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ORIGINAL ARTICLE

ENVIRONMENTAL FACTORS INFLUENCING INDOOR AIRBORNE FUNGI IN STUDENTS DORMITORY – A CASE STUDY IN NAKHON SI THAMMARAT, THAILAND

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ABSTRACT

Background. Indoor airborne fungi are a significant health concern that can cause respiratory symptoms and other health problems. Indoor fungi are influenced by various factors such as meteorological conditions and dwelling characteristics.
Objective. This study aims to evaluate the association between indoor airborne fungi and environmental factors in a student dormitory in southern Thailand.
Material and methods. The study was conducted at Walailak University in southern Thailand from September to December 2020. Air samples were collected from rooms in thirteen dormitories, and the fungal load was determined using the passive air sampling method. The study also measured meteorological parameters and gathered data on occupant behaviors and exposure-related symptoms through a self-administered questionnaire.
Results. In a total of 135 student rooms, the average concentration (mean ± SD) of indoor airborne fungi was 409.72±176.22 CFU/m3, which showed the highest concentration on the first floor. For meteorological parameters, the averages of RH (%), temperature (°C), and CO2 (ppm) were 70.99±2.37, 31.11±0.56 and 413.29±76.72, respectively. The abundance of indoor airborne fungi was positively associated with an increase in RH (β=0.267, 95% CI: 5.288, 34.401) and building height (β=0.269, 95% CI: 16.283, 105.873), with values of 19.845 and 61.078, respectively. Conversely, temperature exhibited a negative effect on indoor airborne fungi (-92.224, β=-0.292, 95% CI: -150.052, -34.396).
Conclusion. The findings highlight the influence of RH, temperature and building height on indoor airborne fungi in the student dormitory. Therefore, effective management strategies are necessary to improve indoor air quality and reduce associated health risks in student dormitories.

Key words: *airborne fungi, meteorological factors, indoor air quality, dormitory room, dwelling characteristics*

INTRODUCTION

Indoor airborne fungi have been recognized as a significant health concern due to their potential to cause respiratory symptoms and increased time spent indoors, particularly in enclosed spaces such as university student dormitories [1]. Fungi can proliferate in moist environments and produce allergens, irritants, and toxic substances [2, 3, 4]. Exposure to indoor fungi could cause adverse health effects, including asthma, allergic rhinitis, respiratory infection, and other respiratory symptoms [5, 6]. Previous studies have shown an association between indoor fungal exposure and respiratory symptoms in students [7, 8, 9, 10, 11]. High indoor humidity and inadequate ventilation were also associated with respiratory problems [12, 13]. Furthermore, exposure to microbial volatile organic compounds (MVOC) produced by fungi can also increase the risk of other health problems, such as headaches, fatigue, and eye, nose, and skin irritation [14, 15, 16].

The presence of the indoor fungi is influenced by various factors, including meteorological conditions and dwelling characteristics [17, 18, 19, 20, 21]. Several studies have shown that temperature, humidity, and airflow can all play a role in the growth and spread of indoor fungi [17, 19, 22, 23, 24, 25]. They found that high temperature and relative humidity levels have been found to promote the growth of indoor airborne fungi. Airflow has been discovered to have a direct impact on the dispersion of these microorganisms. The study of the student dormitory indoor environment

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revealed a negative correlation between indoor airborne fungi and temperature, while RH was positive [26] . Large concentrations of airborne fungal spores are associated with a musty odor, water intrusion, high indoor humidity, inadequate ventilation through open windows, few extractor fans, and failure to eradicate mold growth from indoor environments [3]. In addition, previous indoor environmental studies demonstrated the association between building characteristics and a high abundance of fungi and dampness in dormitories [2, 27].

In tropical regions such as Thailand, the high relative humidity can contribute to the growth and development of indoor fungi, which may pose a greater risk to the health of occupants, especially in crowded environments such as student dormitories. Therefore, there is a growing need to identify the environmental factors that contribute to the growth and spread of indoor airborne fungi in these settings and to develop effective management strategies to reduce the associated health risks. Several studies have examined the relationship between indoor airborne fungi and environmental factors, but few have focused specifically on student dormitories in Thailand.

