009

[11] Yu Y, Cai M, Zhou L, Shao J. Study on the aging and yellowing properties of sebum-soiled cotton fabrics. Fibers and Polymers. 2016;**17**(2):305-309. DOI: 10.1007/s12221-016-5182-z

[12] Kamel FH, Ismael HM, Mohammadamin SA. Microbial deterioration of historical textiles and approaches for their control. International Interdisciplinary Research Journal. 2014;**4**:10-17

[13] Kavkler K, Gunde-Cimerman N, Zalar P, Demšar A. Fungal contamination of textile objects preserved in Slovene museums and religious institutions. International Biodeterioration & Biodegradation. 2015;**97**:51-59. DOI: 10.1016/j.ibiod.2014.09.020

[14] Onet A, Ilies DC, Buhas S, Rahota D, Ilies A, Baias S, et al. Microbial air

contamination in indoor environment of university sport hall. Journal of Environmental Protection and Ecology. 2018;**19**(2):694-703

[15] Triki E, Dolez P, Vu-Khanh T. Tear resistance of woven textiles—Criterion and mechanisms. Composites Part B: Engineering. 2011;**42**(7):1851-1859. DOI: 10.1016/j.compositesb.2011.06.015

[16] Akyuz T, Akyuz S, Balci K, Gulec A. Investigations of historical textiles from the Imperial pavilion (Hunkar Kasri) of the new mosque Eminonu-Istanbul (Turkey) by multiple analytical techniques. Journal of Cultural Heritage. 2017;**25**:180-184. DOI: 10.1016/j.culher.2016.12.009

[17] Quye A. Factors influencing the stability of man-made fibers: A retrospective view for historical textiles. Polymer Degradation and Stability. 2014;**107**:210-218. DOI: 10.1016/j.polymdegradstab.2014.03.002

[18] Patra K. Application of nanotechnology in textile engineering: An overview. Journal of Engineering and Technology Research. 2013;**5**(5):104-111. DOI: 10.5897/jetr2013.0309

[19] Tissera ND, Wijesena RN, Perera JR, de Silva KMN, Amaratunge GAJ. Hydrophobic cotton textile surfaces using an amphiphilic graphene oxide (GO) coating. Applied Surface Science. 2015;**324**:455-463. DOI: 10.1016/j.apsusc.2014.10.148

[20] Comes R, Buna Z, Badiu I. Creation and preservation of digital cultural heritage. Journal of Ancient History and Archaeology. 2014;**1**(2):50-56. DOI: 10.14795/j.v1i2.55

[21] Laine-Zamojska M. Digitization of cultural heritage (Forskningsprojekter). Nordisk Museologi. 2011;**1**(1):125-132

[22] Madanan M, Hussain N, Ahmad KA. A study of the digitization process to preserve the culture and heritage of a civilization using natural language processing and it's impact on the social, economic and scientific aspects. Journal of Theoretical and Applied Information Technology. 2018;**96**(16):5550-5568

[23] Pavlidis G, Koutsoudis A, Arnaoutoglou F, Tsioukas V, Chamzas C. Methods for 3D digitization of cultural heritage. Journal of Cultural Heritage. 2007;**8**(1):93-98. DOI: 10.1016/j.culher.2006.10.007

[24] Sotirova K, Peneva J, Ivanov S, Doneva R, Dobreva M. Digitization of cultural heritage—Standards, institutions, initiatives. In: Ivanova K, Dobreva M, Stanchev P, Totkov G, editors. Access to Digital Cultural Heritage: Innovative Applications of Automated Metadata Generation. Plovdiv: Paisii Hilendarski Plovdiv University Publishing House; 2012. pp. 25-67

[25] Bonici UM. The Human Right to the Cultural Heritage—The Faro Convention's Contribution to the Recognition and Safeguarding of this Human Right. Council of Europe: Heritage and Beyond; 2009. pp. 53-59

[26] Scharff AB, Bolt JL. Evaluating transmission electron microscopy as a method for assessing the condition of archaeological wool. In: Bridgland J, editor. ICOM-CC 18th Triennial Conference; 4-8 September; Copenhagen. Paris: International Council of Museums. 2017. Preprints. art. 1807

