Environmental Engineering and Management Journal

March 2021, Vol.20, No. 3, 459-466
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

"Gheorghe Asachi" Technical University of Iasi, Romania

MICROCLIMATIC CHARACTERISTICS AND AIR QUALITY INSIDE THE NATIONAL ARCHIVES OF BIHOR COUNTY, ROMANIA

Ovidiu Gaceu[1], Dorina Camelia Ilieș[1*], Ștefan Baias[1], Mihai Georgiță[2], Alexandru Ilieș[1], Tudor Caciora[1], Liliana Indrie[3], Adina Albu[3], Grigore Vasile Herman[1], Adriana Baidog[4], Raluca Buhaș[5], Florin Marcu[4], Luminița Șipoș[4], Nicolaie Hodor[6]

[1] University of Oradea, Faculty of Geography, Tourism and Sport, 1University Street, Oradea, 410087, Romania
[2]National Archives, Bihor County Office, Romania, Traian Blajovici Street, Oradea, 410209, Romania
[3] University of Oradea, Faculty of Energy Engineering and Industrial Management, 1 University Street, Oradea, 410087, Romania
[4] University of Oradea, Faculty of Medicine and Pharmacy, 10 Piața 1 Decembrie Street, Oradea, 410068, Romania
[5] University of Oradea, Faculty of Social-Humanistic Sciences, 1 University Street, Oradea, 410087, Romania
[6]Babes-Bolyai University of Cluj Napoca, Faculty Geography, 5-6 Clinicilor Street, 400006, Cluj-Napoca, Romania

Abstract

Written heritage is an important part of the national cultural heritage, including old books, documents and maps of remarkable significance for defining the identity of a nation. These elements, considering the perishability of the material of which they are made are liable to be damaged by internal and external risk factors. A good preservation of the documents must take into account both the nature of the material and the microclimate conditions in which they are stored. Considering these, the paper focuses on the microclimatic characteristics and the air quality inside of the National Archives of the Bihor County Office (Romania), highlighting the influence they have on the documents and the health of the employees. Using digital devices to monitor the risk factors of physical and chemical nature, as well as specific techniques for determining microbiological contamination, the internal microclimate in an archive storage was monitored in the period 01.03.2019 - 21.06.2019. At the same time, a focus group was held in which the employees of the institution participated. The results show that the values of the main elements of the microclimate (temperature, humidity, CO_2 and speed of air currents) are kept with small exceptions within the allowed limits, not posing a hazard to the employees or stored documents. But the air quality is considerably tainted by detected dusts in suspension and fungi, the employees being exposed to several professional illnesses. These conditions impose the introduction of modern HVAC systems to filter the air and improving the microclimate conditions.

Keywords: air quality, employees' health, historical documents, microclimatic characteristics, national archives

Received: June, 2020; Revised final: December, 2020; Accepted: January, 2021; Published in final edited form: March, 2021

1. Introduction

The written books and documents constitute an important part of cultural heritage, proven by the large number of studies whose aim is the preservation, in good condition, of the old writings that are housed in the national archives of the different states (Borrego et al., 2012; Cappitelli et al., 2008; Feber et al., 1998; Guiamet et al., 2011; Karbowska-Berent et al., 2011; Li et al., 2019; Mašková et al., 2017; Mousavi et al., 2016; Pinheiro et al., 2012; Rădvan et al., 2017; Zubairi et al., 2014). Determining the values of temperature, humidity, carbon dioxide (CO_2) and fungal contamination, with implications for human health (Hayleeyesus and Manaye, 2014; Ilieș et al., 2018a; Jones, 1999), and protecting the valuable heritage elements stored under such conditions is the object of present studies (Ilieș et al., 2018c; Indrie et

*Author to whom all correspondence should be addressed: e-mail: iliesdorina@yahoo.com; Phone: +40757142952

al., 2019). The risks that are posed for human body, which have resulted from exposure to an environment containing fungi of different species, have been analysed in several papers (Egbuta et al., 2017; Fairs et al., 2010; Oneț et al., 2018; Palmero et al., 2011; Pitt, 2000; Schwab and Straus, 2004; Zheng et al., 2015). The predominant organic composition of the written documents and of the textile materials makes them prone to damage caused by bacteriological microflora, which have been observed in several studies (Abdel Kareem, 2010; Blümich et al., 2003; Pinzari et al., 2010) conducted on the topic.

