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# Indoor vs Outdoor Bacteria in the Air

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**Abstract**

Airborne microbes are not really a researched topic along with concerns regarding airborne toxins passed from one sick person to the next through the air, without physical contact, causing irritation. Airborne diseases are a threat to the common public and need to be studied correctly and more to protect the public. This paper aims at a difference in bacterial distribution in the air based on indoor vs. outdoor locations on Bard campus by exposing agar plates in the air in the respective sites. The results show that there was not a significant difference in the indoor vs outdoor bacteria because the study was short, and not a lot of variability was observed in the data.

**Introduction**

Bacterial aerosols can highly impact ecology, climate, and public health both locally and globally (Dueker et al., 2018). Aerosols are all over in nature. The airs of planets of the solar system are rich in suspended particulate matter, as in interplanetary and interstellar space (Hidy, G.M., 2003). Atmospheric aerosols contain the chemical signature of the sources of direct particle emissions into the atmosphere as well as that of the conversion of gaseous molecules into particulate-phase species. Atmospheric aerosols are generated from the Earth's surface except from aviation emissions or meteorite debris. The height of aloft aerosol layers is a critical

determinant of global aerosol transport and dispersion. Despite its importance in geo-locational characteristics of aerosols, aerosol's vertical information is typically unknown (Lee, Kwon H. 2018).

Not all particles of a similar size in a similar environment have a similar chemical arrangement, as particles emerge from various sources and have various roles in the air. Particle mass focuses shift over the globe, from the order of 1 μg m−3 in the cleanest air masses to more than 100 μg m−3 in polluted urban regions. These aerosol particles could be natural sources as well as man-made. Particles naturally transfer and settle in the air, when doors are shut, fans and ventilation systems move the air and people walking also leads to the movement of the particles in the air. Large particles settle easily in the environment and bounce from the surface whereas it is difficult for small particles to deposit on the surface. Aerosol will expand because of particle-particle repulsion. Particles are also generated when they are deposited in carpet, footstep crushes fibers against each other and it compresses carpet, creating high velocity air flow. Bacteria can be carried into the air by drops from bursting bubbles and that the concentration of bacteria (numbers per milliliter) in the drops can far exceed that in the water in which the bubbles broke (Duncan C, 1970). EPA is concerned about particles that are 10 micrometers in diameter or smaller because these are the particles that can pass through our nostrils and throat and can go to the lungs affecting our heart and lungs.

Are particles in the air dangerous? Sometimes the particles are of type that at sufficient concentration, are toxic to our body and the organ in our body most sensitive to particle exposure

is the respiratory system. Our respiratory system is efficient at removing aerosols, but if they fall within particular size ranges, are highly concentrated, or toxic, they may cause bad health effects. They may also deposit on skin or eyes, generally only causing irritation, though more toxic effects may occur; very small particles may pass through the skin and enter the body that way soluble particles may dissolve and pass through the skin (Baron, Paul).

Airborne microbes are biological airborne contaminants (also known as bioaerosols) like bacteria, viruses or fungi as well as airborne toxins passed from one sick person to the next through the air, without physical contact, causing irritation. This usually happens when an infected person sneezes, coughs, it is hard to prevent this kind of transmission. Airborne microbes are a major cause of respiratory ailments such as allergies and pathogenic infections (virus or bacteria). Examples of airborne bacterial disease: Meningitis- fever, rash, nausea. Bacterial meningitis is the most severe and can be life-threatening. It occurs when bacteria in the bloodstream travel to the spinal cord and brain; though it can also be the result of bacteria that directly attack the meninges. Pneumonia- spectrum of illness ranges from asymptomatic infection to severe disease, it is mainly caused by the bacteria Streptococcus pneumoniae. Pneumonia is an infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus (purulent material), causing cough with pus, fever, chills, and difficulty breathing. Streptococcus respiratory infection- an example is strep throat. Streptococcus pneumoniae, Haemophilus influenzae and Moraxella catarrhalis are the most common bacterial pathogens in upper and lower respiratory tract infections. Streptococcus pyogenes is the

predominant bacterial pathogen in pharyngitis and tonsillitis. Bacterial pathogens adhere to mucous membranes and colonization ensues (Cappelletty, D).