[27] Ryde ML, Gabra-Sanders T. The application of microscopy to textile history. Textile History. 1985;**16**(2):123-140

[28] Henry PA. Current techniques of ancient textile analysis: A critical review [Durham E-Theses]. Durham University; 1994. Available from: http://etheses.dur.ac.uk/5599/

[29] Abdel-Kreem O, El-Nagar K. Non-destructive methods to investigate the deterioration of Coptic Egyptian textiles. Journal of Textiles and Apparel Technlogy and Management. 2005;**4**(4):1-15

[30] Wei QF, Wang XQ, Mather RR, Fotheringham AF. New approaches to characterisation of textile materials using environmental scanning electron microscope. Fibres and Textiles in Eastern Europe. 2004;**12**(2):79-83

[31] Garside P, O'Connor S. Assessing the risks of radiographing culturally significant textiles. E-Preservation Science. 2007;**4**:1-7

[32] Zemlicka J, Jakubek J, Kroupa M, Hradil D, Hradilova J, Mislerova H. Analysis of painted arts by energy sensitive radiographic techniques with the pixel detector Timepix. Journal of Instrumentation. 2011;**6**(01):C01066-C01066. DOI: 10.1088/1748-0221/6/01/c01066

[33] Brooks MM, O'Connor SA. X-Radiography of Textiles, Dress and Related Objects. Oxford, United Kingdom: Elsevier/Butterworth-Heinemann; 2007. p. 360

[34] Ahmed HE, Liu Y, Bousquet B, Baudelet M, Richardson M. Investigation of historical Egyptian textile using laser-induced breakdown spectroscopy (LIBS)—A case study. Journal of Textile and Apparel, Technology and Management. 2013;**8**(2)

[35] Demenchuk E, Ilieș DC, Wendt J, Koroleva Y, Ilieș A, Goikhman A, et al. Spectroscopy study of heritage objects for the digitisation of cultural heritage. Under evaluation. Environmental Engineering and Management Journal. 2020

[36] Mannes D, Schmid F, Frey J, Schmidt-Ott K, Lehmann E. Combined neutron and X-ray imaging for non-invasive investigations of cultural heritage objects. Physics Procedia. 2015;**69**:653-660. DOI: 10.1016/j.phpro2015.07.092

[37] Šimić K, Zamboni I, Fazinić S, Mudronja D, Sović L, Gouasmia S, et al. Comparative analysis of textile metal threads from liturgical vestments and folk costumes in Croatia. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms. 2018;**417**:115-120. DOI: 10.1016/j.nimb.2017.06.015

[38] Abdel-Kareem O. Fungal deterioration of historical textiles and approaches for their control in Egypt. e-Preservation Science. 2010;**7**:40-47

[39] Chadeau E, Oulahal N, Dubost L, Favergeon F, Degraeve P. Anti-*Listeria innocua* activity of silver functionalised textile prepared with plasma technology. Food Control. 2010;**21**:505-512. DOI: 10.1016/j.foodcont.2009.07.013

[40] Abdel-Kareem O. The long-term effect of selected conservation materials used in the treatment of museum artefacts on some properties of textiles. Polymer Degradation and Stability. 2005;**87**:121-130. DOI: 10.1016/j.polymdegradstab.2004.07.014

[41] Smith MJ, Holmes-Smith AS, Lennard F. Development of non-destructive methodology using ATR-FTIR with PCA to differentiate between historical Pacific barkcloth. Journal of Cultural Heritage. 2019;**39**:32-41. DOI: 10.1016/j.culher.2019.03.006

[42] Ahmed HE, Darwish SS. Effect of museum conditions on historical dyed silk fabric with madder dye. Journal of Polymers and the Environment. 2012;**20**:596-606. DOI: 10.1007/s10924-012-0421-x

[43] Cerempei A, Ciobanu L, Muresan E, Măluțan C, Butnaru R. Textile materials functionalised with natural biologically active compounds.