The archival institution dates back to the Organic Regulations in 1831, when, in Transylvania, the archives were organised on a county and mayoral office level. After having instituted the Hungarian National Archives in 1875, the oldest and most important Transylvanian funds were transported to Budapest. By decision of the Supervising Council of 15 March 1920, the Directorate of the State Archive of Transylvania was founded to house all documents relating to the Romanian past originating in Transylvania and the western parts of Hungary. In accordance with a decree of the Ministry of Internal Affairs, and in line with HCM no. 472/1951, eleven Regional Services of the State Archives were established. The Regional Service of the State Archives of Oradea oversaw several branches, with the head office being in Rayon, and the branches being situated in Beiuș, Șimleul Silvaniei and, from 1954, Ineu. The Regional Service of the State Archives of Oradea organised its first office on 24 September 1952, inside the offices of the former Popular Council of Oradea (City Council, nowadays). In 1961, due to the growing size of the overall collection, it was moved to the medieval fortress of Oradea, where it operated until September 2012.

However, the storage conditions inside the medieval fortress of Oradea were inadequate for the safe storage of 1112 collections and funds, including documents, with most of them being on paper, and with a small portion being on parchment paper, of which the oldest was dated 1291. Therefore, the increased temperature and humidity fluctuations during summer and winter that, for half a century, affected textiles and paper, favouring the development of microorganisms with potentially harmful effects on human health. The change in location of the archive since 2013, and the keeping of the temperature and humidity variations only within normal limits (established by the Decision no.92 of the General Director of the National Archives from the date of 14.05.2009) might have contributed to the stagnation of the development of microorganisms. However, the organisms remained present on the paper, from where they spread into the environment, leading to the need for the present study to establish to what extent working in such an environment has or does not have negative effects on human health.

The current offices of the National Archives of Bihor County, with a surface area of 3800 m^2, and designed with a basement, a ground floor and three upper floors, as well as with an anti-aircraft shelter, is located on Traian Blajovici Street, next to the Municipal Police offices in Oradea, Bihor County, Romania (Fig. 1).

