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ORIGINAL PAPER

Assessment of fungal aerosols in a public library with natural ventilation

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Abstract Fungal aerosols deteriorate library collections and can impact human health, mainly via respiratory diseases. Their spread is influenced by factors such as temperature and relative humidity. This study aims to assess the concentration of fungal aerosols in the interior environment of the Popular Library of Gaira in the District of Santa Marta, Colombia, using a two-stage cascade impactor utilizing Sabouraud dextrose agar on Petri dishes for the collection of samples. The sampler was positioned at 1.5 m above ground level, operated with a flow rate of 28.3 l/min for 4 min and thermo-hygrometric conditions were also recorded. Concentrations in the air of up to 1197.0 CFU/m^3 were reported, with a mean value close to 150 CFU/m^3. Higher values during the morning samples were noted. Seven genera of fungi were found, *Aspergillus* and *Curvularia* were the most abundant. The temperature was between 30.80 and 33.51 °C, and the relative humidity was between 62.61 and 64.80%. Statistical analysis showed a significant correlation between the fungal aerosol concentration and relative humidity, where an increase of 10% in moisture could double the fungal aerosol concentration. We concluded that potentially favorable conditions exist indoors for the growth and survival of the following fungi: *Aspergillus*, *Penicillium*, *Cladosporium*, and *Curvularia,* and to a lesser extent for *Chrysonilia*, *Cunninghamella*, and *Paecylomices*. Relative humidity was seen to be the factor that affects the concentration of aerosols fungal in the library most significantly.

Keywords *Aspergillus* · Books collection · Cascade impactors · Indoor environment · Thermo-hygrometric conditions

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1 Introduction

Air quality in the indoor environment can be influenced by biotic agents such as microorganisms, spores, mites, and pollen. With these particle types general termed bioaerosols (Jeong et al., 2022). These

habitual components of the indoor environment can be transported from the outside by dust particles (Li et al., 2022). In tropical areas, these aerosols have an important risk factor owing to the presence of fungal spores (Sánchez Espinosa et al., 2021), which could proliferate on various materials when the humidity and temperature are optimal (Okpalanozie et al., 2018). Due to the impact on human health of these bioaerosols (Manibusan & Mainelis, 2022), the relevance to air quality studies has increased in terms of their concentration in libraries (Savoldelli et al., 2021), commercial areas (Sykes et al., 2007) and industrial facilities (Thorne, 2019), offices (Mandal & Brandl, 2011), hospitals (Abbasi et al., 2020; Liu et al., 2020), childcare centers (Hoseinzadeh et al., 2017), schools (Pyrri et al., 2020b), and universities (Hayleeyesus et al., 2015; Li et al., 2020).

Indoor environments of archives and libraries are a reservoir of bioaerosols (Borrego, 2020), that not only pose a risk to their collections (Hassan et al., 2021) but also to human health (Li et al., 2022). Due to their specific functional character, libraries constitute a unique microenvironment where the possibility of contamination with microorganisms is high (Kalwasinska et al., 2012), especially when the exposition route is by inhalation (Pyrri et al., 2020a). Lower respiratory tract diseases (bronchitis and pneumonia) are predominantly caused by bacteria and fungal cells/spores (Marcovecchio & Perrino, 2021). Likewise, environmental exposure to fungi is linked to acute and severe asthma attacks (Van Tilburg Bernardes et al., 2020; Welsh et al., 2021), allergic fungal rhinosinusitis (Rowan et al., 2020), and upper respiratory infections (Kwan et al., 2020). In circumstances with total concentrations of total fungal load more than 1000 CFU/m^3 is considered a risk for inhabitants with hypersensitivity to allergens (Reboux et al., 2019). The magnitude of the impact depends on the type, concentration of fungal aerosol, and the biological/immunological response of each person (Borrego & Perdomo, 2014; Chakrabarti et al., 2012).

Libraries require specific thermos-hygrometric conditions (Fizialetti et al., 2017), which are necessary for conserving bibliographic material (Micheluz et al., 2015). It is recommended to control temperature and relative humidity (Haleem Khan & Mohan Karuppayil, 2012), keeping in a range of 19–24 °C and 50–60% relative humidity. These conditions, together with books material, supply a source of nutritional and environmental requirements for microorganisms (Kalwasinska et al., 2012). Hence, the materials affected by biodeterioration include organics such as paper, wood, textiles, parchment, leather, paintings, and plastics. This denotes the importance of protecting library materials such as manuscripts, books, magazines, paintings, and paper maps (Chadeganipour et al., 2013).

