Chapter

A Survey of Physical Parameters and Natural Radioactivity in the Wooden Church of "Archangels Mihail and Gavril," Draghia

Ancuța Țenter, Marin Coteț iu, Alexandra Cucoș, Bety Burghele, Kinga Szacsvai and Verginica Schroder

Abstract

The aim of this chapter is to present information about the current environmental survey conducted in a wooden church in Draghia, Maramures County, Romania. The wooden church "Archangels Michael and Gavril" was built in 1706 and is registered as a category A historical monument in the national heritage. A mural painting of popular bills, in a precarious state of preservation, can be observed inside the church. A study was performed to analyze the correlation between the indoor/outdoor climatic parameters and degree of degradation in mural paintings. Additionally, an indoor radon screening was carried out in order to assess the potential exposure for workers and public. One of the most important environmental problems is the global climate change and its impact on the historical monuments in their natural space of conservation. The obtained results highlight how dangerous the climate can be in the long term regarding the state of conservation of the mural paintings inside the wooden church located in a natural environment.

Keywords: church, paintings, national heritage, physical parameters, natural radioactivity

1. Introduction

The preservation and promotion of the existing cultural values are important issues in order to preserve the inherited physical and spiritual richness and to transmit it to future generations.

The preservation of wooden churches was not perceived throughout history with troubled times, with the same importance as today.

It is now understood as a moral duty to preserve this cultural and spiritual treasure, to be passed on to future generations. According to the new philosophy of heritage, the concept of conservation was imposed, which implies a scientific approach based on research. Risk factors on heritage objects have been exposed by different specialized studies [1].

The environment can present multiple factors causing heritage degradation, such as geographic, climatic, and biological factors. The interdisciplinary research

helps the restaurateurs to know the general state of conservation from the perspective of the physical, chemical, and biological parameters which generated the current state. This knowledge is a necessity for the correct evaluation of the operations to be performed in the future: cleaning, consolidation, structural stabilization, hydrous, and chromatic [2].

The modern society is facing a rapid evolution technology with the price of high environment pollution. Additionally, climate change has become a priority on the list of the Sustainable Development Agenda of European countries [3].

Romania has a rich cultural heritage through the places of worship located throughout the country represented by wooden churches built over the centuries of Christianity. This fact is being favored by the political conditions specific to each period, as well as the accessibility of the construction materials and low cost [4, 5].

The wooden architecture represents one of the most magnificent examples of built heritage almost all over the world. They occupy an important place in the traditional building in Russia, North and Eastern Europe [6]. Unfortunately, all historical monuments can be affected by different factors under natural environmental conditions, i.e., aging of the materials, lack of maintenance, inadequate use, or natural hazards [7]. A better understanding of the structural behavior of these buildings is a crucial step to prevent social, cultural, and economic losses [4].

This study aims to be the first in a larger project focusing on monitoring the physical parameters of temperature, humidity, and natural radioactivity, inside wooden churches or walls with interior murals painting that are in an advanced state of degradation. The study was conducted in the wooden church of "Archangels Mihail and Gavril" in the village of Draghia in the Lapuș Country.

Determining the relative humidity (rH) of the air inside the church is the first step in the study—humidity is one of the most important causes of degradation being suffered by churches historical monument, especially those lacking waterproof insulation [8].

An essential condition is to know the history of the church, its characteristics, the geographical position, the previous restorations and consolidations, and the current degradation state. The action of degradation factors is cumulative and the consequence is not necessarily immediate, but over time, they can cause significant losses.

2. Historical and geographical area description of Lapuș Country

Over time, in the geographical area of Romania where the Romanian population lives or lived, several historical regions have emerged, which throughout history have belonged in whole or in part to the voivodeships founded in the tenth century (for Transylvania) and the fourteenth century (Moldova, the Romanian Country, and Dobrogea), either to the neighboring states. The boundaries and the names of these regions also known as "countries" evolved over time. Some or all of them have, temporarily or more permanently, constituted the territory of Romania.

Prior to the establishment of the traditional regions, there were Romanian countries (founded in the post-Roman period, in the early Middle Ages), called by historians the popular Romania and by the foreign chroniclers of Vlahii, some constituted in the form of cnese, others as simple rural communities, such as the lands of Crasne, Lăpuș, Gurghiului, Moți, Almaș, Făgărașului, and Bârsei (in Transylvania).

Transylvania or Ardeal (in Latin Transylvania or Transsylvania, in Hungarian Erdély, in German Siebenbürgen, in the Saxon dialect of Siweberjen, in Turkish Erdelistan) is a historical and geographical region located within the Carpathian