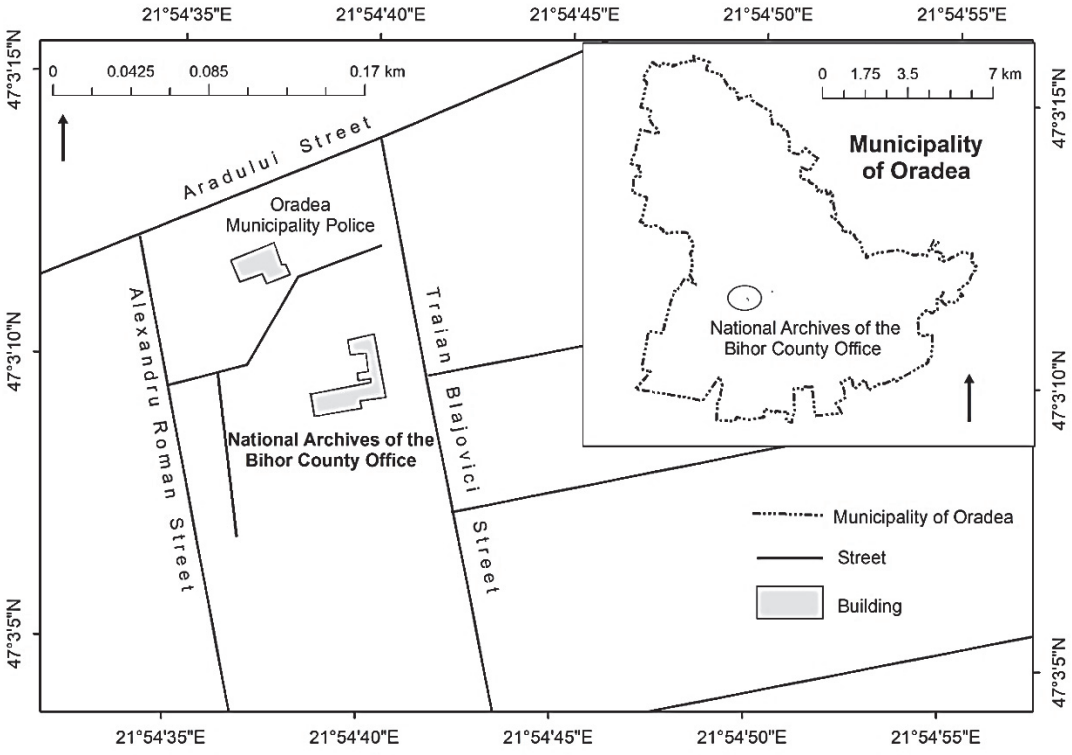

Fig. 1. The geographical position of the National Archives, Office in the city of Oradea in Bihor County

2. Methods

To carry out the present study, a complex interdisciplinary research team was appointed, consisting of geographers, historians, physicians, engineers and sociologists, who, depending on their speciality, have collected data concerning the characteristics of the microclimatic elements (i.e. temperature, humidity, carbon dioxide, speed of air currents, fungi) and the elements directly influencing the air quality (i.e. carbon dioxide, dusts in suspension, fungi) inside Storage Room no. 3 of the National Archives of Romania, Bihor branch. The data collection was carried out between 1 March 2019 and 21 June 2019, so as to identify the influence of the human activity on the values of the main indicators characterising the microclimate and the air quality inside the storage area.

To monitor and store the data regarding the temperature, the relative humidity, and the CO_2 content of the air, the following equipment was used: a KLIMALogg Pro data logger, with eight sensors spread out to all the key spots in the room, and a Trotec BZ30 data logger. These are fixed devices, which remained located in the warehouse throughout the measurements. The KLIMALogg Pro device used for the monitoring of the air temperature and the humidity inside the room had a ±1 °C precision for the temperature determination, respectively ± 3 % for relative humidity. The Trotec BZ30 used for monitoring air quality inside the room (in terms of measuring the air temperature, the relative humidity and the carbon dioxide values concerned) had a precision of ± 1 ppm for carbon dioxide determination, a precision of ± 0.1 °C for air temperature and a precision of ± 0.1 % for relative humidity of the air.

At the same time, mobile devices for detecting the characteristics of the microclimate were used. These were used twice a day, at the beginning (8:00 a.m.) and the end (4 p.m.) of the employees' working schedule. The indicators such as the amount of CO_2, temperature, humidity and speed of air currents were determined using devices from Extech Instruments, CO2 meter + CO250 and Delta Ohm HD 32.3. The Extech Instruments CO_2 meter + CO250 device measures the carbon dioxide quantity in air with a precision of ±5%. Using the SKC 224 – PCXR8 pump the amount of suspended particles within the total volume of air and from the surfaces inside the archive was determined in mg/m^3, by means of specific air sampling techniques (Asadi et al., 2011; Azari et al., 2008; Cernei et al., 2013) with a precision of ± 0.05%.

The calibration of the measuring instruments was done with the calibrated rotameters. For a good coverage of the storage spaces, the devices were placed on three rows, with a uniform distribution. The sensors were located both in the centre of the room and on the sides, at a height of approximately 1.7 m (Fig. 2). The height was chosen based on the average height of an adult. Thus, being able to better determine the stress to which employees are subjected.

In order to determine the microbe contamination, the Koch sedimentation method of open plates was used. Thus, the plateaus were positioned at several points within the deposits and at different heights, both on open surfaces and on the historical documents stored (of which, some old maps dating from the 19th – 20th centuries).

In order to obtain relevant information concerning the perception of archives employees regarding indoor air quality, a qualitative investigation was also conducted. In this regard, qualitative data was collected from employees in a focus group session in order to identify their experiences, attitudes and opinions on the topic.

