Environmental Engineering and Management Journal *November 2018, Vol. 17, No. 11, 2731-2739*
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

INVESTIGATIONS ON AIR QUALITY IN THE HISTORIC WOODEN CHURCH IN ORADEA CITY, ROMANIA

Dorina Camelia Ilieș[1]*, Aurelia Oneț[2], Florin Mihai Marcu[3], Ovidiu Răzvan Gaceu[1], Adrian Timar[2], Ștefan Baias[1], Alexandru Ilieș[1], Grigore Vasile Herman[1], Monica Costea[2], Marius Țepelea[4], Ioana Josan[1], Jan Wendt[5]

[1]Faculty of Geography, Tourism and Sport, University of Oradea, 1st University Street, Oradea, 410087, Romania
[2]Faculty of Environmental Protection, University of Oradea, 26th Gen. Magheru Street, Oradea, 410048, Romania
[3]Faculty of Medicine and Pharmacy, University of Oradea, 10th Piața 1 Decembrie Street, Oradea, 410068, Romania
[4]Faculty of Orthodox Theology, University of Oradea, 1st University Street, Oradea, 410087, Romania
[5]Faculty of Oceanography and Geography, University of Gdańsk, 4 th Bażyńskiego Street; 80-952 Gdańsk, Poland

Abstract

The present study describes the results of air quality analysis and surfaces inside the Orthodox Church in Oradea City, Romania, a wooden monument (BH-II-m-B-20958), originally built in the village Letca from Sălaj County and displaced in 1991 to the campus of the University of Oradea. The paper focuses on the degree of microbial and fungal contamination of surfaces and air inside the wooden church. It also identifies various microbial species with potential risk on the health of parishioners and those in charge of maintaining the halidom.

Key words: carbon dioxide, microaeroflora, relative humidity, temperature, wooden church

Received: June, 2017; Revised final: May, 2018; Accepted: June, 2018; Published in final edited form: November 2018

1. Introduction

1.1. General framework

Wooden churches constitute an inestimable wealth, consisting of sacred and liturgical items as well as the patrimony preserved in museum and historical buildings (Lompa et al., 2006). The Romanian wooden churches are a category of monuments which belong to the great family of European Wooden architecture (Bucșa and Bucșa, 2008). A number of studies around the world have documented wood decay problems in important historical wooden structures. Among the many different microorganisms that can colonize wood, fungi are the predominant agents that destroy wood (Ortiz et al., 2014).

The wooden churches microclimate and air pollutant levels differ significantly from outdoors and from other indoor environments because of the specific building characteristics and usage (tourists, burning of incense, candles and oil lamps etc.) (Lompa et al., 2006). Extremes of temperature, relative humidity, the concentration of carbon dioxide and other indoor parameters can lead to a range of problems, such as chemical and biological deterioration with a potential risk on the health of parishioners (Sadłowska and Bieda, 2010). This paper analyses the impact of some indoor air parameters on air quality inside a wooden historic church in Oradea, Bihor County, Romania, and the degree of microbial and fungal contamination of the surfaces and of the air inside the historic monument wooden church.

* Author to whom all correspondence should be addressed: e-mail: E-mail: iliesdorina@yahoo.com; Phone: +40742775814

1.2. Location and description

The wooden church "St. Martyrs Constantin Brancoveanu and his sons" – "Archangels Michael and Gabriel" was built in the latter part of the 18th century in Letca village, Salaj County (Fig. 1a).

The historic monument is built of wooden beams (durmast and hornbeam) (Baias et al., 2015; Ilieș et al., 2011; Ilieș, 2013; Ilieș et al., 2014) and is located on a river stone foundation. The church is covered with shingles of pine wood, thus keeping the original features and authenticity completely (Fig. 1. a, b, c). The original decoration was made "in the early 19th century, with vivid colours and rich floral borders which were partly destroyed" (Godea et al., 1978) and it was redecorated in 1993, when it was relocated to the new location of the Oradea campus. The wooden church is on the new list of historical monuments since 2010 (BH-II-m-B-20958 m).

2. Materials and methods

Measuring the concentration of carbon dioxide in the historic monument wooden church was done using the air monitoring station Nova 5000, and the temperature and relative humidity of the air was monitored using the thermo-hygrometer with data function logger Klimalogg Pro, which allowed detailed records of temperature and humidity values as well as active monitoring of them in the months of March-April 2016, being placed nine sensors (Fig. 2). In terms of assessing the microbial and fungal contamination of surfaces and the air inside the wooden church, samples from surfaces were taken from 5 places represented by: painted canvas located in the entrance hall of the church, interior left wall, interior right wall, alter apse and the right exterior wall under the roof (Fig. 2). The method of identifying micro fungi from the dust on surfaces inside the historic monument wooden church is now described. This method was designed to isolate and identify fungi which may be incriminated in the bio deterioration of church wood and in the production of respiratory and allergic diseases in the case of some species with pathogenic risk. The materials used consisted of swab tubes with rod (sterile), sterile water, metal outline mould with sides of 10 cm sterilized, agar sterile culture medium Sabouraud with the addition of chloramphenicol (0.5g/L), forceps, sterile Petri plates.