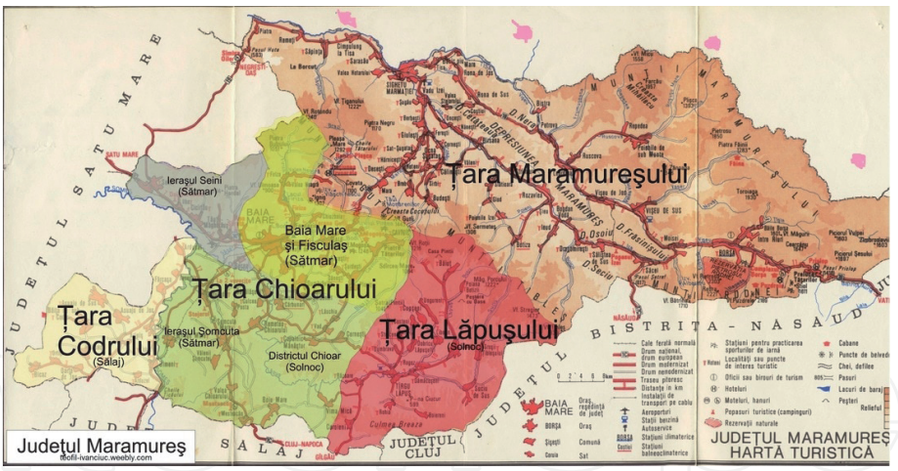

Figure 1.
Map Lăpuş Country.

Arch, one of the historical regions of Romania. Over time, it was part of Dacia, the Roman Empire, the Kingdom of Hungary, and the Austrian Empire. For about 170 years, between 1526 and 1699, it was autonomous, under the sovereignty of the Ottoman Empire, under the name of the Principality of Transylvania. In this capacity, it played a significant role in the 30-year war, on the part of the Protestant coalition. With the imperial victories on the anti-Ottoman front, Transylvania came under Habsburg administration, but formally retained its statehood until 1867, being governed by governors appointed by Vienna.

Transylvania is an important province of the Romanian political space, with a history that is strongly reflected through its multicultural particularities and the material evidence of its inhabitants. In time, heterogeneity, both ethnical (Romanians, Ukrainians, Hungarians, Germans, Jewish, etc.) and confessional (Orthodox, Catholics, Protestants, Neoprotestants, etc.), materialized into religious edifices [9, 10].

The northern area of Transylvania is the land of Maramureş, Lăpuş, Chioar, and Codrului, where we found over 100 wooden churches built since the seventeenth century (**Figure 1**) [11].

All wooden churches (main map) belong entirely to the Orthodox and Greek-Catholic confessions. Among these, there are eight remarkable churches included in the UNESCO world heritage list [12–16]. Built of wood, they continue to exist today thanks to the skill of the craftsmen and to the historical monument status enjoyed by 33 of the edifices (LMI, 2015) [17].

The land of Lapuş is the land of wood, tradition, and monasteries. In this region of Maramures, the time seems to have remained in place, and people have kept the centuries-old traditions. In the area of Lăpuşului, the remains of the authentic dowry still remain, from the ancestral architecture to the style, shape, and size of the households. Here you can admire the old wooden houses, with narrow porches (logs), supported by ornate oak pillars, glued with clay on the floor, shaded by garlands of vines, the large courtyards, and before, to the oilfield, the small kindergartens, flowers, shaded by plum, pear, or cherry [18].

3. Presentation of wooden church "Archangels Mihail and Gavril," Draghia

Drăghia is a small village in the land of Lăpuş, in Maramureş County. The first mention of the village dates from 1393 with the Hungarian name of Dragusfalva

[19]. Its name is mentioned in the document attesting that members of the Bánffy family of Losonc split between them certain holdings, among which Dragusfalva, on the 13th of October 1392, in Gilău [20].

In this village, one of the many wooden churches of the Lapuș Country built in 1706 is located, according to the Latin inscription above the entrance: Anno 1706 D. 14 obrys. According to the Orthodox tradition, the church was under the patronage of Saints Archangels Mihail and Gavril, and today, it is part of the Lăpuș Deanery, belonging to the Romanian Orthodox Diocese of Maramureș and Sătmar. It is made of oak wood, a very common building material in this geographical area.

The church is 12.40 m long, 4.45 m wide, 7.50 m high at the ridge, and 15.50 m high at the tower's spire. The base and the walls are all made of oak beams placed on a dry laid stone foundation [21] (**Figure 2**).

The entrance to the church is 161 cm high and 85 cm wide, forcing most people to bow in reverence while entering. The door was painted on the outside with the Archangel Mihail, but unfortunately it has faded to the point where one can barely make out a shade of the Archangel.

The building plan is similar to others found throughout the area; the church being divided into a narthex, nave, and altar [22]. The narthex has a polygonal shape, covered with a straight ceiling, above which the bell tower is situated. The ceiling is painted with cherubs, and the walls are painted with images of the Myrrhbearers, and of wise and foolish virgins from the Gospel of Mathew. The narthex was where the women would attend mass (**Figure 3**).

According to the requirements of the Orthodox church construction, the nave is rectangular, with a large dome and separated from the rest of the area by a wall with a door [23]. This wooden door is painted on with two saints (**Figure 4**).

The lower half of the door is painted with the tree of life in a pot. The door frame is engraved with area-specific symbols and historical times rosette with six petals, honeycombs, and wolf teeth. The opening is provided with slightly turned columns

Figure 2.
The church "Archangels Mihail and Gavril," Draghia.

Figure 3.
Holy women with cups in their hands.

Figure 4.
The door with two saints.

of different shapes that have been painted white [24]. Between the nave and the altar is the iconostasis. The altar is in a polygonal apse with domes.