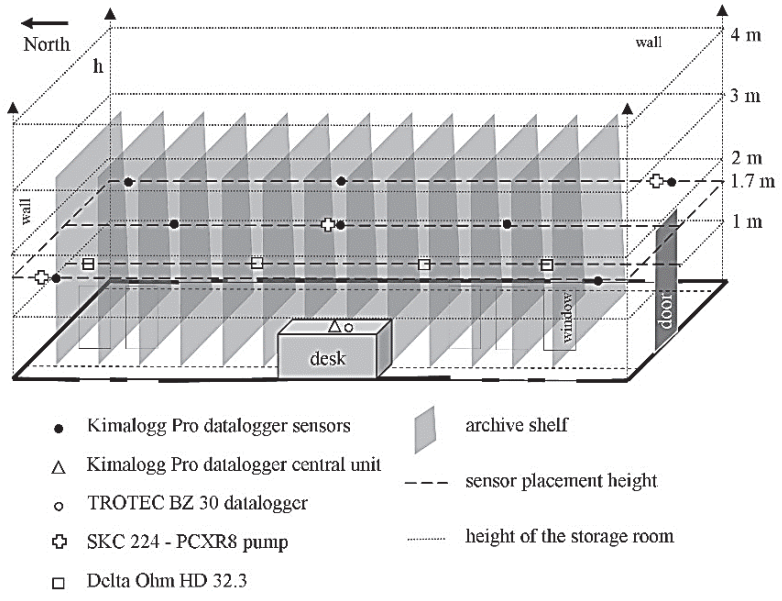

Fig. 2. The distribution of the devices and the sensors for monitoring the microclimate and the air quality in storage room no. 3 of the National Archives, Bihor County Office (Romania)

Therefore, based on the focus group, we aimed to obtain complex and detailed data (Flick, 2009; Krueger and Casey, 2005). The authors have successfully used the focus group method to carry out other researches and interdisciplinary studies (Ilieș et al., 2018a, 2018b). Those who took part in the research were the employees of the above-mentioned institution, who were randomly selected in terms of their willingness to participate in the group discussion. The total number of participants in the focus group was six (being half the number of employees at the Bihor County Office of the National Archives of Romania), consisting of two women and four men, with ages between 38 and 58 years old. All of the participants had worked in the Bihor County Office building since 2014.

In accordance with the structure of the interview, following the guidelines given for such focus group discussions, the moderator encouraged all participants to discuss and express their opinions, ideas and attitudes freely concerning the set topic. The interview was structured on the following thematic dimensions: professional activity, self-perception of the indoor air quality, health problems caused by poor indoor air quality, subjects` health state, proposals to increase indoor air quality. Further, interview questions were elaborated based on these dimensions. All the answers were recorded in detail and then analysed.

3. Results and discussion

The monitoring of the microclimate inside Storage Room no. 3 of the Bihor County Office of the National Archives of Romania was conducted over three-and-a-half months, from 1 March to 21 June 2019. The collection of statistical data was carried out to emphasise the characteristics of the microclimatic elements inside the storage room, in terms of air temperature, humidity, dust in suspension, speed of air currents as well as the quantity of carbon dioxide and the microorganisms (bacteria and fungi) present, with potential damage effects to archived documents and employee health.

3.1. The values of temperature, humidity and carbon dioxide

Figure 3 shows the fluctuations during the monitoring period of the values of temperature, humidity and carbon dioxide in the storage room no. 3.

As can be seen in the Fig. 3, from 1 March 2019 to 21 June 2019, the air temperature had normal values, with an average of 23.2 ^{0}C, and with extremes that varied from 20.1 ^{0}C on 7 May 2019 at 17:00 to 26.5 ^{0}C on 16 June 2019 at 15:00. Therefore, a thermal amplitude of 6.4 ºC was present in terms of the outside weather conditions (with 7.6 ºC and 30 ºC, as recorded by the Oradea Weather Station during the daylight hours, being the extreme values that were recorded inside the storage room), with the outside windows being open for ventilation.

Generally, an inversely proportional relationship exists between the air temperature and the air humidity. As the inside of the archives was uniformly heated, the humidity values were relatively small for most of the period under investigation. Therefore, between 10 March and 21 June 2019, the relative humidity of the air varied slightly, with it remaining under 10%, considering that the temperature varied by 6.4 ^{0}C, with a similar situation having been observed during the first decade of March 2019, when the variation in the relative humidity of the air inside the storage room was consistently less than 10%, considering that the temperature varied slightly, by 2 ^{0}C (Fig. 3).

