Indoor Microbial Air Quality of a 42-Year-Old Elementary School

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BIOL 230 and BIOL 695 research project presented at the 2015 SACNAS Conference

Abstract

The average public school building in the U.S. is over 40 years old and 29% have never been renovated. Almost any building surface can nourish microbial growth. Elevated levels of indoor airborne microorganisms can result in significantly higher rates of illness, particularly in those with increased susceptibility (e.g., children). The objective of this study was to perform a survey of indoor microbial air quality of a water-damaged 42-year-old school operating as a child development center in the San Francisco Bay Area.

We collected 496 air samples within the old building and 180 air samples from nearby newer buildings and outdoor locations. Air samples were taken with an impact air sampler onto nutrient media selected for bacteria and fungi. Data were examined using a three-dimensional approach and multivariable analysis.

Indoor airborne bacteria were 139% higher in the old building compared to neighboring renovated buildings and 76% higher than outdoor air. Airborne fungi were 128% more numerous compared to the renovated buildings and 112% lower than outdoors. The variety and number of microorganisms inside the older building were different than outdoors. No direct source of contamination was found, however, open windows correlate with a 105% increase in indoor fungal concentration ($P<0.001$). Our data confirm that ventilation and filter maintenance help lower microbial aerosols and should be maintained in accordance with California regulations.

Aim

To assess and resolve factors contributing to increased airborne microorganisms in a child development center.

Background

- Americans spend on average 90 percent of their day indoors, in which the quality of air may be two to five times more polluted than outdoor air (6).
- Particulate matter smaller than 10 µm may enter the respiratory tract and increase the risk of illness (1). Symptoms including headaches, fatigue, dizziness, nausea, and irritation of the eyes, nose, throat, and lungs, in association with a particular building are known as Sick Building Syndrome (SBS).
- Factors that can contribute to SBS include inadequate ventilation, poor building design, temperature, humidity, occupant activities, and chemical or biological contaminants (3).
- The high occupant density in schools increases the concentration of airborne particulate matter from human microbiota (5). Schools are required to meet ventilation standards, but despite this, there are still no concentration standards or personal exposure limits for airborne microbes (4). Additionally, children may more susceptible to indoor pollutants than the general population (7).
- The Loma Chica building, functioning as a Child Development Center, was the test site for this study. This building has water damage on the ceiling, rusted ventilation panels, inadequate ventilation

flow, and furnishings all of which promote the growth of microorganisms and potentially reduce indoor air quality (IAQ) (**Figure 1**).

Figure 1. Loma Chica, is apparent on windows sills (shown in the photo) and ceilings. currently a child development center, was built in 1973 for a middle school. Water damage is apparent on windows sills (shown in the photo) and ceilings.

Materials & Methods

- Air samples were taken inside the Loma Chica building near the ceiling, air vent, midroom, and floor in all 10 rooms. All air vents were located near or on the ceiling and midroom samples were taken in the center of the room approximately 1 m above the floor.
- As a control, air samples were collected outside the building and in nearby renovated buildings.
- Bacterial samples were collected onto Nutrient Agar and incubated for 72 hours at 35°C.
- Fungal samples were collected onto Sabouraud Dextrose Agar and incubated for 72 hours at 25°C.
- Four 700L air samples were taken with two MicroBio Impact Air Samplers at each location.
- Surface samples from the test site floor and ceilings were collected using Rodac plates.
- Air filters from the test site were enumerated using heterotrophic plate counts of 1 cm^3 samples cut from the filters.
- Analysis of variance (ANOVA) calculations were performed using JMP software to determine significant factors affecting airborne microbial concentrations.

Results

- Airborne bacterial concentrations in Loma Chica were 139% greater than in renovated buildings and 76% greater than outdoor air samples. Airborne fungal concentrations were 128% greater than in nearby renovated buildings (**Figure 2**).