Different fungal aerosols with cellulolytic and lipolytic properties are responsible for library stocks' biodeterioration, which include *Alternaria, Aspergillus, Botrytis, Chaetomium, Cladosporium, Penicillium,* and *Verticillium* (Delgado et al., 2020; Harkawy et al., 2011). These aerosols have been reported in several studies in public libraries, such as the National Library of Greece (Pyrri et al., 2020a); the library of a Nigerian museum (Okpalanozie et al., 2018); Lafragua library of Benérita Universidad Autónoma de Puebla, Mexico (López-García et al., 2011); five libraries in Havana, Cuba (Rojas y Aira, 2012); and in the library of New Delhi University, Indian (Ghosh et al., 2013).

Based on this evidence, it is crucial to identify the potential sources and dispersion of predominant fungal aerosols species in the indoor environment of libraries as started point to analyze the risk of exposition (Pyrri et al., 2020a; Carmargo Caicedo, 2011). Thus, this work aimed to assess fungal aerosols in the interior environment of the Popular Library of Gaira in the District of Santa Marta, Colombia. The analysis is broken into three aspects: (i) the concentrations levels, (ii) the fungal species, and (iii) the relationship between the thermo-hygrometric conditions and the concentrations reported in the library.

2 Materials and methods

2.1 Study area

This study was undertaken in the Popular Library of Gaira located in the northwest (commune 7) of the District of Santa Marta, Colombian Caribbean region, where there are no seasons but pluviometry regimens characterized by dry and rainy times (IDEAM—Instituto de Hidrología, Meteorología y Estudios Ambientales, 2014). The library under investigation has a collection of 3500 items (mainly books), with a natural ventilation system through two windows and the

main access door, in addition to the use of ceiling fans for environmental conditioning of the site. The monitoring campaign was commenced between February–June (one sample per month) and avoided sampling during rainy days because the library closes its windows, which changes the air mass fluxes.

2.2 Sampling

In the library, two monitoring stations were ubicated as follows: Point 1 around the bookshelves and point 2 in the reading area, using the available space, the location of the collections, avoiding the direct influence of the ventilation systems as selection criteria, and workdays. For sampling, a two-stage cascade impactor from Tisch Environmental was used, which allows for the collection and differentiation of coarse particles from respirable ones while simulating the human respiratory system (Fig. 1). The impactor was operated at the height of 1.5 m so that particulates would be captured at the respirable level (Grzyb et al., 2022; Jeong et al., 2022), at a flow rate of 28.3 l/min verified by a rotameter attached to the device.

The sample collection time was determined by applying a pre-sampling at three times (4, 6, and 10 min) established from previous studies (Grinshpun et al., 2016; Vélez-Pereira & Camargo Caicedo, 2014a, 2014b; Vélez-Pereira et al., 2010), and using for the selection of the optimal collection time, the statistical parameters confidence limits and precision of the concentrations reported in the tests at different times, which allowed establishing an optimal time of 4 min. The thermo-hygrometric conditions were established through temperature (T, °C) and relative humidity (RH, %). These parameters were collected with HOBO U12 Temp/RH/ Light/External Data Logger.

All samples were taken throughout two periods of the day: morning and afternoon. Four samples were performed at each station daily at 40-min intervals, using the pre-established sampling intervals. This was done to obtain a value for each day, where the thermo-hygrometric conditions and the activities were representative. The culture medium used to support the growth of the fungal aerosols was Sabouraud dextrose agar (SDA) at 4%.

To guarantee the quality of the samples, quality assurance and control protocols were applied, as shown in Fig. 2, which consisted of the preparation of additional Petri dishes that were incubated at the end of each phase of the process for taking and processing the sample, and to verify the absence of growth of microorganisms due to contamination or inadequate processes. Additionally, other measures were applied for quality assurance and control, by wrapping Petri dishes in plastic film to avoid exposure to external contaminants and subsequent sealing of the collection boxes with paraffin film to allow microorganisms to breathe but prevent the entry of particles and/or microorganisms that contaminate the sample. Another complementary measure consisted of sterilizing the cascade impactor between changes of each Petri dish through a combination of disinfection with alcohol and thermal shock (flaming).

