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Microbiome of Low Profile and Well Ventilated Houses and Human Health Risks

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Abstract:
Indoor environments have become a predominant habitat for modern individuals, as urban individuals spend the majority of their time in the indoor reservoir, mostly in homes, workplaces, schools, public transports, hospitals, and other indoor spaces. Concomitant with this rapid growth and expansion of indoor reservoirs, there is also a quest to maintain and protect the well-being of indoor occupants. The awareness of exposure to the indoor microbiome and its health effects is lacking. Individuals in indoor reservoirs co-exist with a myriad of bacteria, fungi, viruses, and microbial parasites such as mites. Different rooms within the same building (e.g., bedroom vs. bathroom) exhibit distinct microbiomes. In this article, we review the origins and the components of the microbial communities in low-profile and well-ventilated houses and their possible effect on human health. It is, therefore, necessary to monitor and control indoor airborne microbes for occupational safety and public health.

INTRODUCTION

Microorganisms are ubiquitously found in the built environment; they cover contact surfaces; our skin and are ample in the air we breathe (Qian *et al.*, 2012). Indoor air is a complex blend of inorganic and organic constituents with an abundance of microbes including bacterial and fungal species (Jayaprakash *et al.*, 2017).

People need safe and healthy living environment, as millions of children and adults spend most of their lives in homes, schools, hospitals, and office buildings. House dust serves as a repository for several compounds originating from both indoor and outdoor environments (Rintala *et al.*, 2012). The description of house dust composition can help us to understand the impact of dust exposure on human health (Rager *et al.*, 2016).

Indoor environments have become a major habitat for modern human beings. There is a quest to preserve the well-being of indoor inhabitants. Individuals in indoor reservoirs co-exist with several microbial communities including bacteria, fungi, viruses, and parasites. Air pollution which contains these microorganisms is a global problem regardless of stagnating trends for some pollutants (Guerreiro *et al.*, 2014). Indoor environments exhibited a great distinction in the total concentration of air pollutants (Moon *et al.*, 2014).

Plants are a potential source of airborne microbes in the environment (Berg *et al.*, 2014). Indoor environment surfaces provide an ultimate interface for particle accumulation. Human inhabitants emit microbes mainly from the skin and have been documented as the key source of indoor airborne microbes (Stephens, 2016). In many indoor environments, the growth of fungi or molds serves as an important source of airborne microorganisms. Common inhabitants of different parts of the human body can be found in indoor reservoirs. The indoor airborne microbial community is closely mirrored with outdoor air after proper ventilation. Naturally ventilated historical buildings are appropriate sites to explore the effect of the environment on indoor air quality (López-Aparicio *et al.*, 2011).

Transmission of Microbes

The direct evidence of transmission of microorganisms between air and indoor environment is lacking. It is assumed that the majority of the microbes on built environment surfaces is dumped from indoor air, or is the outcome of direct invasion from the outdoor environment. Discrete microbial communities can be seen on various surfaces, that are influenced by occupants (Adams *et al.*, 2015).

The skin-associated microbes can re-establish in schools following routine cleaning. More frequent cleaning is required to decrease the transmission of pathogenic microbes between inhabitants. The use of a single wipe with a wet fabric and the management using disinfectant lessens the burden of pathogens (Kwan *et al.*, 2018). There are reports of phylogenetically distinct fungal communities in household dust with more diversity and abundance in temperate zones than in the tropics.

The transmission of microbes occurs mainly by skin-surface contact. Microbes can also be transmitted indoors by the shoes of the inhabitants. Fecal indicator *Escherichia coli* contamination was found in linoleum floors in rural residences coming from outdoors with boots (Abreu *et al.*, 2012). Household dust is comprised of a bacterial community with human dermal, vaginal and fecal origins affected by the number and sex of inhabitants. The resuspension of settled dust is documented for aerosolizing indoor microbes (Barberán *et al.*, 2015).

Microbes in the Environment

Microorganisms inhabit both indoor and outdoor environments. The amount of water and other nutrients in the environment determines the number of microbes in a particular area where they can develop extensively. The common carriers of microorganisms to buildings are the doors, windows, air conditioners, and the people entering from outside. The type of species and abundance of microbes is influenced by viscosity, temperature, lighting, and food availability. Each day, the air inspired by a human usually comprises 10^6 airborne microbes (Mandal and Brandl, 2011).

Airborne particulate matter (PM) is a mixture of airborne particles. The size of ambient particles is directly related to their capacity to cause health concerns. Fine particles can enter the pulmonary alveoli as well as the deep part of the respiratory tract (alveolar and bronchia) or even pass into the bloodstream through the blood-gas barrier and thus have more adverse effects on humans and animals (Franck *et al.*, 2011). Animals also serve as an important source of airborne microflora with pathological implications.

