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Assessment of exposure to fungal aerosol in the lecture rooms of schools in the Lesser Poland region

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Abstract: The paper presents an assessment of the mycological air quality in classrooms of school buildings located in Lesser Poland. In 10 schools, 5 sampling points were designated: 4 indoors and 1 as an "outdoor background". A 6-stage Andersen impactor was used to collect fungal aerosol samples. During sampling, dust measurements were made (using the DustTrak II dust meter) as well as temperature and relative humidity. The predominant genera of fungi were determined by the MALDI-TOF MS method. The results indicated no statistically significant differences in indoor air fungal concentrations among the tested locations ($p>0.05$). The highest concentrations were observed in large classrooms (max. 2,678 CFU·m-3), however, these differences were not statistically significant across different types of school rooms (Kruskal-Wallis test: $p>0.05$). All rooms exhibited similar levels of fungal aerosol contamination. Relative air humidity had a significant influence on the number of microorganisms. The most frequently isolated fungi belonged to Cladosporium, Penicillium, and Aspergillus genera. Fungal aerosol concentrations in the tested classrooms did not exceed proposed limit values for this type of indoor environment. The results suggest that natural ventilation in classrooms is insufficient to ensure adequate microbiological quality of indoor air.

Introduction

Air pollution is a key factor that impacts the air quality of indoor and outdoor environments. It is affected not only by indoor pollutants, but also by external ones. In the contemporary world, this issue has been elevated to the status of a critical environmental concern. Globally, the air pollution is the primary environmental cause of death (Piersanti et al. 2021). Increasingly, inadequate microbiological air quality is noticed inside buildings that are constantly exposed to microbial colonization. If microorganisms are present in low concentrations and there are no pathogenic organisms among them, they do not pose a threat to humans. Contamination becomes an issue arises when the level of microbial contamination exceeds established natural limits for a specific environment (Kim et al. 2018, Grzyb and Lenart-Boroń 2020). This is particularly relevant for public buildings, including kindergartens and schools, because children, due to their lower body weight, inhale a larger volume of air compared to adults. Additionally, their developing are more vulnerable to harm than fully grown individuals (Canha et al. 2015, Brągoszewska et al. 2018). Children in Poland spend up to 8 hours a day in school and in its immediate vicinity. The quality of the air they breathe during this period is particularly important for their health and development. Many studies indicate that the occurrence of increased air pollution in classrooms with microorganisms can cause both health problems of students and employees, as well as affect the comfort of their study and work (Ejdys 2009, Mainka et al. 2015, Brągoszewska et al. 2018).

Fungi are a significant concern among the microorganisms found in the air of school buildings due to their ability to easily spread, potentially negatively impacting the health of people who occupy these rooms and breathe air contaminated mycologically. The presence and development of certain mold species can be linked to the release of allergens, mycotoxins, volatile organic compounds and glucans into the environment. These substances have the potential to cause a range of adverse health effects in humans (Górny 2019, Jiayu et al. 2019).

According to various authors, from 80 to 100 species of fungi have been causally linked to the symptoms of allergic respiratory diseases. Among them, species from genera such as *Alternaria, Cladosporium, Aspergillus, Penicillium, Trichoderma,* and *Mucor* are the primary culprits responsible for fungal allergies (Lang-Yona et al. 2016). In the literature on this subject, there is a notable shortage of research addressing this significant issue. Consequently, the extent of exposure to fungal aerosols within school premises is still insufficiently recognized. Moreover, studies on pollution have typically been limited to one or two schools. Only in a few instances have analysis been conducted in several schools (Eytyugina et al.

2010, Dumała and Dudzińska 2013). So far, most research has focused only on the total concentration of bioaerosols, however, their size distribution is also an important aspect. Given the potential of airborne bioaerosols to cause disease, information about particle size distribution is of crucial importance in practice. Moreover, in Poland, no standards or guidelines have been established yet. Therefore, specialized knowledge and research are essential for determining acceptable concentrations of biological pollutants in the air and assessing the associated risks. Thus, this study can raise awareness and provide a reference for improving our understanding of indoor air quality.

In light of this issue, the paper presents an assessment of the mycological air quality within ten schools situated in southern Poland in comparison to outdoor air pollution.

