Architectural Design, Light Exposure, and Microbial Viability in the Built Environment

BIOLOGY AND THE BUILT ENVIRONMENT
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Kyla Martichuski[1,2], Adam E Altrichter[1,2], Mark Fretz[1,4,5], Jeff Kline[1,4,5], Dale Northcutt[1,4,5], G Z Brown[1,4,5], Brendan Bohannan[1,2], Jessica Green[1,2,6]

[1] Biology and the Built Environment Center, University of Oregon; [2] Institute of Ecology and Evolution, U of O; [3] Department of Ecology and Evolutionary Biology, University of Arizona; [4] Energy Studies in Buildings Laboratory, U of O; [5] Department of Architecture, U of O; [6] Santa Fe Institute, Santa Fe, NM

Introduction

Researchers working at the intersection of biology and architecture have begun to investigate how building design influences the microbial communities of indoor environments. Given that we spend approximately 90% of our lives indoors, there is great potential to impact human health by incorporating biological understanding into building design. Ultraviolet light and direct daylight have well-known detrimental effects on the growth and viability of bacteria, but this relationship has not yet been applied to indoor environments. We designed an experiment to test how different architecturally relevant daylighting schemes impact the viability of microorganisms in the built environment.

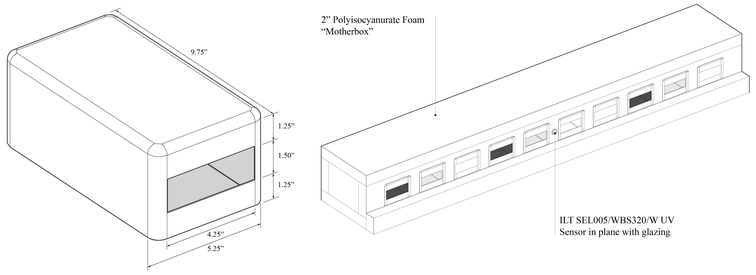

Figure 1: Model of boxes and outdoor setup. The image on the left represents a model of each box used in this experiment. Each box is a 1:32 scale model of a 14' x 26' x 10'-8" classroom with a 4' view window and a 3'-4" sill. The image on the right represents the arrangement of the boxes when placed on the roof of Pacific Hall.

Methods

In order to test how different daylighting schemes impact the viability of microorganisms in the built environment, we constructed 3 sets of 1:32 scale models of a classroom with window glass panes transparent to either UV, visible, or no light. Bacteria were grown on 35 mm nutrient agar petri dishes, which were placed at 15 distinct locations throughout each box to reproduce the distribution of light exposure in a typical classroom. The test organisms that have been used thus far are *Pseudomonas monteilii* and *Escherichia coli*. To inoculate the media with these organisms, we pipetted 100 uL of diluted liquid culture onto the petri dishes. After approximately 6 hours of light exposure on the roof, the dishes were incubated at 30 °C for 24 hours and colonies were counted. We measured bacterial viability after light treatment as the colony counts relative to counts on boxes receiving no light treatment.

Figure 2: Experimental setup on the roof of Pacific Hall. Each box is equipped with a temperature probe and insulated to reduce external solar heating. Surface temperature is regulated to approximately normal indoor levels by heating or cooling a water-filled chamber below the boxes.

Results

Levels of both UV and visible light typically experienced in the built environment impacted the viability of *Pseudomonas monteilii* and *Escherichia coli*—two human-associated bacteria commonly found indoors. *P. monteilii* viability was reduced in areas near windows with higher visible and UV light exposure. *E. coli* viability was slightly reduced with UV treatment, but not as greatly affected by visible light. Here we show preliminary results from early trial experiments.

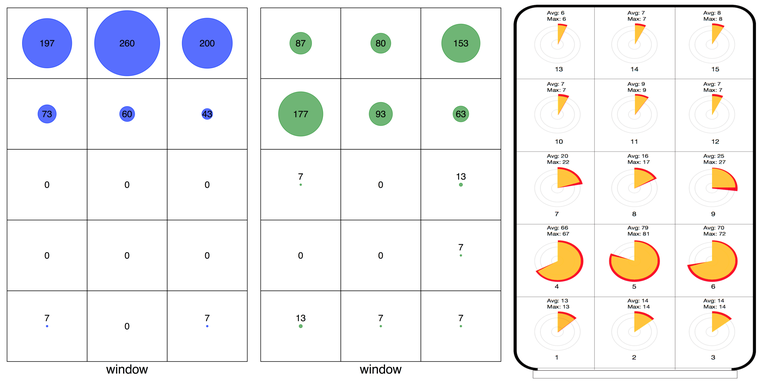

Figure 3: Average colony counts and incident light exposure for each location in the boxes using *P. monteilii* as the test organism. The blue and green circles represent the average number of colonies in the UV and visible boxes, respectively. On the right, the yellow and red in the pie charts represent the average and maximum proportion of total daylight received, respectively.

