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INDOOR AIR QUALITY ISSUES. CASE STUDY: THE MULTIPURPOSE SPORTS HALL OF THE UNIVERSITY OF ORADEA

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Abstract

The present paper is a multidisciplinary investigation of the indoor air quality inside the Multipurpose Hall of the University of Oradea, based both on specific monitoring and questionnaire-based survey to identify people's perception in this regard. The monitoring, carried out during October-November 2016 when the heating did not work, was focused on: relative air temperature and humidity (Thermohygrometer data logger Klimalogg Pro), carbon dioxide (CO_2) (Extech Instruments CO250 model automatic gas analyzer), air microflora investigation (Koch sedimentation method in accordance with applicable standards). Monitoring results showed: an optimal level of temperature and humidity, so that sports competitions can be carried out at a good level, and a small to medium level of microbial contamination. The sociological survey showed that only a small percentage of respondents identified negative aspects of indoor air quality or had negative physical symptoms related to poor indoor air exposure.

Key words: air quality, indoor, microclimate, microaeroflora, sports hall

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1. Introduction

Studies on indoor air quality have been conducted in order to analyze: interiors of buildings (Andersson et al., 1993; Ishaq et al., 2016; Majumdar et al., 2016; Nordström et al., 1995; Reijula et al., 2004; Scheepers et al., 2017), the microaeroflora inside sports halls (Dales et al., 1997; Mukherjee et al., 2014), the athlete's performance in the context of indoor microclimate (Prozuments et al., 2016).

It is important to assess indoor air problems in the case of the Multipurpose Sports Hall – University of Oradea because the environment in which sport activities are developed differs from typical private business offices, schools, libraries etc. The present study also examines the prevalence of activity-related symptoms among people developing their activity within the sports hall (http://www.djstcluj.ro/_Files/documente/legislatie/proiectarea-salilor-de-sport.pdf).

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For a complex perspective, research regarding indoor air quality was also undertaken by using questionnaire-based surveys. For example, Finnish researchers used a modified *Indoor Air Questionnaire* established by the Finnish Institute of Occupational Health to assess indoor air issues in offices (Reijula et al., 2004); their study highlighted major issues related to indoor air quality (e.g. dry and stuffy air etc.), as well as various symptoms reported by people (e.g. irritated nose and eye, fatigue etc.).

Health aspects: it is mentioned that at concentrations of carbon dioxide (CO_2) above 1000 ppm, after several exposures, some pathologies in the respiratory tract may develop: e.g. bronchial asthma, chronic bronchitis (Bornehag et al., 2001); other symptoms may be accelerated pulse, sweating, fatigue, headaches and drowsiness, nausea, dizziness, respiratory tract infections, cough, eye, nose and throat irritation, hearing loss, erythema, rashes, mental fatigue etc. (Gianluigi de Gennaro et al., 2014; Hajian and Mohaghegh, 2015; Lipsa et al., 2016).

Negative effects could also be observed in the results of the sports activity (Doroshenko, 2012; Robertson, 2006). If high temperatures are registered inside the multipurpose sports hall during effort, this may lead to the exacerbation and aggravation of pre-existing cardiovascular affliction, and the occurrence of a well-shaped clinical framework for the start it can cause cephalalgia, drowsiness, fatigue, dizziness, paresthesia in the extremities, then it may even reach severe hypoxia, disorientation, balance problems (O'Keefe et al., 2012; Sawka et al., 2015; Sawka et al., 2011; Sheikhmohammadi et al., 2016). Depending on the frequency and duration of exposure to pathogenic aeroflora inside a sports hall, performing sports activities could be harmful to the health of those who perform physical exercise and they could experience headaches, dizziness, decreased capacity of concentration etc., as well as sensitization with the occurrence of local or general allergic manifestations (bronchial asthma, eczema, urticaria etc.) and, subsequently, the aggravation of existing pathologies can even appear especially in what regards the respiratory tract: tracheobronchitis, chronic bronchitis, chronic obstructive bronchopneumopathy - COPD or even pneumonia (Hajian and Mohaghegh, 2015; Mukherjee et al., 2014; Pastuszka et al., 2004).