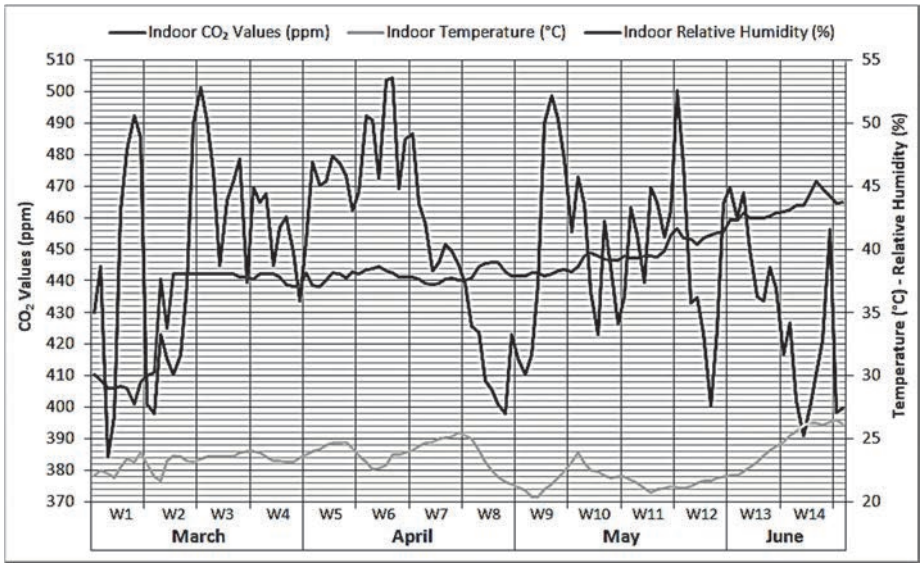

Fig. 3. The variation of air temperature, relative humidity and carbon dioxide values in the warehouse belonging to the Bihor County Office of the National Archives of Romania during the period of measurement (01.03.2019 – 21.06.2019)

The cause of such variation in both situations was determined by the weather variations that were felt indoors, due to the opening of the windows for ventilation and, to a lesser extent, due to the heating agent supplied through the municipality's heating network (Ilieș et al., 2018a). Therefore, the relative humidity of the air, with an average of 38% and an amplitude of 21%, resulted from the extreme values that ranged between 46% on 18 June 2019 at 14:00, when the exterior humidity was 80%, and 25% on 18 June 2018 at 07:00, when the exterior humidity was 37%, which fell within normal limits, with the air being dry, in general.

The carbon dioxide concentration remained within the optimum parameters of up to 600 ppm during the entire monitoring period in respect with the indoor microclimate, according to ANSI/ASHRAE Standard (2003), therefore no negative effects were present for the employees working in the storage area. The average value of the carbon dioxide concentration between 1 March 2019 and 21 June 2019 was 448.6 ppm, with a peak of 570 ppm being recorded on 28 May 2019, and with a minimum of 383 ppm being recorded on 16 June 2019 between 18:00 and 19:00. The increased quantity of carbon dioxide during the second half of the day, especially after 16:00, was attributed to the human activity undertaken during the working day.

According to order no. 92 / 14.05.2009 of the General Director of the National Archives, the internal microclimate favourable to the preservation of documents is between 15°C and 25°C in terms of temperature, between 40% and 65% in terms of relative humidity and below 0.3 m/s air current speed. The conclusion drawn, based on the observations made, was that the values of the microclimate elements met the set requirements in terms of their limits, even though the relative humidity of the air recorded was a value 2% lower than was the admissible limit. The value concerned was seen as being too insignificant, considering the given error of the measuring device and the short data collection and observation period, for making an objective determination.

3.2. The amount of dust in suspension

A problem is registered at the values referring to the amount of suspended dust in the storage. This was maintained between 0.10 and 0.15 mg/m^3 throughout the monitoring period. A value at least doubles the allowed limit (0.05 mg/m^3), established by law no. 104/15.06.2011 and the European standard EN12341 regarding the air quality in the rooms where the people carries out their activity. The values recorded are far from the recommended ones of approximately 0.025 mg/m^3, which can inevitably lead to respiratory tract disorders at people exposed to such an environment; and regarding the archived documents, the excess dust leads in time to their degradation.