2.3 Sample processing and analysis

Subsequently, the Petri dishes with samples are incubated at 25 °C for five days. Then, the resultant colonies were counted and divided by the air volume sampled (0.1132 m^3 for each sample), resulting in concentrations of the Colony Forming Units (CFU/m^3). The calculation of the concentration of a fungal aerosol test corresponds to the sum of the arithmetic

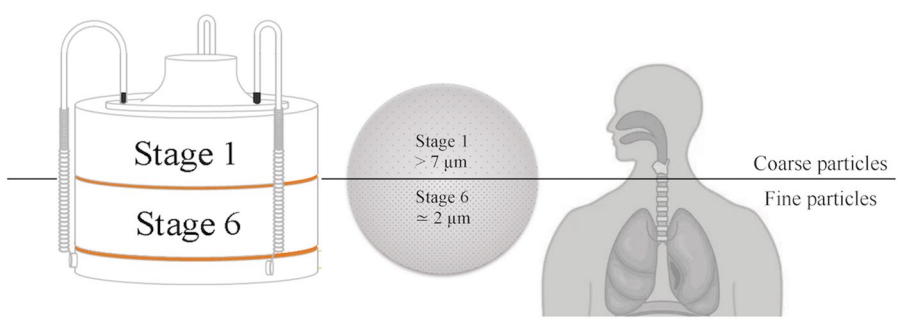

Fig. 1 Cascade impactor diagram, its relationship to aerodynamic particle size and the human respiratory system. Adapted from Camargo et al. (2011)

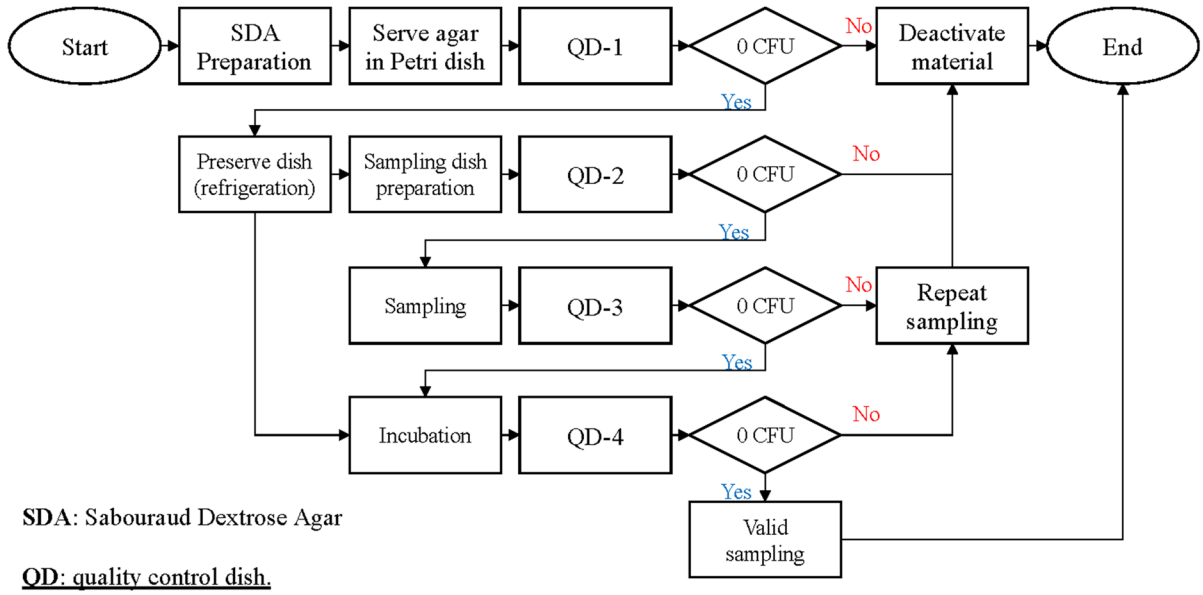

Fig. 2 The protocol for quality assurance and control in samples

average between the origin and the replica of each stage.

The genera were found by macroscopic and microscopic analysis. The microscopic examination was carried out by staining with lactophenol blue and specimen observation under the 10X, 40X, and 100X objectives. Morphological fungal identification was based on taxonomic keys by Barnett and Hunter (1987), Raper and Fennell (1965), and Carrillo (2003) from the presence of conidia, spores, or other resistance structures.

