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Original article

Indoor air microbial counts in dormitory of nursing students, Bangkok

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Background: Most medical and nursing students live in institute dormitories located in a university hospital where a variety of biological and chemical hazards are used and probably diffuse into the dormitory environments.
Objectives: This study aimed to investigate bacterial and fungal counts, and microbial groups in a dormitory of nursing students in Bangkok, Thailand.
Methods: Two-time assessments of bacterial and fungal counts in indoor air samples collected from a dormitory of nursing students including 8 floors with 95 rooms were carried out. A total of 380 indoor air samples (190 for bacteria and 190 for fungi) were collected from all dormitory rooms using a BioStage Impactor and 48 outdoor air samples were collected for comparison. Air samples were collected twice, i.e., in the first month and the third month of the study.
Results: The mean bacterial counts were 151 ± 109 cfu/m^3 and 158 ± 92 cfu/m^3 and those of fungal counts were 374 ± 273 cfu/m^3 and 363 ± 257 cfu/m^3 from the first and the second assessment. The lower floors of the dormitory (1 - 4 floors) had significantly higher levels of bacterial and fungal counts in both assessments when compared with the higher floors of the dormitory (5 - 8 floors) ($P < 0.001$). The percentages of bacterial and fungal counts with > 300 cfu/m^3 in the lower floors were significantly higher than those in the higher floors in the first and the second assessments ($P < 0.05$ and $P < 0.001$, respectively). Additionally, the most common isolated bacteria and fungi were *Staphylococcus spp*., and *Aspergillus spp*., respectively.
Conclusion: This study reveals that the lower floors of the dormitory had significantly higher levels of bacterial and fungal counts when compared with the higher floors of the dormitory from both assessments. Most isolated microbes do not generally present a health hazard but high loads may trigger allergic reactions in susceptible hosts.

Keywords: Indoor air, bacterial counts, fungal counts, nursing student dormitory.

Indoor air quality (IAQ) is a major concern to businesses, schools, building managers, tenants, and workers because it can impact the health, comfort, well-being, and productivity of the building's occupants.[1, 2] Good indoor air quality leads to improved productivity at the workplace. On the other hand, poor indoor air quality causes productivity to drop because of comfort problems, illnesses of health and sickness absenteeism.[1] At present, most people spend up to 90% of their time indoors and in an office environment.[3] The World Health Organization (WHO) estimates that 30 % of the buildings may have problems with indoor air quality which will lead to sick building syndrome.[4]

Microbial indoor air comes from hundreds of species of bacteria, fungi and moulds that grow indoors when sufficient moisture is available. Exposure to microbial contaminants is clinically associated with respiratory symptoms, allergies and asthma, and can affect the immunological system. [4 - 7] A previous study reported that dampness

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problems at dorms of Chinese students was a risk factor in irritating allergic symptoms; hence, there is a need for dorm environment improvement.[8] Another previous study demonstrated that dorm rooms are a kind of residential environment for students, and may be more polluted than the home environment, especially when dorms tend to be more crowded due to a low ventilation rate.[9] Furthermore, healthcare workers, such as doctors, nurses and others are exposed to infectious diseases and demanding work conditions in healthcare settings. [10, 11] In addition to the danger of air-borne microbes and diseases being spread in hospitals, there are also a number of chemicals released from typical hospital activities that occupants should be aware of. [12] A study in a Thai university dormitory reported that most students spent time in their university dormitory. The dormitory should have good air quality, be convenient, clean, hygienic and safe which will enhance not only the quality of life, physical and mental health, but also the academic performance achievement. [13] However, this study assessed only physical environment and sanitation of the dormitory; the biological contaminants were not included.

Medical and nursing students living in their dormitories might be at risk for acquiring biological hazards from the dormitories because most of the dormitories are located in university hospitals. There are a variety of infectious hazards in hospital environments which might affect dormitory environments. In a recent period, there have been some complaints from some nursing students living in the institute dormitory about symptoms related to indoor air quality. The 2-time assessments of microbial indoor air quality in this nursing student dormitory were carried out to investigate bacterial and fungal counts, and microbial groups.

