Impact of Human Occupancy on Indoor Air Microbiome

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Abstract

According to the *National Human Activity Pattern Survey* (NHAPS), an average person spends 80-90% of their time indoor while breathing in 14 L of air per day (5). Due to this significant exposure to airborne microorganisms, indoor air quality has direct impact on occupants' health. The microbiome in a built environment (BE) is shaped by a wide range of factors including occupants, building design such as the HVAC system and nearby outdoor environments (4,6,8). The contribution of living occupants to indoor air microbiome raises concerns for the spread of antibiotics resistant bacteria from humans and other animals via air. In 2011, the methicillin resistant *Staphylococcus aureus* (MRSA) caused 80,461 invasive infections and 11,285 related deaths in the U.S. alone (2). Although the prevalence of MRSA in hospitals and community settings has been studied, there is little research done on the MRSA presence in indoor air (3,6,8). One goal of this study is to analyze the impact of human occupancy on indoor air microbiome and to detect the presence of MRSA in school atmospheres. Air samples were taken at three different elevations in each room of before and after human use. The bacterial concentration (CFU/L) significantly increased after occupancy, particularly at high elevation in all trials. Through coagulase and antibiotics susceptibility tests, MRSA was detected in at least 1 out of 15 samples taken from each room. These findings suggest the strong impact of human occupancy on indoor air microbiome, and the evidence of MRSA in classroom environment.

Background

1. Compared to mechanically ventilated rooms, naturally ventilated rooms tend to have microbiomes similar to outdoor air, which, in turn, is influenced by weather and season (6,9).
2. Source apportionment of airborne microorganisms collected in a pet-friendly office showed that 40 % of them originated from humans, 30 % from outdoors, and 30 % from dogs. Many of the microbes associated with normal human skin such as *Staphylococcus* spp., *Micrococcus* spp,, and *Acinetobacter* spp. have been identified in BEs (8).
3. There were at least 2 million infections caused by antibiotic resistant bacteria in the United States and roughly 23,000 people die each year as a result (1).
4. Methicillin resistant *Staphylococcus aureus* (MRSA) is known to cause skin and wound infections and, in serious cases, infection can lead to pneumonia and sepsis. CA-MRSA appear to have enhanced virulence and adaptability to colonize environmental surfaces (3,5,7,10).
5. Five to ten percent of community-associated MRSA (CA-MRSA) infections are potentially life-threatening (10).
6. Most MRSA infections were health care–associated: 5250 (58.4%) were community-onset infections, 2389 (26.6%) were hospital-onset infections; 1234 (13.7%) were community-associated infections (5).

Table 1. Collection sites

Room	Dimensions	Heating vents	Windows that open	Doors
CR	4.66 × 3.45 × 2.45	2	0	1
ER	11.89 × 10.67 × 2.74	3 + 1 AC	2 (open during class time	2
LR	17.83 × 12.45 × 3.30	10	0	2

CR=conference room, ER=exercise room, LH=lecture hall

Materials and Method

- Samples were collected from three locations at Skyline College: a seldom-used conference room, a lecture hall, and a spinning room (**Table 1**).
- At each room, 1000 L of air was taken from three elevations, close to the floor (0.2 m), the standing height of human (1.0 m) and near the ceiling (2.3-2.7 m), using the MicroBio MB2-RSH air sampler.
- Samples were directly inoculated onto Nutrient agar (NA), Mannitol Salt agar (MSA), Sabouraud Dextrose agar (SDA), Eosin Methylene Blue agar (EMB) and Trypticase Soy agar (TSA). Plates were incubated at 37°C for 48 hr. Fungal (SDA) plates were incubated at the room temperature for 120 hr.
- Coagulase tests were performed on mannitol fermenters (**Figure 1**). Coagulase + colonies were grown in nutrient broth and incubated at 37°C for 24 hr.
- Mannitol +, coagulase + colonies were tested for susceptibility to oxacillin, vancomycin, and penicillin by disk diffusion assay (Figure 1, 2).