Inside the church, the painting is tempera on canvas and wood and covers the whole interior. The painters applied the strips of hemp cloth glued with animal glue to the gaps between the beams and planks to create a continuous dyeing environment.

The painting in the nave is badly damaged, many scenes being unrecognizable, only a few color spots left. Among the visible images are the stairs of Jacob, the Holy Trinity, Elijah riding to heaven in his chariot of fire, and the four evangelists. The paintings on the iconostasis, which were somewhat sheltered, can be fully identified. As an example, the 12 Apostles are depicted with Jesus as a high priest in their

midst, and at the top of the iconostasis is a wooden cross painted with crucified Jesus. Portraits of the six Old Testament prophets are painted on the frame of a semicircular opening above the iconostasis, and on both sides of the cross are painted the sun and the moon.

4. Assessment of the conservation status of the mural painting in the church of "Archangels Mihail and Gavril," Draghia

Due to the inclement weather, the precarious conditions of the periods of the two World Wars, and the different social and environmental factors, the painting inside of the church is in an advanced state of degradation. In 2006–2007, the architecture of the church was consolidated and restored, on which occasion the shingle covering, which served as a roof, specific to the Transylvania area was rebuilt. The roof was damaged by rain and perforated in many places of woodpeckers. During the consolidation works, some planks from the vault of the nave were considered by the builder to be much degraded. It is possible that those splinters may have kept vague traces of the paint layer.

Tannins from the wood support and solubilized organic substances were migrated in the pictorial layer in the infiltration zones (**Figure 5**).

Due to the large variations in temperature between day and night, there have been volumetric changes of the wood support, which have caused cracks and detachments at the level of the pictorial layer on extended surfaces. This phenomenon is observed especially on the south side of the church, which is much more strongly heated by the sun's rays compared to the other sides. Due to the unfavorable conditions of microclimate and against the background of some flaws in the technique of painting execution, there is an accentuated dustiness of the painting layer, produced as a result of the degradation of the binder and the loss of cohesion between the constituent materials of the painting layer. Visually, there is a chalky appearance of the surface.

As a result of the degradation of the binder, combined with the volumetric changes of the wood substrate under the action of absorption and loss of humidity, the adhesion of the pictorial layer on the substrate also occurred, resulting in evolutionary detachments, the exfoliation being mainly in the form of roof slabs or scales and isolated alveolar forms.

These degradations were highlighted by direct visual examination and with magnifying glass, in shining light. There are massive losses of pictorial layer, up to the support, due to the wear caused by deletion and involuntary hit of the surface (**Figure 6**).

Figure 5.
Semicap altar—degradation caused by humidity infiltration.

Figure 6.
Section from the north wall.

The partial detachments of the textile strips (initially bonded to the joints to create a continuous field for painting) led to exfoliation and loss of paint layer on the respective surfaces. Many such textile strips were completely detached from the support, along with the pictorial layer, and were lost.

5. Statistical analyses of microclimate parameters: temperature and relative humidity

The microclimatic regime inside the church is influenced by the characteristic climate of the latitude and the specific geographical position of the Lapuș Country. Lapuș Country, due to its Nordic position, presents a temperate continental climate with western and Scandinavian-Baltic ocean influences from the north, having a cooler character. Air masses bring abundant snow from the north in winter, and cold rain in spring and autumn. In order to have a better understanding of the changes in the microclimate values inside the church, two stages of temperature and relative air humidity monitoring have been carried out. To this end, different temperature and humidity monitoring systems were installed inside the church to establish an average, and to obtain a high accuracy of the measured values. Passive and active monitoring systems for natural radioactivity (i.e., radon) were installed alongside climatic monitors. The church not being connected to the electrical network, limited the types of equipment used and the time span of measurements. The specific characteristics of monitored environment, i.e., wooden construction, placed directly on stone vaults, without being plastered on the outside and inside walls, and having no heating during the cold periods were taken into consideration for data analysis. Meteorological data were acquired from a local weather station.

The first monitoring stage was chosen during winter (February 2019). A Radon Scout (SARAD GmbH, Germany) was placed inside the church and set to record data every 60 minutes. During this period, a minimum value of −5.5°C and a maximum of 8.5°C were recorded, with an average value of 1.73°C (**Figure 7**). The