2.4 Statistical analysis

In the statistical analysis of data, analysis of variance (ANOVA) was applied to determine significant differences in concentrations of fungal aerosols and thermo-hygrometric conditions by experimental parameters: points, time of the day, and interval of the time of de day. A simple and multivariate regression was applied for the correlation analysis between thermo-hygrometric conditions and concentration. Different adjustment models were assessed during the simple regression, which was looked to find the best mathematical relationship between a pair of variables. The multivariate regression was sought to determine the incidence of the thermo-hygrometric conditions over the concentration of fungal aerosols. All tests were performed with 95% interval confidence with a p-critical value of 0.05.

3 Results

3.1 Fungal aerosol concentrations

The maximum concentrations of fungal aerosols recorded during the five monitoring campaigns were reported in Campaign 3 in point 2, with a concentration of 1197.00 CFU/m^3 in the afternoon and 627.21 CFU/m^3 in the morning (Fig. 3). On the other hand, the minimum concentration values were reported in the second campaign—point 1, with 26.50 CFU/m^3 in the morning and 30.92 CFU/m^3 in the afternoon. The median value of point 1 has 167.84 CFU/m^3 in the morning and 108.22 CFU/m^3,

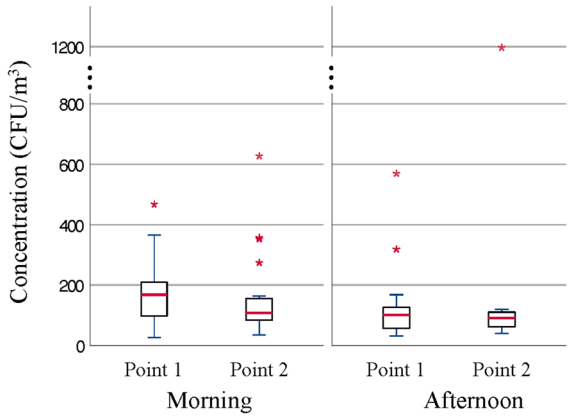

Fig. 3 Concentration of fungal aerosols in the Popular Library of Gaira by the time of the day and sampling point

3.2 Fungal aerosol genus and species

Figure 4 shows the results of the concentration of found genera of fungal aerosols. In total was identified seven species. Only in the case of *Aspergillus* was a differentiation of species obtained, eight in total. In the morning, *Cladosporium* reported the absolute highest concentration (481.45 CFU/m^3), while in the afternoon, it was *Aspergillus* (383.17 CFU/m^3); in both cases, the values were reported in point 2 during campaign 3. In the morning, the most predominant species is *Aspergillus* (48.5%), followed by *Cladosporium* (18.4%) and *Curvularia* (14.5%), while in the afternoon are *Aspergillus* (54.0%), Yeasts (11.4%) and *Cladosporium* (8.9%).