This study aims to fill this gap in knowledge by evaluating the association between indoor airborne fungi and environmental factors in a student dormitory at Walailak University in southern Thailand. The results of this study could provide valuable insights into the fungal composition and health impacts in student dormitories and highlight the need for ongoing monitoring and management strategies to maintain indoor air quality.

MATERIAL AND METHOD

Study design and sampling sites

A cross-sectional study was conducted in 2020 at Walailak university, located in the southern region of Thailand. The dormitory has thirteen buildings, composed of ten traditional dormitories without air conditioning and three suite-style dormitories with air conditioning. All traditional dormitories consist of three floors, while suite-style dormitories have five floors. Of all the traditional dormitories, two were designated for male students, while the others were reserved for female students. Additionally, there were two suit-style dormitories designed for female students and one for male students. The recruitment criteria for selecting the target rooms were as follows: 1) Rooms with students who lived in the present room for more than three month; 2) Rooms must be occupied by at least two student; 3) Rooms without member smoking; 4) Rooms must not have been affected by any renovation or maintenance work during the sampling period; 5) Room must not have been recently treated with fungicides or other anti-fungal products 6) were willing to participate in this investigation. The rooms were randomly selected from every floor in each of the 13 dormitories. Sampled from student rooms of each dormitory were collected in the wet season in 2020.

Ethical approval

The study was approved by the Human Research Ethics Committee of Walailak University, study code: WUEC-20-258-01. All the volunteers gave informed consent to participate in this study. The objectives and other important information of this study were explained and informed.

Indoor airborne fungi and indoor air quality parameters measurement

The student rooms were accessed, and occupants were asked for allowance to collect the data. The sampling procedure was standardized across all rooms to avoid bias from air pollutants and physical factors such as temperature and humidity. Firstly, culturable fungi were collected using the gravity sampling technique and immediately transported to the laboratory for analysis to minimize any potential contamination. Following this, indoor temperature, RH, and CO_2 were measured within the rooms. To minimize the potential influence of external factors, the doors and windows of the target rooms were closed for at least 6 hours before sampling. In addition, all air conditioners, fans, and other equipment that may interfere with the airflow were turned off during the sampling period. The fungal load was examined in the evening by the passive air sampling method (settle plate technique) using standard 9 cm diameter Petri dishes comprising Potato Dextrose Agar (PDA) (Oxoid, England). The amount of indoor airborne fungi was determined by counting the fungal settlement on the Petri plates left open to the air for 30 minutes at 1 m above the floor in the center of the dormitory room and 1 meter away from the walls. The sample was taken to the Center for Scientific and Technological Equipment Laboratory at University and incubated at 25 °C for 3 to 5 days. For quality control, the contamination of culture media in every batch was tested before use for sampling, and one control medium was used for each batch to examine the contamination during sample collection and transportation. All air sampling was performed aseptically to avoid contamination.

Colony forming units (CFU) was calculated and CFU/m^3 fungal concentration was determined using the following Equation [28, 29, 30]

$$N = \frac{a \times 10{,}000}{bt \times 0.2}$$

Where: N= Microbial CFU/m^3 of indoor air; a = Number of colonies per Petri dish; b = Dish surface area (cm^2); t = Exposure time. All the Petri dishes with growth media were exposed for 30 min.

Indoor air quality parameters in this study included RH (%), temperature (°C) and CO_2 (ppm). All parameters were measured using a multi-parameters portable device (AMI 300, KIMO, Canada). The average value of 10 continuous monitoring values recorded on a 3-minute interval was taken as the final representative value for one site in the room. The measured indoor pollutants were interpreted following the Indoor air quality monitoring for public buildings in Thailand [31] and the Guidelines for Good Indoor Air Quality of Singapore [32]. The standard for indoor airborne fungi was specified that the concentration should not exceed 500 CFU/m^3.

