Quantitative assessment of bio-aerosols contamination in indoor air of University dormitory rooms

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Abstract

Objectives: The purpose of this study is to provide insight into how students are exposed to indoor bio-aerosols in the dormitory rooms and to figure out the major possible factors that govern the contamination levels.

Methodology: The Bio-aerosols concentration level of indoor air of thirty dormitory rooms of Jimma University was determined by taking 120 samples. Passive air sampling technique; the settle plate method using open Petri-dishes containing different culture media was employed to collect sample twice daily.

Results: The range of bio-aerosols contamination detected in the dormitory rooms was 511- 9960 CFU/m^3 for bacterial and 531-6568 CFU/m^3 for fungi. Based on the criteria stated by WHO expert group, from the total 120 samples 95 of the samples were above the recommended level. The statistical analysis showed that, occupancy were significantly affected the concentrations of bacteria that were measured in all dormitory rooms at 6:00 am sampling time (p-value=0.000) and also the concentrations of bacteria that were measured in all dormitory rooms were significantly different to each other (p-value=0.013) as of their significance difference in occupancy (p-value=0.000). Moreover, there were a significant different on the contamination level of bacteria at 6:00 am and 7:00 pm sampling time (p=0.015), whereas there is no significant difference for fungi contamination level for two sampling times (p= 0.674).

Conclusion: There is excessive bio-aerosols contaminant in indoor air of dormitory rooms of Jimma University and human occupancy produces a marked concentration increase of bacterial contamination levels and most fungi species present into the rooms air of Jimma University dormitory were not human-borne.

Key words: indoor air, bio-aerosol, bacteria, fungi, sedimentation technique, dormitory room.

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Introduction

Bio-aerosols in the indoor environment are the presumed or confirmed causative agents of various infectious diseases, and their components are associated to the development and exacerbation of chronic respiratory illness including asthma. [1-5] In many epidemiological studies a link has been seen between mold damage or moisture in indoor environments and increased risk of upper respiratory symptoms ranging from cough to shortness of breath. [5,6,7] Moreover, the WHO report based on the review of several epidemiological studies indicated that, there is sufficient evidence of the link between indoor dampness-related factors and a wide range of respiratory health effects, including asthma development, asthma exacerbation, current asthma, respiratory infections, upper respiratory tract symptoms, cough, wheeze and dyspnoea. [8] In general, there are three major groups of diseases linked with bio-aerosols exposure are infectious diseases, respiratory diseases and cancer. [2] So, it's crucial to control bio-aerosols contamination level and maintaining a clean and healthy indoor environment in order to sustain the health of the occupants.

Mostly, indoor air quality is only a problem when building occupants report symptoms. However, bio-aerosols contamination continues to pose a significant threat to health worldwide. [8, 9] Among different indoor air pollutants, bio-aerosols are one of the important pollutants that seek more attention, that contribute about 5-34% of indoor air pollution. [10, 11] As of these, assessments of bio-aerosols contamination level in different indoor environments have gained more attention in the recent decades. [12, 20]

Several studies have been indicated that the housing conditions, the human activities and life style of occupants is thought to be the principal factor contributing to the buildup and spread of bio-aerosols contamination in indoor environment. [10,12,19,21] Other important sources of biological particulate matter may be human oral and respiratory fluid emitted via talking, sneezing, coughing, and breathing [22,23] or the direct shedding of skin related micro biota. [24, 25, 26]

Thus bio-aerosols concentration level in indoor air is an important criterion that must be taken into account when indoor environments are designed, operated and occupied to reduce human exposure to bio-aerosols that cause adverse health effects. Therefore, the purpose of this study is to provide insight into how students are exposed to indoor bio-aerosols from the environment and other humans in the dormitory rooms and to figure out the major possible factors that govern the contamination levels.

Methods and Materials

Study Area

Jimma University (JU) is a public higher educational institution established in December 1999 by the amalgamation of Jimma College of Agriculture (founded in 1952), and Jimma Institute of Health Sciences (established in 1983). The University is located in Jimma town, which is 345km south west of Addis Ababa, Ethiopia. It has an altitude of 1740-1760m above sea level and its temperature range from maximum 25-30°C and minimum 7-20°C and annual rain fall range from 1200-2000mm. In this University, currently a total of 28583 students are enrolled in-campus programs. The University provides dormitory services, mostly for the regular undergraduate students. Students are assigned in different number to reside together according to the size of the rooms. Usually range from 6 to 26 students per each dorm room.