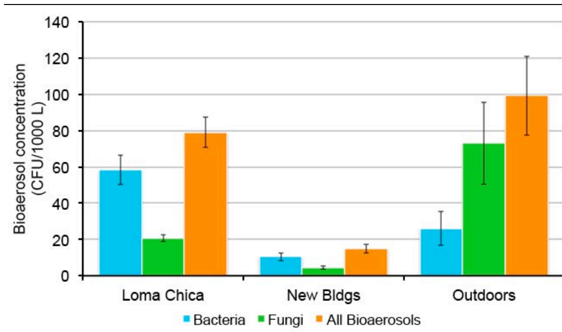

Figure 2. Bioaerosols concentrations were 139% greater in Loma Chica than in nearby renovated buildings. Error bars = 1 S.D.

- Inside Loma Chica, airborne bacterial concentrations were 95.2% higher than fungal, while outdoor the fungal concentration was 112% higher; however, no direct source of contamination was identified.
- Lack of rain was the only factor that influenced indoor bacterial aerosol concentrations, correlating with a 79%

increase 10-17 days without prior rain (P=0.0087).

- Open windows were the dominant factor increasing indoor fungal aerosols by 105% (P<0.0001) (**Figure 3**).

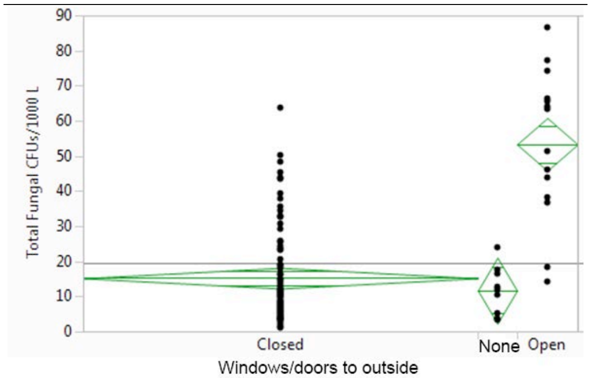

Figure 3. One-way analysis of total fungi. Spikes in outdoor fungal aerosols correspond to spikes in fungal aerosols inside Loma Chica.

- Other factors that correlated with increased indoor fungal aerosols include lack of rain in preceding days (P<0.0001), floor and midroom locations (P=0.0002), water-damaged ceilings (P=0.0245), area rugs (P=0.1066), and use of ventilation (P=0.2260).
- Surface and air filter samples did not show any significant microbial growth.
- Dominant fungi were *Rhizopus*, *Aspergillus*, *Cladosporium*, and *Penicillium spinulosum* (**Figure 4**).

Figure 4. An air sample taken inside Loma Chica's toddler room showing the diversity of dominant fungi.

Discussion & Conclusion

- Higher bacterial aerosols may be due to the occupants themselves. Although occupant density did not show statistical correlation, bacteria are commonly shed from skin, hair, nostrils, and mouths. This may be exaggerated with the typical activities and hygiene of children.
- Loma Chica was the only building tested in which windows were reported as the primary method of ventilation. Proper ventilation and filtration should prevent indoor spikes in microbial aerosols that occur outdoors, as reflected by the ventilation units in renovated buildings.
- Rain has been known to decrease airborne microorganisms, thus improve air quality in terms of respiratory health. The time range and amount of rain that significantly lowers bacterial and fungal aerosols was not determined, but given its significance, this could be a focus for future research.
- Airborne microorganisms settle with gravity and become resuspended with local air turbulence; thus, increased microbial concentrations in the floor and midroom samples may be due to microbial growth from water-damaged ceilings, vents, or other nearby sources of

contamination. This behavior may also explain variability in the surface and air filter samples.

- Localized IAQ problems might remain in spaces where contaminant sources are concentrated and that are poorly ventilated. Proper ventilation and building care is recommended to prevent and fix IAQ problems. Surfaces and decoration that can trap and store microorganisms should be replaced.

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Acknowledgements

We thank Dr. Christine Case for her guidance and support; The Biology Laboratory Technicians, Kylin Johnson and Gary Cheang, for providing the media and equipment used in the experiment; Facilities and Security at Skyline College for their assistance, and the faculty and staff at the Children's Center.