2. Material and methods

The multipurpose sports hall of the University of Oradea is located inside the university campus (Fig. 1) and was built in 2005; its dimensions are: 46.14 m long, 27.08 m wide and 9.5 m high, while the total area is 1.250 sqm, and the interior volume capacity is of 11.870 mc. The sports hall is built from a lightweight structure, supported by space hollow metal posts and the walls are made of thermo-insulating multilayer panels. The roof is also made of thermo-insulating multilayer panels. The building is equipped with six windows that cannot be opened. The ventilation (which also has a heating role) is provided by two heaters placed on the roof of the building. On one side, the multipurpose sports hall has 143 seats.

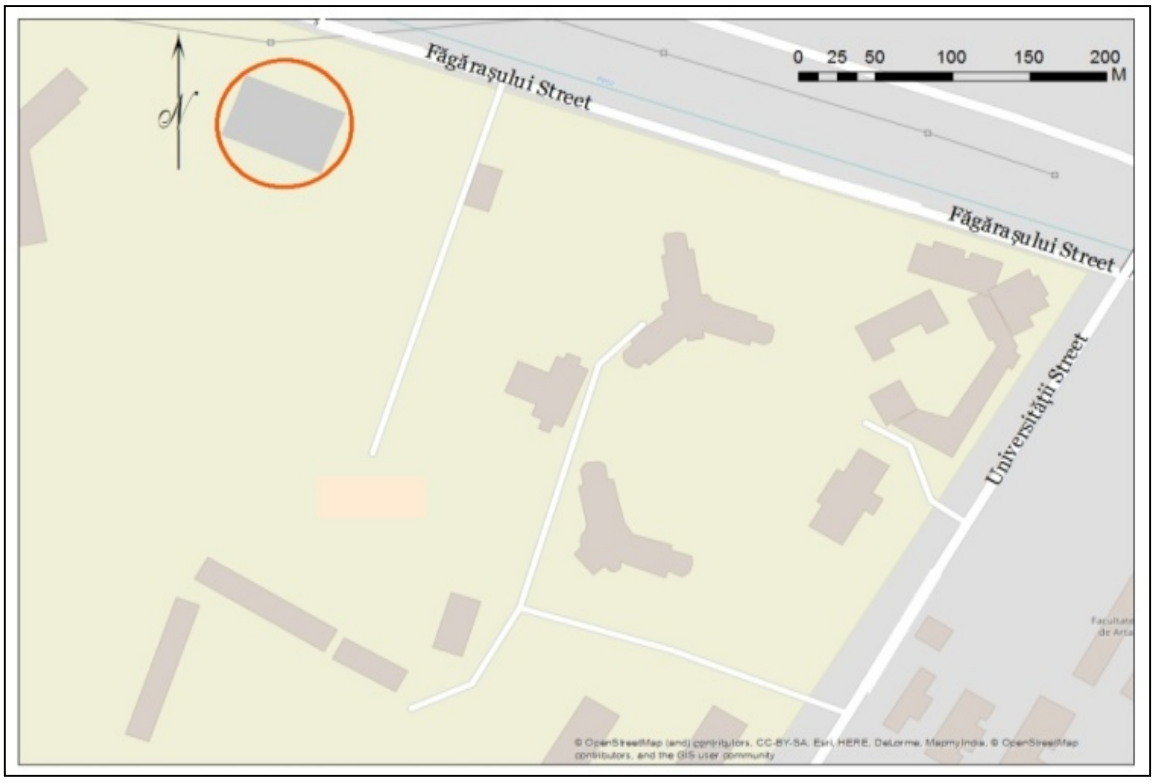

Fig. 1. The location of the Multipurpose Sports Hall, University of Oradea, Romania Source: http://www.openstreetmap.org./#map=17/47.04450/21.91707