The microbial contamination levels in indoor houses might be influenced by numerous sources such as the heating, ventilation, and air-conditioning system, humidifiers, water towers, transmission among people through coughing, sneezing, and talking. The health implications of microorganisms in air-conditioned indoor environments can be virulent or immunological (Sonmez *et al.*, 2011). Housing systems using bedding materials cause more air quality complications. The type of bedding material determines the concentration of microbes in the air. It is documented that a housing system that seemed cleaner contained an abundance of airborne bacteria. The composition of airborne bacteria differs over seasons (Franzetti *et al.*, 2011).

Environmental pathogens spend a substantial part of their lifecycle outside human hosts, but when hosted to the human body cause disease. Exposure to environmental microbes causes adverse effects on human health. Microorganisms are expected to grow on conventional building materials under high humidity (Andersen *et al.*, 2011). The main difference between environmental pathogens and other human pathogens is their capability to live outside the host. Ventilated indoor spaces have been documented as more advantageous to human health than comparatively stagnant spaces (Ege *et al.*, 2011). Humans discharge the microbes into the built environment in the form of aerosols while coughing, sneezing, breathing, and talking (Johnson *et al.*, 2011). Human health is linked with the stability of microbial communities. The human microbiome protects from skin pathogens (Grice and Segre, 2011), helps digestion of food, supplies nutrients, and triggers the immune system.

Indoor Air Quality

Indoor air pollution has triggered increasing fear in recent years. Air pollution can be in the form of solid particles, liquid drops, or gases and they could arise from natural sources which include atmospheric reaction, dust, and aerosols, microorganisms, pollens, and radioactivity or man-made sources which emanate from the combustion of fuel, thermal and nuclear power plants, industries, vehicular population, construction materials, and system of radiation. Household dust serves as a good proxy to estimate indoor air pollution. Different rooms in a building reveal distinct microbiomes (Adams *et al.*, 2014).

The indoor air quality is polluted by a variety of pollutants. Humans are persistently exposed to dust particles through ingestion, skin, and inhalation (Blanchard *et al.*, 2014). Exposure to polluted air is a serious threat due to the diversity of the pollutants. The environmental microorganisms can deteriorate different heritage objects as well as affect human health (Konya *et al.*, 2014). It is vital to explore the microbial community in indoor air at archives and libraries to preserve the cultural heritage. In practice, evidence concerning particle size dissemination is critical (Latif *et al.*, 2014).

Indoor air pollution has been documented as a risk factor to public health (Gawrońska and Bakera, 2015). The health effects related to poor air quality are responsible for heart and lung ailments (Shin *et al.*, 2015). During the two decades, many studies conducted in a variety of indoor environments revealed a great diversity of air pollutants. Among the indoor microbial community; some microbes may be pathogenic and could secrete toxic metabolites (Karottki *et al.*, 2015). The outdoor air might determine the indoor air microbiome by improving the air quality of a particular area (Adams *et al.,*, 2015). Indoor and outdoor air quality relationships had shown that indoor air quality is a complex function of outdoor pollutant concentration, building, permeability, meteorological conditions, ventilation system, and indoor pollutants (Fuoco *et al.*, 2015).

The productivity of people is also affected by the quality of the air they breathe. The composition and concentration of biological aerosols reflected the hygiene and health, the pathogen carrying status, and their diseases (Lovanh *et al.*, 2016). A previous study proposes that fungi may aid the growth of sporozoites (Alum and Isaacs, 2016).

Sources of Bacteria

Airborne bacteria can be managed if their origin is recognized. Human inhabitants and outdoor air are expected to be the main sources of airborne bacteria. Most indoor environments are tremendously scarce in water and nutrients though microbes are disseminated onto surfaces (Gibbons, 2016). The bacterial communities distributed in offices, hospitals, classrooms, and other community places include human and soil bacteria (Hoisington *et al.*, 2016). Effective protocols are urgently required to fight the bacteria, pollens, smoke, humidity, chemical substances, and gases in indoor air which has adverse effects on human health (Singh, 2016). In university buildings, the microbial diversity increased during the occupied periods (Triadó-Margarit *et al.*, 2017).

Bioaerosols

A bioaerosol is a colloidal suspension of liquid droplets and solid particles in the air. Bioaerosols can be a serious threat to public health due to the disease-causing ability of airborne bacteria and fungi. Microbes from the soil or plants can be carried by office workers or dust particles from the outdoor air (Nazaroff, 2016). Bioaerosol particles can cause a reduction in Indoor air quality (IAQ) in office buildings (Gizaw *et al.*, 2016). The collection of bioaerosol particles should be done using volumetric methods following hygienic standards (Górny *et al.*, 2011).