Materials and methods

The research was conducted in ten school buildings located in various towns in Lesser Poland (Małopolskie Voivodeship): Kraków/K1 and K2, Tarnów/T, Nowy Sącz/NS, Chrzanów/CH, Myślenice/M, Olkusz/O, Andrychów/A, Limanowa/L, Korzkiew/KO. In each of the surveyed schools, 4 sampling points were designated inside the building: a small classroom, a large classroom, a gymnasium (sports hall), and corridor, which served as an "indoor background" for determining the concentration of fungal aerosol within the buildings. All tested rooms were naturally ventilated. The area of the examined school rooms varied as follows: small classrooms ranged from 35 to 40 m^2, large classrooms from 50 to 60 m^2, and gymnasiums (sport halls) from 340 to 620 m^2. In all the schools, gymnasiums were situated on the ground floor of the building, while the classrooms in which tests were conducted were located on the first floor. In addition, at each location, one sampling point was designated 50 meters in front of the main entrance to the building, referred to as "outdoor background". This allowed us to assess the possible migration of mycological pollutants to the environment of the tested interiors. Samples of fungal aerosol and dust were collected during the typically warmer months, which include April, May, and September. For this purpose, a 6-stage Andersen impactor (model 10-710, Graseby-Andersen, Inc., Atlanta, GA, USA) was used to collect air samples within the study classrooms and outdoor. The samples were collected during regular classes, with students and employees present. The device was placed in the center of the room at a height of 1.0-1.5 m above the floor or ground (for outdoor measurements) to collect samples from the human respiratory zone. A 5-minute fungal aerosol collection time with controlled air flow was employed. The sequence of analysis in each school was the same: outdoor air, corridor (indoor background), small classroom, large classroom, and gymnasium. In between test series, the equipment was chemically disinfected. All analyses were performed in duplicate.

The fungal aerosol was tested on malt extract agar (MEA; Oxoid Ltd., Basingstoke, Hampshire, Great Britain). During the sampling, dust measurements were conducted using the DustTrak II dust meter (model 8530, TSI Inc., Shoreview, MN, USA) and microclimatic parameters, including temperature and relative humidity, were monitored using the Kestrel 4000 anemometer (Nielsen-Kellerman, USA).

Petri dishes with microbiological media were transported to and from the laboratory to the sampling points and on the way back, in a thermally insulated transport container, maintaining a constant temperature of approximately 4°C to prevent any possible damage.

MEA plates with collected samples were incubated for 4 days at 30°C and then for 4 days at 22°C. The extended incubation period for fungal cultures was designated to facilitate the growth of strains that develop more slowly at lower temperatures. After incubation of the samples, both quantitative and basic qualitative analyses of the grown microorganism colonies were carried out. To assign the prevailing fungi to their respective genera, the MALDI-TOF MS technique was employed.

The fungal aerosol concentration was calculated as the number of colony-forming units per cubic meter of air ($CFU \cdot m^{-3}$).

Since the obtained data exhibited a non-parametric distribution, statistical analyses were performed using the Kruskal-Wallis test, as well as Spearman correlation analysis with Statistica v. 13.1 (StatSoft, Inc., Tulsa, OK, USA), assuming statistically significant p-values<0.05.

Results and discussion

The concentration of the fungal aerosol in the air of school buildings, including classrooms and indoor background, as well as the outdoor air, was measured using the Andersen impactor. The results are presented in Table 1 and in Figures 1 - 3. The research findings showed significant diversity

Table 1. Concentration of fungal aerosol in the indoor and outdoor air.

Sampling points		Total fraction ($CFU \cdot m^{-3}$)		Respirable fraction ($CFU \cdot m^{-3}$)	
		Range	Median	Range	Median
School rooms	Small classrooms	35 – 1 646	338	28 – 1583	286
	Large classrooms	21 – 2 678	343	21 – 2565	336
	Sports halls	35 – 1 314	297	28 – 1194	269
Indoor backgrounds (corridors)		91 – 2 041	371	77 – 1879	350
Outdoor air (background)		21 – 1 845	370	7 – 1350	335