The swab was used to wipe an area of 100 cm^2 delineated by the outline. Before the taking of samples began, the swab was moistened in sterile water. Taking the samples was performed by passing the swab rod 3 times through the same place in different directions (Rached et al., 2013).

The samples where inseminated from the liquid of the tubes with swab rod in Petri plates with Sabouraud agar with the addition of chloramphenicol at the microbiology laboratory in the Faculty of Environmental Protection, University of Oradea (Ilieș et al., 2018). The plates were incubated for 5 days at 25°C. Thereafter the fungi were identified based on the developed colonies (shape, colour, texture etc.) as well as microscopic examination techniques (morphological characteristics of the hyphae and cells of conidia developed). The bacteriological examination method of microaeroflora inside the wooden church is further described.

(a) (b) (c)

Fig. 1. The historic monument wooden church (a) (left) in Letca, Salaj County (Godea et al., 1978); (b) (center) in the campus of Oradea, October 2015; (c) (right) with shingle roof covering recently rebuilt, May 2016

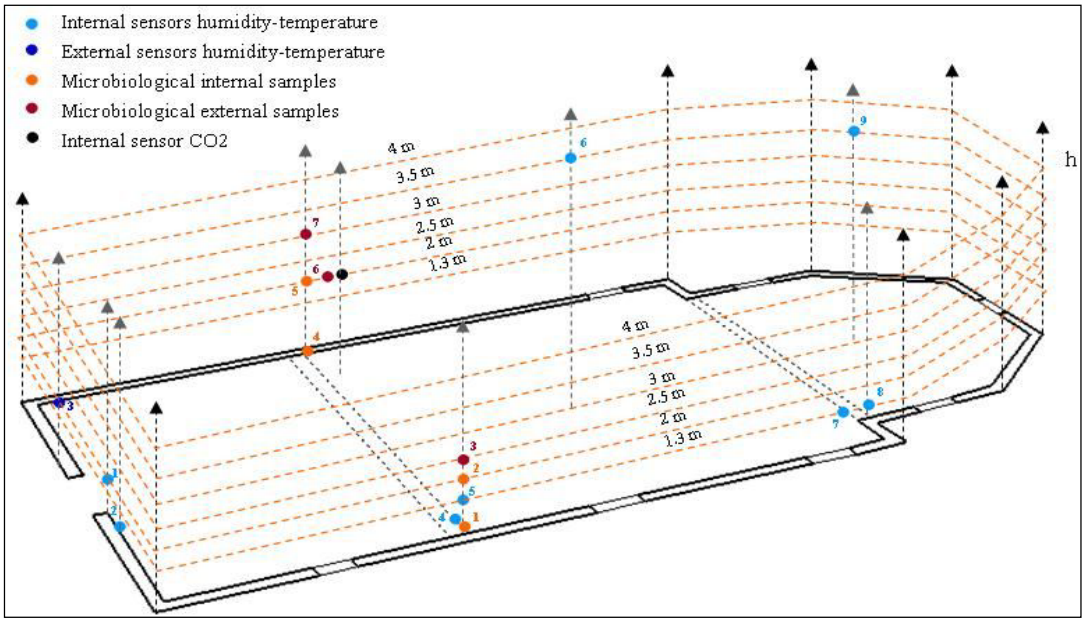

Fig. 2. The wooden church sketch "St. Martyrs Constantin Brancoveanu and his sons "-"Archangels Michael and Gabriel" with sensors location for measuring humidity and temperature, carbon dioxide, microbiological sampling points, respectively

To evaluate the bacterial and fungal charge of the air in the church the aeroflora was analysed by conventional techniques of open plates called Koch sedimentation method (Spengler et al., 2001). The materials needed were mainly Petri plates with a diameter of 10 cm, nutrient agar for bacteria and Sabouraud agar with the addition of chloramphenicol (0.5 g/L) for the fungi were used.

The sedimentation method consisted in exposing the Petri plates with a diameter of 10 cm that were containing the specific culture medium in 2 places inside the church for 5 minutes. 4 Petri dishes were used, two Petri plates with nutrient agar culture medium for quantitative analysis of bacteria and two Petri dishes with Sabouraud agar culture medium with the addition of chloramphenicol (0.5 g/L) for the quantitative determination of fungi. After a four hour period of exposure the Petri plates were coated and subsequently transported to the laboratory. They were incubated in a thermostat for 5 days at 25ºC in order to determine the total number of fungi in CFU/m of air (colony forming units), and thereafter for 24 hours at 37ºC in order to establish the total mesophilic aerobic bacteria (CFU/m air). Following incubation the colonies were counted on each plate to determine the arithmetic mean calculated by the average number of colonies found in the two plates of the same culture medium (Azari et al., 2008; Ilieș et al., 2018).

Calculating the number of bacteria present in a volume of air require a transformation of the number of germs on the surface of the plate, to the number of germs per volume of air. Thus, the results were expressed with the help of the calculus formula of Omelianski (Eq. 1) based on the observation according to which on a surface of 100 cm^2 exposed a certain period of time is deposited a number of germs equal to that contained in 10 dm^3 of air (Cernei et al., 2013). The formula of Omelianski is given by (Eq.1):

$$Total\ number\ of\ germs\ m^3 air = (n^* 10.000)/(S^* T/5) \quad (1)$$

where: n = total number of colonies developed on the surface of the culture medium; S = surface of Petri plates; T = exposure time (in minutes).