Fungal spores and fragments usually in the sub-micrometer size range can be released from contaminated materials into air, and if inhaled, may cause adverse health effects on people and animals (Mensah, J et.al, 2019). Microorganisms, especially fungi, from damp indoor environments are known to be one of the main causes of degradation of air quality and can pose serious health hazards to people because of the production of airborne particles. Individuals are exposed to fungi from various sources and in various conditions. The exposure may occur when the fungi grow in hidden areas and on materials that are in common areas and released under various conditions. Fungal spores grow when deposited on favorable material surfaces. The types and amounts of intact spores and fragments aerosolized depend on factors such as air velocity blowing over the growth surface, the type of substrate, type of fungi, and relative humidity of the growth and the age of the fungal growth (Mensah, J et.al, 2019). The high humidity and/moisture content may occur from leaky pipes or cracks in the basement walls that allow groundwater to penetrate the basement. The kitchen and bathroom sections of a building may also encourage the growth of fungi since these places have a high moisture content. Outdoor generated fungi enter a building through the ventilation system. This can be a mechanical ventilation system without enough air filter for pollutants or through a naturally ventilated building with open windows and doors where outdoor to indoor ratio of pollutants can be close.

A ventilation system can also be a house for indoor fungi especially when the ducts and filters are dirty with dust that serves as a substrate for fungi growth.

The health effects associated with fungal exposures may be caused by the fungi themselves. Fungus can cause diseases such as asthma, respiratory infections, cough, allergic rhinitis, eczema and bronchitis. The World Health Organization (WHO) has stated that approximately 25% of residents in social housing stocks are prone to experience elevated health risks associated with their exposure to indoor molds (Mensah, J et.al, 2019). The type of building material and fungal species affect the amount of growth of fungi. In addition, these factors together with air and other meteorological factors affect the properties of the fungal particles.

For my paper, I will be studying whether there is a difference in bacterial distribution in the air based on indoor vs. outdoor locations on Bard campus? I will also be looking at the fungi distribution along with bacteria and for this I will be exposing agar plates in the respective locations. I will be looking at the distribution of bacteria in two different sites, outdoor and indoor on Bard college campus and the sites are David Rose Science Laboratories (Rose Lab) and Reem-Kayden Center for Science and Computation (RKC).

The question is important to study because it is related to public health and air is not usually on people's mind and how bad air can affect us. Airborne bacteria are the cause of many nosocomial and community-acquired infections in humans; approximately two million hospital-acquired infections occur in the United States each year (Utrup, Linda J et. al, 2003). People also don’t know much about bacteria in the air and can not manage without science to guide us so we need

more research around bacteria in the air. I hypothesize that indoor bacteria would be higher than outdoor bacteria, that means bacteria inside will be higher than bacteria outside, because the inside sites are closed and more people come in and out which brings more bacteria inside through their shoes and themselves whereas outdoors is open and bacteria is more scattered and bacterial concentration is also dependent on the weather, if it rains the bacteria will be washed away by rain, therefore less bacteria would be there in the surroundings.

**Materials and Methods**:

**Study Sites**

For the experiments I chose two sites: Rose laboratory and Reem-Kayden Center for Science and Computation (**RKC**) (Fig. 1). I chose these two sites because these are the laboratories that are used the most by the students and I thought the more activity in and around the labs, more bacteria and fungi presence would be there. I conducted the first set of experiments at Rose laboratory, outside Rose was tested first during the daylight hours and with suitable wind speed because it would be easy to run the test with right wind speed because enough bacteria would fall on the plates and the Rose entryway was tested as well.

On November 14, 2021, Rose first floor near the heater (Inside) was the second round of the test, this site was chosen because the plates were placed near the heater and its warmth would allow more bacterial growth. On the same day, the Rose Bathroom was also tested to check the

bacterial and fungal growth because the bathroom is a place that is used by everybody and I assumed the bathroom would have higher bacterial and fungal growth because of its usage. The second site RKC was examined March 18, 2022, I had an assumption that as RKC is a well finished laboratory and has high quality filters, bacterial growth would be less here. So I decided to test this side. And outside RKC was tested too.

**Meteorological Parameters**

**Relative humidity**

Relative humidity is the amount of moisture in the air at a certain temperature compared to what the air can "hold" at that temperature. The relative humidity can be lower in warm air and higher in cold air (Vanvuren, C, 2018). I got higher relative humidity during the tests because it was cold when the experiment was conducted. The relation between humidity and temperature simply says they are inversely proportional. If temperature increases it will lead to a decrease in relative humidity, thus the air will become drier whereas when temperature decreases, the air will become wet means the relative humidity will increase.

**Temperature**

The lowest temperature at which the organism can survive and replicate is its **minimum growth temperature**. The highest temperature at which growth can occur is its **maximum**

**growth temperature**. I measured the temperature in celsius. It is an important factor while testing for bacteria and fungi because it gives a rough estimate of what temperature do bacterias and fungi tend to grow.

