MICROBIAL ANALYSIS OF INDOOR AIR QUALITY AT A COMMUNITY COLLEGE

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ABSTRACT

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. Recurring outbreaks of respiratory illness in office workers have been described since 1970; these nonspecific illnesses became known as sick building syndrome and their causes attributed to a variety of microorganisms. At present, there are no uniform national standards for airborne bacteria and fungi. The purpose of this study was to enumerate airborne bacteria and fungi in indoor air at Skyline College. We examined 84 air samples (48 indoor samples and 36 outdoor samples) from four buildings between June and August 2004 using an MB2 air 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 33% higher than those in outdoor air. The variety and number of microorganisms inside Building 1 was significantly higher than outdoors, which may indicate an internal source of contamination. The air filters in Building 1 were cultured to determine the microbial concentration. Nearly all tests revealed <500 fungi/mm^3. This could be indicative of the air filter's inability to trap smaller fungal and/or bacterial particles. We recommend strict adherence to the published schedule for replacing heat-ventilation filters in all buildings.

BACKGROUND

Dirty heating ventilation air conditioner (HVAC) filters can contain up to 3,400 fungal cfu and 6,700 bacterial cfu per gram of dust (4). Fungi specifically, in indoor air, are increasingly being proposed as a cause of sick building syndrome. In buildings where microbes grow in the moist environments afforded by leaky pipes or roofs and decaying building material, the chances of experiencing adverse health effects ranging from mild allergies and colds to nasal bleeding and bronchitis increase (6). With the popularity of energy efficient building construction and less ventilation with outside air, the indoor environment has become an ideal setting for mold. Maintaining optimum indoor air quality therefore is of great importance. Although the U.S. Food and Drug Administration recognizes the health risks associated with indoor air pollution, at present, it cannot provide national health standards for air filter performance as research data on the relationship between air filtration and actual health improvement is lacking (9). 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 (14). Information obtained from air samples can assist in medical evaluations, determination of remediation, and assessment of health hazards.

The purpose of this study was to enumerate airborne bacteria and fungi in indoor air at Skyline College, and to test the bacterial/fungal filtration performance of HV filters being used.

MATERIALS & METHODS

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.

Areas to be tested were identified by inspecting for water damage or off-odors.

Collected microorganisms and inoculated culture media using the MicroBio MB2 (Spiral Biotech) impact sampler; June-Aug. 2004.

The MB2 is a statistical air sampler identified for use by the American Conference of Governmental Industrial Hygienists (2). **(Figure 1, Table 1)**.

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 2 days was used to culture bacteria.

1cm × 1cm and 2 cm × 2 cm pieces of 3 and 6-month-old polyester Air Handler® (manufacturer) 5W102 air filters used at the ventilation intake on the roof of Building 1 were vortexed in 99-ml aliquots of sterile water; Jan-May 2005 **(Figure 2)**.

Aseptically made serial dilutions of the filter slurry ranging from 1:10-1:10^7.

Performed standard plate counts on SDA and nutrient agar (Criterion, NA).

SDA plates were incubated at 25°C for 5-7 days; NA plates at 35°C.

Rodac plates containing SDA (Criterion) were used to culture fungi from inside the Building 1 intake vents; May-July 2005.

After the incubation period, plates were examined and counted for bacteria and fungi.

Table 1. Location of indoor samples

Location	*n*	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		

Figure 2. Air intake filters from Building 1 were tested for bacteria and fungi.

RESULTS

We examined 84 air samples (48 indoor samples and 36 outdoor samples) from four buildings at Skyline College. Indoor and outdoor humidity ranged from 40-60% during this study. The average number of fungi in indoor air was approximately 33% higher than outdoor air. The average number of bacteria in indoor air was approximately 43% lower than outdoor air **(Figure 3)**. Biocontamination levels varied by building and increased with increased age of the buildings; Building 1, the oldest at 35 years, showed the highest levels of both bacteria and fungi **(Figure 4)**. Cultures obtained from indoor air samples taken with the MB2 air sampler failed to show large numbers of any single fungal or bacterial species **(Figure 5)**.

From outdoor air, one actinomycete bacterium and one *Stachybotrys* fungus were cultured **(Figure 6)**. Both are found naturally in soil and indoor accumulations of these organisms have been shown to cause various adverse health effects (7, 12). Bacteria cultured included endospore-forming aerobes (*Bacillus*) and a variety of pigmented cocci **(Figure 5b)**, but these bacteria are expected in air because they can withstand desiccation and ultraviolet radiation.

Between 9-13 × 10^7 fungal cfu/15cm^3 were cultured from Building 1 rooftop intake filters in use for 3 months and 6 months **(Figure 7)**. No bacteria were cultured from the filters. Rodac plates containing Sabouraud dextrose agar pressed directly onto the grates inside the Building 1 intake vent showed fungal counts >100 cfu/47 mm^2 **(Figure 8)**; no fungi or bacteria grew on Rodac plates pressed against the vent walls. The filters concentrated airborne fungi: the highest number of fungi was on the filters, and the lowest number, outdoors **(Figure 9)**.