3. Results and discussion

In normal conditions the content of oxygen, in the air is about 20%, in volume and the minimum percentage of oxygen in the air is recommended not to be less than 19.5%. Below this value there appear the first signs of hypoxia (lack of oxygen): increased pulse - tachycardia, increased respiration rhythm - polypnea, problems with coordinating the movements etc (Bornehag et al., 2001). At a concentration of about 16% oxygen in the air, in addition to the signs and symptoms of hypoxia, the subjects exposed may have dyspnoea, difficulty in concentrating and processing information with the subsequent state of acute tiredness. A concentration of less than 12% oxygen can cause emotional disorders, fainting, nausea and vomiting etc.

The study highlights situations in which about 60 people enter the historic monument wooden church and attend the religious service on Sundays or religious holidays; the average weight of each subject being around 75 kg and time interval under study is 9-11a.m., in March-April, 2016. The chemical composition (%) of the air inhaled and exhaled by humans differs mainly in terms of the amount of oxygen and carbon dioxide (Ainsworth et al., 2000). Thus in the air inhaled oxygen is almost 21% (20.90%)

and the carbon dioxide is in very low concentration 0.03-0.04%; compared to the air exhaled oxygen is less, about 16%, and carbon dioxide over 10 times more, 3.4 to 4.5% respectively.

In the wooden church the volume is about 150 m^3, which contains 20% oxygen. Initially, at 9 a.m., the moment when the wooden church is empty, there are about 30000 litres of oxygen. The exact consumption of oxygen of each subject in the church, is virtually impossible to calculate (due both to individual constitutional factors and also the physical activity of each subject separately in the wooden church), thus we can only make an estimative hypothetical calculus of the total amount of oxygen consumption of the 60 subjects in the 2-hour religious service.

Among the existing methods we can mention the estimative methods for calculating this consumption, when considering only the basic consumption of oxygen, without taking into account the physical effort during the religious service. Thus, it is known that an adult in basic conditions (at rest) inhales and exhales air about 7-8 litres air/min, which means an average of about 11000 litres of air per day (Khare and Khare, 2012). It is known that the difference in oxygen content between the air inhaled and exhaled is about 5%, thereby obtaining an approximate consumption of 550 litre of pure oxygen (5% of the total air) per day. Thus, in 2 hours an adult consumes about 45 litres of oxygen and 60 adults will use about 2 700 litres of pure oxygen, so that in the wooden church, after the religious service, there would remain about 27300 litres of oxygen. Reported to a room with about 150 m^3 air volume, the percentage of oxygen O_2 (volume) after two hours of religious service is about 18.2%. The 60 adults (the average number of people attending the liturgical service on Sunday) in the wooden church will consume in 2 hours, about 10 800 litters of oxygen (180 min x 60 adults); in the first hour about 5 400 litres of oxygen is consumed. That is, after the first hour of religious service about 1\6 of the total amount of oxygen inside the wooden church is consumed and there remains about 25 m^3 of oxygen. Reported to a room with about 150 m^3 air volume, the percentage of oxygen (volume) after the first hour of liturgical service is about 16.6%. After 2 hours the oxygen consumption doubles, and in the wooden church will remain around 20 m^3 of oxygen 13.3% in percentage. The possible symptoms of hypoxia, described above, can be felt mainly by people with cardio-respiratory problems.

Analysing the concentration of carbon dioxide recorded in the wooden church before, during and after the religious service (Sunday between 9-11 a.m.) it is observed that during liturgical services there are cases in which the carbon dioxide levels increase to values of 361-605 parts per million- (ppm) (the value doubles), and in the next hour it exceeds the value of 1000 ppm (the initial amount at 9 a.m. practically triples after 11 a.m., a fact correlated with temperature due to the presence of about 60 people inside the wooden church and an heating system that does not allow temperature regulation.

Immediately after the end of the religious service, within about 1 hour, the carbon dioxide values return to normal almost 397 parts per million, ppm. Along with the increase of the carbon dioxide concentration value we notice a temperature increase inside the room during liturgical service (from 21.7ºC at 9 a.m. to 22.6ºC at 10 a.m. and 29.4ºC at 11 a.m. on 06.03.2016; from 24.1ºC at 9 a.m. to 28.6ºC at 10 a.m. and 33.5ºC at 11 a.m., on 13.03.2016; from 25ºC at 9 a.m.- to 29.4 ºC at 10 a.m. and 34.1 ºC at 11 a.m., on 27.03.2016. According to specialty studies, a carbon dioxide concentration not exceeding 600 parts per million (ppm) is considered the acceptable level (ANSI/ASHRAE Standard 62.1-2010, 2003). A level approaching 1000 parts per million (ppm) can lead to sleepiness, unpleasant odours and subsequently even lack of air (Usha et al., 2012) and can even exacerbate the possible symptoms of subjects inside the wooden church leading to: somnolence, dizziness, heavy sweating, disorders of balance etc. (Figs. 4-6).