Materials and methods

Study design

This study design was a cross-sectional study on 2-time assessments of microbial indoor air quality in dormitory rooms of nursing students in 2015. The first air sample collection was performed in the first month after complaints from some nursing students about symptoms related to indoor air quality, and the second was performed again in the third month of the study to confirm the association between indoor air quality and related symptoms (data are not presented in this study). All air samples were collected using a BioStage Impactor QuickTake 30 sample pump (SKC Inc, USA) to assess total bacterial and fungal counts. A nursing student dormitory included 8 floors with 95 rooms (approximately 15 m^2 for each room). In each assessment, at least 2 air sampling points in each room were collected and some outdoor air samples were collected in the same period of indoor air collection for comparison following the Guidelines for Good Indoor Air Quality in Office Premises, Ministry of the Environment, Singapore (1996). [14] As for the outdoor air samples, 2 - 4 air sampling points on each floor of the dormitory were collected. In total, 380 indoor air samples (190 for bacteria and 190 for fungi) and 48 outdoor air samples (24 for bacteria and 24 for fungi) were included in each assessment time. This study was part of the research protocol approved by the Ethics Committee for Human Research, the Faculty of Medicine, Ramathibodi Hospital, Mahidol University (Ref. No. 10-56-01).

The microorganisms collected by a BioStage Impactor are impacted onto an agar surface in accordance with the USP reference method (USP 24, p. 2099). A sample pump draws the air through the sampler where multiple jets of air direct airborne particles toward the surface of the agar collection medium. The BioStage Impactor contains a 400 hole jet classification stage and is operated at 28.3 L/min for four minutes. In this study, 113.2 liters of air were collected. The air collection technique followed the active air sampling method by Pasquarella C, *et al*, 2008. [15] Details were described in Luksamijarulkul P, *et al*, 2015. [16] The plate count method was used to estimate bacterial or fungal counts. General bacteria were cultured in plate count agar at 37°C for 48 hours, and general fungi were cultured in a Sabouraud 4% dextrose agar, at room temperature for 5 days with daily observation. After incubation, the bacterial and fungal colonies were counted and calculated to be expressed as colony forming units/m^3 (cfu/m^3) by the following:

$$\text{Microbial counts (colony forming units/m}^3\text{)} = \frac{\text{Total colonies} \times 10^3}{28.3 \times 4}$$

The isolated colonies of bacteria and fungi were identified by group or genus by Gram staining and with lacto-phenol cotton blue dye following Larone's guide. [17]

Interpretation for microbial indoor air quality

Following the recommended guideline of the American Conference of Governmental Industrial Hygienists (ACGIH) [18] and the Guidelines for Good Indoor Air Quality in Office Premises, Ministry of the Environment, Singapore (1996)[14], if the microbial count was more than 500 cfu/m³, it was an indication of overcrowding or poor ventilation. However, for general offices, bacterial counts or fungal counts should be less than 300 cfu/m^3. [4, 5]

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 22.0. A comparison of means between the 2 groups was employed using student's unpaired *t* - test. $P < 0.05$ was considered for statistically significant differences.

Results

Two-time assessments on microbial indoor air quality were performed in a nursing student dormitory including 8 floors with 95 rooms to investigate bacterial and fungal counts. In each assessment, 2 points of air samples were collected from each dormitory room in the morning (190 samples for bacterial count and 190 samples for fungal count). The first-time assessment found that the mean ± standard deviation (SD) of bacterial counts in dormitory rooms was 151 ± 109 cfu/m^3 (outdoor air samples = 175 ± 75 cfu/m^3). The highest mean level was found on the 1st floor (257 ±111 cfu/m^3) and the lowest level was found on the 7th floor (85 ± 66 cfu/m^3). The second-time assessment found that the mean ± SD of bacterial counts in dormitory rooms was 158 ± 92 cfu/m^3 (outdoor air samples = 162 ± 53 cfu/m^3). The highest mean level was found on the 1st floor (239 ± 160 cfu/m^3) and the lowest level was found on the 6th floor (112 ± 35 cfu/m^3). Details are shown in Table 1. As for fungal count, the first-time assessment found that the mean ± SD was 374 ± 273 cfu/m^3 (outdoor air samples = 409 ± 136 cfu/m^3). The highest mean level was found on the 2nd floor (674 ± 333 cfu/m^3) and the lowest level was found on the 6th floor (135 ± 66 cfu/m^3). The second-time assessment found that the mean of fungal counts in dormitory rooms was 363 ± 258 cfu/m^3 (outdoor air samples = 364 ± 153 cfu/m^3). The highest mean level was found on the 2nd floor (695 ± 317 cfu/m^3) and the lowest level was found on the 8th floor (126 ± 27 cfu/m^3), as shown in Table 1.

Table 1. Means ± SD of bacterial and fungal counts (cfu/m^3) in air samples collected from the dormitory rooms (the first and the second round assessment).

