

Quantitative Analysis of Microbial Aerosols in a Community College

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Abstract

The purpose of this study was to enumerate airborne bacteria and fungi in indoor air at Skyline College. We examined 112 samples (62 indoor and 50 outdoor samples) from 5 buildings between June and August 2004. For all buildings, both indoor and outdoor air samples were collected with an MB2 sampler. Culturable airborne bacterial concentrations in indoor air were equal to or lower than in outdoor air. The culturable airborne fungal concentrations in indoor air were 45% higher than those in outdoor air. The variety and number of microorganisms inside Bldg 1 was different than outdoors which may indicate an internal source of contamination. We recommend strict adherence to the published schedule for replacing heat-ventilation filters in all buildings.

Background

According to the U.S. Environmental Protection Agency (EPA), the average American spends nearly 90% of his or her time indoors, consequently the EPA considers indoor air pollution a high priority health risk (13). Recurring outbreaks of respiratory illness in office workers have been described since 1970 (5); these nonspecific illnesses became known as sick building syndrome. Symptoms include headache, fatigue, muscle aches, chills, and fever. These outbreaks have been attributed to bioaerosols composed of thermophilic actinomycetes, nonpathogenic amoeba, several fungi, and mycotoxins, and *Legionella* bacteria (13).

Increasingly, fungi in indoor air are being proposed as a cause of sick building syndrome. To evaluate the relationship between airborne fungi and adverse health effects, fungi and their frequency in both indoor and outdoor air need to be known (11). Information obtained from fungal air samples can assist in medical evaluations, determination of remediation, and assessment of health hazards.

Molds thrive in environments that contains excessive moisture, such as from leaks in pipes, walls, or roofs (10). Moreover with the popularity of energy efficient building construction and less ventilation with the outside air, the indoor environment has become an ideal setting for mold growth. Another key factor that contributes to molds growing indoors is the fact that many building materials are suitable nutrient sources for fungal growth. Cellulose substrates, including paper, cardboard, ceiling tiles, and wood are particular favorites for the growth of mold (1).

The most common indoor molds are *Penicillium*, *Rhizopus*, and *Cladosporium*. The pathogenic molds, *Aspergillus* and *Stachybotrys*, are less frequently isolated from indoor air (6).

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Materials and Methods

Microorganisms were collected and inoculated onto culture media using the MicroBio MB2 (Spiral Biotech) impact sampler (**Figure 1**). The MB2 is a statistical air sampler identified for this use by the American Conference of Governmental Industrial Hygienists (2). Sabouraud dextrose agar (SDA) (Criterion) incubated at 20°C for 5 to 7 days was used to culture fungi. Tryptic soy agar (TSA) (Criterion) incubated at 35°C for 48 hr was used to culture bacteria. Areas to be tested were identified by inspecting for water damage and asking all faculty and staff to report water damaged walls and floors and areas with off-odors.

Skyline College is a suburban community college consisting of buildings between 11 and 35 years old. Buildings 1 and 5 have had recurrent floor flooding. Samples were taken at ventilation inflows, at water damaged sites, and in the general area of rooms (**Table 1**). Ventilation intake is from the roof, or side for the Children's Center. We did not have the history of heating/ventilation filter maintenance; filters are scheduled to be replaced monthly.

Table 1. Location of indoor samples

Location	<i>n</i>	Age (yrs)	Heating/Ventilation
Skyline College			
Bldg 1, 1 st floor	18	35	HV
Bldg 2, 1 st floor stairs	10	22	HVAC
Bldg 5, 2 nd floor	16	11	HVAC
Children's Center (portable)	4	20	HVAC
Outdoor	36		
District Office, 1 st floor			
Outdoor	14	26	HVAC



a) Collecting from a water damaged area



b) Collecting from a ventilation inflow.

Figure 1. Air samples were collected with the MB2, which collects airborne bacteria and fungal spores from air flowing at 100 liters/minute through a series of 1 mm diameter air inlets, onto an agar filled 47 mm contact plate.

Results

We examined 112 air samples (62 indoor samples and 50 outdoor samples) from four buildings at Skyline College and at the San Mateo County Community College District Office. Samples were taken between June and August 2004. Indoor and outdoor humidity ranged from 40-60% during this study. The average number of fungi/m³ in indoor air was approximately 45% higher than outdoor air at Skyline College and at the District Office (**Figure 2a**). The average number of bacteria/m³ in indoor air at Skyline College was approximately 42% lower than outdoor air and 5% higher at the District Office (**Figure 2b**). Biocontamination levels varied by building (**Figures 3 and 4**) and increased with increased age of the buildings (**Figure 5**).