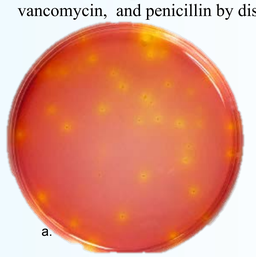

Figure 1. (a) Acid produced by mannitol-fermenting bacteria changes the phenol red indicator to yellow on MSA. **(b)**Coagulase + bacteria coagulate blood plasma.

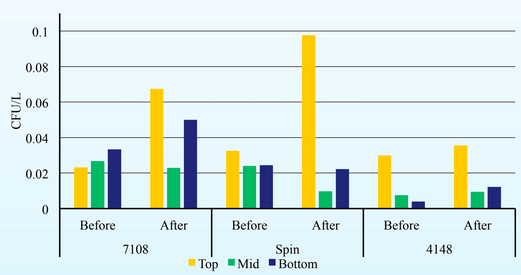

Figure 3. Total bacterial counts before and after human occupancy

Results

- Bacteria were uniformly distributed in the CR and ER before use, andmore concentrated at high level in the LH. After human use, the upper region had the highest CFU/L in all rooms (**Figure 2**).
- Generally, all three rooms had less than 0.04 bacterial CFU/L before occupancy. The concentrations tripled in the CR(from 0.02 to 0.0675 CFU/L) and ER (from 0.03 to 0.097 CFU/L), particularly at the highest elevation in both rooms after-use (**Figure 3**).
- Mannitol-fermenting staphylococci increased after human occupancy with the highest elevation having the most significant increase in all three rooms.
- After occupancy, the ER and LH had 1100% and 950% increase in *S. aureus*, respectively. *S. aureus* in the C, increased by 42% (Figure 4).
- A few non-lactose fermenting gram-negative bacteria were observed on EMB plates.
- Fungi growing on SDA plates were identified (**Table 2**).

Figure 4. Mannitol-fermenting staphylococci increased after human occupancy.

Table 2. Fungi grown in each room

Room	Fungi
Conference Room	*Penicillium* sp., *Cladosporium* sp., *Aspergillus* sp.
Exercise Room	*Cladosporium* sp., *Crysosoprium* sp., *Aspergillus* sp.
Lecture Hall	*Trichophyton* sp., *Penicillium* sp.

Acknowledgements

We would like to give special thanks to our mentor, Dr. Christine Case, for all her guidance and patience with us in completing this research from the very beginning. We are also grateful to Skyline College lab technicians, Kylin Johnson and Gary Cheang, for their critical support in our study.

Discussion

- The bacterial concentrations in ER and CR increased after human occupancy. Bacteria that are naturally found on human skin and in the respiratory tract can spread enter the air via breathing, skin shedding, or physical movements, increasing the bioaerosols of the rooms.
- The absence of a significant difference between the overall bacterial concentration of LH before (0.03 CFU/L) and after (0.035 CFU/L) human occupancy might be related to room size.
- The higher concentration of bacterial colonies in upper region of all rooms after human occupancy can be explained by the air vents located in the ceiling, which causes the upward air flow in the rooms.
- The gram-negative bacterial concentrations were very low (<0.005 CFU/L) in all rooms. This agrees with the fact that enteric bacteria are not usually airborne.
- The most common fungus identified was *Penicillium*, which is ubiquitous in nature. Other fungi identified arecommonly found in soil, which were most likely brought into the room through the air currents (6).
- MRSA was present in at least 1 out of 15 trials in each room.

Conclusion

The findings in our study highlight the impact of human occupancy on the indoor air microbiome. Our data also suggest that building design such as the location of the air vents influences the bacterial distribution in built environments. The presence of MRSA highlights the importance of community-acquired MRSA.

Future Studies

More trials need to be performed in order to identify the effect of human occupancy on room air quality.

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