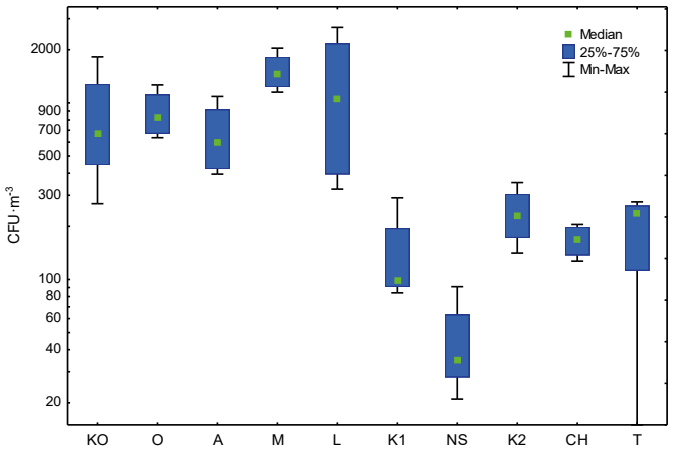

Figure 1. Fungal aerosol concentrations (CFU·m^{-3}) in the classrooms. (Kraków/K1 and K2, Tarnów/T, Nowy Sącz/NS, Chrzanów/CH, Myślenice/M, Olkusz/O, Andrychów/A, Limanowa/L, Korzkiew/KO).

among the measurements The analysis of fungal aerosol concentrations indicated no statistically significant differences in the concentrations of the tested microorganisms in the indoor air (Kruskal-Wallis test: p>0.05) (Fig. 1). All examined school rooms exhibited similar levels of fungal aerosol contamination (Kruskal-Wallis test: p>0.05). However, the indoor fungal aerosol concentrations ranged from 21 to 2,678 CFU·m^{-3}. The highest concentration was observed in a large classroom (2,678 CFU·m^{-3}), however, these differences were not statistically significant between the different types of classrooms studied (Kruskal-Wallis test: p>0.05). Data analysis showed that in the classrooms, the measured fungal concentrations ranged from 21 to 2,678 CFU·m^{-3}, while in the gymnasium, they ranged from 35 to 1,314 CFU·m^{-3} (Table 1). This variation was probably due to the influx of microbes from outdoor air entering the room through open windows, which remained open for extended periods during this time of year. Studies conducted by other researchers in 5 selected schools in Lublin, Poland, have shown that the occurrence of microbial concentrations in the air of classrooms can be affected by factors such as the age of the building and inadequate air exchange in the room (Dumała and Dudzińska 2013). The highest level of fungi found in indoor air in these schools was 6.9·10^{2} CFU·m^{-3}. A similar situation was observed in research conducted in Portugal, where the concentration of fungi reached the level of 8.0·10^{2} CFU·m^{-3} in two schools (Eytyugina et al. 2010).

When comparing the median fungal concentrations among the study rooms, the largest differences were observed between the corridors (indoor backgrounds) with a median of 371 CFU·m^{-3} and the large classrooms with a median of 343 CFU·m^{-3}. However, no statistically significant relationship was found (Kruskal-Wallis: p>0.05. The natural environment serves as a significant source of microorganisms, with doors, windows, and fresh air intakes providing easy access for microorganisms inside buildings. This phenomenon is especially important in summer when the concentration of fungal spores in the atmospheric air increases. Nevertheless, there is still a lack of available information regarding the quantitative relationship between indoor and outdoor levels of bioaerosols (Li et al. 2020). In the examined rooms, the values of fungal concentrations in the indoor background (corridor) of the examined rooms ranged from 91 to 2,041 CFU·m^{-3}. The comparison of fungal aerosol concentrations in school rooms and in the indoor background did not show statistically significant differences in the measured values (Kruskal-Wallis: test p>0,05). These findings align with the existing body of knowledge, as the degree of air pollution with microorganisms depends on many factors, including population, human activity, intensive air exchange, dust, humidity and temperature (Mainka et al. 2015). The measurements also demonstrated that the number and activity of students had no significant effect on the levels of fungal aerosol concentrations in the classrooms (Kruskal-Wallis test: p>0,05). The concentration of microorganisms (primarily bacteria) in the indoor air of schools depends on many factors, one of which is the number of children in a classroom and their physical activity (Dumała and Dudzińska, 2013). Although people are not the source of fungi, they can contribute to bringing them into buildings from the outdoor (e.g. on clothes and shoes).

While in the case of a fungal aerosol, the most significant sources of emission are in the outdoor environment (e.g. soil, plants, etc.), the constant, albeit varying influx of outdoor air into buildings remains the primary process contributing to the biological contamination of indoor air (Wlazło et al. 2008). However, when bioaerosols have indoor sources, ventilation plays a crucial role in improving indoor air quality (Faridi et al. 2015).