The study was conducted from April to May 2014 by selecting seven main dormitory buildings for sampling. From all selected dormitory buildings (Namely: Abajifar, Abdisa, Comoros, Sawa, Sheraton, Bladen and Whitehouse) 30 dorm rooms have been picked by simple random sampling from each buildings after proportionally allocated.

Sampling procedure

Sampling method following the standard 1/1/1 schedule (Petri dish must be left open to the air for 1 h, 1 m above the floor, 1 m from the wall). [27] Bacteria and fungi were collected on 2% nutrient agar and 4% sabouroad agar respectively. Moreover, samples were collected twice a day at 6:00 am and 7:00 pm. At 6:00 am by assuming that most of the students remain in their dormitory room after spending the whole night in their rooms and at 7:00 pm by assuming that most of students

spent their day time outside their dormitory for learning activities and remain there until 7:00 pm. So, after collecting the sample at specified times, were taken to the laboratory (Department of Environmental Health Science and Technology, Jimma University) and incubated at 37°C for 24 hours for bacteria and at 25°C for 3 days for fungi.

Once colony forming units (CFU) were enumerated, colony forming units per cubic meter (CFU /m^3) were determined, taking into account the following equation described by Omeliansky. [28, 29]

$N = 5a * 10^4 (bt)^{-1}$,
Where:
N: microbial CFU/m^3 of indoor air;
a: number of colonies per Petri dish;
b: dish surface, cm^2;
t: exposure time, minutes.

In line with bio-aerosols sample collection, data on: the number of students in each room during sampling, temperature and relative humidity were collected.

Statistical Analysis

SPSS Statistics 16.0 software was applied to determine the likelihood of statistically significant differences between the concentrations of bacteria and fungi measured at different sampling rooms with occupancy and other environmental factors like temperature and relative humidity.

Results

The indoor air bio-aerosols loads of thirty dormitory rooms of Jimma University were determined by taking 120 samples. The results of the research into the concentration, concentration range, arithmetic mean and standard deviation of bio-aerosols present in the investigated dormitory rooms and environmental parameters that have been measured are presented in Table 1and 2.

As can be calculated from Table 1, during early morning sampling (6:00 am) in 70% of dormitory rooms the bacterial concentrations were higher than the fungi ones, but in the afternoon sampling (7:00 pm) the bacterial concentrations higher only in 53% of dormitory rooms. And from the total 120 samples, 95 of the samples (79%) were a microbial load above 1000 CFU/m^3.

The highest level of bio-aerosols contamination was detected in the dormitory rooms that found in Sawa and Comoros buildings at 6:00 am sampling time, which are bacterial 9960 CFU/m^3 (Sawa 01) and fungi 6568 CFU/m^3 (Comoros 02) respectively. The lowest bacterial contamination was measured in Abajifar dormitory building (Abajifar 03) at 7:00 pm sampling time, which is 511 CFU/m^3, while the lowest fungi colony forming unit per m^3 air was recorded at 6:00 am in Sheraton dormitory building (Sheraton 02), which is 531 CFU/m^3.

During at 6:00 am sampling time, the average number of occupants varies from 21 to 26 in the dormitory rooms in which 26 students assigned to live, namely; Sawa and Comoros, where as in the dormitory rooms in which 6 students assigned to live, namely; Sheraten, Abdisa and Abjifar varies from 4 to 6 and in the dormitory rooms in which 12 students assigned to live, namely; Bladen and Whitehouse, the number of students varies from 10 to 12.

All examined dormitory rooms did not have HVAC (heating, ventilation, and air conditioning) systems. The temperature and relative humidity during sampling ranged from 23 to 31°C and 42 to 65% respectively (Table 2). As can be seen in Table 3 the Pearson correlation test indicated that neither the temperature nor the relative humidity in the selected dormitory rooms had a statistically significant effect on the measured bio-aerosols concentrations with p-value= 0.063 and 0.246 for bacteria and fungi respectively at 6:00 am sampling and p-value= 0.528 and 0.622 for bacteria and fungi respectively at 7:00 pm sampling.