Due to its complexity, the present research is based on an interdisciplinary methodological framework. Specific technical measurements done inside the multipurpose sports hall – University of Oradea - and the sociological survey are complementary methods that can create a complex perception of indoor air quality. All the measurements and the questionnaire were applied between October - November 2016, when the indoor heating system didn`t work. Monitoring and data analysis in what regards air temperature and relative humidity were done using *Thermohygrometer* with *data logger Klimalogg Pro,* the carbon dioxide (CO_2) was analyzed by using the automatic gas analyzer *Extech Instruments CO250 model* and for the ambient noise the *monitoring station Nova 5000* was used. The air microflora was investigated (Onet et al., 2018) by using the *Koch sedimentation method* in accordance with applicable standards. The culture media used were: nutritive agar (mesophilic bacteria), agar with blood 5-10% (hemolytic bacteria) and *Sabouraud* agar (fungi) (Karowowska, 2003). The *sociological survey method* was used to identify and explain to a wider extent the effects that indoor air quality can have upon people. More specific, on the one hand, the survey aimed at identifying the air characteristics that can be uncomfortable for active people, inside the multipurpose sports hall of the University of Oradea; on the other hand, there was a focus on identifying the eventual physical symptoms that may be generated by indoor air quality. Obviously, our objectives were traced in relation to the specifics of people`s activities.

Data was collected by applying a questionnaire (Herman et al., 2016; Secor, 2010) directly to two categories of people who undertake physical activity inside the multipurpose sports hall, namely: teachers/physical trainers and students/athletes. The sample was randomly selected, in accordance to subjects` availability to answer the questions. The method can help us understand better the effects that a poor indoor air quality might have upon the people who are conducting their activities in a closed space – the Multipurpose Sports Hall of the University of Oradea, in particular.

3. Results and discussion

3.1. Data analysis and interpretation

The maximum recorded air temperature inside the multipurpose sports hall was 19.9^0 C (the outdoor air temperature was 13.9^0C); the minimum air temperature was 12.4^0C (the outdoor air temperature was -3.4^0C). The average value of the air temperature inside the multipurpose sports hall was 15.9^0C. The analysis of the recorded data indicates that, during the monitored period, the indoor air temperature for the multipurpose sports hall falls within the comfort conditions for sports competitions (Order 1993 /13.12.2002). "The regulation for the design of sports halls" mentions that within a sports hall the ambient air temperature (Ta) should be Ta= 20-22°C for warming up and training, and Ta = 16-20°C for sports competitions (www.djstcluj.ro).

In what regards the carbon dioxide (CO_2) inside the multipurpose sports hall of the University of Oradea, the values measured between October-November 2016 were rated between 420-1310 ppm (the maximum values correspond to the ones needed for some sports competitions). Within a working day (eight hours), the carbon dioxide (CO_2) exposure level for healthy adults should not exceed 5.000 ppm; the optimum level for carbon dioxide (CO_2) level within sports halls should be between 400 ppm - 600 ppm (OSHA- Occupational Safety and Health Administration- https://www.osha.gov/).

The average value for the *relative indoor air humidity* for the multipurpose sports hall (Fig. 2) was 49.06%; the highest value in this regard was 63%, and the minimum was 39.8%. The relative air humidity levels inside the multipurpose sports hall *are falling within the standards of international comfort criteria* ISO 7730, (2005) - relative indoor air humidity should vary between 30% and 70% (Ramos, 2016); but these measured values are optimal also for Romania, where the relative air humidity, both for comfort conditions and in order to avoid the condensation phenomenon, must be 50% during winter, and 60% during summer (www.djstcluj.ro).

Regarding microaeroflora, the results of the studies indicate a small to medium level of microbial contamination of the Multipurpose Sports Hall according to the guidelines of the European Commission. It proves that it's necessary to develop standards of indoor air quality related to microbial population for the educational settings.