Floors	The first round		The second round	
	Bacterial counts (mean ± SD)	Fungal counts (mean ± SD)	Bacterial counts (mean ± SD)	Fungal counts (mean ± SD)
Floor 1	257 ± 111	210 ± 106	239 ± 160	199 ± 63
(n = 10)	(88 - 442)	(62 - 380)	(80 - 504)	(133 - 309)
Floor 2	112 ± 56	674 ± 333	170 ± 112	694 ± 317
(n = 26)	(27 - 265)	(88 - 1228)	(88 - 530)	(194 -1,237)
Floor 3	214 ± 138	293 ± 179	222 ± 102	224 ± 105
(n = 32)	(35 - 689)	(62 - 769)	(50 - 477)	(72 - 592)
Floor 4	183 ± 132	595 ± 267	124 ± 41	601 ± 266
(n = 28)	(53 - 574)	(256 – 1,060)	(88 - 212)	(265 – 1,067)
Floor 5	136 ± 68	340 ± 202	122 ± 70	255 ± 86
(n = 28)	(44 - 327)	(71 - 936)	(88 - 459)	(88 - 468)
Floor 6	100 ± 65	134 ± 66	112 ± 34	256 ± 79
(n = 28)	(18 - 274)	(18 - 292)	(62 - 212)	(115 - 424)
Floor 7	85 ± 66	383 ± 147	168 ± 86	343 ± 193
(n = 28)	(17 - 283)	(177 - 839)	(88 - 530)	(106 - 848)
Floor 8	210 ± 107	141 ± 79	148 ± 46	126 ± 27
(n = 10)	(62 - 380)	(44 - 283)	(97 - 239)	(88 - 168)
Total	**151 ± 109**	**374 ± 273**	**158 ± 92**	**363 ± 257**
(n = 190)	**(17 - 689)**	**(18 – 1,228)**	**(50 - 530)**	**(72 – 1,237)**
Outdoor	**175 ± 74**	**409 ± 136**	**162 ± 53**	**364 ± 153**
(n = 24)	**(80 - 345)**	**(88 - 553)**	**(97 - 292)**	**(88 - 675)**

From both assessments, it was found that the lower floors of the dormitory (1 - 4 floors) had significantly higher levels of microbial counts when compared with the higher floors of the dormitory (5 - 8 floors) ($P < 0.001$). Details are shown in Table 2. Additionally, the percentages of bacterial and fungal counts with > 300 cfu/m^3 on the lower floors (1 - 4 floors) were significantly higher than those on the higher floors (5 - 8 floors) in the first and the second assessment ($P < 0.05$ and $P < 0.001$, respectively) (Table 3). However, the percentages of only fungal counts with > 500 cfu/m^3 (higher the recommended indoor air guideline of American Conference of Governmental Industrial Hygienists, ACGIH) on the lower floors (1 - 4 floors) were significantly higher than those on the higher floors (5-8 floors) ($P < 0.05$) (Table 3).

Isolated bacteria were preliminarily identified and it was found that 64.5% and 22.1% were *Staphylococcus spp.* and *Streptococcus spp.*, respectively. Whereas, 62.5% of *Staphylococcus spp.* and 12.5% of *Streptococcus spp.* were found in outdoor air samples. Isolated fungi were found 62.1% of *Aspergillus spp.*, and 21.3% of *Penicillium spp.*, respectively. Moreover, 58.3% of *Aspergillus spp.* and 20.8% of *Penicillium spp.* were found in outdoor air samples. Details are shown in Table 4 and Table 5.

Table 2. Comparison of bacterial and fungal counts (means ± SD) between dormitory rooms on lower floors and dormitory rooms on higher floors (the first and the second round assessment).

Floors	The first round		The second round	
	Bacterial counts (n = 190) (mean ± SD)	**Fungal counts (n = 190) (mean ± SD)**	**Bacterial counts (n = 190) (mean ± SD)**	**Fungal counts (n = 190) (mean ± SD)**
1 - 4 (n = 96)	183 ± 92	469 ± 189	179 ± 82	448 ± 194
5 - 8 (n = 94)	120 ± 67	274 ± 129	137 ± 58	271 ± 128
P - value from *t*-test	< 0.001	< 0.001	< 0.001	< 0.001

Table 3. Comparison of number and percentage of bacterial and fungal counts with >300 cfu/m^3 and >500 cfu/m^3 between dormitory rooms on lower floors and dormitory rooms on higher floors (the first and the second round assessment).