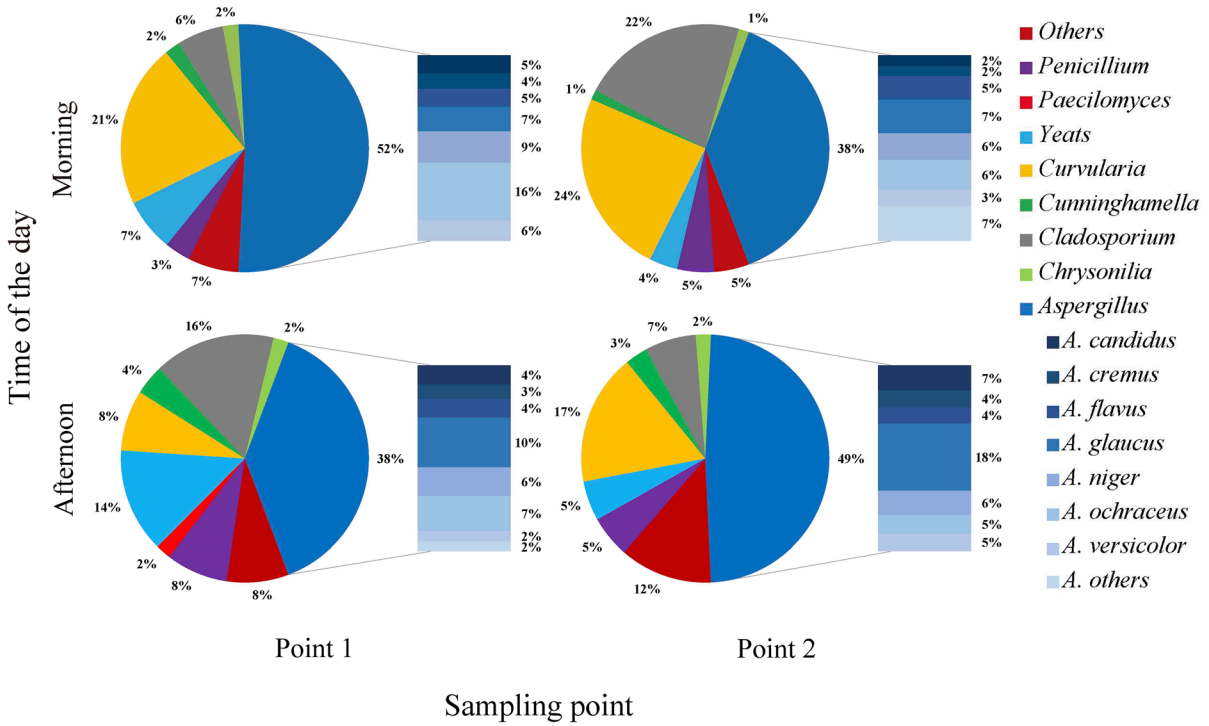

Fig. 4 Percentage distribution of genera and species of fungi identified in the Popular Library of Gaira by the time of the day and sampling point

while point 2 shows 101.59 and 90.55 respectability. Also, we can observe that morning has higher values than afternoon, with more concentration variability throughout the sampling campaigns. The mean value of the samples was 167.40 CFU/m^3 in the morning and 133.39 CFU/m^3 in the afternoon.

3.3 Thermo-hygrometric conditions

Figure 5 shows the behavior temperature (Temp, °C) and relative humidity (RH, %). These data allow us to infer that a lower average temperature was recorded

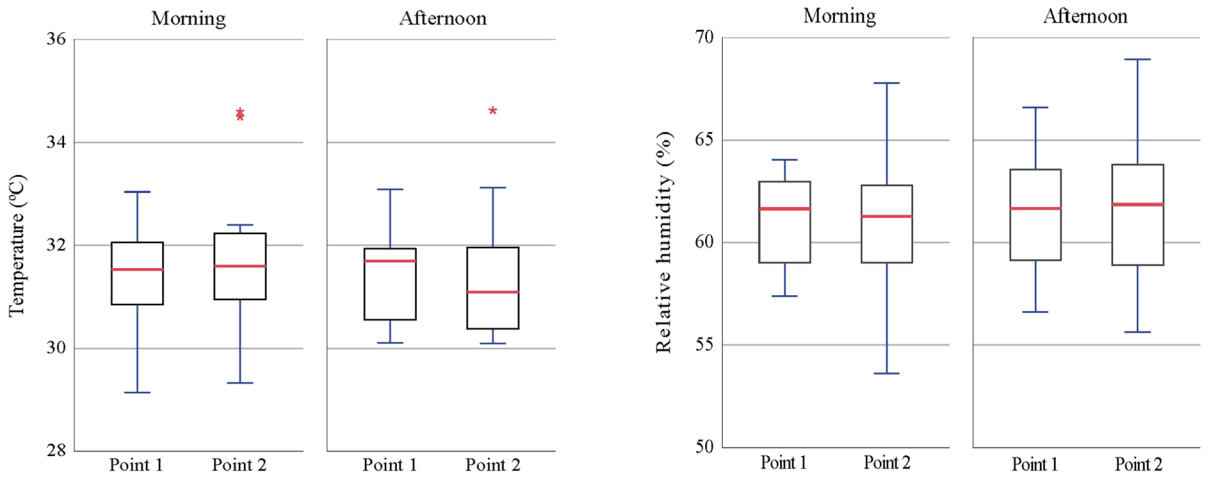

Fig. 5 Thermo-hygrometric conditions in Popular Library of Gaira. Left side temperature. Right side relative humidity

in the morning (30.82 °C) compared to the afternoon (32.65 °C). The sampling point does not show a significant difference; however, a slight increase was seen from the first sampling interval. This result is ratified by the ANOVA test, where only the interval of a sampling (P-value of 0.00) shows influence on Temp mean values. The relative humidity has inverse behavior to that of temperature. For this case, the morning (62.96%) registered a higher value and decreased to the afternoon (58.28%). Also, the ANOVA test shows the influence of interval sampling on the variation of RH.