3.2. Questionnaire-based survey - data analysis and discussions

At the end of our survey, the total number of subjects in the sample was 306 (231 females and 75 males). The medium value of subjects` age was 20.29, which indicates a larger percentage of students/athletes who responded to the questionnaire. The amount of days spent per week by subjects inside the sports hall is not very much: on an average they spend 1.18 days/week, respectively 1.42 hours/day. For the objectiveness of our analysis, we should note that most of the subjects were not facing health issues at the moment of the survey (only 11.6% are diagnosed with health problems and 6.6% have contact lenses) and only 22.6% are smoking.

Indoor air quality

Even if, in general, the majority of the subjects (81.8%) evaluated the indoor air quality in the sports hall as being rather good, according to Fig.3 there are quite important percentages of respondents who were disturbed by some aspects related to indoor air quality. Therefore, summing up the answers registered for ”Sometimes”, ”Often”, ”Very frequent”, we have the

following percentages: low air temperature (50.9%), unpleasant odors (45.6%), stale air/unventilated air (44.6%), and dust(43.7%). We can state that the fore mentioned air related aspects could generate health (especially breathing problems) for people who are developing their activity indoor, namely inside the multipurpose sport hall form University of Oradea.

Respondents who evaluated indoor air quality as being rather poor declare that all those unpleasant aspects regarding air quality were felt during the entire period of their activity inside the sports hall (Pearson Chi-square = .000, $p < 0.05$). Subjects who evaluate the indoor air as being rather poor/very poor are significantly affected by dry air, high humidity, unventilated air, unpleasant odors, dust, visible mold (all elements correlating significantly at Pearson Chi-square = .000, $p < 0.05$). If the physical state is taken into account, respondents who are under medication seem to be disturbed mostly by low indoor air temperature (Pearson Chi-square = .001, $p < 0.05$). An interesting fact is that as the amount of time spent inside the sports hall is increasing, the indoor air quality is evaluated by subjects as being poorer ($r = -.205$, $p < 0.02$), and also they feel more disturbed by some air characteristics such as low indoor air temperature ($r = .304$, $p < 0.02$), dry air ($r = .149$, $p < 0.02$), unventilated air ($r = .142$, $p < 0.02$) dust ($r = .118$, $p < 0.05$).

Occurrence of physical symptoms

According to Fig. 4 we registered high percentages of respondents who declared that they have never experienced physical symptoms since they activate indoor, in the sports hall. Yet, we cannot ignore the data registered in the case of some particular physical aspects, such as: sore throat (42.8%), pronounced fatigue (31.6%), joint/bones pain (26.6%) or frequent cough (24%). We mention that these percentages were obtained by summing up the corresponding answers for" Sometimes", "Often", "Very frequent".