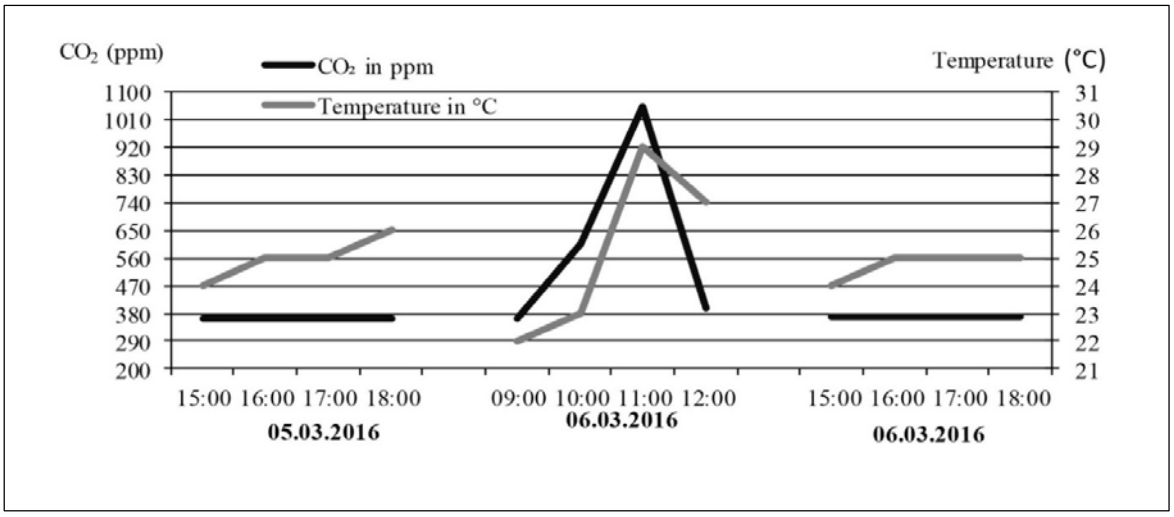

Fig. 4. The air temperature and the concentration of carbon dioxide inside the historic wooden church, 05/03/2016 – 06/03/2016

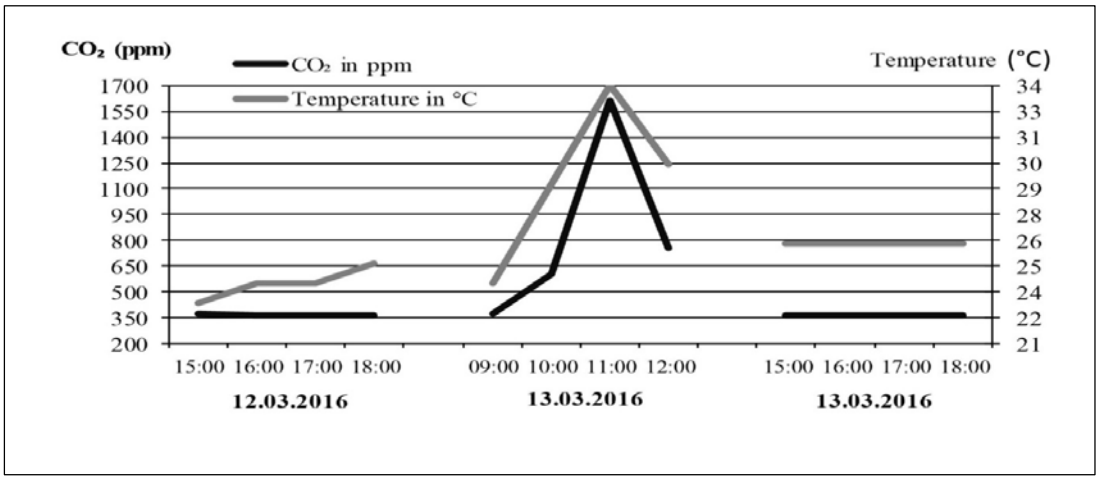

Fig. 5. The air temperature and the concentration of carbon dioxide inside the historic wooden church, 12.03.2016 – 13.03.2016

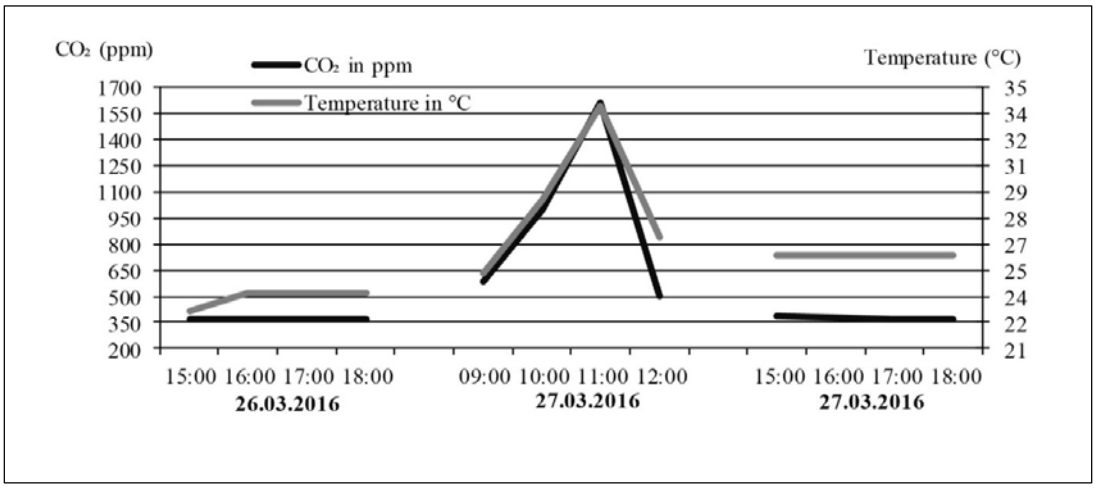

Fig. 6. The air temperature and the concentration of carbon dioxide inside the historic wooden church, 26.03.2016 – 27.03.2016