Finally, Table 1 summarizes the statistical parameters presented in the correlation analysis between the thermo-hygrometric conditions (Temp and RH) and the concentration of fungal aerosols in the Popular Library of Gaira. The best fit model for Temp presents a low correlation between the data showed by the R2 coefficient, ratified by ANOVA (*P*-value 0.091), rejecting the model's hypothesis that significantly fits the data. While the adjustment model selected for RH presents a higher coefficient R2, and the ANOVA test (*P*-value: 0.000) shows a significant correlation. The multiple correlation analysis shows an R2 coefficient of 10.96%, but the ANOVA test shows that the Temp is not significant for the model.

4 Discussion

Poor indoor air quality is one of the leading factors of Campo's global disease burden (Zhao et al., 2022). Fungal aerosols can be abundant in the indoor environment and are associated with adverse health effects through inhalation and epidermal exposure (Li et al., 2022). Fungi can behave as allergens, and if the concentration of spores exceeds 2000 CFU/m^3, they are a health risk factor (Morales

Table 1 Statistical summary of the correlations established between the thermo-hygrometric conditions and the concentration of fungal aerosols in Popular Library of Gaira

Experimental design	Best-fit equation	Value of the coefficients	Coefficient R2 (%)	MAE
$f(T, [])$	$y = \beta_0 + \frac{\beta_1}{x}$	β_0: − 584.84 β_1: 23,274	3.61	91.55
$f(HR, [])$	$y = e^{(\beta_0 + \beta_1 x^2)}$	β_0: 1.83 β_1: 0.0007	18.20	0.0001
$f(T, HR;[])$	$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2$	β_0: − 1572.36 β_1: 14.88 β_2: 20.63	10.96	0.011

et al., 2015). It is important to bear in mind that microbial concentrations above 100 CFU/m^3 of air can be important levels from the point of view of biodeterioration of materials (García et al., 2014). Numerous studies in libraries throughout the world have shown the presence of fungi aerosols in libraries (Anaya et al., 2016; Flores et al., 2014; Harkawy et al., 2011; Pasquarella et al., 2020; Wu et al., 2020), and due to the fact that bibliographic materials are composed primarily of organic materials they are vulnerable to attack by biological agents. Besides, the growth of microorganisms is favored by certain physical and chemical factors, such as high temperature and humidity (Almaguer et al., 2020).

The difference in the concentration behavior throughout the day could be attributed to the specific environmental conditions of sporulation of the genera found. The variation between the data reported between night to morning, indicate the temperature increased, and the RH decreased, a situation reported as ideal for the sporulation of these genera (Díez et al., 2006; Rúa Giraldo, 2013; Sindt et al., 2016; Vélez-Pereira et al., 2021). In addition, if taken into account that the opening of the library in the morning generates a high(outdoor)/low(indoor) pressure system, which causes the infiltration of ambient air through the air currents of the building (Erhart et al., 2015; Harkawy et al., 2011; Wang et al., 2021).

According to Harkawy et al. (2011), fungal aerosol concentrations did not exceed 100 CFU/m^3 with natural ventilation in Poland, where air temperature and relative humidity ranged between 19.0–20.1 °C and 51–60%, respectively. However, temperature values of the Gaira library are higher than previous work, favoring proliferation, and may explain the slightly higher concentrations. Likewise, other studies affirmed dust particles' transport from the outside in tropical areas due to the content of fungal spores that grow when the temperature and relative humidity are optimal (Hassan et al., 2021; Okpalanozie et al., 2018; Savoldelli et al., 2021). On the other hand, A study conducted in the libraries of a public university located in Islamabad (Pakistan) found that fungal concentrations ranged within 20–250 CFU/m^3 indoors and 280–510 CFU/m^3 in outdoor, concluding that the outdoor air was the major contributor of indoor fungal buildup (Hassan et al., 2021). All earlier arguments establish that concentrations can be influenced by the outdoor environment rather than by the indoor conditions of the library.

However, the point close to bookshelves (point 1) shows higher values. Then, it is inferred that books could be infected and will be a potential source of emission of fungal aerosols (Wu et al., 2021). The concentration recorded of 1197.00 CFU/m^3 in the afternoon could be attributed to unusual activity or events in the library. The ANOVA test confirms this because the sampling campaign was the only statistical design criteria that showed a significant influence on the variation of the concentration.