**Wind Speed**

I measured the wind speed because wind speed is another important factor affecting the composition of bacteria (Cao, Yue et.al, 2021). If there is heavy wind it would cause a lot of movement of bacteria that would lead to falling of bacteria on the plates. Less wind would likely have any movement of bacteria and hard for it to fall on the agar plates.

To measure all these meteorological parameters Kestrel Meter was used. A Kestrel meter measures heat stress index, relative humidity, dew point temperature, wind chill, air/water/snow temperature, current/average/maximum wind speeds. A kestrel meter was used to measure temperature, wind speed and relative humidity because it is easy to carry because it is battery operated and gives accurate measurements.

**Particulate Matter**

Particulate matter also known as PM, is a mixture of fine particles and liquid droplets. It is made up of many components including acids like nitrates, sulfates, chemicals, soil, metal and dust. As said by EPA, the size of particles is directly related to the health effects of pm on people. An Aerocet was used to measure PM. The Aerocet 532 simultaneously measures and records

PM1 , PM2.5, PM4, PM7, PM10 and total suspended particulate matter (TSP) and PM count. This instrument was used because it is chargeable and once charged overnight runs the whole day and the measurements are rapidly computed and counted in 60 seconds. The equipment was placed on a normal stool height and was run for 60 seconds and total time taken to calculate PM mass and count was less than 5 minutes.

**Bacteria and Fungi**

**Agar plate exposure**

For conducting the experiments, I used agar plates to collect bacteria samples, and also used the Bioaerosol impactor to measure bacteria. For making the LB (Luria Broth) Agar plates, I mixed 10g tryptone, 5g yeast extract, 10g Nacl, 15g Agar, 1L DI water, all together in a dish and kept mixing the solution, so that the agar does not settle on the bottom and it's mixed properly, I autoclaved the broth to kill the unwanted bacteria and sterile the broth. After it was done autoclaving, let the mixture cool down before pouring it onto the plates. After all the mixture was transferred to the plates, the plates were placed in a cooling station for the broth to harden. After a few days of keeping the plates in the cooler, I went to the first location, then with gloved hands sterilized the area where the agar plates were placed. Then carefully opened the lid of the plates, three agar plates at each site were used during the experiment and exposed them for 10 minutes and moved away from the testing site so that I was not a part of the experiment and labeled the plates.

**Bioaerosol Impactor**

Then for the second part of the experiment I place one agar plate in the Bioaerosol impactor and let it sit for 15 minutes. The A6 Bioaerosol impactor sampler is an aluminum device consisting of a top inlet "cone", a sampling head impactor stage which contains over 400 precision drilled holes and a base section which holds the agar plate. When air is drawn through the sampler, multiple jets of air direct any airborne particles toward the surface of the agar plate. For the next part they were taken to the lab and incubated  in a dark area for a few days or until the bacteria started to grow. After three days of the experiment, I counted the number of bacterias and fungi and then placed it back in the dark place to let them grow more. Same procedure was followed for the 5th day count. And after all the counting was done, I looked at the morphology of the bacteria. Different kinds of bacteria were found during the counting circular bacterias with off-white color, irregular form with yellow color.

**Results**

The site map is shown in Fig 1 and their gps coordinates are shown in Table 1 and tests were run indoor and outdoor Rose laboratory and RKC. The variables assessed in order to determine the overall environment are temperature, relative humidity and wind speed (Table 2). These variables were chosen to be tested during the experiment because these variables relate with bacterial and fungal growth. Rose bathroom, Rose first floor (near the heater), Outside RKC and Inside RKC relative humidity, temperature and wind speed were not measured because the Kestrel Meter stopped working. As shown in the table, relative humidity means it is not that high for a lot of fungi and bacteria to grow. The temperature was not that high because the testing was done during fall semester and winter break. The wind speed was also low, which means there was not a lot of suspension of bacteria so not a lot of bacteria fell on the agar plates.

As shown in Table 3, the particulate matter for Rose first floor (near the heater) is higher than other sites which means they are the fine particles which cannot be seen through the naked eye and have more chances to get in our respiratory system and affect our lungs and heart.

The population of bacteria on the fifth day at the Rose laboratory and RKC is depicted in Fig 2. Highest number of bacteria was shown in the seventh site, which is outside Reem-Kayden Center for Science and Computation (**RKC**). The error bar for site 7 was overlapping with site Rose hegmen triangle (Site 4), Inside Rose near the heater (Site 6) and Inside RKC (Site 8), which meant that their data is not significantly different from each other, therefore site 7 has the highest bacteria population whereas the lower average of bacteria existed in site 3 which was the Rose

hallway and the error bar overlaps with sites outside Rose lab (Site 1), Rose entryway (Site 2), and Rose bathroom (Site 5) which was outside and inside Rose laboratory, meaning there was a significant portion of data from sites 1, 2, and 5 that ended up being lower than or same as the data from site 3, therefore it can not be exactly told which of these have a lower number of bacteria.