Inside the historic monument wooden church, the average air temperature value within the time interval in which the measurements were made was 25.8 ºC. The highest value of air temperature was 34.1 ºC on 27/03/2016 at 11 a.m., while the lowest was 21.7 ºC on 06/03/2016 at 09 a.m. It should be mentioned that within the interval when the measurements were taken the air temperature inside the historic monument building was heated with thermal agent (at 80ºC) from the heating system of the University of Oradea and the entrance door and windows were closed.

The average air temperature outside the historic wooden church in the interval when the measurements were made was 10.4 ºC . The highest temperature value outside the church was 13.4 ºC on 13/03/2016 at 03 p.m., and the lowest was 6.4 ºC on 27/03/2016 at 09 a.m.

Inside the historic monument wooden church, the average value of the air relative humidity in the interval when the measurements were made was of 38%. The highest value of relative humidity was 49% on 06/03/2016 at 09 am, and the lowest was 31% on 26/03/2016 at 03 p.m. The average relative humidity of the air outside the historic wooden church in which the measurements were made was of 68%. The highest relative humidity value was 80% on 27/03/2016 at 09 a.m., and the lowest was 51% on 13/03/2016 at 03 p.m. (Fig. 7).

The deteriorations caused by fungi as well as rainwater infiltration are the most common causes of degradation of most historic wooden buildings (Dumitrescu, 2004). The development of fungi is influenced by a number of factors such as temperature, humidity and appearance of nutrients. In certain conditions of microclimate specific to multiplication, the fungi can contaminate almost all surfaces. The presence of fungi in the indoor air should not be tolerated because the fungi spores, mycelial fragments and mycotoxins are factors with a major role in the production of respiratory diseases and allergies (Howard-Reed et al., 2003; Lipsa et al., 2016). The flora from the rooms' air and generally the enclosed spaces plays an important role in airborne transmission of infectious diseases, especially in crowded or poor ventilation conditions (Howard-Reed et al., 2003).

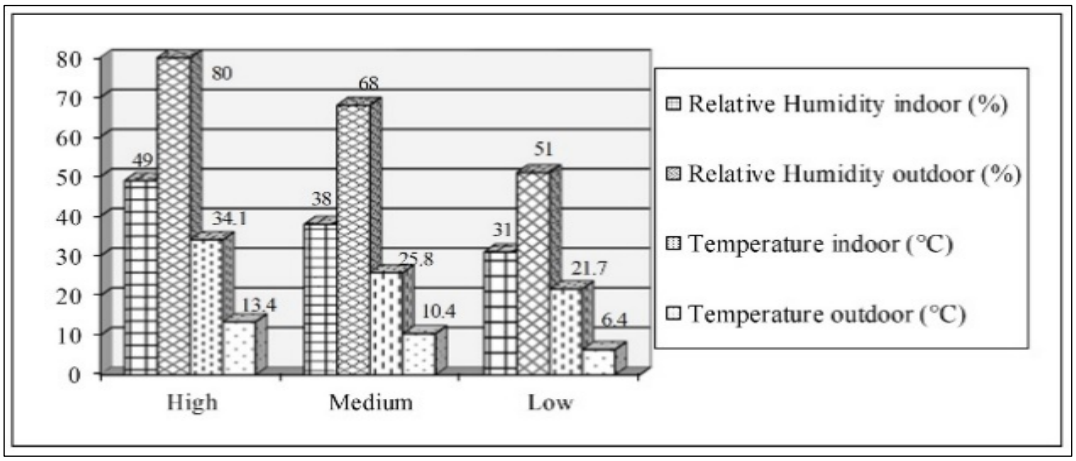

Fig. 7. The air temperature and relative humidity inside the historic monument wooden church, March 2016

The pathological significance of fungi is growing daily and can determine sensitivity to local or general allergic symptoms, such as bronchial asthma, eczema, urticaria, angioedema, allergic reactions etc. (Vlad, 2009; Yildiz et al., 2017).

The degree of microbial contamination of the air and surfaces reflect a potential risk of disease which increases proportionally with the density of bacteria and the presence of pathogenic or potentially pathogenic species. Air contamination is closely related to the degree of contamination of surfaces and objects, which are frequently contaminated with microbial flora in the air. On the dust is rising from surfaces, many microorganisms and spores fill the air. The significance of the presence and number of germs on surfaces is proportional to their presence in the air, so that a high density of germs reflects an increased epidemiological risk in the rooms and leads to evidence of inadequate sanitary conditions (Gent et al., 2002). Determining the total number of germs developing in the air inside a room at 37 ^{0}C allows us to appreciate the air loading level with flora of human origin as well as the hygiene specific conditions (overcrowding, ventilation, cleanliness, etc.) that influence the transmission of airborne infections. Currently there are no clear standards and rules regarding the microbial load of the air. Based on research, however, there were established some indicative norms by which the degree of contamination of the air could be indicated. The limits regarding the microbial contamination (bacterial and fungal) recommended by the US Federal Standard are shown in Table 1.