On-site inspection and questionnaire survey

A self-administered questionnaire was developed and modified from the previous studies [17,19, 27]. All questions were reviewed and evaluated by three different experts in the field of environment and medicine to check the content, relevance, and readability. The questionnaire was modified until it had a content validity index of 0.87, which was acceptable [33, 34]. The research was performed under relevant guidelines/regulations. Participants who decide to take part in this study will be asked to sign a consent form. Data regarding dwelling characteristics (building age and height, wall and floor materials and ventilation system), occupant behaviors (cleaning, window open, and number of students in the room), room dampness-related indicators (fungal spot, water leak and wall crack), and fungal exposure-related symptoms (asthma, allergic rhinitis, wheezing, dry cough, itchiness, and other respiratory diseases) were obtained from a self-administered questionnaire, Inspectors gathered and recorded additional information about dwelling characteristics, wall and floor materials, and room dampness-related indicators.

Data analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS 25) and Microsoft Excel 2019. Descriptive data were reported as frequencies and percentages, while continuous variables were described as mean ±standard deviations (SD). Chi-square test was utilized to determine the correlation between occupant behaviors and indoor airborne fungi levels. Pearson correlation was used to evaluate the correlation between indoor airborne fungi, indoor meteorological parameters, and dwelling characteristics. The factors that affect indoor airborne fungi were determined using linear regression analysis. Significance in all statistical analyses was set at p-value < 0.05.

RESULTS

Building and demographical characteristics

The air samples were collected from a total of nine student dormitories, representing 89.40% (135/151) of the total rooms. The majority of the samples were taken from female rooms (85.93%, 116/135). All the dormitories were constructed in 1989 and had three levels. The second floor had the highest number of samples (40.00%, 54/135), followed by the first floor (31.85%, 43/135) and the third floor (28.15%, 38/135). The rooms were occupied by students from different schools and academic years, with a maximum of four students (69.63%, 94/135), followed by three students (11.11%, 15/135), and two students (19.26%, 26/135). The students typically spent an average of more than 15 hours per day in their rooms. In addition, the study identified room dampness-related indicators such as fungal spots (14.07%, 19/135), water leak spots (11.11%, 15/135), and wall cracks (9.63%, 13/135).

Occupant health symptoms and indoor airborne fungi

Only 59.20% (280/473) of the occupants in the 135 rooms responded to the health status survey, which consisted of 1.29% (40/280) of males and 85.71% (240/280) of females. The results of the health symptoms survey showed that only 30.36% (85/280) of occupants had symptoms related to fungal exposure in the past year. Among these occupants, most of them showed only one symptom, while some occupants had multiple symptoms up to five symptoms. The most symptom was respiratory symptoms 87.06% (74/85) followed by itchiness 29.41% (27/85). The health symptoms of occupants in different fungal level room are shown as Figure 1. There was no significant difference in the prevalence of health symptoms between the rooms with different levels of fungal concentration (P>0.05).

The concentrations of cultivable indoor fungi

In this study, a concentration of indoor airborne fungi over 500 CFU/m^3 was found in 41 (30.37%) rooms, while the remaining 94 (71.85%) had a lower concentration than 500 CFU/m^3. Among all student dormitories, the average concentration of indoor airborne fungi was 409.72±176.22 CFU/m^3. The highest concentration of indoor airborne fungi was found in first floor (411.82±181.43 CFU/m^3), followed by third floor and second floor (410.50±168.49 and 407.50±180.57 CFU/m^3, respectively) - Figure 2 (a). There is no significant difference of indoor fungal concentration among all three floors (P>0.05). For meteorological parameters, the averages of RH (%), temperature (°C), and CO2 (ppm) were 70.99±2.37, 31.11±0.56 and 413.29±76.72, respectively. The results