Floors	The first round		The second round	
	Bacterial counts (n = 190) > 300 cfu/m^3	**Fungal counts (n = 190) > 300 cfu/m^3**	**Bacterial counts (n = 190) > 300 cfu/m^3**	**Fungal counts (n = 190) > 300 cfu/m^3**
1 - 4 (n = 96)	24 (25.0%)	63 (65.6%)	22 (22.9%)	55 (57.3%)
5 - 8 (n = 94)	6 (6.4%)	33 (35.1%)	4 (4.3%)	28 (29.8%)
P - value	< 0.05*	< 0.001*	< 0.05*	< 0.001*
Floors	**> 500 cfu/m^3**	**> 500 cfu/m^3**	**> 500 cfu/m^3**	**> 500 cfu/m^3**
1 - 4 (n = 96)	3 (3.1%)	33 (34.4%)	2 (2.1%)	32 (33.3%)
5 - 8 (n = 94)	0 (0.0%)	7 (7.4%)	0 (0.0%)	3 (3.2%)
p-value	NC	< 0.05*	NC	< 0.05*

*Statistical significance at $\alpha = 0.05$ by Proportional Z test
NC = Not calculation

Table 4. Number and percentage of isolated bacterial groups in air samples collected from the dormitory rooms (n = 428 colonies).

Air sampling site	No (%) of Bacterial groups				
	Staphylococcus spp.	***Streptococcus spp.***	***Micrococcus spp.***	***Bacillus spp.***	**Gram-negative rods**
Floor 1 (n = 20)	10 (50.0)	5 (25.0)	3 (15.0)	2 (10.0)	0 (0.0)
Floor 2 (n = 52)	35 (67.3)	10 (19.3)	5 (9.6)	2 (3.8)	0 (0.0)
Floor 3 (n = 64)	42 (65.6)	16 (25.0)	3 (4.7)	2 (3.1)	1 (1.6)
Floor 4 (n = 56)	40 (71.4)	11 (19.6)	2 (3.6)	3 (5.4)	0 (0.0)
Floor 5 (n = 56)	30 (53.6)	16 (28.6)	5 (8.9)	3 (5.4)	2 (3.5)
Floor 6 (n = 56)	42 (75.0)	11 (19.6)	2 (3.6)	1 (1.8)	0 (0.0)
Floor 7 (n = 56)	36 (64.3)	12 (21.4)	5 (8.9)	2 (3.6)	1 (1.8)
Floor 8 (n = 20)	10 (50.0)	3 (15.0)	2 (10.0)	3 (15.0)	2 (10.0)
Total (n = 380)	**245 (64.5)**	**84 (22.1)**	**27 (7.1)**	**18 (4.7)**	**6 (1.6)**
Outdoor (n = 48)	**30 (62.5)**	**6 (12.5)**	**6 (12.5)**	**4 (8.3)**	**2 (4.2)**

Table 5. Number and percentage of isolated fungal groups in air samples collected from the dormitory rooms (n= 362 colonies).

Air sampling site	No (%) of fungal culture			
	Aspergillus spp.	***Penicillium spp.***	***Fusarium spp.***	**Others***
Floor 1 (n = 16)	5 (31.2)	4 (25.0)	4 (25.0)	3 (18.8)
Floor 2 (n = 40)	25 (62.5)	10 (25.0)	5 (12.5)	0 (0.0)
Floor 3 (n = 56)	35 (62.5)	12 (21.4)	6 (10.7)	3 (5.4)
Floor 4 (n = 50)	30 (60.0)	10 (20.0)	8 (16.0)	2 (4.0)
Floor 5 (n = 50)	34 (68.0)	7 (14.0)	6 (12.0)	3 (6.0)
Floor 6 (n = 46)	30 (65.2)	9 (19.6)	5 (10.9)	2 (4.3)
Floor 7 (n = 46)	32 (69.6)	11 (23.9)	3 (6.5)	0(0.0)
Floor 8 (n = 10)	4 (40.0)	4 (40.0)	2 (20.0)	0(0.0)
Total (n = 314)	**195 (62.1)**	**67 (21.3)**	**39 (12.4)**	**13 (4.2)**
Outdoor (n = 48)	**28 (58.3)**	**10 (20.8)**	**7 (14.6)**	**3 (6.3)**

* Such as *Cladosporium spp*., *Alternaria spp*., and *Rhizopus spp*.