Table 1. The bacteria and fungi concentration levels, the number of occupants, temperature, relative humidity of student dormitory rooms of Jimma University at each sampling time

No.	Examined dormitories	Bacteria (CFU/$m^{3)}$ in both sampling time		Fungi (CFU/$m^{3)}$ in both sampling time		Number of occupants during sampling time		Relative humidity during sampling time		Temperature during sampling times (°C)	
		6:00 am	7:00 pm	6:00 am	7:00 pm	6:00 am	7:00 pm	6:00 am	7:00 pm	6:00 am	7:00 pm
1	Sawa 01	9960	4010	4744	1825	25	2	42	54	31	26
2	Sawa 02	3670	2123	929	1559	22	3	47	59	29	25
3	Sawa 03	1599	1284	1062	2787	21	-	45	53	29	27
4	Sawa 04	5059	2674	2090	1360	23	1	54	61	26	24
5	Sawa 05	1913	1638	4611	1990	22	-	56	51	26	27
6	Comoros 01	2228	1900	2488	1626	21	-	46	54	29	26
7	Comoros 02	2516	2149	6568	5042	24	4	44	51	30	27
8	Comoros 03	4456	3670	962	1825	23	1	48	43	28	30
9	Comoros 04	3748	2713	3981	2787	21	-	49	57	28	25
10	Comoros 05	3172	2569	3782	3467	22	1	42	61	31	24
11	Sheraton 01	1258	747	730	1294	6	-	45	57	29	25
12	Sheraton 02	1180	865	531	1128	5	-	48	54	28	26
13	Sheraton 03	996	813	813	746	6	1	65	54	23	26
14	Abajifar 01	1153	839	1460	1758	4	1	54	57	26	25
15	Abajifar 02	747	590	1261	1692	4	-	46	57	29	25
16	Abajifar 03	891	511	1576	1825	6	2	44	51	30	27
17	Abajifar 04	1442	1127	1161	962	6	1	52	65	27	23
18	Abdisa 01	996	983	763	1028	6	-	55	57	26	25
19	Abdisa 02	813	629	929	730	5	1	51	54	27	26
20	Abdisa 03	1389	1245	1062	1692	6	-	44	57	30	25
21	Bladen 01	2202	852	1825	1990	11	1	42	54	30	26
22	Bladen 02	4194	3145	1725	1493	12	1	45	48	29	28
23	Bladen 03	2018	1389	1576	1742	10	-	43	54	30	26
24	Bladen 04	1494	1258	3400	2040	12	-	57	48	25	28
25	Bladen 05	1992	1415	1526	1178	11	1	54	48	26	28
26	White house 01	2136	2569	2488	3981	12	-	48	65	28	23
27	White house 02	1546	734	3483	6403	12	-	54	57	26	25
28	White house 03	1992	1415	4313	2919	10	-	50	51	28	27
29	White house 04	1678	2307	896	1758	11	-	53	61	27	24
30	White house 05	1900	1389	1062	1310	11	-	57	51	25	27

Table 2. Statistical summary of bio-aerosols concentration, temperature and relative humidity in student dormitory rooms of Jimma University

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Bacteria (CFU/ m^3) at 6:00 am	30	747	9960	2345	1831
Bacteria (CFU/ m^3) at 7:00 pm	30	511	4010	1652	945
Fungi (CFU/ m^3) at 6:00 am	30	531	6568	2127	1531
Fungi (CFU/ m^3) at 7:00 pm	30	730	6403	2065	1256
Temperature at 6:00 am	30	23	31	28	2
Temperature at 7:00 pm	30	23	30	26	2
Relative Humidity at 6:00 am	30	42	65	49	6
Relative Humidity at 7pm	30	43	65	55	5
Valid N (listwise)	30				

Table 3. Correlation coefficient matrix: - bacteria, fungi, temperature, relative humidity, and Occupancy in both sampling times (6:00 am and 7:0 pm) of Jimma University student dormitory rooms.