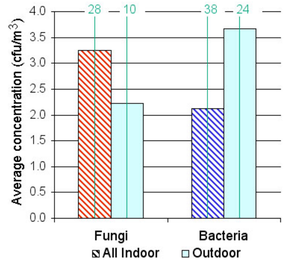


Figure 3. Concentrations of airborne microorganisms at Skyline College. Bars show ranges from all samples.

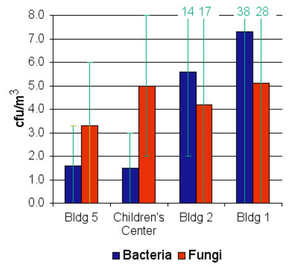


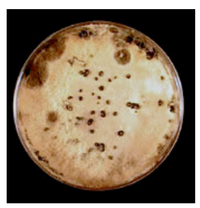
Figure 4. Comparison of airborne microorganisms by building. The buildings range from 11 years (Bldg 5) to 35 years (Bldg 1). Bars show ranges from all samples.

a. Fungi from 1m^3 air collected on SDA plates.

b. Nine species of bacteria including endospore-forming aerobes were collected from 0.5m^3 of air on a TSA plate

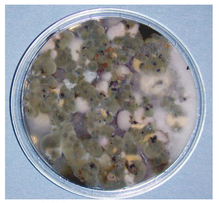
Figure 5. Microbes cultured from Building 1, stairwell, indoor air.

a. Actinomycete bacteria from 1m^3 of outdoor air (Bldg 1 roof).



b. *Stachybotrys* cultured from 1m^3 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 6. Microbes collected from outside air.



a. *Penicillium,* sometimes associated with sick building syndrome (15), was the predominant fungus cultured.

b. *Rhizopus,* an opportunistic pathogen that can cause respiratory complications (13), was also found.

Figure 8. Fungi cultured on SDA from filter vents.

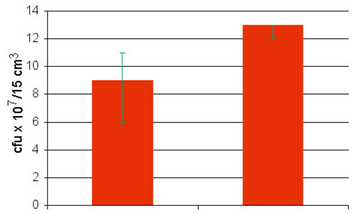


Figure 7. Comparison of fungi in 3- and 6-month-in-use filters from Building 1. Bars show ranges from all samples.

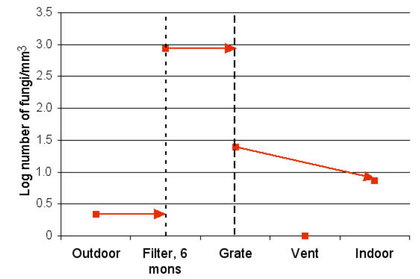


Figure 9. Comparison of fungi along the path of air into Building 1.

DISCUSSION & CONCLUSIONS

Shelton (14) reports mean outdoor airborne fungal concentrations of 930 cfu/m^3 and mean indoor concentrations of 300 cfu/m^3 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% (5). Additionally, foot traffic and vacuuming have been shown to increase fungal counts (3), and human activity in and around sampling sites occurred during indoor air sampling.

Overall, Building 1 showed the highest counts and greatest diversity of microorganisms found; the variety and number of microorganisms inside Building 1 was different than outdoors, which may indicate an internal source of contamination due to microbial growth in water damaged walls resulting from recurrent winter flooding.

As many as 30 percent of the buildings in the developed world may have problems leading to occupant complaints and illness (1). Despite this and myriad health issues associated with poor quality indoor air, government regulation of air filters remains nonexistent. The American Society of Heating, Refrigeration, and Air Conditioning Engineers standards for HVAC filters are based on particle size (10). Our results indicate the Air Handler® is filtering out larger particles, but is too porous to catch many of the smaller bacterial particles. Rodac plates pressed directly into the rooftop intake vents of Building 1 grew *Penicillium* and *Rhizopus* **(Figure 8)**.

Our study showed that outdoor fungal aerosols were at the 25th percentile in the United States (14), and indoor air biocontamination levels were within published recommendations (8, 11) at the 25th percentile for buildings in the United States (14).

We recommend strict adherence to the published schedule for replacing heating/ventilation filters in all buildings; possibly a change to pleated air filters that offer removal efficiencies well above 20%, provide extended surface area allowing the capture of more particulates without causing air flow problems, and competitive costs with other filtration options (2); and periodic steam cleaning of the grates.

Rhizopus gets caught in the filter

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ACKNOWLEDGEMENTS

We thank Dr. Christine Case for her advice and patient encouragement throughout this process; Patricia Carter and the other Biology laboratory technicians for their timely supply of materials, and helpful suggestions; Megan Abadie, Tim Ashton, Richard Davis, Myra Grace Gray, Cao Hoang, Arran Phipps, and Sasha Rose for collecting samples; and Tony Vassalle and Tony Gulli for taking us through the vents.