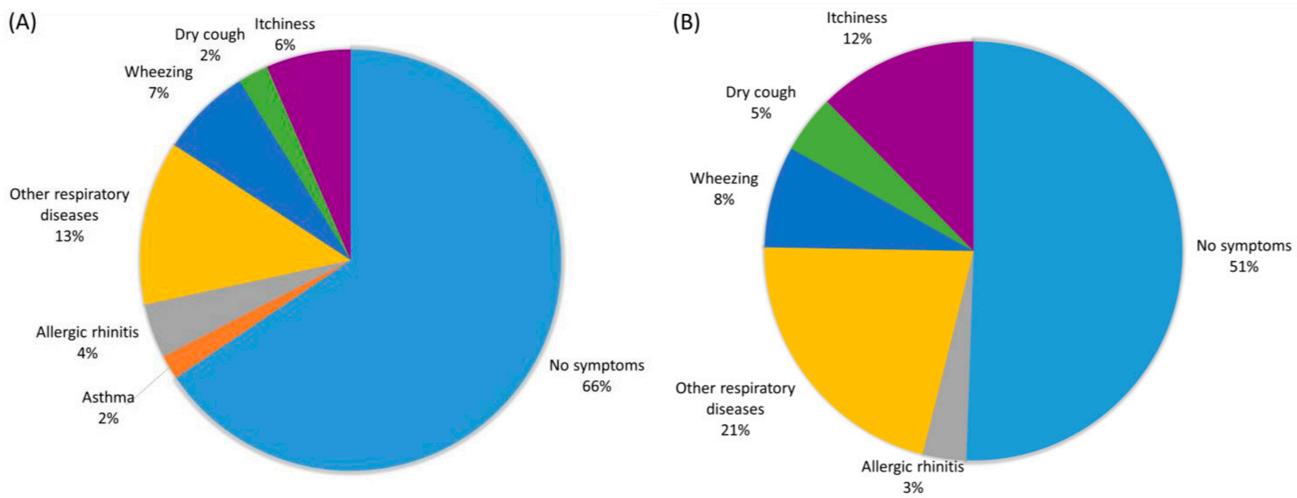

Figure 1. The symptoms related with fungal exposure among occupant in student dormitory: (A) room with > 500 CFU/m^3, (B) room with < 500 CFU/m^3

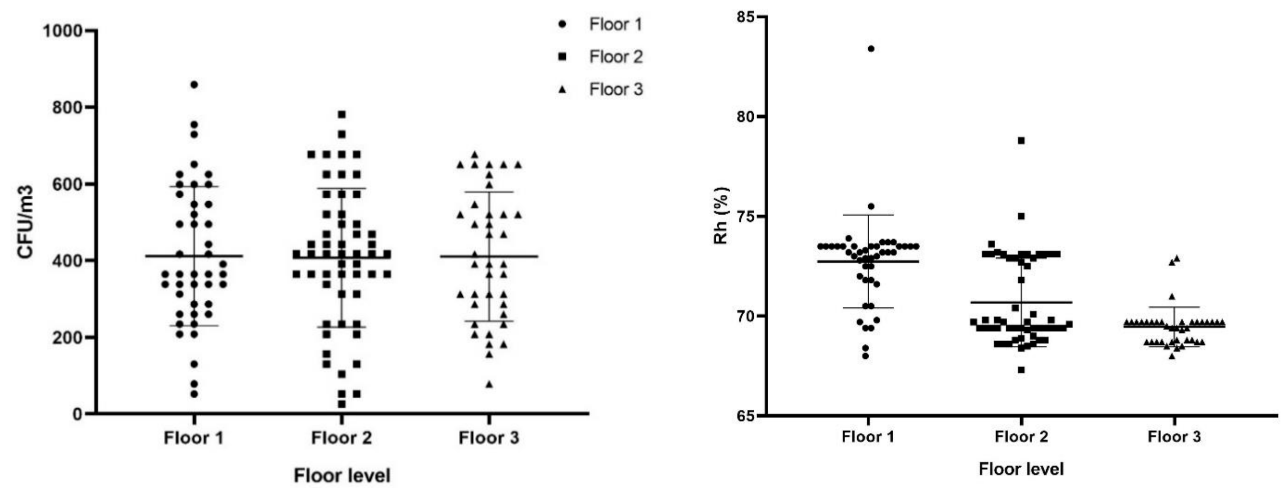

Figure 2. The average indoor airborne fungi (a) and RH (b) among different floor level. (•) was 1st floor; (■) was 2nd floor and (▲) was 3rd floor

of this study showed that the highest relative humidity (RH) was observed on the first floor (72.74 ± 2.34%), followed by the second and third floors (70.68 ± 2.22% and 69.46 ± 0.99%, respectively) ($P<0.05$)- Figure 2 (b). Moreover, the maximum temperature was recorded on the highest floor (31.41±0.45°C), followed by the second floor (31.17±0.55°C) and the first floor (30.78±0.50°C) ($P<0.05$).