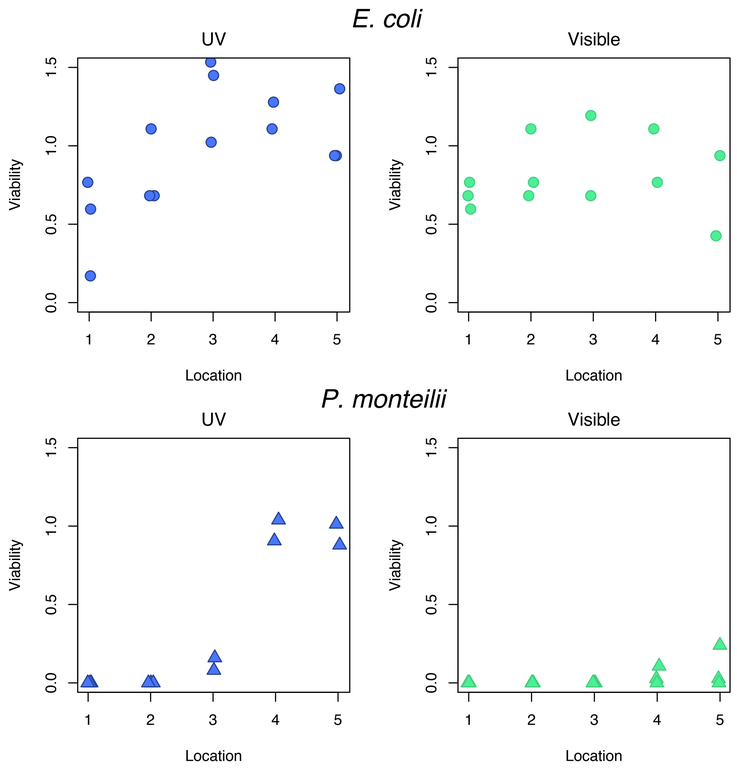

Figure 4: The effect of UV and visible light on the viability of *P. monteilii* and *E. coli* relative to the average colony count of dark boxes. Viability is equal to the plate count divided by the mean of the dark box plate counts. Location 1 is closest to the window and location 5 is furthest from the window; all samples were placed down the center of the box. Some counts appear to have enhanced viability over background counts (mean of the dark box); however a viability greater than one is simply due to variability in the method and will dissipate with additional replication.

Future Directions

In these experiments we have found that the relative humidity inside each of the boxes rapidly reaches 100%. This saturated environment is much more humid than the atmosphere in a typical classroom. This also causes condensation to build up on the windows, which blocks incoming light and can alter the light distribution pattern in the boxes. In order to reduce the relative humidity experienced in the boxes, we are exploring the idea of placing an inert desiccant in each of the boxes to regulate the relative humidity in the boxes between 30-70%.

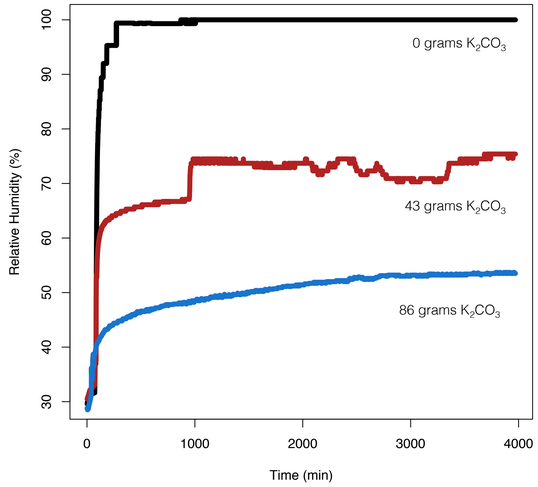

Figure 5: The effect of potassium carbonate on the relative humidity in each of the boxes at room temperature. Potassium carbonate maintains the relative humidity within the desired range depending on the amount used. However, we have not yet tested the effect, if any, that the desiccant has on organismal viability. We aim to find a desiccant that can be used in small quantities and be packaged in a compact way and still achieve the desired relative humidity.

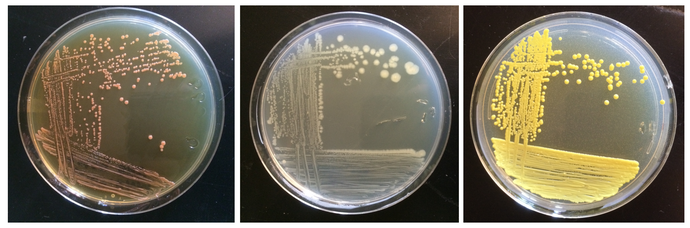

Figure 6: Photos of cultured organisms. From left to right, *Methylobacterium extorquens, Pseudomonas moneilii, Sphingomonas mali*. In future experiments, we plan to apply this technique to other organisms that have been found indoors including *Deinococcus radiodurans*, *Streptococcus mutans*, *Methylobacterium extorquens*, and *Sphingomonas mali*.

Thus far, experiments have been limited to small trial sizes to optimize growth and culturing techniques. In the future, the sample size will be increased to cover all 15 positions in the box and replicated under a variety of daylight conditions.

Conclusion

The preliminary evidence obtained in our previous experiments suggests that the viability of microorganisms in the built environment is impacted by light exposure. These findings could inform future decisions about lighting schemes in hospitals and other healthcare facilities where biological insight is crucial. This study aims to demonstrate that integrating biological knowledge into architectural decisions can create a bioinformed perspective on buildings that promotes human health.

To follow our progress, visit the open lab notebook for the Green Lab at greenlabnotebook.tumblr.com (#LightBox)