Fungal aerosol concentrations in the atmospheric air (outdoor background) did not exceed the value of 1,845 CFU·m^{-3}. The analysis of fungal aerosol concentrations measured outdoor at all studied school buildings did not show statistically significant differences (Kruskal-Wallis test: p>0.05). Comparing the obtained measurement results for the outdoor air and indoor background showed that the concentrations of the fungal aerosols outdoors were not significantly lower (Kruskal-Wallis test: p>0.05) than the concentrations of the "background" measured inside the tested buildings (fig. 2). In the case of fungal aerosols, no statistically significant differences were found in the concentration levels of this group of microorganisms between the outdoor environment

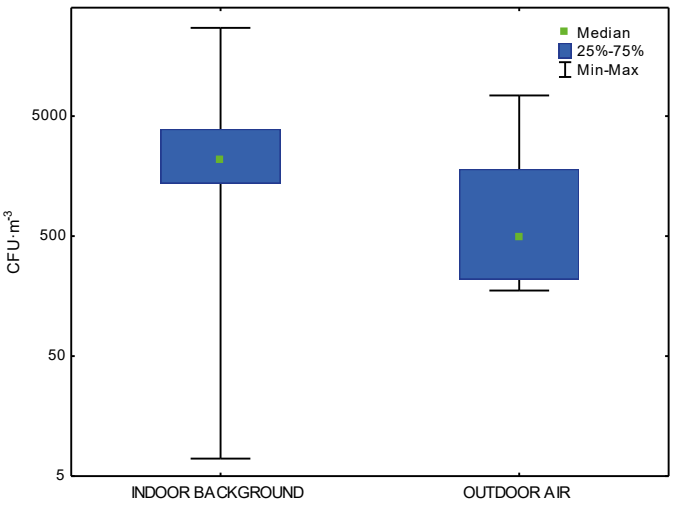

Figure 2. Average concentration of fungi (CFU·m^{-3}) in the indoor background (corridors) and outdoor air.

Table 2. Values of microclimate parameters of the indoor and outdoor air.

Sampling points		Temperature (°C)			Relative humidity (%)		
		Range	Mean	Standard deviation	Range	Mean	Standard deviation
School rooms	Small classrooms	19,8 – 27,0	22,7	2,2	33,0 –58,9	48,9	7,8
	Large classrooms	21,0 – 25,0	22,5	1,6	42,9 – 65,0	51,3	8,1
	Sports halls	18,2 – 23,1	21,1	1,8	32,0 – 61,1	46,2	10,8
Indoor backgrounds (corridors)		19,6 – 26,0	21,5	1,9	36,0 – 60,2	45,6	8,3
Outdoor air (background)		2,8 – 14,1	9,3	1,6	40,7 – 80,4	66,5	13,1

and the interior of the studied school premises (Kruskal-Wallis test: $p>0.05$). For naturally ventilated school interiors, the unhindered inflow of bioaerosol from the outside ensured the removal of pollutants resulting from indoor emission, achieved by diluting or displacing pollutants with outdoor air. The results obtained for both indoor and outdoor bioaerosol concentration measurements were compared with the recommended Polish threshold values, which are 5×10^3 CFU·m^{-3} for fungi in both indoor and outdoor environments (Augustyńska and Pośniak 2016). Any exceedance of these values, as confirmed by measurement, would suggest the presence of an additional source of pollution (Górny et al. 2011, Górny 2019). However, it is worth noting that the concentrations of fungal aerosol in the atmospheric air and within all tested school rooms were lower than the recommended threshold values.

Concurrently with the measurements of the fungal aerosol, environmental parameters, specifically temperature and relative humidity, were also measured. The results of these measurements, presented in Table 2, showed that they did not differ significantly among individual school rooms (Kruskal-Wallis test: $p>0.05$). Similar disparities did not arise when comparing the relative humidity of indoor and outdoor background, however, statistically significant differences were observed for temperature (Kruskal-Wallis test: $p<0.05$). The temperature and relative air humidity ranges were as follows: indoor – temperature: 18.2 - 27.0˚C, relative humidity: 32.0 - 65.0%; outdoor - temperature: 2.8 - 14.1˚C, relative humidity: 40.7 - 80.4%.