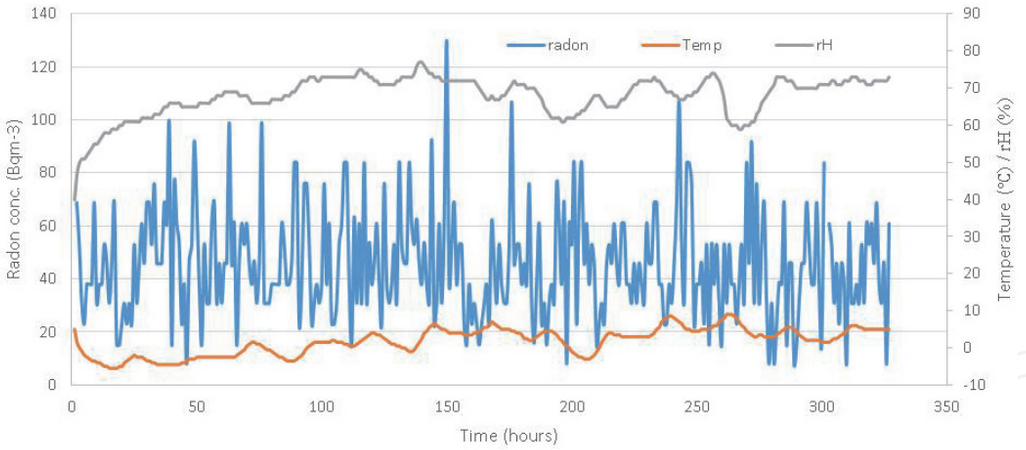

Figure 7.
Time series distribution of radon and physical parameters in the wooden church of "Archangels Mihail and Gavril," February 2019.

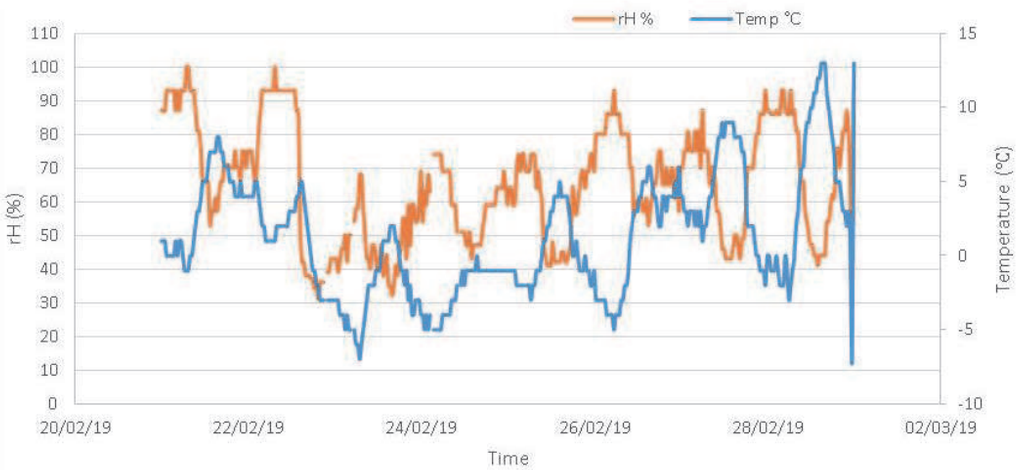

Figure 8.
Weather conditions in the area at the time of study (February 2019).

average relative humidity of the recorded air was 67.95%, which was well above the recommended of 50–60% [25].

The data provided by the Baia Mare weather station for the time interval of interest showed the following outdoor conditions: an average temperature of 1.27°C, with a minimum of −7°C and a maximum of 13°C (**Figure 8**). This fact explains the naturally low temperatures recorded inside the church, which is not equipped with a heating system.

The high values of relative humidity of the indoor air, prompted a second stage of measurements, carried out for 30 consecutive days in September–October 2019. The autumn of 2019 presented unusually warm and dry conditions.

During the second measuring campaign, indoor temperature was recorded using two portable data loggers placed in the two rooms of the church. These data loggers were set to record indoor temperature every 5 min in order to assess the temperature fluctuations with great accuracy. The short-term temperature sampling was used to identify the minimums and maximums of temperature during the 30 days of measurements (**Figure 9**). These extreme values are paramount in assessing the impact of the indoor microclimate on the preservation of wood painting.

Overall, an inside average temperature of 13°C was recorded during the monitoring period. However, the temperature inside the wooden church ranged between 1°C and a maximum of 33.44°C. A 36 h window (23.09.–24.09) showed a

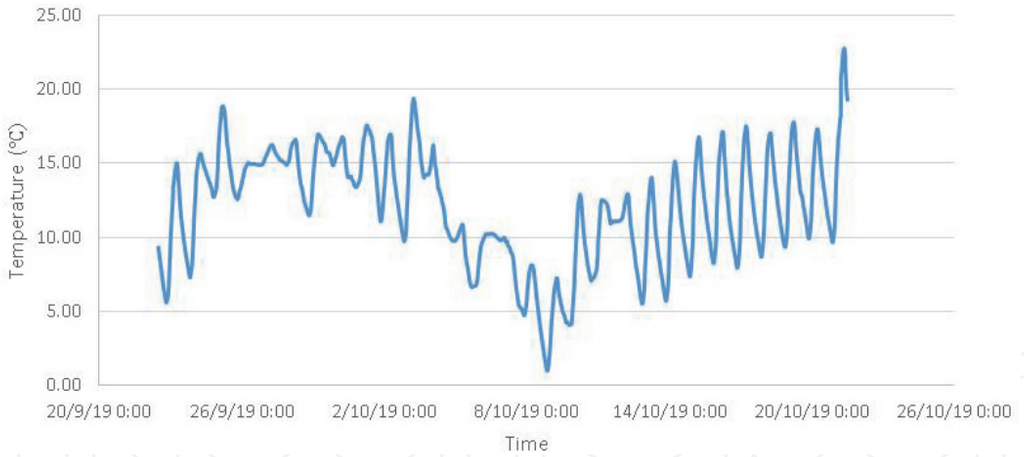

Figure 9.
Time series of indoor temperature during the second measuring campaign (September–October 2019).