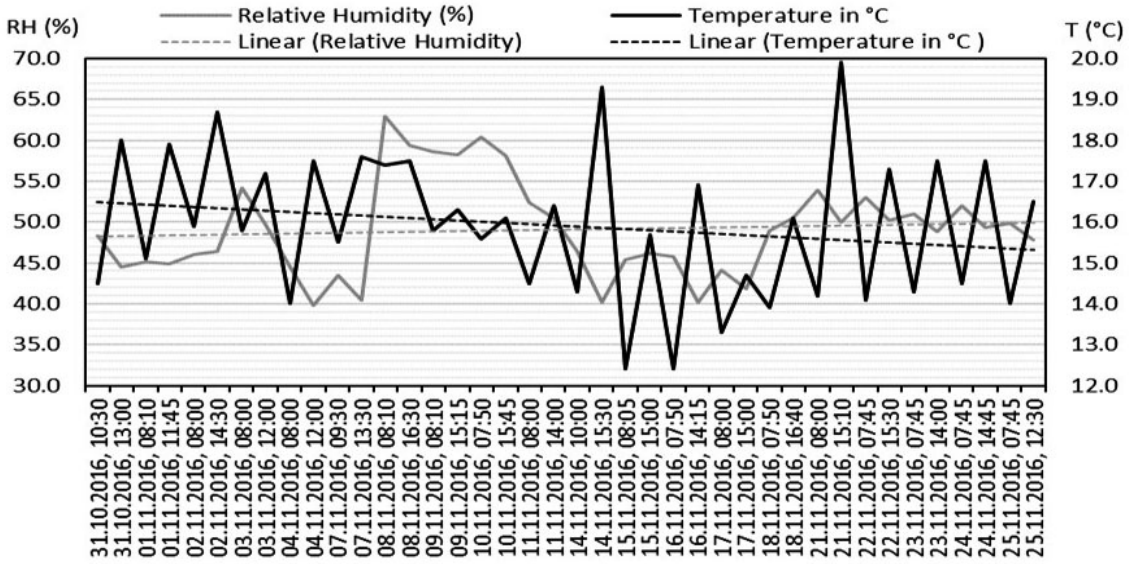

Fig. 2. Variation of *air temperature* and *relative humidity* indoor of the Multipurpose Sports Hall, Oradea University in the period 31/10/2016 – 25/11/2016