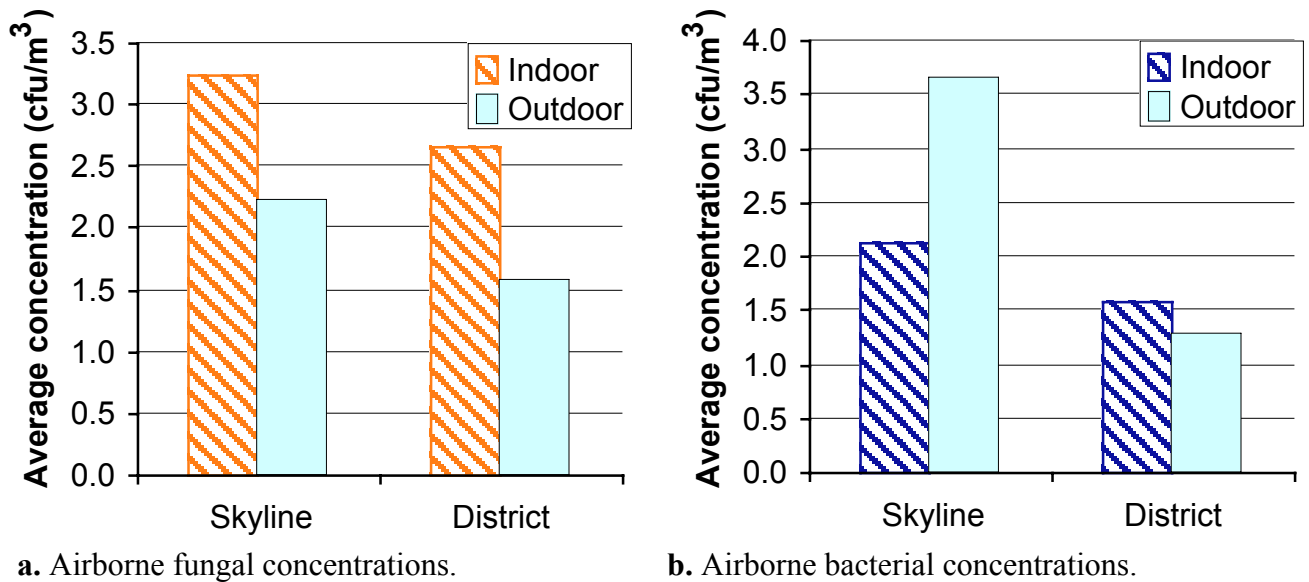


Figure 2. Concentrations of airborne microorganisms.

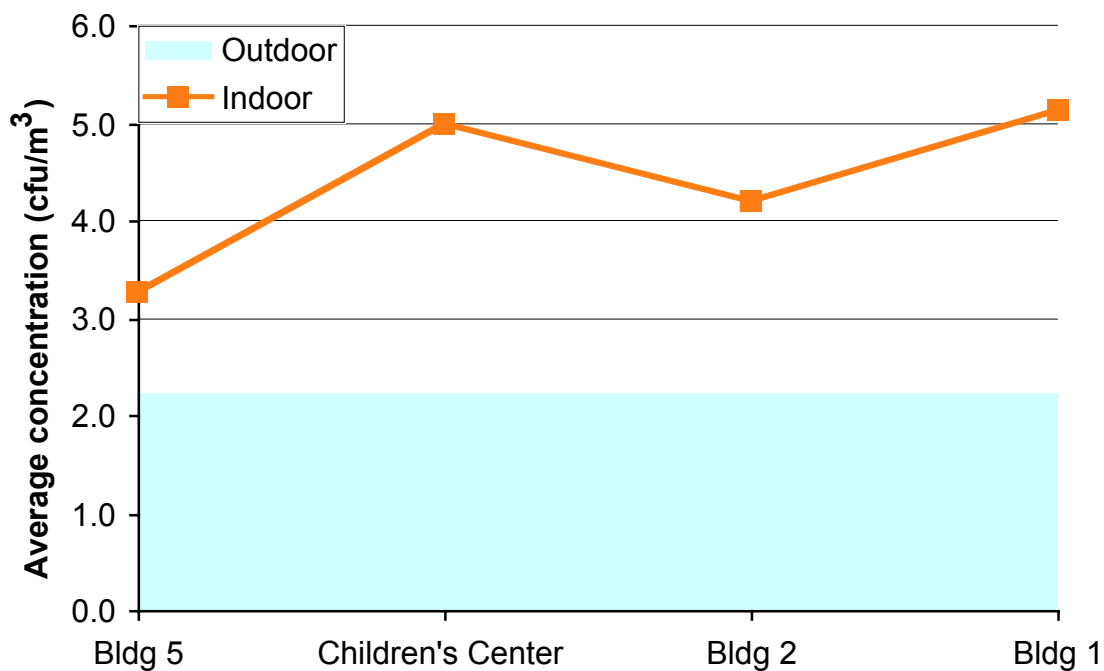


Figure 3. Comparison of airborne fungi by building.