In order to calculate the number of germs present in 1 m^3 air, the results obtained were interpolated in Omelianski's formula to give 100 bacterial cells/m^3 of air and 65 colony-forming units/m^3 of air regarding the concentration of fungi (Ilieș et al., 2018). According to the data presented in Table 1 the bacterial contamination of the air has reached the maximum limit of 100 CFU/4 h meanwhile the fungal contamination has exceeded the contamination level C which provides 50 CFU/4 hours. On the basis of these results we can highlight the fact that the air inside the small wooden church is a potential risk to human health. The viable cultures of fungi produce spores called conidia. The size and shape of the conidial structures visualized by light microscopy light can provide information on the types or species of fungi (Capatina et al., 2007). The fungi identified from surfaces samples and from aeroflora by the microscopic examination method (Ilies et al., 2018) belong to the genus: *Aspergillus, Penicillium, Stachybotrys, Scopulariopsis, Arthrinium, Mucor, Rhizopus, Absidia, Geotrichum* and present the microbial cultures of microfungi identified in 5 places monitored (Timar et al., 2009). Bacteria of the type *Bacillus* and yeasts of the type *Rhodotorula* have been identified.

Table 1. Bacterial and fungal contamination limits

Class/Level	***Sedimentation method (CFU/4h)***
A	1
B	5
C	50
D	100

Penicillium is a ubiquitous fungi, found in soil, in decaying vegetal matters in the indoor air, dust but also in building materials. It produces toxins and allergies. *Aspergillus* can cause the disease called aspergillosis and is an opportunistic pathogen known as one of the most infectious fungi (Anagnost et al., 2006; Ilies et al., 2018; Miller, 1992). The genus *Scopulariopsis* is an isolated fungi found in soil, decaying organic matter, dust, carpets, paper etc. It produces orange-brown colonies on Sabouraud solid agar culture medium. The air represents the vector dispersing the spores. *Scopulariopsis* is a fungi potentially pathogenic to human health being frequently incriminated in the production of onychomycosis. According to OSHA (Occupational Safety and Health Administration) species from *Scopulariopsis* genus are classified as allergens and

irritants being the cause of production of dermatitis and allergic alveolitis (Gorny et al., 2002).

Fungi of the *Stachybotrys* genus are fungi that reside in materials rich in cellulose and produce mycotoxins called trichotecene. They are found commonly in the air in homes and the spores can cause possible health risks. *Stachybotrys chartarum* is a black fungi, toxic that can cause serious respiratory problems, especially among children (Brunekreef et al., 1989; Gent et al., 2002). The species belonging to the genus *Mucor* and *Rhyzopus* are potentially pathogenic contaminants which are found in indoor air, dust particles, soil and rotting vegetable matter. It is observed that whereas *Mucor* is a minor allergen that produces zygomycosis, *Rhizopus* is viewed as a major allergen responsible for causing several occupational allergies (Ilieș et al., 2018; Yassin and Almouqatea, 2010). *Arthrinium* is a contaminat mostly encountered in soil and decaying plants, preferring moist cellulose. Its presence does not raise serious health problems although some species are known as allergens (Dales et al., 1991).

The species of the genus *Absidia* are filamentous fungi, which are ubiquitous in nature and common contaminants of the environment. *Trichoderma* is a potentially pathogenic fungi found in soil. It can be found in indoor air because it prefers cellulose and ceramic kitchens materials. *Trichoderma* produces mycotoxins similar to *Stachybotrys chartarum* fungi which accounts for its significance in research concerning indoor air quality (Ilieș et al., 2018; Stark et al., 2003). *Rhodotorula* are pigmented single-celled yeast, being common contaminants of the environment. They are met in air, water, soil, food etc.

Few species have been reported as causes of epidermal infections in humans and animals. Fungi produce irritant substances of allergen type, but in addition, they can produce mycotoxins. The best known and most frequently described allergic reactions resulting from exposure to fungi and the spores thereof are: sneezing, runny nose, cough, eye irritation, cutaneal rash etc. (Bush et al., 2006). The crisis of asthma or bronchoconstriction may be encountered in patients with asthma or only allergic exposure to fungi and spores. Sometimes these symptoms can very severe (Terr, 2014).

4. Conclusions

Increasing the concentration of carbon dioxide inside the historical monument wooden church (to almost triple the normal values), along with reducing the amount of oxygen (values calculated below 20 mL/min) (by the end of religious services) on Sunday (around 11 a.m.) and the increasing of temperatures inside the church during liturgical services (ex. 29-30°C at 10 a.m.), has a dual impact, on the one hand it can contribute to the exacerbation and aggravation of pre-existing cardiovascular affliction; on the other it can lead to the occurrence of a well shaped clinical framework for the start of cephalalgia, drowsiness, fatigue, dizziness, paresthesia in the extremities, it may even reach severe hypoxia, disorientation, balance problems (more rapidly for the elderly and for the children who experience an increased fragility in their body).