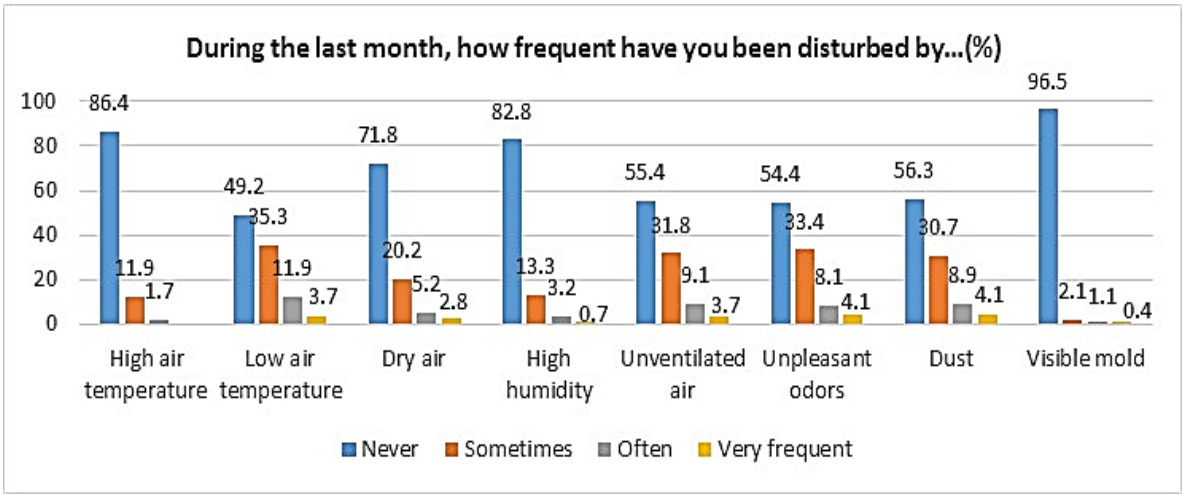

Fig. 3. Disturbance factors inside the multipurpose sports hall

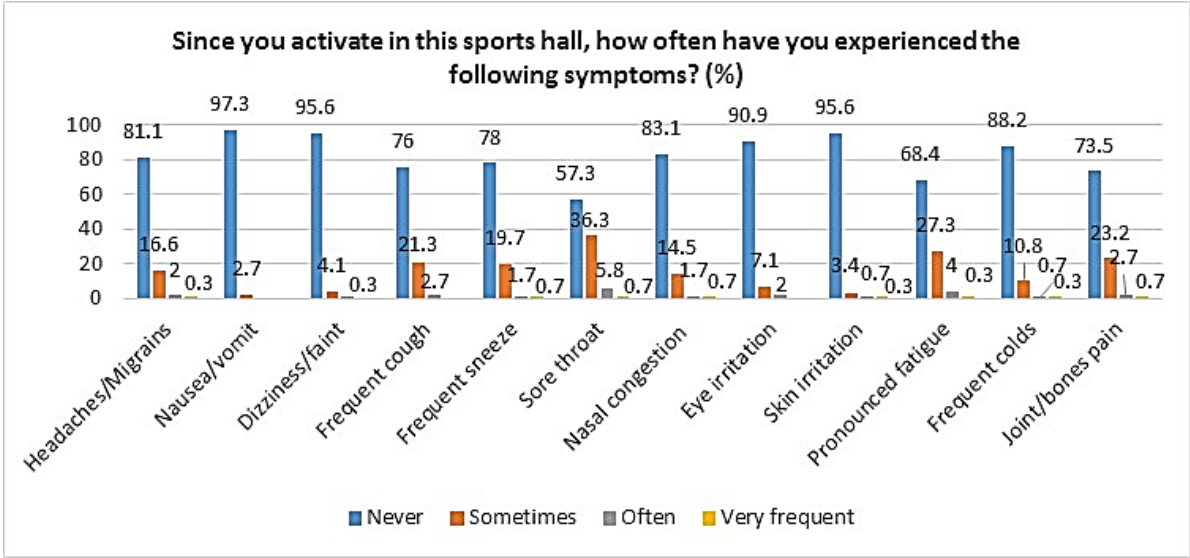

Fig. 4. Experienced symptoms inside the multipurpose sports hall during the monitoring period

By conducting a statistical analysis (Pearson's chi-squared test), the data showed that the occurrence of negative physical symptoms is increasing as the medium value of the amount of time spent inside the sports hall is higher: frequent cough ($r = .197$, $p < 0.02$), frequent sneeze ($r = .247$, $p < 0.02$), nasal congestion ($r = .139$, $p < 0.02$), eye irritation ($r = .180$, $p < 0.02$), joint/bone pain ($r = .150$, $p < 0.02$). Poor indoor air quality can generate the occurrence of certain physical symptoms like frequent colds, eye irritation, nasal congestion, sore throat (Pearson Chi-square = .000, $p < 0.05$), and also frequent sneeze (Pearson Chi-square = .001, $p < 0.05$), but most of those symptoms are disappearing in maximum 1-2 hours after leaving the sports hall.

Visible mold is often associated with the occurrence of colds, eye irritation, nasal congestion, frequent sneeze (Pearson Chi-square = .000, $p < 0.05$), while indoor dust is significantly correlated with eye irritation, nasal congestion, sore throat, frequent cough, headaches/migraines (Pearson Chi-square = .000, $p < 0.05$). High air humidity is very frequently generating headaches, cough, sneeze, sore throat, nasal congestion, colds (Pearson Chi-square = .000, $p < 0.05$), while a dry indoor air is associated with the occurrence of eye irritation, colds, pronounced fatigue, sore throat, cough (Pearson Chi-square = .000, $p < 0.05$).

If the indoor air temperature is not proper for physical activities, it can generate various negative symptoms; a too low air temperature is significantly correlated with the occurrence of headaches, dizziness, cough, sore throat, nasal congestion, pronounced fatigue (Pearson Chi-square = .000, $p < 0.05$), but also with joint/bone pain (Pearson Chi-square = .037, $p < 0.05$). On the other hand, if the air temperature is too high, headaches, sore throat, cough, pronounced fatigue can occur (Pearson Chi-square = .000, $p < 0.05$).

3.3. Discussion

The interdisciplinary methodology used in the research allows us to present the results from a complementary point of view. Taking into account both the monitoring and survey results, it is stated that, in general, the indoor air quality inside the sports hall of University of Oradea is rather good, and is not generating major health problems for those engaging in sports activities there. Only a small percentage of respondents identified negative aspects regarding air quality or had negative physical symptoms related to poor indoor air exposure.