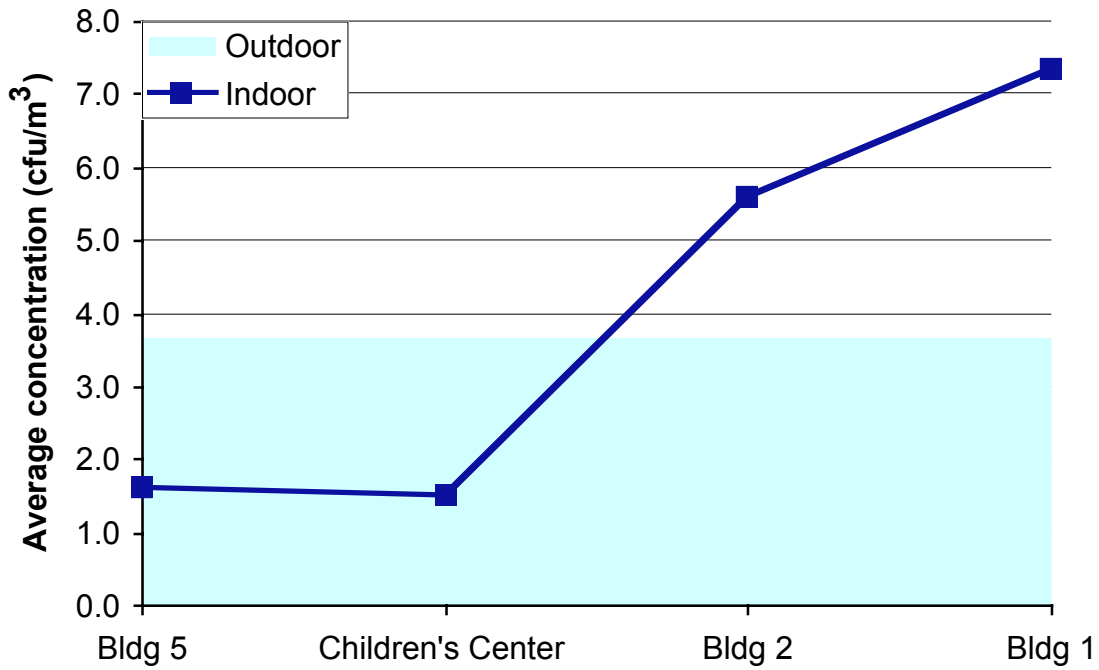


Figure 4. Comparison of airborne bacteria by building.