3.3. Identification of fungal species and their negative effects

Taking into account the air quality noted, isolated cases existed in the buildings where air conditioning had been installed and where the rooms used were carpeted. Under such conditions, any fungi present tended to flourish (i.e. in cases where the relative air humidity was over 20%, and the air temperature was between 5°C and 30°C). The development of the fungi involved can contribute in time to the irrecoverable degradation of the archived documents, at the same time endangering the health of the employees.

At the time of the current study, air-conditioning installations constituted a risk factor in terms of the hygiene levels prevalent in a room. Therefore, the problem of interior air contamination is of great importance in the contemporary world, while the bacterial and viral particles that can be present in such an environment can induce airborne infections. Food, potted plants, dust, carpets, wood material and furniture can harbour such fungal spores as those of *Alternaria*, *Aspergillus*, *Botrytis*, *Cladosporium*, *Penicillium* and *Scopulariopsis*, which can be present in aerosols (Łukaszuk et al., 2011). Exposure to fungal allergens contained within buildings can result in the development of a variety of allergenic illnesses, including chronic rhinosinusitis, atopic conjunctivitis and atopic dermatitis (Bundy et al., 2009).

Aspergillus species was found through the investigations in the archive storage indoor air (Table 1), but also on other surfaces, including a series of old archived maps (dating to 1895 and 1910) investigated in a former study (Ilies et al., 2019). Their mycological content was determined by specific means and methods, which highlighted the presence of: *Penicillium ssp* and *Fusarium spp.*

Due to the production of mycotoxins, some of the *Aspergillus* species can cause infections, allergies and intoxications (Zubairi et al., 2014; Egbuta et al., 2017). Overall, the most common form of transmission of such fungi is through inhalation. Aspergillosis affects those with pre-existing afflictions, lungs problems and low immunity (Egbuta et al., 2017).

Three different stages of illness can be observed:

i. The first stage, due to impared host defence mechanisms in aspergillosis, is represented by pulmonary alveoli colonization, which could be accompanied by a large panel of disease, such as: onychomycosis, sinusitis, otitis, meningitis, encephalitis and endocarditis, osteomyelitis, and nosocomial infections in catheterized patients.

ii. The 2nd stage is characterized by bronchopulmonary allergic reactions.

Table. 1. Fungi identified in the archive room indoor air and on the old maps from the archive (dating to 1895 and 1910) (Ilies et al., 2019)

Location	***Fungi genera identified***
Archive room indoor air	*Aspergillus* spp.
From old maps surface from the archive (dating to 1895 and 1910)	*Penicillium* ssp. *Fusarium* spp.

iii. The 3rd one is marked by aflatoxin (*Aspergillus spp* toxin) synthesis, having carcinogenic effect upon liver tissue (hepatic-carcinoma). In immune-compromised patients (mainly in case of decreased in neutrophils function, in transplantation medicine) *Aspergillus spp* could cause both acute and chronic infections, because of the rapid germination of inhaled conidia, especially in pulmonary tissue, with potential aggression of some other organs (Pattron et al., 2006; Mousavi et al., 2016; Armstrong-James et al., 2017).

3.4. Interpretation of the Focus Group results

The focus group aimed to analyze the perceptions of archives employees concerning the quality of air inside their building, where they worked 8 hours a day / 5 days a week, in an environment with low air quality. The information provided by the employees was found to be relevant concerning their perceptions of the quality of air inside the building.