Variables	1	2	3	4	5	6	7	8	9
Bacteria 6:00 am	-								
Bacteria 7:00 pm	0.849**								
Fungi 6:00 am	0.392*	0.372*							
Fungi 7:00 pm	0.043	0.130	0.646**						
Temperature 6:00 am	0.344	0.292	0.218	0.201					
Temperature 7:00 pm	0.100	0.120	0.096	-0.094	-0.050				
Relative Humidity at 6:00 am	-0.311	-0.263	-0.154	-0.197	-0.986**	0.021			
Relative Humidity at 7:00 pm	-0.079	-0.071	-0.119	0.100	0.060	-0.991**	-0.033		
Number of occupant at 6:00 am	0.684**	0.749**	0.577**	0.344	0.279	0.185	-0.243	-0.131	
Number of occupant at 7:00 pm	0.259	0.196	0.431*	0.301	0.358	0.095	-0.300	-0.077	0.393*

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

Discussion

The excessive bio-aerosols contaminants in indoor air can cause significant health effects including those collectively known as sick building syndrome. [5, 6, 7, 30, 31, 32] Even though, there is no standard at international level to determine whether an indoor environment is contaminated or not, it has been recommended that environments with a microbial load above 1000 CFU/m^3 should be labeled as contaminated. [9] Evaluation of the air quality in the selected dormitory rooms of Jimma University, from the total 120 samples 95 of the samples were above this recommended level, which is 79%. Other research work also considered that total microbial load (bacteria and fungi combined) should not exceed 750 CFU/m^3, higher than this the environment is labeled as contaminated[33] and still other authors consider that 300 CFU/m^3 and 750 CFU/m^3 should be the limit for fungi and bacteria respectively. [34, 35]

When comparing indoor air environments of dormitory rooms of Jimma University, it can be seen that the rooms which found in the Sawa and Comoros dormitory buildings, have the highest bio-aerosols load and the rooms which found in Abajifar and Sheraton dormitory buildings, have the lowest load of bio-aerosols.

These can be mainly explained by the variation of occupancy during sampling times. The statistical analysis showed that, occupancy were significantly affected the concentrations of bacteria that were measured in all dormitory rooms at 6:00 am sampling time (p-value=0.000). But at 7:00 pm sampling time, there is no statistical significance between bacterial contamination levels with occupancy (p-value=0.298). These might be due to that, at 6:00 am sampling time, the sample is collected while most of the students were on the bed and there is no much air exchange with the outdoor air as of the doors and window were closed throughout the night. But at 7:00 pm sampling time, compare to 6:00 am sampling time there is high air exchange with the outdoor as of the windows left open throughout the daylight time starting from 8:00 am till around 8:00 pm., beside these, only few students were in the dormitory rooms, even, more than 50% of the dormitory rooms were no students at a time of sampling. In addition to these, there were a significant different on the contamination level of bacteria at 6:00 am and 7:00 pm sampling time (p=0.015), whereas there is no significant difference for fungi contamination level for two sampling times (p= 0.674). Moreover, as shown in Table 1, during early morning sampling (6:00 am) in 70% of dormitory rooms the bacterial concentrations were higher than the fungi ones. But, during 7:00 pm sampling time this figure decreased to 53%. This difference might be due to the fact that, at 6:00 am sampling there was higher occupancy than 7:00 pm sampling.

The concentrations of bacteria that were measured in all dormitory rooms were significantly different to each other (p-value=0.013) as of their significance difference in occupancy (p-value=0.000). And also the concentrations of fungi that were measured in all dormitory rooms were significantly different to each other (p-value=0.034). This variation could be explained as of their variation in ventilation conditions and dampness situation of the building that might create favorable condition for the fungi contamination. There are numerous studies reported worldwide on moisture damage and subsequent mold contamination in different indoor environments. [36, 37, 38, 39]

Therefore, this study revealed that, human occupancy produces a significant concentration increase of bacterial contamination levels into the rooms air of student dormitory and most fungi species present into the rooms air were not human-borne as it has been discussed above statistical analysis showed the occupancy hadn't have a significant effect on fungi contamination. These observations were in agreement with similar studies in indoor air. [12, 20] Moreover, the Pearson correlation test indicated that, there were no statistically significant correlations between bio-aerosols concentrations and the temperature or the relative humidity of the sample sites. These strengthen that, the principal factors contributing to the buildup and spread of bio-aerosols contamination in indoor environment of Jimma University student dormitory rooms were occupancy took the lion share for the bacteria contamination and other moisture containing organic materials might be the principal factor for fungi contamination.

Conclusion

There is excessive bio-aerosols contaminant in indoor air of dormitory rooms of Jimma University and human occupancy produces a marked concentration increase of bacterial contamination levels and most fungi species present into the rooms air of Jimma University dormitory were not human-borne.

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