Discussion

Indoor air quality is one of the most significant factors affecting the health and well-being of individuals who spend more than 90% of their lives indoors. [1, 3] According to the World Health Organization (WHO) roughly 3 billion people around the world are suffering from diseases caused by indoor air pollution; dormitory rooms are a kind of residential environment which may be more polluted due to the crowded dormitory environments. [2] In dorms, a low ventilation rate is a risk factor for asthma, allergy and adverse health. [2, 9] However, students who are susceptible to illnesses related to indoor air quality might suffer from physiological and personal health conditions, personal hygiene and environmental factors. [19] Dormitories are one of the important indoor places for students in a university and its environments probably affect students' health. Ventilation systems and indoor air quality (IAQ) also affect the health of students. [9] Many studies have shown that indoor air pollutants, especially in hospitals were higher than outdoor air pollutants and that occurrence, concentration, and duration of indoor volatile organic compounds exposure in residences may contribute to the occupant's short and long-term adverse health effects. [11, 12, 20] Previous studies in China reported that dormitory environment factors, such as dampness and poor ventilation were related to asthma and respiratory infections among college students. [8, 9]

This short-time follow-up study of microbial indoor air quality in a nursing institute dormitory was conducted 2 times during a 3-month observation due to the students' complaints before the study was done. Indoor air samples were collected from dormitory rooms using a BioStage Impactor (QuickTake 30 sample pump) to assess total bacterial and fungal counts. After that, the isolated bacteria and fungi were preliminarily identified by group or genus by Gram's staining and lacto-phenol cotton blue. Results showed that higher mean levels of bacteria and fungi were found at the lower floors (especially, floor 1 or floor 2) and the lower levels of bacterial and /or fungal counts were found at the higher floors (floor 6 or over) in both assessments. It might be due to the lower floors, especially in the first and the second floors, having inadequate ventilation and the effects of surrounding environment air. Data from observations and interviews showed that most of dorm rooms on the lower floors, especially, floor 1 and floor 2 did not regularly open the windows due to the smell from the surrounding environment. Additionally, the common bathroom facilities were regularly wet and the exhaust fans were out of order. The higher relative humidity supported the growth of microbial organisms. [7] Whereas, most of dorm rooms on the higher floors regularly opened the windows and the common bathroom facilities were regularly dry due to the exhaust fans working well. Moreover, on the lower floors, each dorm room was shared by 4 - 5 students with crowded space and poor room hygiene practices that trended to have higher bacterial and fungal counts than other higher floors of dormitory with lower density of students (2 - 3 students in each room). A previous study showed the lower ventilation in studied rooms, gave a perceived higher stuffy smell. [9] Another study in China explained that cleaning routines and crowded spaces may be important factors for the propagation of respiratory infections in students. [8] Many reviews have shown that dampness with a low ventilation rates in the building is strongly associated to health problems like asthma and respiratory symptoms due to higher fungal contamination in indoor air. [7 - 9]

The isolated bacteria and fungi from air samples were identified by group or genus; it was found that the most common bacteria were *Staphylococcus spp.* and *Streptococcus spp.*, and the most common fungi were *Aspergillus spp.*, and *Penicillium spp.* Although, these isolated micro-organisms do not generally present a health hazard, high loads of bacteria and fungi suggested overcrowding and poor air hygiene. They may trigger allergic reactions, such as, allergic rhinitis and cough, allergic skin problems, and non-specific symptoms particularly among children, the elderly and immune-compromised hosts. [4 - 6] These groups are normally present in the air, environments and on human skin. [21] They can survive for a long periods in the air and the environment. A previous study demonstrated that most *Staphylococcus spp.* found in air and the environment was *S.epidermidis*, the normal flora of the human skin and respiratory tract. [22] This present study of airborne isolated fungi was similar to academic dormitories in several studies [9, 22, 23] which found that *Aspergillus spp.* was the most common fungi. This fungal genus could compromise the health and well-being of humans. [22] Mold or fungi can live practically anywhere and particularly favor growth conditions inside residential houses and dormitory rooms.

Preventive measures to reduce the probable effects from poor indoor air quality in dormitories should be considered. Increasing the amount of air ventilation in dormitory rooms, especially dormitory rooms at lower floor (1 - 4) should be done, probably by opening the window or exhaust fans and minimizing moisture accumulation or protecting stored materials from moisture in the room, such as waste paper. Indoor environments should be sufficiently cleaned, especially dorm room cleaning. Additionally, environmental surveillance, especially biological and chemical hazards contaminating outdoor air of the dormitory surroundings should be done.

Conclusion

This study reveals that the lower floors of the dormitory had significantly higher levels of bacterial and fungal counts when compared with the higher floors of the dormitory from both assessments. Most isolated bacteria and fungi do not generally present a health hazard, but high loads may trigger allergic reactions in susceptible hosts.

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Conflict of interest

The authors, hereby, declare no conflict of interest.

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