Exposure to indoor fungi and mycotoxins can have adverse consequences for human health. Various species of fungi, in high concentrations, were present in the air inside the wooden church. The high values obtained in terms of bacterial and fungal charge of air and the prolonged exposure to indoor fungi may constitute a potential health risk for the human health. Beside these inconveniences the bio deterioration is not visible as it affects the internal structure of the wood substrate.

As a result of the present work we propose the following recommendations:

- removing the carpet inside the wooden church monument that is loaded with bacteria spores and fungi;
- install mechanic ventilation;
- improvement of natural ventilation;
- installing a bactericidal lamp for sterilizing the air; frequent cleaning of the air conditioner filter;
- maintaining a state of optimal cleanliness to reduce the existing dust;
- installing a system to adjust the temperature inside the wooden church;
- changing the cover of shingles to prevent rainwater penetration, which in the meantime has been done (May-June 2016) (Fig. 6).

Acknowledgements

We must refer that the monitoring and sampling activities were not invasive for the historic wooden church. We want to thank everyone who helped us in the revision of this material, the advice and the recommendations received and to acknowledge the support of research grant PN-III-P1-1.2-PCCDI-2017-0686.

References

Ainsworth E.B., Haskell W.L., Whitt M.C., Irwin M.L., Swartz A.M., Strath S.J., O'Brien W.L., Bassett D.R., Schmitz K.H., Patricia E., Court J., David R., Leon A., (2000), Compendium of physical activities: an update of activity codes and MET intensite, *Medicine and science in sports and exercise*, **32**, 498-516.

Anagnost S.E., Setliff E.C., Zhou S., Wang C.J.K., (2006), *Frequency of Basidiomycete Fungi in the Indoor Air of Urban Homes*, Proc. of the Air and Waste Management Symp. on Indoor Environmental Quality, Durham, North Carolina, July 16-17, On line at: https://www.researchgate.net/publication/288807466_Frequency_of_basidiomycete_fungi_in_the_indoor_air_of_urban_homes.

ANSI/ASHRAE Standard 62.1-2010, (2003), Ventilation for acceptable indoor air quality, Atlanta, GA, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., On line at: https://www.ashrae.org/file%20library/doclib/public/200418145036_347.pdf.

Azari M.R., Ghadjari A., Nejad M.R. M., Nasiree N.F., (2008), Air borne microbial contamination of dental units, *Tanaffos*, **7**, 54-57.

Baias Ş., Gozner M., Herman G., Măduța F., (2015), Typology of wooden churches in the drainage basins of Mureș and Arieș, Alba county, *Annals of the University of Oradea, Geography Series*, **2**, 221-233.

Bornehag C.G., Blomquist G., Gyntelberg F., Järvholm B., Malmberg P., Nordvall L., Nielsen A., Pershagen G., Sundell J., (2001), Dampness in buildings and health. Nordic interdisciplinary review of the scientific evidence on associations between exposure to "dampness" in buildings and health effects, *Indoor Air*, **11**, 72-86.

Brunekreef B., Dockery D., Speizer F.E., (1989), Home dampness and respiratory morbidity in children, *American Review of Respiratory Disease*, **140**, 1363-1367.

Bucşa L., Bucşa C., (2008), *Wood Science for Conservation of Cultural Heritage. Romanian Wooden Churches Wall Painting Biodeterioration*, Proc. of the Int. Conf. Wood science for conservation of cultural heritage, Braga, **67**, 75-80.

Bush R.K., Portnoy J.M., Saxon A., Terr A.I., Wood R.A., (2006), The medical effects of mold exposure, *Journal of Allergy and Clinical Immunology*, **117**, 326-333.

Capatina C., Racoceanu C., Lazar G., (2007), Researches on air micro flora determination from public indoor spaces and hospital wards in an urban area, *Environmental Engineering and Management Journal*, **6**, 285-295.

Cernei E.R., Maxim D.C., Mavru R., Indrei L., (2013), Bacteriological analysis of air (aeromicroflora) from the level of dental offices in Iași County Romanian, *Journal of Oral Rehabilitation*, **5**, 53-58.

Dales R., Zwanenburg H., Burnett R., Franklin C., (1991), Respiratory Health Effects of home dampness and molds among Canadian Children, *American Journal of Epidemiology*, **134**, 196-203.

Dumitrescu L., (2004), Researches regarding the chemical modification of wood, *Environmental Engineering and Management Journal*, **3**, 591-912.

Gent J.F., Ren P., Belanger K., Triche E., Bracken M.B., Holford T.R., Lederer B.P., (2002), Levels of house hold mold associated with respiratory symptoms in the first year of life in a cohort at risk for asthma, *Environmental Health Perspectives*, **110**, 781-786.

Godea I., Cristache-Panait I., Chiriac A., Mălinaș M., (1978), *Historic Monuments from Eparhia of Oradea, Bihor, Slaj, Satu Mare Counties, Wooden churches* (in Romanian), Romanian Orthodox Diocese Publishing House, Oradea, Romania.

Gorny R.L., Reponen T., Willeke K., Schmechel D., Robine E., Boissier M., Grinshpun S.A., (2002), Fungal fragments as indoor air biocontaminants, *Applied and Environmental Microbiology*, **68**, 3522-3531.