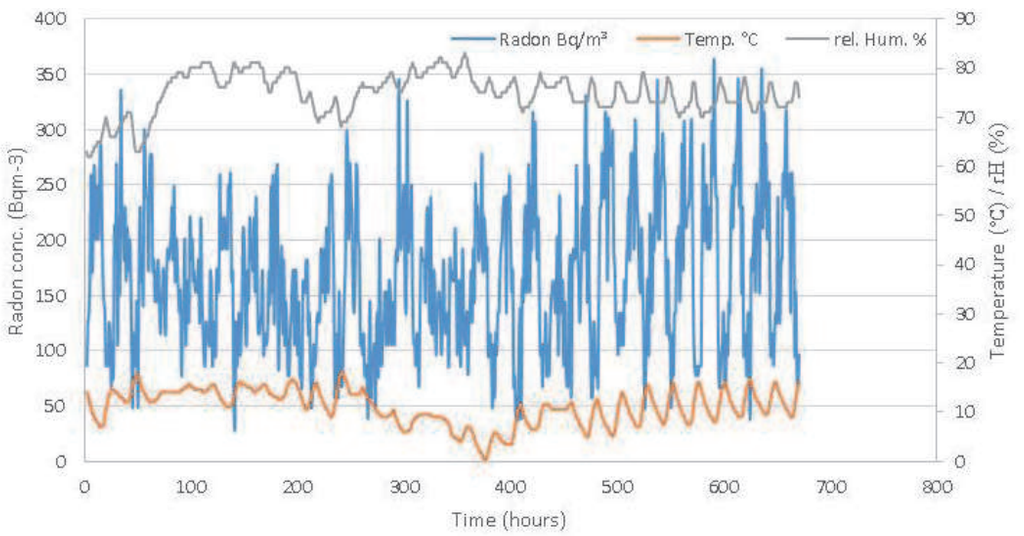

Figure 10.
Time series distribution of radon and physical parameters in the wooden church of "Archangels Mihail and Gavril," September–October 2019.

temperature difference of 11°C indoors. These increases and decreases in temperature at such short intervals, which occur quite frequently during the monitored period, are not the most suitable conditions for the state of conservation of the painting. They produce expansions and contractions of the material, causing ruptures and cracks in the oil on the canvas. These frequent repetitions cause the material to become excessively friable [26].

Alongside temperature data loggers, a Radon Scout was installed to record hour-by-hour data of radon, temperature and rH indoors. During this period, a minimum value of 0.5°C and a maximum value of 18°C were recorded, leading to an average value of 12°C (**Figure 10**).

The data provided by the Baia Mare weather station for the time interval of the second measuring campaign showed an average temperature of 13°C, with a minimum of −4°C and a maximum of 27°C. On the other hand, the values of the relative humidity of the outdoor air had very high values during this period, with an average of 73%, which may have caused and maintained the high humidity inside the church (**Figure 11**).

In order to have a more complete overview and to identify the areas with high risk of degradation, during the second campaign, we carried out humidity measurements at different points of the church, both outside and inside [4]. A manually

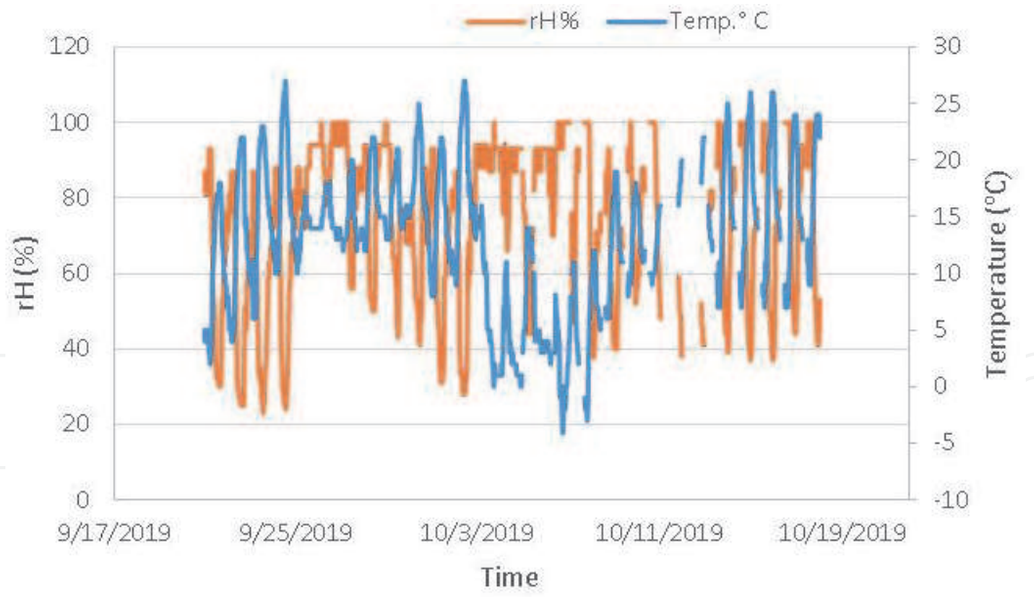

Figure 11.
Weather conditions in the area at the time of study (September–October 2019).