Occupant behavioral factors for indoor airborne fungi

The associated occupant behaviors of airborne fungi in the student dormitory are shown in Table 1. There is no significant difference between occupant behavior and indoor airborne fungi. In this study, occupants open the room window for approximately 15 hours a day for ventilation because there is no air conditioner in this type of dorm. The dorms were allowed to function with only natural ventilation and an electric fan for cooling. Most occupants clean their rooms by sweeping the floor, followed by wiping with water, primarily done for 2–6 days a week. There was a marked decrease in the number of airborne fungi in the room where the floor had been cleaned and mopped with water. The number of students per room number of students per room did not show a significant correlation with indoor fungal level and dampness (P=0.066). Additionally, the number of student occupants in a room was not significantly correlated with the presence of fungal spot (P=0.231), water leak spot (P=0.951) and wall crack (P=0.446).

The correlation between indoor fungi and environmental factors

The correlation of indoor airborne fungi and environmental factors was shown in Table 2. Among

Table 1. Behavioral factors associated with indoor airborne fungi

Behavioral factors	< 500 CFU/m^3		> 500 CFU/m^3		P-value
	No	Prevalence (%)	No	Prevalence (%)	
Duration of the window open a day (h) (mean ± SD)	15.28 ± 9.40		15.07 ± 9.90		0.903
Opening room window					
Every Day	13.00	13.83	10.00	24.39	0.279
Often	73.00	77.66	28.00	68.29	
Never	8.00	8.51	3.00	7.32	
Sweeping the floor					
Yes	91.00	95.79	40.00	100.00	0.188
No	4.00	4.21	0.00	0.00	
Wiper with water					
Yes	61.00	64.21	24.00	60.00	0.644
No	34.00	35.79	16.00	40.00	
Wiper with water and detergents					
Yes	7.00	7.37	2.00	5.00	0.614
No	88.00	92.63	38.00	95.00	
Sweeping cobwebs					
Yes	8.00	8.42	2.00	5.00	0.488
No	87.00	91.58	38.00	95.00	
Room cleaning frequency per week					
Every day	31.00	32.63	7.00	17.50	0.151
Often	62.00	65.26	31.00	77.50	
Once a week	1.00	1.05	2.00	5.00	
Never	1.00	1.05	0.00	0.00	
Number of students per room					
2	21	22.11	5	12.50	0.066
3	7	7.37	8	20.00	
4	67	70.53	27	0.00	

all measured rooms in the student dormitory, indoor airborne fungi showed a positive correlation with RH and a negative correlation with temperature ($P<0.05$). The results indicated that the fungal concentration of fungi increased in a high-damp and low-temperature room. The decrease in temperature resulted in an increase in RH, which demonstrated a negative correlation between RH and temperature ($P<0.05$). In addition, only building height shown a negative correlation with RH, while temperature demonstrated a positive correlation. The RH in the student dormitory decreases at the higher building level, while the temperature increases at the higher building level. There are no association between indoor airborne fungi and room dampness-related indicators (fungal spot, water leak spot, wall crack) (data not shown). When examining the indoor airborne fungi and environmental factors on each floor, no correlation was found between indoor airborne fungi and room dampness-related indicators on each floor ($P>0.05$). However, temperature exhibited a negative correlation with indoor airborne fungi on the second floors ($r=-0.537$, $P<0.05$) and third floors ($r=-0.309$, $P<0.05$), whereas RH displayed a positive correlation with indoor airborne fungi on the first floor ($r=0.575$, $P<0.05$). Additionally, a negative correlation was reported between temperature and RH on the first floor ($r=-0.537$, $P<0.05$).

Factors associated with indoor airborne fungi

The results of linear regression analysis of the association between indoor airborne fungi and environmental variables showed in Table 3. The results of correlation between fungal abundance and environmental factors revealed that increased relative humidity and building height is associated with increased growth of fungi in indoor environments. The abundance of indoor airborne fungi was positively

Table 2. Correlation between indoor airborne fungi concentration and indoor temperature and RH

	Indoor fungi	RH	Temp	CO_2	Floor level
Indoor fungi	1				
RH	0.244**	1			
Temp	-0.286**	-0.422**	1		
CO_2	-0.065	-0.168	0.158	1	
Floor	0.003	-0.541**	0.439**	-0.010	1

* – Correlation is significant at the 0.05 level (2-tailed)
** – Correlation is significant at the 0.01 level (2-tailed).