Using the Spearman's correlation coefficient, the impact of microclimatic parameters on the concentration of fungal aerosol in the school premises, environment was assessed. Based on the results of the analysis, it was found that the relative humidity of the air had a significant impact on the observed levels of the tested microorganisms. The correlation analysis showed that each increase in the value of this meteorological parameter resulted in a significant increase in the levels of fungi in the air of classrooms and indoor background ($R=0.32$ $p<0.05$). Similar relationships were noted by Ejdys (2009) when assessing the seasonal impact of atmospheric air on the quality of bioaerosol in school rooms in urban conditions. On the other hand, the number of fungi in the examined indoors was statistically significantly ($p<0.05$) negatively correlated with air temperature (respectively $R= - 0.38$ $p<0.05$). As the analysis showed, there was no significant correlation ($p>0.05$) between air temperature and relative humidity or between air temperature and the occurrence of the tested microorganisms in the outdoor air.

The results of measurements of general dust concentrations obtained with the DustTrak II impactor in school premises and in the outdoor background are presented in Table 3.

Dust is a factor that can have a significant impact on the amount of microorganisms present in the air (Jurado et al. 2014, Grzyb and Lenart-Boroń 2020). The concentration of dust in the air of the tested rooms ranged from 0.06 mg·m^{-3} to 0.41 mg·m^{-3}, and in the outdoor background in vicinity of the tested objects from 0.05 mg·m^{-3} to 0.60 mg·m^{-3}. The

Table 3. General dust concentrations in the indoor and outdoor air.

Sampling points		Total fraction (mg·m^{-3})			Respirable fraction (mg·m^{-3})		
		Range	Mean	Standard deviation	Range	Mean	Standard deviation
School rooms	Small classrooms	0,07 – 0,25	0,13	0,05	0,06 – 0,17	0,10	0,03
	Large classrooms	0,06 – 0,20	0,12	0,04	0,06 – 0,19	0,11	0,04
	Sports halls	0,08 – 0,41	0,17	0,09	0,06 – 0,24	0,14	0,06
Indoor backgrounds (corridors)		0,06 – 0,39	0,16	0,09	0,06 – 0,32	0,14	0,07
Outdoor air (background)		0,05 – 0,60	0,18	0,15	0,05 – 0,46	0,16	0,11

average concentration of total dust indoor schools ranged from 0.12 mg·m^{-3} to 0.17 mg·m^{-3} and was the highest in sport halls during physical activity, confirming that dust was elevated in the hall due to increased air movement (Basińska and Małkiewicz 2016, Fsadni et al. 2017). However, the analysis of correlations between the concentrations of total dust in the air and the concentrations of fungi in school rooms did not show statistically significant relationships ($p>0.05$). The presented relations differ from those observed in other school environments (Fsadni et al. 2017, Sheik et al. 2015). The analysis of total dust concentrations measured in the outdoor background and indoors the tested objects also showed that they did not differ statistically significantly (Kruskal-Wallis test: $p>0.05$).

Literature data show that an important parameter for assessing the effects of biological aerosols on the human body is the determination of the aerodynamic diameter of their particles. This feature determines their behavior and dynamics in the air, and thus determines their deposition in a specific space or on the surface (Auger and Moore-Colyer 2017, Górny et al. 2020). The use of the 6-stage Andersen impactor in the bioaerosol research allowed us to obtain data on the size distribution of fungi in indoor and outdoor air in schools. The results of the analysis are presented in Figure 3.

The analysis of the grain distribution of the fungal aerosol in the studied school rooms indicates the presence