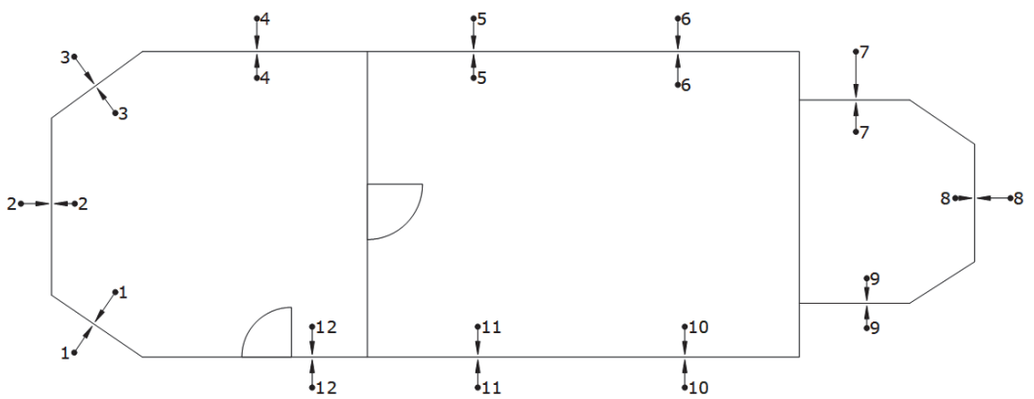

Figure 12.
Drawing plan of the wooden church with markings of the 12 indoor and outdoor sampling points.

operated particle measuring device (Trotec GmbH, Germany) was used to record important climate data such as the relative humidity and the air temperature. The measurements were performed every day between 19 and 19.30 p.m. The 12 points on the outside and inside the church were set at the ground level (**Figure 12**). The recorded data allowed the observation of relevant variations in the values of rH, between the outer and the inner points of the wood surface.

The highest average values (80.30, 80.90, and 80.30%) were recorded in sampling points 10, 11, and 12, behind the door of the church. This may explain the state of advanced degradation, the painting being almost completely obliterated, more so than in other areas inside the church (**Figures 13** and **14**).

It is well known that the most important and difficult conservation method is the constant maintenance of the indoor climate of the heritage building by attaining the most favorable temperature and humidity conditions. Taking into account the construction characteristics of the church and research data, it is mandatory to undertake fast solutions in order to stop the advancement of the degradation.

The outdoor climatic changes increase the preservation issues inside the wooden church, causing a constant indoor microclimate fluctuation, making the task of keeping the mural painting in optimal conditions in the long term a very difficult one. Under these conditions, a recommendation would be to install a portable air

Figure 13.
Degradation state of paintings near sampling point 10, 11, and 12.

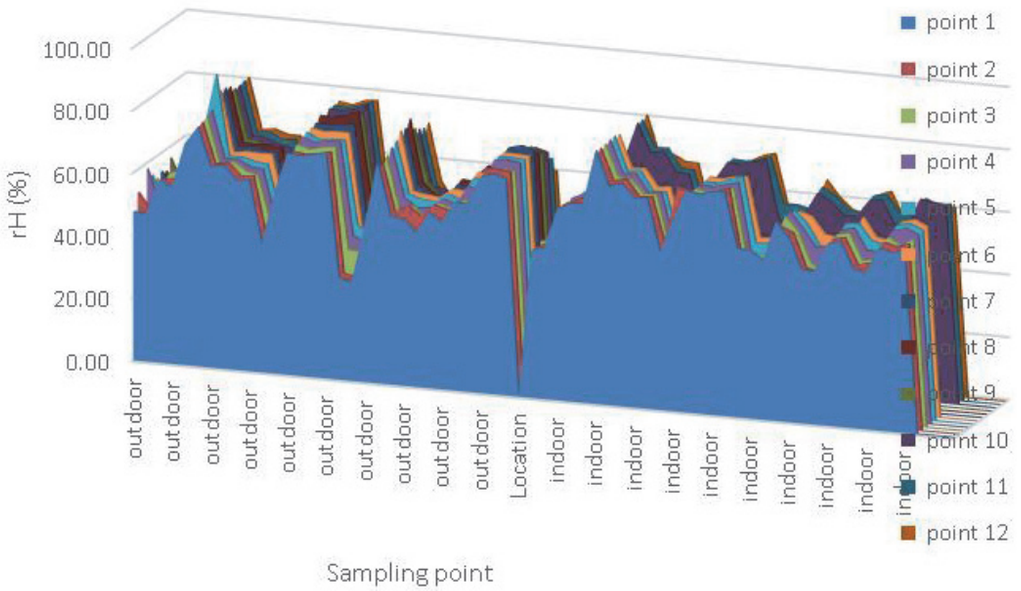

Figure 14.
Indoor/outdoor variations of relative humidity.

dehumidifier with a setting function allowing the relative humidity of the indoor air to be decreased between 50 and 60%.