Table 2 shows a comparison of genera predominant found in different studies. *Aspergillus* shows high consistency as the most predominant; *Cladosporium* is reported as a second, and in other studies, is usually the third; and *Curvularia* reports third, but it is not reported in other studies as predominant. All these genera are reported in the aerobiological spectrum studies (Alam et al., 2022; Alzate Guarín et al., 2015; Dey et al., 2019; Vélez-Pereira et al., 2021); also, they are recognized as aeroallergens particles (De Linares et al., 2022; Hernandez-Ramirez et al., 2021; Kasprzyk et al., 2021; Rúa Giraldo, 2013). The high concentration and predominance of *Aspergillus* can be attributed to the small size of their spores which can allow a long lifetime in the air (Reponen et al., 2001; Richardson & Rautemaa-Richardson, 2021). While *Cladosporium* is the most abundant outdoor fungal spore (Anees-Hill et al., 2022; Sánchez Espinosa et al., 2021), and *Curvularia* is highly frequent in tropical or subtropical climates (Almaguer et al., 2021).

Equally, *Penicillium* species are present in the air and dust of indoor environments. They could grow even if the relative humidity is low or there is enough moisture on a given surface. Moreover, species belonging to the genera *Aspergillus* and *Penicillium* can digest additives, adhesives, or fabrics used in bookbinding (Apetrei et al., 2009). Likewise, it is important to note, that the genus *Cunninghamella* it not been reported in another study, however, some recent studies on India and Cuba reported low-concentration levels of this genus in the air (Díaz et al., 2020; Prakash et al., 2020). *Cunninghamella* is characterized by rapid growth and by producing an invasive zygomycosis due to a large number of fungal pathogens, which correspond to a set of mycoses afflict immunodeficient patients and stand out due

Table 2 Comparative results of predominant and quantity fungal genus on library

Continent	Country	Sampling methods	Type of library	Most predominant genus			Total genus	Reference
America	Colombia	Active	Open	*Aspergillus* (51%)	*Cladosporium* (14%)	*Curvularia* (11%)	8	Present work
		Passive	Close	*Mucor* (37%)	*Penicillium* (28%)	*Cladosporium* (8%)	11	Toloza-Moreno & Lizarazo-Forero, (2011)
	Cuba	Passive	Not reported	*Cladosporium*	*Aspergillus*	*Penicillium*	6	Borrego & Perdomo, (2014)
		Active	Not reported	***Aspergillus* (65%)**	*Penicillium* (NR)	*Cladosporium* (NR)	21	Rojas & Aira, (2012)
	Ecuador	Passive	Not reported	*Penicillium* (80%)	*Mucor* (8%)	*Chaetomium* (4%)	9	Rodríguez-Segovia et al., (2020)
		Active	Close	*Cladosporium*	*Penicillium*	*Aspergillus*	16	Carrera et al., (2017)
	Mexico	Passive	Not reported	*Monilia*	*Aspergillus*	*Penicillium*	6	López-García et al., (2011)
		Active	Not reported	*Cladosporium* (53%)	*Penicillium* (13%)	*Mycelia sterilia* (12%)	28	Morales et al., (2015)
Asia	China	Passive	Open	***Aspergillus*** (94%)	***Cladosporium*** (3%)	*Schizophyllum* (3%)	8	Wu et al., (2021)
	India	Active	Open	***Aspergillus* (63%)**	*Rhizopus* (15%)	*Cladosporium* (11%)	6	Ghosh et al., (2013)
	Pakistan	Active	Open/ Close	*Penicillium* (44%)	***Cladosporium*** (31%)	*Aspergillus* (13%)	5	Hassan et al., (2021)
Europe	Polonia	Active	Not reported	***Aspergillus***	***Cladosporium***	*Penicillium*	19	Skóra et al., (2015)
	Romania	Passive	Close	***Aspergillus*** (15%)	*Penicillium* (15%)	*Cladosporium* (14%)	16	Apetrei et al., (2009)
	Serbia	Active	Close	***Aspergillus***	*Penicillium*	*Fusarium*	23	Savković et al., (2021)
	Spain	Active	Not reported	*Cladosporium* (46%)	*Alternaria* (18%)	*Penicillium* (18%)	5	Soto, (2009)

Bold letter indicate concordance between our results and other studies

to its severity and difficult treatment (Ferrara et al., 2017).

The high concentrations of related genres in the Popular Library of Gaira are associated with the natural ventilation system and the use of fans for conditioning the areas, which favors the exchange of air from the outdoor to the indoor environment. In addition, other factors can be considered, such as poor hygiene, dust accumulation, and the presence of a substrate that provides adequate nutrients for the development of fungi, e.g., wood, cellulose, and fabrics (Rojas & Aira, 2012), knowing that many fungal aerosols are cellulose degraders in the natural environment, which means that books or wooden furniture are ideal substrates for their development in libraries. It has been experimentally shown that fungi

can even eat iron and other elements in the ink composition (Apetrei et al., 2009).