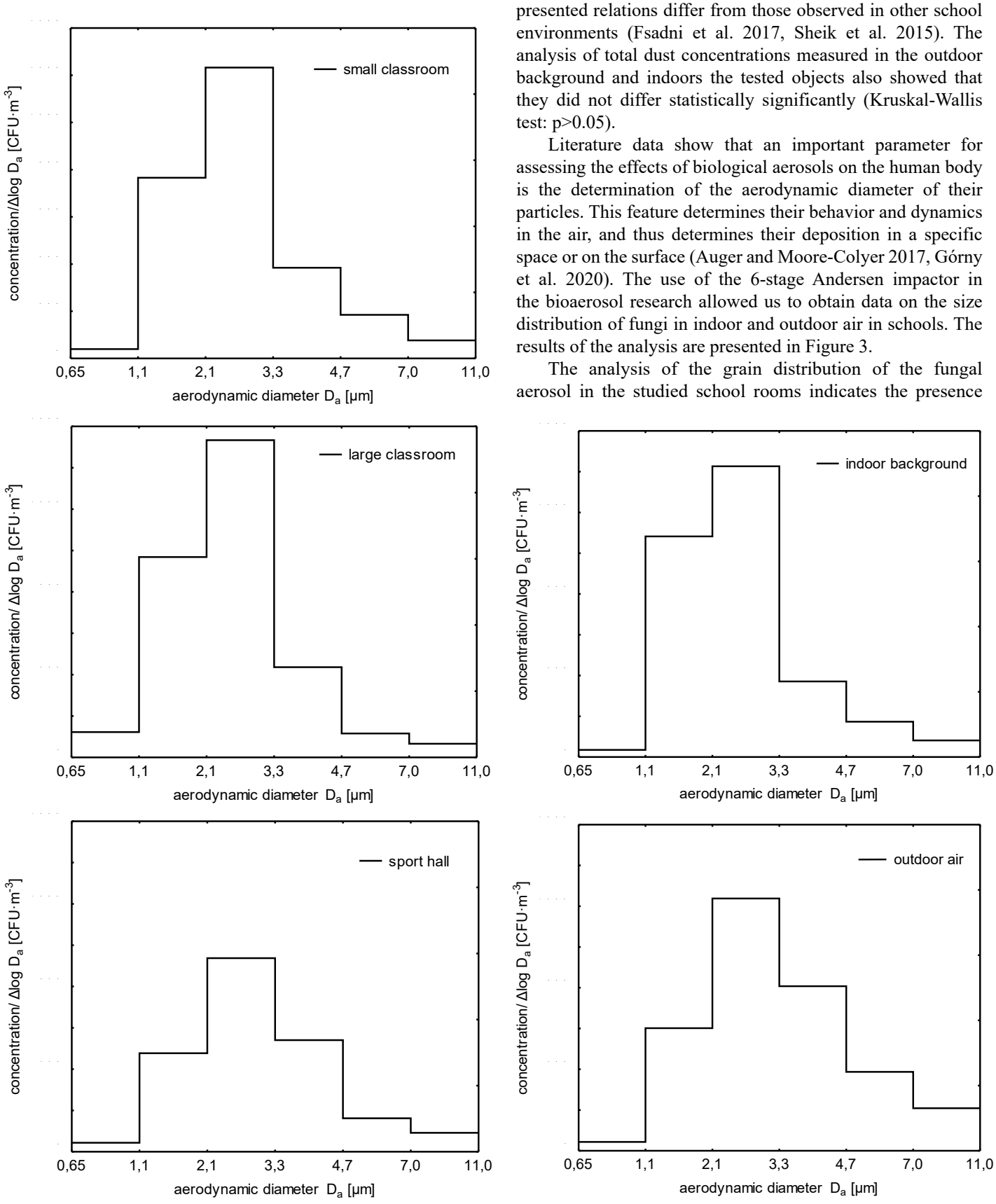

Figure 3. Grain distributions of the fungal aerosol (mean values) in the air: (a) Small classrooms, (b) Large classrooms, (c) Sports halls, (d) Indoor backgrounds (corridors), (e) Outdoor air (backgrounds).

of these microorganisms mainly in the form of single spores (2,1–3,3µm).

The analysis of the fungal aerosol grain distribution curve for the "indoor background" shows that the fungal aerosol also reached its maximum concentrations in the diameter range of 2.1-3.3 µm. This suggests that, as in the case of classrooms, the fungi present here dominate as single spores dispersed in the air. Furthermore, the analysis of the grain distribution of the fungal aerosol for the "outdoor background", determined for school rooms, reveals a similarity in the course of both curves, which leads to the conclusion that in the outdoor environment, fungi were also present in the form of single spores (2.1-3.3 µm). This aligns with the trend observed by other researchers. This fact can significantly impact on the actual exposure and the dose of inhaled particles (Clauß 2015, Gołofit-Szymczak et al. 2015, Górny et al. 2020). Particles smaller than 2.5 µm in diameter (PM2.5) can remain in the air for a long time, can interact with other substances and are harmful for human health (Feng at al. 2021). Based on the conducted tests and the obtained data on particle size distributions, it can be inferred that in the case of a fungal aerosol, the "load" of microorganisms of the above-described sizes can penetrate into the lower respiratory tract, reaching the region of the bronchioles and the alveolar region of the lungs. This information is particularly important for the assessment of the effects of the fungal aerosol on the human body because the site of deposition of the harmful agent enables the prediction of potential adverse health effects resulting from this type of exposure (Clauß M. 2015, Estillore et al. 2016, Górny at al. 2020).