Before relocating, in 2014, to its current location, the activity of the Bihor County Office of the National Archives of Romania was carried out in several different rooms of the Fortress of Oradea, where the air quality was perceived by the respondents to be relatively low, and the ambient temperature to be inadequate, with the air tending either to be too cold or too hot. The present building was new and refurbished, with much-improved conditions: the air quality was perceived as being much better than before, while the variations regarding the temperature values being within the limits allowed by the regulations in force, which is a very important aspect for the storage of archived documents. Nevertheless, the air inside the building was perceived to be of low quality, with the employees stating that they were "accustomed to the indoor air", although they were adversely affected by different smells, like those of mould, dust and unventilated air. The unpleasant characteristics of the air were experienced especially in the storage area, where the documents are archived:

"The storage rooms are not sealed because the doors may be opened…but the way in which air circulates…"

Subjects state that the air quality indoors decreases as they get closer to the rooms of the archives:

"We are accustomed to the air inside and we no longer feel it, but if somebody else comes here and remains for a longer period of time … not here, where our offices are, but at approximately 4, 5 meters from the storage area … you may feel the bad air, or if one goes downstairs in the basement…";"From the entrance to the storage area the quality of air is degraded".

The Bihor County Directorate for Public Health monitors the indoor air quality, and, when necessary, it takes samples from different surfaces or documents, which it then sends for examination in the laboratory.

In terms of the health problems caused by the low quality of indoor air, as well as in relation to the general health of the employees, the latter have complained of having experienced various symptoms, like coughing, difficulty in breathing, irritated skin and eyes and/or respiratory allergies.

"If one decides to enter a storage room and stays there for 2 minutes, they shall feel the need to cough".

Such symptoms as coughing and sneezing were found to be relatively frequent when the employees carried out activities involving direct contact with the archived documents in the storage rooms.

"We directly touch the documents almost every day … maybe for some minutes, but it may last up to a day".

The participants in the study also complained of their heightened sensitivity to getting cold. In order to prevent these possible health problems, the employees are given cow milk, this being recognized as a food that helps to immunize the respiratory tract, while also having beneficial effects in treating respiratory allergies and asthma (Abbring et al., 2018; Perdijk et al., 2018; Sozańska, 2019). All of the respondents declared that their general health was good, despite some of them being heavy smokers.

The employees also stated that they were not supplied with the personal protective equipment that they needed to carry out their mandatory activities. When they handled archived documents, they were equipped with simple medical masks, gloves and a robe, which they did not consider to be special equipment. Therefore, they highlighted that it was necessary to improve the air quality indoors, as well as the equipment with which they were supplied when they were required to handle certain documents. Although they were aware of the advantages of the new heating, ventilation and air conditioning (HVAC) systems may bring to the work place but they have no access to such improvements momentarily:

"We are aware they exist, but…"

The new technologies that they mentioned included air circulation systems, dusting and disinfecting systems, and special protective equipment. Moreover, the study participants stated that some of the archived documents were in such a

bad state that they needed to be restored and exposed to a series of special chemical treatments for enhanced preservation.

4. Conclusions

As a result of the findings made in the current study, the following conclusions may be drawn:

a) The characteristics of the microclimatic elements were favourable for employee safety as well as for the proper preservation of the documents. The temperature values, the relative humidity and the carbon dioxide content recorded situated the work environment within the admissible limits in force.

b) The air quality, expressed through the values for dusts in suspension, and through the values for fungi detected in the air of Storage Room no. 3 of the Bihor County Office of the National Archives of Romania, was found to be inadequate. The values highlighted the impurities present in the environment, which were not conducive to human activity, with the employees involved being exposed to a range of professional illnesses.

c) The employees of the Bihor County Office of the National Archives of Romania confirmed, for the inquiry, that they felt certain negative effects of the indoor air that resulted from the presence of mould, unventilated air and dust. They claimed that their general health was negatively affected, to a certain measure, by all the above-mentioned factors. However, they all affirmed that, since their activity had been relocated to the present building, the quality of the indoor air had considerably improved. Nevertheless, there was still a need to introduce new technological systems that might further improve the air quality and, thereby, reduce the negative symptoms experienced, together with promoting the betterment of their general health.

Acknowledgements

The current research was made possible by the equal degree of scientific involvement of all the authors concerned. The authors wish to thank an anonymous reviewer for their thoughtful suggestions and comments, and to acknowledge the support provided in the form of the grant PN-III-P1-1.2-PCCDI-2017-0686. Also, the authors would like to thank Tembi Tichaawa, Associate Professor at the University of Johannesburg, South Africa, for his editorial assistance on the paper.

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