Moreover, the incidence of those negative aspects is increasing as the amount of time spent inside the sports hall is higher. Taking into consideration the physical symptoms most indicated by the respondents (cough, sneeze, sore throat, eye irritation, nasal congestion etc.), and the fact that the multipurpose sports hall presents a small to medium level of microbial contamination, it can be stated that health issues that may occur are more because of air ventilation problems and better disinfection needs. Thus, it is advocated that the air ventilation system must be constantly improved and monitored in order to provide an effective management of air quality, overall.

The perception of air quality by both students and teachers who are undertaking their activity in the Multipurpose Sports Hall – University of Oradea is broadly related to objective measurements, but it is not sufficiently precise to characterize the indoor environment.

4. Conclusions

The results of the present study bring into discussion the necessity to optimize the indoor air temperature in what regards warming up and training

activities inside the multipurpose sports hall of the University of Oradea; instead, the temperature is adequate for sports competitions. Also, humidity and carbon dioxide concentration inside the sports hall during the monitoring period (October-November 2016) shows a level that fits within favourable standards for the development of sport activities. With regard to microaeroflora the results of the studies indicate a small to medium level of microbial contamination.

In general, respondents evaluated the indoor air quality within the multipurpose sport hall from University of Oradea as being rather good. Yet, low air temperature, unventilated air or even unpleasant odors are aspects that should be taken into consideration when analyzing the indoor air quality because they can create disturbances when different activities are being developed inside the sports hall. Therefore, specific solutions should be considered for improving the general indoor air quality. Also, it is important to take into account the fact that some indoor air characteristics can generate negative physical symptoms (like sore throat, cough or pronounced fatigue), which, on long term, could develop major health issues for active people inside a closed space.

The symptoms identified by subjects are originating from air ventilation problems, and not because of poor indoor air quality, in general. Thus, sports halls must be equipped with systems that allow the control of ventilation / air conditioning (natural, air-conditioning or mixed), the monitoring of indoor air quality, so that athletes can perform better both in terms of comfort and energetic efficiency.

References

Andersson K., Stridh G., Fagerlund I., Aslaksen W., (1993), The MM-questionnaires – A tool when solving indoor climate problems, Department of Occupational and Environmental Medicine, Örebro University Hospital, Örebro, Sweden, On line at: https://www.aivc.org/resource/mm-questionnaires-tool-when-solving-indoor-climate-problems.

Andersson K., Fagerlund I., Bodin L., Ydrebog B., (1988), Questionnaire as an instrument when evaluating indoor climate, On line at: http://www.inomhusklimatproblem.se/publikations/publikationer/Referens50ny.pdf.

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

Dales R., Miller D., McMullen E., (1997), Indoor air quality and health: validity and determinants of reported home dampness and moulds, *International Journal of Epidemiology*, **26**, 120-125.

Doroshenko Z., (2012), *Productivity and indoor climate*, Bachelor's Thesis, Mikkeli University Applied Science, Finland.

Gennaro de G., Dambrouso P. R., Demarinis A., Gilio A., Giungato P., Tutino M., Marzocca A., Mazzone A., Palmisani J., Porcelli F., (2014), Indoor air quality in schools, *Environmental Chemistry Letters*, **12**, 467-482.

Herman G.V., Grama V., Buhas R., Ilies D. C., Stance L., (2016), Research on the professional trajectory of the highschool and university students from the fields of geography and physical education, *University of Oradea Annals*, Geography Series, **1**, 54-62.

Ishaq M., Khan R. A., Majeed M. A.,(2016), Performance analysis of the HVAC system in a hospital building in Hyderabad, *International Journal of Scientific & Engineering Research*,**7**, 234-237.