The predominant fungi isolated from the air of the tested rooms were identified to the genus level. The conducted qualitative analysis showed the presence of mold and yeast fungi both indoors and outdoors. In total, 10 genera of fungi were isolated and identified, which illustrates the typical composition of the mycobiota of this type of environment. The most frequently isolated fungi were represented by genera *Cladosporium*, *Penicillium* and *Aspergillus*, which are considered typical for this type of indoor environment. The clear dominance of these genera of fungi in the air of school buildings is also confirmed by the results obtained by other researchers who analyzed this type of interior (Jo and Seo 2005, Chegini et al. 2020). The main habitat for molds is the natural environment, mainly soil and plants. Their spores can migrate into rooms via clothing, hair of students and employees, and through open windows, doors and any other openings, thus colonizing the indoor environment. In the environment of the classrooms, spores can live long on the equipment used, elements of heating and ventilation systems, building materials, books and papers, maintaining the ability to survive for a long time (Puspita et al. 2012). The obtained results are consistent with findings from tests conducted in other buildings (Gołofit-Szymczak and Górny 2010). The percentage shares of individual genera of fungi in relation to the total mycobiota isolated from air samples collected indoors and outdoors are shown in Figure 4.

The qualitative identification of fungi showed that the most numerous representative of fungal microorganisms found in the air were fungi belonging to the genera *Cladosporium* and *Penicillium*. Their percentage share was 43.8–51.4% and 19.1–24.8%, respectively, in relation to the total identified air mycobiota. The share of other isolated types of fungi, such as *Aspergillus, Alternaria, Absidia, Epicoccum, Fusarium, Rhizomucor, Scopulariopsis, Trichoderma,* did not exceed 31.4% of the total mycobiota of the air of the examined indoors. These results are consistent with data obtained in tests of other rooms, including residential and other commercial premises (Lee and Jo 2006, Bulski and Frączek 2021). The literature on the subject shows that mold fungi, mainly of the genera *Aspergillus*, *Cladosporium* and *Penicillium*, may pose a particular threat to human health, as they are the most common cause of allergy to molds. It is believed that around 30% of health problems related to

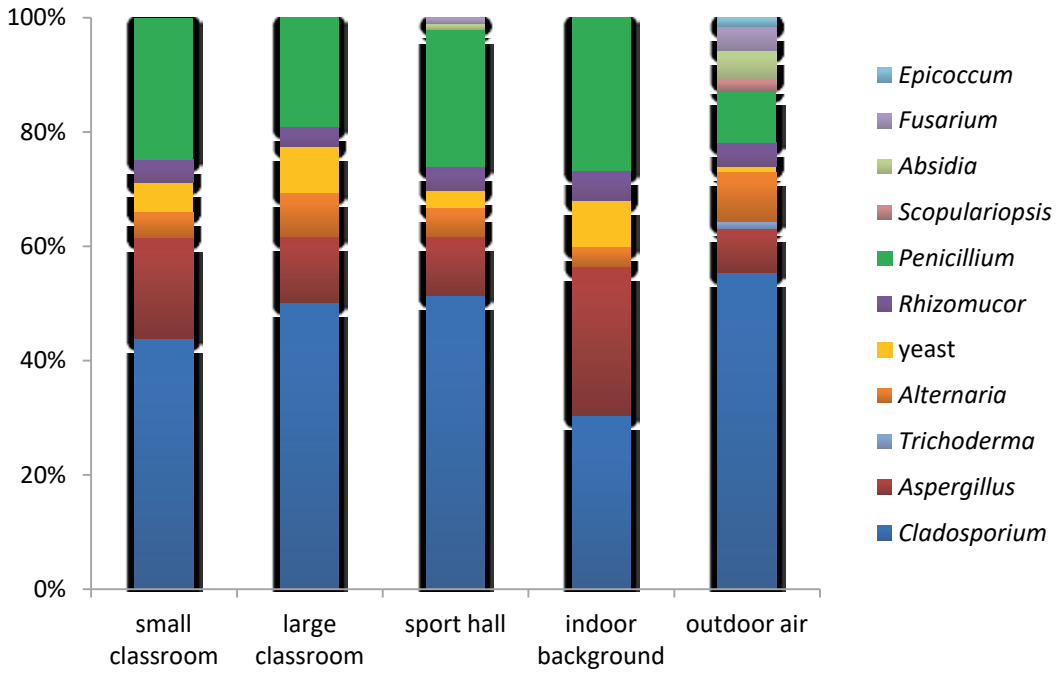

Figure 4. The share of predominant fungi genera isolated from the air in the studied school indoors and in the outdoor air.