In the indoor environments of public libraries, the conditions of temperature and relative humidity are additional factors that favor the growth of fungal aerosols; this is how in the Popular Library, the temperature is above the records presented in similar studies (Ghosh et al., 2013; Molina-Veloso & Borrego-Alonso, 2017; Rojas & Aira, 2012; Skóra et al., 2015; Toloza-Moreno & Lizarazo-Forero, 2011; Wu et al., 2020, 2021). This may be one of the reasons why concentration values are lower than in other studies. However, the relationship between the values of temp and concentration is direct with low statistical significance, in agreement with different results and regression analysis test.

Although in the referenced studies, the temperatures are lower than those of the present study, in all of them, there is a probability of fungal microorganisms. When the temperature is high (above 23 °C), and at the same time, the relative humidity exceeds 65%, there is a greater appearance of harmful genera and fungi such as *Alternaria, Aspergillus*, *Chaetomium*, *Cladosporium*, *Fusarium*, *Paecilomyces, Penicillium*, and *Trichoderma* among others (Almaguer et al., 2020). This is confirmed in studies with analyzes of different climatic seasons, with lower concentrations in the cold (winter and autumn) and higher in the warm (spring and summer) seasons (Vélez-Pereira et al., 2016, 2019; Wu et al., 2020, 2021). In addition, other studies have shown that environmental temperature and humidity conditions can limit or favor fungal sporulation processes (Grinn-Gofroń & Bosiacka, 2015; Skjøth et al., 2016; Vélez-Pereira et al., 2019, 2021).

Regarding RH, the results are more consistent with other studies (Ghosh et al., 2013; Okpalanozie et al., 2018; Rojas & Aira, 2012; Savoldelli et al., 2021; Toloza-Moreno & Lizarazo-Forero, 2011). As was mentioned, RH values reported in the different studies reveal that scenarios conducive to the development of fungal microorganisms can be generated because RH has profound effects on the release of spores and particles from fungal structures (Frankel et al., 2012; Madsen, 2012). This confirms the regression analysis results that show the most significant influence on the concentration.

Temperature and RH are basic parameters associated with the growth of fungal aerosols, so in public libraries, paper and wooden furniture contain the substrate that is an additional source of growth, which can add to the dispersion of fungal contaminant aerosols in indoor environments. Mechanical movements are sometimes required to initiate the dispersion, which in the case of users of the library service consist of removing books from the shelves or opening the pages, or in the case of workers during the cleaning of books and/or shelves. In this sense, results these are important as they show that the library should control its relative humidity conditions (preferably in the range of 50–60%); Also, they should implement a periodically cleaning plan for their collections, especially those that are at greater risk of deterioration due to age. These two simple recommendations have shown a significant impact on fungi present in libraries (Walker, 2013).

Finally, one of the major limitations of this work is the short period of sampling in the year, the lack of resources to continue the analyses through the year, and the inclusion of an outdoor near area of the library. likewise, absence of regulations governing the maximum permissible values of fungal aerosols, that promote research like this in our country; as Europe has through the directives 2000/54/EC (Comission Directive (EU), 2000) and 2019/1833 (Comission Directive (EU), 2019) on the protection of workers from risks-related to exposure to biological agents at work.

5 Conclusions

The reported concentration of the fungal aerosol genera found in the Popular Library of Gaira allows us to conclude that there are potentially favorable conditions in indoor environments for the growth, proliferation, and survival of the following fungal: *Aspergillus, Penicillium, Cladosporium,* and *Curvularia*, and in less quantity *Chrysonilia, Cunninghamella* and *Paecylomices*. Most of them are associated with the development of respiratory and/or topical allergies, and their presence in the indoor environment could be influenced by outdoor aerobiological behavior. Finally, we concluded that RH is the most influential thermo-hygrometric factor that affects the concentration of aerosols fungal in the

library; an increase of 10% in moisture could double the fungal aerosol concentration.

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Author contributions YCC: Conceptualization, Methodology, Discussion of the results, Writing—Original draft preparation. HBP: Visualization, Investigation, Writing- Original draft preparation. MMF*:* Visualization, Investigation, Writing- Original draft preparation. EVV: Discussion of the results, Writing—Reviewing and Editing, AV-P: Methodology, Data curation, Statistical analysis, Graphic representation, Discussion of the results, Writing—Review & Editing.

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Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

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