ISO 7730, (2005) International Organisation of Standardization (ISO), Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria, On line at: https://www.iso.org/standard/39155.html

Karwowska E., (2003), Microbiological air contamination in some educational settings, *Polish Journal of Environmental Studies*, **12**, 181-185.

Hajian M., Mohaghegh Sh., (2015), Indoor air pollution in exercise centers, *International Journal of Medical Toxicology and Forensic Medicine*, **5**, 22-31.

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.

Majumdar D., Patil D., Malviya R., Trivedi J., (2016), Determination of air change rates by using indoor co as tracer: applicability and environmental issues, *Environmental Engineering and Management Journal*, **15**, 421-427.

Mukherjee N., Dowd S. E., Wise A., Kedia S., Vohra V., and Banerje P., (2014), Diversity of bacterial communities of fitness center surfaces in a U.S. metropolitan area**,** *International Journal of Environmental Research and Public Health*, **11**, 12544-12561.

Nordström K., Norbäck D.,Akselsson R., (1995), Influence of indoor air quality and personal factors on the sick building syndrome (SBS) in Swedish geriatric hospitals. *Occupational and Environmental Medicine*, **52**, 170-176.

O'Keefe H. J., Patil H. R., Lavie C. J., Magalski A., Vogel R. A., McCullough P. A., (2012), Potential adverse cardiovascular effects from excessive endurance exercise, *Mayo Clinic Proceedings.*, **87**, 587-595.

Onet A., Ilies D. C., Buhas S., Rahota D., Ilies A., Baias S., Marcu F., Herman G.V., 2018, Microbial air contamination in indoor environment of University Sport Hall, *Journal of Environmental Protection and Ecology*, **19**, 2, 694-703.

Pastuszka J.S., Wlazło A., Łudzeń- Izbińska B., Pastuszka K., (2004), Aerosol bacterial fungi in the gymnastics sports hall, *Air Protection and Waste Problems*, **38**, 62-66.

Prozuments A., Borodinecs A., Strutinska D., Nefedova A., Bykova I., (2016), *Survey-Based Study on Sportsmen Performance under Different Air Parameters in sport Halls, Clima* - Proc. of the 12th REHVA World Congress,7, Aalborg: Aalborg University, Department of Civil Engineering.

Ramos C., (2016), *Exposure to air pollutants during physical activity*, PhD Thesis, Technical University of Delft, Netherlands.

Reijula K., Sundman-Digert C., (2004), Assessment of indoor air problems at work with a questionnaire, *Journal of Occupational and Environmental, Medicine* ,**61**, 33-38.

Robertson D.S., (2006), Health effects of increase in concentration of carbon dioxide in the atmosphere, *Current Science*, **90**, 1607-1609.

Sheikhmohammadi A., Sardar M., Almasian M., (2016), A survey of sick building syndrome prevalence among the inhabitants of Ekbatan in Tehran, *Environmental Engineering and Management Journal*, **15**, 801-807.

SawkaM., Périard J., Racinais S., (2015), Heat acclimatization to improve athletic performance in warm-hot environments, *Sports Science Exchange*, **28**, 755-760.

Sawka M.N., Leon L.R., Montain S.J., Sonna L.A., (2011), Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress, *Comprehensive Physiology,***1**, 1883-1928.

Scheepers P. T. J., Wel V. L.,Beckmann G.,Anzion R. B. M.,(2017), Chemical characterization of the indoor air quality of a university hospital: penetration of outdoor air pollutants, *International Journal of Environmental Research and Public Health*, **5**, 497.

Secor A.J., (2010), *Social Surveys, Interviews, and Focus Groups*, In: *Research Methods in Geography. A critical introduction Wiley-Blackwell. Sussex*, Gomez B., Jones J.P (Eds.), 194-205.

Web sites:

https://www.osha.gov/

http://www.djstcluj.ro/_Files/documente/legislatie/proiectarea-salilor-de-sport.pdf

www.djstcluj.ro.

www.openstreetmap.org.