indoor air quality are the result of the human body's response to molds (Ejdys 2009, Simon and Duquenne 2014). The air samples collected outdoor were dominated by fungi of the genus *Cladosporium*, which constituted 55.5% of the total isolated mycobiota. Fungi belonging to the genus *Alternaria* (8.6%) and *Aspergillus* (7.7%) were next in terms of the frequency of isolation, which illustrates the typical composition of the outdoor mycobiota.

Conclusions

The results of the research showed that the quality of the tested school rooms located in Lesser Poland (Małopolskie Voivodship) in terms of their mycological contamination of the air is good. Fungal aerosol concentrations in the tested classrooms did not exceed the proposed limit values for this type of interior. It was found that fungal aerosol concentrations in both indoor (classrooms and corridors) and outdoor air did not differ significantly in the tested environments. In the studied school premises, the highest fungal contamination concentrations were typically recorded in large classrooms when students were present. However, there were no significant differences in contamination between the classrooms. The qualitative assessment of the aerosol mycobiota showed that fungi of the genera *Cladosporium*, *Penicillium*, and *Aspergillus* were most often isolated from the indoor air. Based on the data on particle size distributions, fungi can reach the bronchioles and alveoli in the human respiratory system of students and employees. The analysis of the correlation between the concentrations of total dust and the concentrations of fungi in the indoor air showed no statistically significant dependencies. The analysis of the relationship between microclimate parameters and fungal aerosol concentrations confirmed that only relative air humidity had an impact on the level and composition of fungal populations. Such a situation is highly unfavorable for students and employees, especially those with respiratory diseases, as additional exposure to potentially allergenic and/or toxic fungal spores can adversely affect the health. Therefore, constant monitoring of air humidity is crucial in school premises. These findings highlight that natural ventilation is insufficient to maintain adequate indoor air quality in such buildings. Consequently, it is worth considering the installation of efficient ventilation or air-conditioning systems to provide clean air in school rooms.

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Ocena narażenia na aerozol grzybowy w pomieszczeniach szkół województwa małopolskiego

Streszczenie: Ocena jakości mykologicznej powietrza w pomieszczeniach dydaktycznych 10 budynków szkolnych zlokalizowanych w województwie małopolskim (Polska). Do badań aerozolu grzybowego wykorzystano 6-stopniowy impaktor kaskadowy Andersena. Podczas pobierania próbek wykonano pomiary zapylenia (za pomocą pyłomierza DustTrak II) oraz temperatury i wilgotności względnej. Badano powietrze w małych i dużych klasach oraz w salach gimnastycznych, tło wewnętrzne stanowiły korytarze a zewnętrzne powietrze atmosferyczne. Dominujące rodzaje grzybów oznaczono metodą MALDI-TOF MS. Na podstawie uzyskanych wyników stwierdzono, że pomiędzy badanymi obiektami (szkołami) nie wystąpiły statystycznie istotne różnice w stężeniu grzybów w powietrzu wewnętrznym ($p>0,05$). Największe zróżnicowanie aerozolu grzybowego obserwowano w dużych salach lekcyjnych (max. 2678 CFU·m-3), jednak różnice te nie były istotne statystycznie pomiędzy różnymi typami pomieszczeń (test Kruskala-Wallisa: $p>0,05$). Wszystkie pomieszczenia były w porównywalnym stopniu zanieczyszczone aerozolem grzybowym. Najczęściej izolowane grzyby reprezentowały rodzaje Cladosporium, Penicillium i Aspergillus. Wilgotność względna powietrza miała istotny wpływ na liczebność mikroorganizmów. Stężenia aerozolu grzybowego w badanych pomieszczeniach dydaktycznych nie przekraczały proponowanych wartości granicznych dla tego typu wnętrz. Wyniki wskazują, że wentylacja naturalna w pomieszczeniach szkolnych nie wystarcza do zapewnienia odpowiedniej jakości mikrobiologicznej powietrza.