Gorny R.L., (2004), Filamentous microorganisms and their fragments in indoor air, A review. *Annals of Agricultural and Environmental Medicine*, **11**, 185-197.

Howard-Reed C., Wallace L.A., Emmerich S.J., (2003): Effect of ventilation systems and airfilters on decayrates of particles by indoor sources in an occupied town house. *Atmospheric Environment*, **37**, 5295-5306.

Ilieş A., Wendt J.A., Ilieş D., Josan I., Herman G., (2011), The Romanian rural architectural heritage from Maramureş Land - Personality, distinctiveness and protection, *Studia Universitatis Babes-Bolyai, Geographia* , **2**, 187-197.

Ilieş A., (2013), Rural Churches, ”pearls” of rural architecture in Crisana and Maramures, *Annals of the University of Oradea, Geography Series*, **2**, 386-391.

Ilieş A., Baias Ş., Baias I., Blaga L., Buhaş S., Chiriac A., Ciocan J., Dăncuș M., Deac A., Dragoș P., Dumitrescu G., Gaceu O., Godea I., Gozner M., Grama V., Herman G., Hodor N., Hurley P., Ilieș D., Ilieș G., Ilieș M., Josan I., Leșe G., Măduța F., Mojolic D., Morar C., Olaru M., Stașac M., Stupariu M., Sturza A., Ștefănescu B., Tătar C., Vârnav R., Vlaicu M., Wendt J. A., (2014), *Crişana and Maramureş. Geographical Atlas of Tourism Heritage*, University of Oradea Press, Oradea, Romania.

Ilieș D.C., Oneț A., Wendt J.A., Ilieș M., Timar A., Ilieș A., Baias Ș., Herman G.V., (2018), Study on microbial and fungal contamination of air and wooden surfaces inside of a historical Church from Romania, *Journal of Environmental Biology*, **39**, 980-984.

Khare S., Khare R., (2012), Tools and techniques for environment management in industries, *Journal of Chemical, Biological and Physical Sciences*, **2**, 1604-1613.

Lipsa F.D., Ulea E., Chiriac I.P., (2016), Monitoring of fungal aerosols in some educational buildings from Iasi, Romania, *Environmental Engineering and Management Journal*, **15**, 801-807.

Lompa G., Charpanidou E., Kioutsioukis I., Rapsomanikis S., (2006), Indoor microclimate, ozone and nitrogen oxides in two medieval churches in Cyprus, *Atmospheric Environment*, **40**, 7457-7466.

Miller J.D., (1992), Fungi as contaminants of indoor air, *Atmospheric Environment*, **26**, 2162-2172.

Ortiz R., Párraga M., Navarrete J., Carrasco I., De La Vega E., Ortiz M., Herrera P., Jurgens J.A., Held B.W., Blanchette R.A., (2014), Investigations of biodeterioration by fungi in historic wooden churches of Chiloé, Chile, *Fungal Microbiology*, **67**, 568-575.

Rached I., Aviat F., Michel V., Le Bayon I., Gay-Perret P., Kutnik M., Fédérighi M., (2013), Methods for recovering microorganisms from solid surfaces used in the food industry: a review of the literature, *International Journal of Environmental Research and Public Health*, **10**, 6169–6183.

Sadłowska A., Bieda W., (2010), Analysis of thermal environment indices and air quality inside a wooden historic church in Wiśniowa, *Infrastructure and Ecology of Rural Areas*, **11**, 83-93.

Spengler J.D., Samet J.M., McCarthy J.F., (2001), *Indoor Air Quality Handbook*, McGraw–Hill, New York.

Stark P.C., Burg H.A., Ryan L.M., Milton D.K., Gold D.R., (2003), Fungal levels in the home and lower respiratory tract illnesses in the first year of life, *American Journal of Respiratory and Critical Care Medicine*, **168**, 232-237.

Terr A.I., (2014), Are indoor molds causing a new disease?, *Journal of Allergy and Clinical Immunology*, **113**, 221-227.

Timar M.C., Beldean E., Porojan M., Gurau L., (2009), Field testing and microscopy – important tools for a realistic long-term evaluation of wood improvement treatments, *Environmental Engineering and Management Journal*, **8**, 669-679.

Usha S., Mark J., Mendell K.S., Toshifumi H., Douglas S., Siegfried S., William J.F., (2012), Is CO_2 an Indoor Pollutant? Direct Effects of Low-to-Moderate CO_2 Concentrations on Human Decision-Making Performance, *Environmental Health Perspectives*, **120**, 1671-1677.

Vlad C., (2009), Determining the species and number of pathogens present in the air inside public buildings and educational institutions in the Timisoara City, On line at:

www.dmmt.ro/uploads/files/proiecte%20si%20studii/Aeroflora.pdf

Yassin M.F., Almouqatea S., (2010), Assessment of airborne bacteria and fungi in an indoor and outdoor environment, *International Journal of Environmental Science& Technology*, **7**, 535-544.

Yildiz S., Enc V., Kara M., Tabak Y., Acet E., (2017), Assessment of the potential risks of airbone microbial contamination in solid recovered fuel plants: a case study in Istanbul, *Environmental Engineering and Management Journal*, **16**, 1415-1421.