Biological aerosols are clumps of microorganisms attached to solid and liquid particles suspended in the air. The composition of the bioaerosol includes bacterial, yeast, molds, spores of bacterial, and molds, microbial fragments, toxins, metabolites, viruses, parasites, and pollen. The infiltration of the exterior contaminant into the dwellings and also controls the dissipation of the pollutant generated within the dwelling. Air often carries water droplets, ice crystals, and dust, but they are not part of the composition of the air. Alteration of air composition results in air pollution. The driving force of air pollution include; economic development, energy consumption, urbanization, and transportation (Pena and Rollins, 2017).

Sick Building Syndrome (SBS) is the situation in which the inhabitants of a building experience nonspecific symptoms which relate directly to their activities inside the building (Ghaffarianhoseini *et al.*, 2018). High ventilation rates can negatively affect health by holding particulate matter in the air (Carlton *et al.*, 2019). The consequences of constructing heat loss and drought-resistant buildings are separated from the outdoor environment and lesser ventilation rates (Holgate *et al.*, 2020).

Nosocomial Infection

A Hospital Acquired Infection (HAI), or nosocomial infection, is an infection acquired in a hospital or other healthcare facility. Nosocomial infections are one of the major public health complications that vary from one country to the other (Holgate *et al.,*, 2020). There is an upsurge in extended hospital stay, disability, socio-economic trouble, development of antimicrobial resistance, and increased mortality rate with increasing infections (Allegranzi *et al.*, 2011). *Corynebacterium tuberculostearicum* is one of the key components of the skin microbiome (Moon *et al.,*, 2014). *C. tuberculostearicum* was found to cause childhood asthma and chronic rhinosinusitis in patients (Copeland *et al.*, 2018).

It has been established that most abundant nosocomial pathogens like *Staphylococcus* *aureus*, *Sphingomonas paucimobilis*, *Pseudomonas aeruginosa, Stenotrophomonas maltophilia, Clostridium difficile, and Pseudomonas spp.* are developing multidrug resistance, leading to the development of Multi-drug Resistant *S. aureus* (MDRSA) and Multi-drug resistant *P. aeruginosa* (MDRPA) (Ozer *et al.*, 2011). *Aspergillus, Mucor, and Rhizopus* can pose a health hazard to vulnerable individuals. Hospital-acquired fungal infections demonstrate a huge threat to human health (Alangaden, 2011). The transmission of microbes from the environment to students is largely through hand contact. The relative humidity of the air is associated with the number of airborne fungi (Reanprayoon and Yoonaiwong, 2012).

Antimicrobial-resistant bacteria and resistance genes are regarded as environmental pollutants (Balm *et al.*, 2012). Prolonged exposure to *Cladosporium* species of fungi may weaken the immune system (Balm *et al.,*, 2012). The aerosol production in toilet flush without a closed lid may contaminate the surrounding environment with *C. difficile* (Best *et al.*, 2012). Microbial analyses of houses have revealed that microbial aerosols play crucial roles in the air population and affect health (Hong *et al.*, 2012). There could be a correlation between pollutants from indoor air and household dust (Meeker, 2012). Childhood asthma is one of the respiratory disorders in Asian countries due to household dust. A high concentration of indoor air microorganisms causes an allergenic reaction; however, a low concentration of these microorganisms causes serious diseases according to epidemiological studies. Adults spend approximately 34 % of their time sleeping on a mattress, that has an abundance of allergens, fungal spores, and bacteria (Knibbs *et al.*, 2012). The findings of previous studies have demonstrated that indoor microbial communities may mediate the observed association of brain health outcomes with building characteristics (Stilling *et al.*, 2014).

CONCLUSION

This study showed that the indoor air of rural residential houses contained microbes and fungi that caused important health problems. Particulate matter present in high concentrations indoors and outdoors constitutes a great health risk. In conclusion, designing buildings to allow more sunlight and outdoor air may discourage infectious agents with significant health benefits for occupants.

RECOMMENDATIONS

- Indoor reservoirs should be a well-designed ventilation system, properly installed.
- The indoor environment should have maintenance of equipment, humidity control, and natural ventilation.
- There should be proper documentation and eradication of the microbial source in household settings.
- There should be the use of filters in the ventilation system and air cleaning by the use of disinfectants.
- Periodical use of disinfectants should be done to ensure controlled bio-aerosol concentrations.

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CONFLICT OF INTEREST

There is no conflict of interest.

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