6. Study on natural radioactivity by measuring the radon concentration inside the church

Exposure to radon in homes and workplaces is now recognized as the most important natural factor in causing lung cancer [27–31]. The international organizations that aim at protecting the public and the environment from exposure to radiation (UNSCEAR, WHO, IAEA, IRPA, and ICRP) are recently paying an increased interest to radon exposure and radiation protection measures [31, 32]. Based on Articles 35-36 of the Euratom Treaty, the most important objective of EU Member States is to monitor and report the radioactivity of the environment [33]. On the basis of international regulations, the problem of radon was assumed in Romania through the national legislation (HG nr. 526/2018, art.23) clearly stating

that radon concentration is to be determined, irrespective of the priority area, in buildings with public access [34].

The church under discussion is included in the Historical Monuments List, under the code LMI: MM-II-m-A-04569, and this inclusion was approved by the Directorate of Historical Monuments from the Department of Worship, no. 14301-1514 from the 5th of September 1967. The site is a public access building, visited by tourists and religious followers. In the summer of 2019, a group of 50 pilgrims led by a monk, attended the Holy Mass at the church on the hill. In the last few years, the church has been visited by a high number of visitors attracted by this part of country, rich in tradition and culture. Under these circumstances, we considered it necessary to evaluate the natural radioactivity, by radon measurements, of the "Archangels Mihail and Gavril" wooden church.

Active radon measurements carried out during the two separates campaigns yielded indoor radon activity concentrations ranging from 29 to 364 Bq m^{-3}. During the first campaign, one of the windows could not be closed properly; this allowed a high air exchange rate that led to the dilution of indoor radon to an average value of 46 Bq m^{-3}. By the time the second campaign took place, the faulty window was restored. The average value of 166 Bq m^{-3} was recorded during the second monitoring campaign. The indoor radon time series for the two seasons [35] monitored were represented in **Figures 7** and **10**.

At the time of the second campaign, passive radon detectors were installed along the active monitoring system. Indoor passive radon measurements were performed by using CR-39 track detectors exposed for 1 month, in all three rooms of the wooden church (**Figure 15**), according to the NRPB Measurement Protocol [36].

Following the laboratory analyzes performed at the Constantin Cosma Radon Laboratory of Babeș-Bolyai University, an average concentration of 107 Bq m^{-3} was obtained for the monitored period. Taking into consideration the seasonal correction factors implemented through national regulations, the annual indoor radon activity concentration for the investigated public building was calculated to be 140 Bq m^{-3},

Figure 15.
CR-39 detector.

well within the limits allowed by both the European Union, WHO, and by the Romania law regarding the exposure of the population in public spaces [37–39].

7. Conclusion

In the short-term analysis, the results of 30 days of continuous monitoring showed that environmental climate changes can have an influence on the interior conservation status of the studied church.

Future work should focus on the implementation of long-term measurements, deepening these techniques as well as performing chemical and biological analyzes at the mural painting level.

Taking into account these aspects, a short-term recommendation would be to install a portable air dehumidifier with a setting function allowing the relative humidity of the air to be brought in between 50 and 60%.

Acknowledgements

This work was supported by a grant of the Romanian Minister of Research and Innovation, CCCDI–UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0476/51-PCCDI/2018, within PNCDI III, ACRONIM: ARHEOCONS.

Conflict of interest

None of the authors have any competing interests in the manuscript.

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References

[1] Constantin M. The restauration of the iconostasis of Tismana monastery (2013–2015). The influence of microclimate parameters variation on the Restauration interventions. In: Restauration Book 2017. Editura ACS; 2017. pp. 130-157

[2] Paolo M, Laura M, Paul P. La conservation des peintures murales. Bologne: Editrice Compositori; 1977

[3] 2030 Agenda for Sustainable Development. Available from: https://www.mae.ro/node/35919

[4] Aguilar R, Marques R, Sovero K, Martel C, Trujillano F, Boroschek R. Investigations on the structural behaviour of archaeological heritage in Peru: From survey to seismic assessment. Engineering Structures. 2015;**95**:94-111

[5] Karanikoloudis G, Lourenço PB. Structural assessment and seismic vulnerability of earthen historic structures. Application of sophisticated numerical and simple analytical models. Engineering Structures. 2018;**160**: 488-509

[6] Tomaszek T. Authenticity and significance in wooden buildings—The problems of conservation of orthodox churches from Poland. Procedia—Social and Behavioral Sciences. 2016;**225**: 337-347

[7] Zonno G, Aguilar R, Boroschek R, Lourenço PB. Analysis of the long and short-term effects of temperature and humidity on the structural properties of adobe buildings using continuous monitoring. Engineering Structures. 2019;**196**:109299

[8] Stefanita G. Aspects regarding the reconstruction of some stages of restoring the painting from Icoanei Church in Bucharest. In: Restauration Book 2017. Bucuresti: Editura ACS; 2017. pp. 184-195

[9] Cocean P. The land—A typical geographical region of Romania. In: Revue Roumaine de Geograhie. Editura Academiei: București; 1997. pp. 41-50

[10] Stahl PH, Petrescu P. Arhitectura de Lemn a Maramureșului [Wooden Architecture of Maramureș]. RPR: București Arhit; 1958