Romanian Biotechnological Letters. 2010;**15**(5):5537-5544

[44] Oneț A, Ilieș DC, Ilieș A, Herman GV, Burtă L, Marcu F, et al. Indoor air quality assessment and its perception. Case study—Historic wooden church, Romania. Romanian Biotechnological Letters. DOI: 10.26327/RBL2019.264

[45] Ilieș DC, Oneț A, Wendt JA, Ilieș M, Timar A, Ilieș A, et al. Study on microbial and fungal contamination of air and wooden surfaces inside of a historical church from Romania. Journal of Environmental Biology. 2018;**39**:980-984. DOI: 10.30892/gtg.26305-393

[46] Ilieș DC, Oneț A, Herman G, Indrie L, Ilieș A, Burtă L, et al. Exploring the indoor environment of heritage buildings and its role in the conservation of valuable objects. Environmental Engineering and Management Journal. 2019;**18**(12):2579-2586

[47] Oana I, Indrie L, Oneț A, Oana D, Ilieș DC, Hermna GV, et al. Preserving textile objects in Romanian wooden churches. Case study of the heritage wooden church from Oradea, Romania. Industria Textila Journal. 2020;**2**. In print

[48] Ilieș M, Ilieș DC, Oneț A, Baias Ș, Ilieș A, Herman GV, et al. Analysing indoor museum air quality implications: Case study of Salacea Museum House in Romania. In: Timișoara, editor. Global and Regional in Environmental Protection GLOREP; 15-17 November; Romania: Politehnica. 2018. pp. 89-91

[49] Ilieș DC, Gaceu O, Georgiță M, Ilieș A, Baias Ș, Indrie L, et al. Microclimatic characteristics and air quality inside of the National Archives of the Bihor County (Romania) for the long-term preservation of the documents and the health of the employees. Under evaluation. 2020

[50] Ilieș DC, Indrie L, Wendt J, Ilieș A, Gaceu O, Demenchuk E, et al. SEM investigations on old maps with canvas support. In: International Conference TexTeh IX "Advanced Textiles for a Better World"; 24-25 October 2019; Bucharest. Romania: Proceedings. Vol. 9. 2019. pp. 153-157. ISSN 2068-9101

[51] Abdel-Kareem O. Monitoring, controlling and prevention of the fungal deterioration of textile artifacts in the museum of Jordanian heritage. Mediterranean Archaeology and Archaeometry. 2010;**10**(2):85-96

[52] Government Decision of Romania no. 1546 from December 18, 2003 for approval rules for the conservation and restoration of movable cultural assets ranked. Available from: http://www.bcu-iasi.ro/docs/HG1546-2003.pdf

[53] The LS. Textile conservator's manual. In: Butterworth-Heinemann, editor. Conservation and Museology Series. 1998. pp. 17-19

[54] Hayleeyesus SF, Manaye AM. Microbiological quality of indoor air in university libraries. Asian Pacific Journal of Tropical Biomedicine. 2014;**4**:S312-S317. DOI: 10.12980/apjtb.4.2014c807

[55] Lezzerini M, Antonelli F, Columbu S, Gadducci R, Marradi A, Miriello D, et al. Cultural heritage documentation and conservation: Three-dimensional (3D) laser scanning and geographical information system (GIS) techniques for thematic mapping of facade stonework of St. Nicholas church (Pisa, Italy). International Journal of Architectural Heritage. 2014;**10**(1):9-19. DOI: 10.1080/15583058.2014.924605

[56] Campanaro DM, Landeschi G, Dell'Unto N, Leander Touati AM. 3D GIS for cultural heritage restoration: A "white box" workflow. Journal of Cultural Heritage. 2016;**18**:321-332. DOI: 10.1016/j.culher.2015.09.006

[57] The Unit Order of the General Director of the National Archives of Romania no. 235/05.07.1996 supplemented with the Daily Provision of the General Director of the National Archives no. 92 from 14.05.2009. Available from: http://arhivelenationale.ro/site/download/acte_normative/Normativ-depozite-de-arhiva.pdf

[58] ANSI/ASHRAE Standard. Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc; 2003. Available from: https://www.ashrae.org/file%20library/doclib/public/200418145036_347.pdf