Table 3. Meteorological factors and dwelling characteristics associated with indoor airborne fungi, based on linear regression analysis

Variable	Indoor fungi (CFU/m^3)			
	B	β	t	*p*
Constant	1750.294		1.517	0.132
RH	19.845	0.267	2.697	0.008*
Temperature	-92.224	-0.292	-3.155	0.002*
Floor	61.078	0.269	2.697	0.008*

Note. Adjust R^2 for indoor fungi is 0.128; * $p<0.05$; F-value for ANOVA for indoor fungi is 7.547; $p<0.05$.

associated with an increase in RH (β=0.267, 95% CI: 5.288, 34.401) and building height (β=0.269, 95% CI: 16.283, 105.873), with values of 19.845 and 61.078, respectively. Conversely, temperature exhibited a negative effect on indoor airborne fungi (-92.224, β=-0.292, 95% CI: -150.052, -34.396).

DISCUSSION

The present study aimed to evaluate the impact of environmental factors on indoor airborne fungi in student dormitories located in southern Thailand. This study involved monitoring and assessing meteorological factors, dwelling characteristics, indoor airborne fungi, and occupant behaviors and health symptoms in a total of 135 rooms in traditional student dormitories. Due to the COVID-19 pandemic, access to rooms with air conditioning was limited. Consequently, the total culturable fungal count was measured in the traditional dormitories without air conditioning, which were equipped with open windows and electric fans for ventilation.

The presence of indoor airborne fungi in university student dormitories can be influenced by meteorological factors such as temperature, humidity, and air exchange rate. These factors play a crucial role in determining the growth and dissemination of fungi in indoor environments. The correlation analysis demonstrated that RH and indoor airborne fungi were positively correlated, while temperature was negatively correlated. Our findings are consistent with the several indoor microenvironments studies. In India, the temperature was negatively correlated with indoor fungal abundance, while RH was positively correlated [35]. The study of airborne microbes in various university indoor environments found a positive correlation between indoor airborne fungi with RH, while the temperature was negative in the student dormitory [26].

Our findings showed that the presence of indoor airborne fungi was highest in the rooms located on the first floor, which also had the highest relative humidity levels. Both indoor airborne fungi and relative humidity decreased at the upper floor level. The results of this study indicated that RH is one of the most important factors that influences the concentration of airborne fungi in indoor environments, which was also discovered in those other studies. The study of indoor fungi in a public library with natural ventilation revealed the positive effect of relative humidity on fungal aerosols [36]. The study of fungal growth in floor dust also demonstrated the influence of elevated relative humidity on fungal growth [37]. According to the several studies revealed the adverse health effects of indoor RH, therefore RH is one of the important meteorological parameters for indoor air quality measurement [10, 13, 38]. Dampness environments are suitable for the fungal growth, which can then produce the allergenic components and spread them throughout the air [39].

Moreover, several studies demonstrated an increase in airborne fungi when the temperature was increased. The study of airborne culturable fungal load in an indoor environment of the dormitory in Ethiopia revealed a negative correlation between temperature and indoor airborne fungi in the morning (r=−0.2153, P=.0274), while a positive correlation was found in the afternoon (r=0.2046, P=.0363) [40]. The study of airborne fungi in domestic environments in Mexico also found a negative correlation between temperature and fungal abundance in residence [41]. In this study, the abundance of indoor airborne fungi was not influenced by CO2, while the previous studies showed the correlation. The previous study of airborne culturable fungal load in an indoor environment of the dormitory in Ethiopia revealed a negative correlation between CO2 and indoor airborne fungi in the morning (r=−0.3785, P=.0001), while a positive correlation was found in the afternoon (r=0.3183, P=.0009) [40].