[11] Map County of Lapus. Available from: https://teofil-ivanciuc.weebly.com/diferen355a-dintre-bdquo354ara-maramure351uluirdquo-351i-bd quojude355ul-maramure351rdquo.html#

[12] Man G. Wooden Churches from Maramureș. Baia Mare: Editura Proema; 2005

[13] Patterson J. Wooden Churches of the Carpathians, A Comparative Study. New York, NY: East European Monographs; 2001

[14] Porumb M. Biserici de lemn din Maramureș [Wooden churches from Maramureș]. București: Editura Academiei Române; 2005

[15] Bârcă A, Dinescu D. The Wooden Architecture of Maramureș. București: Humanitas; 1997

[16] Godea I. Monumente de arhitectură populară din nord-vestul României, biserici de lemn [Popular architectural monuments from the north-west of Romania, wooden churches]. Vol. 1. Oradea: Editura Muzeului Țării Crișurilor, Oradea; 1972

[17] Nagy F, Ladislaus AM. Documenta Historiam Valachorum. In: Hungaria Illustrantia, Usque Ad Annum 1400 P. Christum. Budapest: Études Sur L'europe Centre-Orientale; 1941. p. 465

[18] Available from: http://euiubescmaramures.ro/blog/tinut-magic-pe-unde-colinda-odinioara-pintea-viteazul-tara-lapusului.html

[19] Suciu C. Dicționar istoric al localităților din Transilvania, vol. I. 1967–1968. p. 210

[20] Nagy F, Ladislaus AM. Documenta Historiam Valachorum In Hungaria Illustrantia. In: Usque Ad Annum 1400 P. Christum. Budapest: Études Sur L'europe Centre-Orientale; 1941. p. 465

[21] Cotețiu M. Proiect de Conservare-Restaurare a Picturii Murale Din Satul Drăghia; 2011

[22] Plan of the Holy Archangels Church from Drăghia. Digital Image of Building Plan. Direcția Județeană pentru Cultură Maramureș. Available from: https://lapus.culturamm.ro/biserica-de-lemn-sfintii-arhangheli-mihail-si-gavril-din-draghia/ [Accessed: 05 November 2019]

[23] Man G. Biserici de lemn din Maramureş. Baia Mare: Ed. Proema; 2005

[24] Pamfil B, Maria B. Biserici de lemn din Țara Lăpuşului. Baia Mare: Ed. Eurotip; 2017. p. 87

[25] Camuffo D. Microclimate for Cultural Heritage: Measurement, Risk Assessment, Conservation, Restoration, and Maintenance of Indoor and Outdoor Monuments. 2nd ed. New York: Elsevier; 2019;(26)

[26] Aurel M. Conservarea Preventiva a Bunurilor Culturale. IV ed. Târgoviște: Editura Cetatea de Scaun; 2010. p. 86

[27] United Nations. Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation: Sources. United Nations Publications; 2000

[28] World Health Organization. WHO Handbook on Indoor Radon: A Public Health Perspective. World Health Organization; 2009

[29] Darby S, Hill D, Deo H, Auvinen A, Barros-Dios JM, Baysson H, et al. Residential radon and lung cancer—Detailed results of a collaborative analysis of individual data on 7148 persons with lung cancer and 14 208 persons without lung cancer from 13 epidemiologic studies in Europe. Scandinavian Journal of Work, Environment & Health. 2006:1-84

[30] Clement CH, Tirmarche M, Harrison J, Laurier D, Paquet F, Blanchardon E, et al. Lung cancer risk from radon and progeny and statement on radon. Annals of the ICRP. 2010;**40**: 1-64

[31] EU. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Official Journal of European Union. 2014

[32] Bochicchio F. Protection from radon exposure at home and at work in the directive 2013/59/Euratom. Radiation Protection Dosimetry. 2014;**160**:8-13

[33] Burghele B, Țenter A, Cucoş A, Dicu T, Moldovan M, Papp B, et al. The FIRST large-scale mapping of radon concentration in soil gas and water in Romania. Science of the Total Environment. 2019;**669**:887-892

[34] HG nr. 526/2018. National Radon Action Plan published in the Official Gazette of Romania. Nr. 645/25. VII.2018

[35] Miles J. Temporal variation of radon levels in houses and implications for radon measurement strategies. Radiation Protection Dosimetry. 2001; **93**:369-375

[36] Cucoş A, Papp B, Dicu T, Moldovan M, Burghele DB, Moraru IT, et al.

Residential, soil and water radon surveys in north-western part of Romania. Journal of Environmental Radioactivity. 2017;**166**:412-416

[37] Council Directive 2013/59/Euratom European Council. Council directive 2013/59/Euratom. Official Journal of the European Union. 2014;**57**(L13):1-73

[38] World Health Organization. In: Zeeb, Hajo, Shannoun, Ferid, editors. Handbook on Indoor Radon, A Public Health Perspective. Geneva, Switzerland: World Health Organization; 2009. p. 110

[39] Available from: http://www.monitoruljuridic.ro/act/hot-r-re-nr-526-din-12-iulie-2018-pentru-aprobarea-planului-na-ional-de-ac-iune-la-radon-emitent-guvernul-203132.html