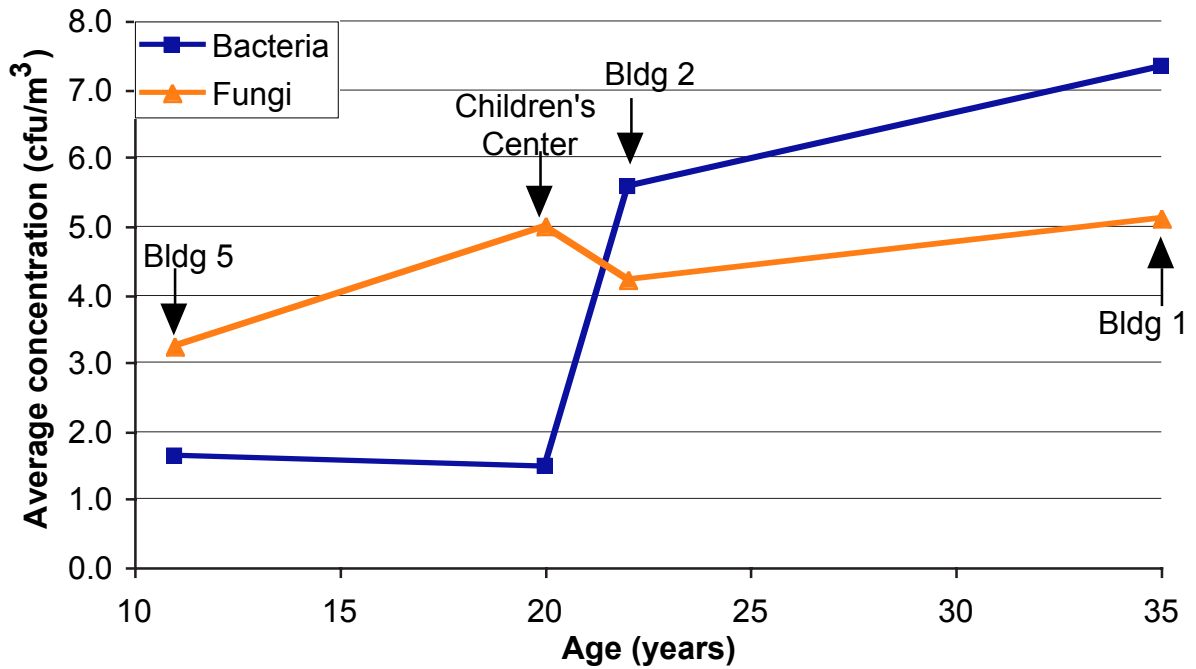


Figure 5. Comparison of building age and airborne biocontamination at Skyline College. The District Office is not included because it is not on the college campus and thus affected by different atmospheric conditions, a different maintenance schedule, and a different use schedule.

Discussion and Conclusions

The geographic location of Skyline College affords clean air. Sheldon (11) reports mean outdoor airborne fungal concentrations of 930 cfu/m³ and mean indoor concentration of 300 cfu/m³ in the far west. The prevalence of microbes in outdoor air in San Mateo County is low because of prevailing westerly winds off the Pacific Ocean that move airborne particulates to the east. Moreover, remaining particulates are likely to precipitate with coastal fog.

Only viable cells were counted in this study. However, it has been found that culture techniques may underestimate the bacterial burden of indoor air by as much as 90% (4). Additionally, foot traffic and vacuuming have been shown to increase fungal counts (3). Human activity in and around sampling sites occurred during indoor air sampling.

Penicillium was the predominant fungus cultured. (Figure 6). Bacteria cultured included endospore-forming aerobes (*Bacillus*) and a variety of pigmented cocci (Figure 7). These bacteria are expected in air because they can withstand desiccation and ultraviolet radiation. Only one actinomycete bacterium (Figure 8a) and one *Stachybotrys* fungus (Figure 8b) were cultured. Both are found naturally in soil and indoor accumulations of these organisms have been shown to cause various adverse health effects (6, 9).

Microbial concentrations increased with increasing age of the buildings. The highest counts and greatest diversity of microorganisms were found in the oldest building. This could be due to microbial growth in water damaged walls resulting from recurrent winter flooding in this building.

The lack of a single official standard for the microbial concentration in indoor air can make answering the question “How clean is clean enough?” difficult. Miller *et al* (7) state that indoor fungal concentrations are acceptable when indoor fungi are qualitatively similar to outdoor air or when indoor fungi are quantitatively lower than outdoors. The OSHA guideline is that ≥ 1000 fungal cfu/m³ indicates contamination (8). The concentration of indoor airborne bacteria was equal to or lower than outdoor air but indoor and outdoor samples differed qualitatively. Airborne bacterial concentrations were less than the indoor average (of 280 cfu/m³) in the EPA’s building assessment survey (12).



Figure 6. Fungi from 1 m³ of air collected on SDA (Bldg 1 stairwell). No indoor samples had large numbers of a single species.

In summary, our study showed that outdoor fungal aerosols were at the 25th percentile in the United States (11). Indoor air biocontamination level are within published recommendation (7, 8) and at the 25th percentile for buildings in the United States (11). The variety and number of microorganisms inside Bldg 1 was different than outdoors, which may indicate an internal source of contamination. We recommend strict adherence to the published schedule for replacing heating/ventilation filters in all buildings.



Figure 7. Nine species of bacteria were collected from 0.5 m³ of air on a TSA plate (Bldg 1 stairwell). No indoor samples had large numbers of a single species.



a. The single actinomycete was cultured from 1 m³ of outdoor air (Bldg 1 roof).



b. *Stachybotrys* cultured from 1 m³ of air outside Bldg 5. The normal habitat of *Stachybotrys* is soil. Soil excavation may have released spores into the air on this sampling day.

Figure 8. Actinomycete bacteria and *Stachybotrys* fungus.

Acknowledgements

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