MICROBIAL SAMPLING IN BUILDING SURVEYS: WHAT AND WHY ARE WE SAMPLING?

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Keywords: Building microbiome, Building ecology, Microbial sources, Moisture damage

INTRODUCTION

Buildings are the main arena where human life unfolds. We share our homes and working places with other humans, animals, and plants, but also with numerous microbes from both building occupants, the indoor, and the outdoor environment (Gravesen, 1979; Adams et al., 2013). These microbes, together with particles of abiotic origin, can settle on surfaces, become airborne, or be removed by surface cleaning and ventilation air. There is always a background level of microbial matter in buildings. But do buildings have their own microbiome? And what happens when this microbiome is altered?

METHODOLOGIES

Sampling in buildings can serve several purposes. For descriptive accounts of indoor microbes, DNA sequencing can provide extensive lists in relatively short time (Ettenauer et al., 2012), although identification is still subject to both technical pitfalls (Huse et al., 2010) and uncertainty about the viability of the detected sequences (Kelley and Gilbert, 2013).

For remediation purposes after moisture damage, sampling may be unnecessary when microbial growth is visible. A tape lift taken on surfaces of building substrates and observed under the optical microscope can document the condition of the surface: whether there is established microbial (especially mould) growth, or just accumulated spores. Identification of the growing species can be done directly from the tape lift, avoiding time-consuming culturing.

In cases of occupant complaints, but no visible growth, sampling and physical inspection should focus on *microbial sources* (indoor microbial growth forming microbial communities, that is, the Building Microbiome), not on *microbial sinks* (accidental assemblages of microbial spores and fragments unable to grow and proliferate on the spot). Microbial sinks are just "noise", distracting from the main remediation purpose, which is setting the Building Microbiome back to normal. The same can be said of deposition of fragments and spores from outdoor environments. In ecology, spores and non-viable microorganisms are not part of active microbial communities (Nunez, 2014), and they are often excluded from community assembly studies (Tilman, 2004).

Focusing on microbial sources has also an impact on human health, as exposure dose is directly proportional to allergen concentration. One single mould spore can produce millions of spores if exposed to suitable moisture conditions, but remains as one spore if the environment is hostile for growth (Rayner and Boddy, 1988).

Indirect sampling techniques such as air sampling can be useful to detect hidden microbial sources in cases where the specific building physics, sampling conditions, and the species involved are well characterized. For epidemiological studies, DNA methods are capable of identifying exposure agents out of very scarce microbial matter (Gibbons et al., 2014).

RESULTS AND DISCUSSION

The microbiome of healthy buildings is usually restricted to surfaces exposed to environmental moisture, as the outer envelope, sinks, or water pipes. Other indoor surfaces are exposed to transitory moisture coming from various occupant activities. Still, due to normal ventilation and limited spills and production of water vapor, most building surfaces are too dry to allow microbial growth, as humans design buildings to keep themselves dry.

Moisture is one of the causes of building damages and negative health effects on occupants (Bornehag et al., 2001). The microbiome of sick buildings can boost exponentially after moisture damage, depending on the damage scope, the background microbial load, and aspects of building design. Sick-building microbiomes share more species with plant microbiomes than with animal microbiomes, because numerous building materials as for example paper, cardboard, wood, and wooden boards contain cellulose and other plant compounds. Soiled and/or dusty, inorganic building materials are often colonized by either plant or soil microbes as well (Korpi et al., 1997).

It is important to bear in mind that microbes from the building microbiome will not grow indoors unless the relative humidity (RH) of surfaces rises over 76-78 % (Adan and Samson, 2011). Other microbes not belonging to the building microbiome will never grow indoors, even if exposed to high indoor moisture levels. Examples of these are plant and animal parasites, anaerobic species, temperature-adapted specialists of endothermic animals (and humans), and obligate mycorrhiza fungi. Focusing on these species is irrelevant for building remediation purposes.

Setting the building microbiome back to normal usually requires opening hidden structures and removing infected building materials. Cleaning and disinfection of surfaces alone is not an effective measure if surfaces are just microbial sinks, and the sources are hidden in building structures, as it often happens. As is the case with the human microbiome, removing symptoms does not restore health.

CONCLUSIONS

Microbial sampling in building surveys can serve to different purposes. Differentiating between microbial sources and sinks, as well as identifying the sources of different

species, is of crucial importance in order to assess the impact of building microbes on building occupants. A thorough consideration about the purpose of indoor sampling will minimize building intervention, occupant burden, and economic costs.

ACKNOWLEDGEMENT

We thank the Sloan Foundation for inviting us to present this paper, and all our colleagues at Mycoteam for their dedication to understanding and untangling the building microbiome.

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