The impact of meteorological factors on indoor airborne fungi can vary depending on the specific microclimate and dwelling characteristics of the student dormitories and the behavior of occupants. The linear regression analysis showed that building height, RH, and temperature were the significant factors in indoor airborne fungi abundance. At the same time, RH and temperature in the student dormitory were influenced by building height. Indoor RH was mostly high on the first floor, while the temperature was highest on the third floor. An inverse behavior between RH and temperature was found in this study, which is consistent with the previous study in a public library with natural ventilation [36]. Furthermore, there is a correlation between the cleaning frequency and floor level, which found that the third-floor room showed more room cleaning frequency than the lower level. These may be the most significant factors contributing to the high levels of airborne fungi and RH on the first floor compared to the upper floors. This finding suggested that the behavior of occupants may also play an important role in indoor air quality. The results of this study, which investigated the impact of meteorological factors and dwelling characteristics, are supported by confidential evidence obtained through a large-scale on-site investigation [42].

The adverse health effects of indoor air quality were also reported, which found no influence of indoor fungi and dampness on health effects in this study. Itchiness (22.50%), wheezing (18.33%), and allergic rhinitis (10.00%) were reported as significant adverse health outcomes. Our study had showed the different findings with previous studies. The study on the health risk of indoor microbial exposure demonstrated that elevated levels of bioaerosols are the foremost risk factor that can lead to various respiratory and general health issues [6]. They reported that the headache (28%) and allergy (20%) were significant indoor health concerns, while Dry, itching, irritated, or watery eyes (10%), Sore or dry throat, and frequent coughing (13%) were also reported. Dampness indicators such as condensation, visible mold, and water damage have been associated with an increase in allergic rhinitis and asthma [43, 44].

The correlation between indoor airborne fungi and meteorological factors in student dormitories highlights the need for ongoing monitoring and management strategies to maintain indoor air quality. Proper ventilation could reduce the mold risk in residential buildings, as indicated by a study of exhaust fan use that demonstrated its ability to remove moisture and reduce indoor mold growth [4, 45, 46]. Natural ventilation from opening windows and mechanical ventilation from electric fans may influence air circulation among all dorm rooms in this study. However, the purpose of using electric fans was to cool down, which would be effective reducing the body temperature [46]. Therefore, to reduce fungal levels and improve air quality in university student dormitories, the effective ventilation systems and monitoring indoor air quality should be more concerned. Furthermore, promoting awareness among students and staff about the importance of Indoor Air Quality (IAQ) and how to maintain it can also be beneficial.

The present study utilized a self-administered questionnaire to obtain additional information regarding dwelling characteristics, occupant behaviors, room dampness-related indicators, and fungal exposure-related symptoms. The results of the study may aid in the identification of potential risk factors for fungal exposure. However, it is important to note some limitations of the study. Firstly, only the total culturable fungal count in traditional dormitories without air conditioning was measured due to the COVID-19 pandemic, and therefore, the findings may not accurately represent the true concentration of airborne fungi in all student dormitories. Secondly, the study was conducted during the wet season, which may not be fully representative of fungal concentrations during other seasons. Thirdly, the study did not examine the health effects of specific fungi species or allergenic components of fungi, which could have varying impacts on human health. Finally, this study provides valuable insights into the impact of meteorological factors and occupant behavior on indoor airborne fungi in student dormitories. However, further research is necessary to fully comprehend the intricate relationships between different factors and their effects on indoor air quality and human health.

CONCLUSION

Our findings reported insights into the factors that influence the growth and distribution of indoor fungi. Specifically, the results reveal that meteorological and dwelling characteristics are significant factors influencing the abundance of airborne fungi in student dormitories. The abundance of indoor airborne fungi was positively associated with an increase in RH and building height, while temperature exhibited a negative effect on indoor airborne fungi. The findings highlight the influence of meteorological factors and dwelling characteristics on indoor airborne fungi in the student dormitory. To improve indoor air quality and minimize health risks in student dormitories, it is imperative to implement effective management strategies such as maintaining low relative humidity levels, enhancing ventilation, conducting regular inspections to identify and repair water leakage or signs of dampness, adopting regular cleaning and disinfection practices, and carrying out routine health checkups of students.

Declaration of interest statement

The authors declare that they have no conflict of interest regarding this article.

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