[59] Dan D, Tanasa C, Stoian V, Brata S, Nagy Gyorgy T, Florut SC. Passive house design—An efficient solution for residential buildings in Romania. Energy for Sustainable Development. 2016;**32**:99-109. DOI: 10/1016/j.esd2016.03.007

[60] Amin E. Conservation of a gauze textile from the Tulunid period in Egyptian textile museum, Cairo. International Journal of Conservation Science. 2018;**9**(1):13-24

[61] Amin E. Technical investigation and conservation of a tapestry textile from the Egyptian textile museum, Cairo. Scientific Culture. 2018;**4**(3):35-46

[62] Coman I, Mareș M. In: Junimea, editor. Micologie medicală aplicată. Iasi, Romania: Junimea Publishing House; 2000

[63] Coman I, Gogu M. Ghid Practic de MicologiePerformantica. In: Performantica, editor. Iasi, Romania: Performantica Publishing House; 2009

[64] Bogomolova E, Kirtsideli I. Airborne fungi in four stations of the St. Petersburg underground railway system. International Biodeterioration & Biodegradation. 2009;**63**(2):156-160. DOI: 10.1016/j.ibiod.2008.05.008

[65] Borrego S, Guiamet P, Gómez de Saravia S, Batistini P, Garcia M, Lavin P, et al. The quality of air at archives and the biodeterioration of photographs. International Biodeterioration & Biodegradation. 2010;**64**(2):139-145. DOI: 10.1016/j.ibiod.2009.12.005

[66] Górny R, Ławniczek-Walczyk A, Stobnicka A, Gołofit-Szymczak M, Cyprowski M. Fibers as carriers of microbial particles. Medycyna Pracy. 2015;**66**(4):511-523. DOI: 10.13075/mp.5893.00231

[67] Steen D, Dupont D. Control of structured white textiles. Coloration Technology. 2003;**119**(4):205-211. DOI: 10.1111/j.1478-4408.2003.tb00173.x

[68] Dinu M, Coman D. An experimental study on the improvement of functionality of knitted composite for mattress. In: Bondrea I, Cofaru NF, Ință M, editors. MATEC Web Conf. 2019. pp. 290-09001. DOI: 10.1051/matecconf/201929009001

[69] Zhao H, Kwak J, Conradzhang Z, Brown H, Arey B, Holladay J. Studying cellulose fiber structure by SEM, XRD, NMR and acid hydrolysis. Carbohydrate Polymers. 2007;**68**(2):235-241. DOI: 10.1016/j.carbpol.2006.12.013

[70] Sterflinger K. Fungi: Their role in deterioration of cultural heritage. Fungal Biology Reviews. 2010;**24**(1-2):47-55. DOI: 10.1016/j.fbr.2010.03.003

[71] Mansour E, Loxton C, Elias RM, Ormondroyd GA. Assessment of health implications related to processing and use of natural wool insulation products. Environment International. 2014;**73**:402-412. DOI: 10.1016/j.envint.2014.08.004

[72] Borrego S, Valdés O, Vivar I, Lavin P, Guiamet P, Battistoni P, et al.

Essential oils of plants as biocides against microorganisms isolated from Cuban and Argentine documentary heritage. ISRN Microbiology. 2012;**1**:1-7. DOI: 10.5402/2012/826786

[73] Brown GD, Denning DW, Gow NAR, Levitz SM, Netea MG, White TC. Hidden killers: Human fungal infections. Science Translational Medicine. 2012;**4**(165:165rv13). DOI: 10.1126/scitranslmed.3004404

[74] Ogórek R, Lejman A, Pusz W, Miłuch A, Miodyńska P. Characteristics and taxonomy of Cladosporium fungi. Mikologia Lekarska. 2012;**19**(2):80-85

[75] Gautam A, Sushil S, Shubhi A, Rekha B. Diversity, pathogenicity and toxicology of *A. niger*: An important spoilage fungi. Research Journal of Microbiology. 2011;**6**:270-280. DOI: 10.3923/jm.2011.270.280

[76] Egbuta M, Mwanza M, Babalola O. Health risks associated with exposure to filamentous fungi. International Journal of Environmental Research and Public Health. 2017;**14**(7):719. DOI: 10.3390/ijerph14070719

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