Figure 3 tells us the population of fifth day fungi in different sites on the campus of Bard College. Highest number of fungi was present in the fifth, which was inside a bathroom in the Rose laboratory. The error bar for site Rose bathroom (5) was overlapping with Rose entryway (2), and inside RKC (8), which meant their data was not significantly different from each other, therefore site 5 has the highest fungi population whereas the lower average of fungi existed in site 1 which was outside rose laboratory and the error bar overlapped with site 6 which was inside Rose first floor near the heater, meaning there was a significant portion of data from site 6 that ended up being lower than or same as the data from site 1, therefore it was hard to tell which site had lower number of fungi.

The difference between inside bacteria and fungi can be seen in Fig. 4. As shown in the figure, bacteria inside were higher than the fungi inside but there was no significant difference between them. On the other hand there was a significant difference between bacteria and fungi outside (Fig.5.) because outside bacteria was higher than the fungi outside. Difference in total bacteria and fungi can be accessed in Fig 6., outside bacteria was higher than bacteria inside which was

not expected. Fungi inside were higher than fungi outside but there was not a big difference in the data and a significant portion of data ended up being lower than or same as fungi inside.

**Discussion**

I hypothesized that indoor air bacteria would be higher than the outdoor air bacteria but the outside bacteria appeared to be higher than the indoor bacteria which was not expected but the difference was not a lot because the experiment was cut short and there was not enough variability to bring out major differences in numbers of bacteria and fungi. Inside fungi was higher than the outside fungi, this could be because fungi need high relative humidity of more than 80% to easily grow (Gist-brocades Food Specialties R&D, Delft, The Netherlands). When the testing was done the temperature was low and relative humidity was low so there was not a lot of fungi in the environment and therefore there was less fungal growth on the plates. Because this study was cut short, further testing should be done on inside and outside bacteria to determine whether outside bacteria is higher than inside bacteria or opposite. The data that was collected in this study showed that the outside bacteria was higher than inside bacteria. This data should be expanded on both by the collection of more data and further analysis. DNA analysis should be done to find the bacteria structure and name.

**Conclusion**

This study aims to assess the extent of inside and outside bacteria and fungi. Because this study was cut short, no DNA was able to be analyzed. This Information is particularly important to know which bacteria is harmful and harmless given that there is a decent amount of people that are on campus and breathe the same air as everyone else and provide better insight into how to properly monitor the air and provide accurate safety standards, particularly for people who are immunocompromised.

**Figures and tables**

| Sites | GPS coordinates |
|---|---|
| Outside Rose Lab | 42°01'16.7"N, 73°54'22.9"W |
| Outside Rose (Hegmen Triangle) | 42°01'16"N, 73°54'25"W |
| Rose first floor hallway | 42°01’6”N, 73°54’24”W |
| Rose entryway | 42°01’16”N, 73°54’23”W |
| Rose Bathroom | 42°01’17”N, 73°54’23”W |
| Inside Rose first floor near the heater | 42°01’17”N, 73°54’23”W |
| Outside RKC | 42°01'13.3"N, 73°54'27.5"W |
| Inside RKC | 42°01'12.5"N, 73°54'28.2"W |

**Table 1. Sites and GPS Coordinates**

| Sites | Meteorological Parameters | Mean | Standard Deviation | Standard Error |
|---|---|---|---|---|
| Outside Rose Lab | Relative Humidity | 62.73333333 | 0.6110100927 | 0.3527668415 |
| | Temperature | 14.6 | 0.2 | 0.1154700538 |
| | Wind Speed | 1.466666667 | 0.4725815626 | 0.2728450924 |
| Outside Rose (Hegmen Triangle) | Relative Humidity | 60.76666667 | 2.433789912 | 1.405149261 |
| | Temperature | 25.3 | 0.3605551275 | 0.2081665999 |
| | Wind Speed | 1.9 | 0.4358898944 | 0.2516611478 |
| Rose first floor hallway | Relative Humidity | 36.46666667 | 1.021436896 | 0.5897268671 |
| | Temperature | 19.56666667 | 0.2081665999 | 0.1201850425 |
| | Wind Speed | 0 | 0 | 0 |
| Rose entryway | Relative Humidity | 63.56666667 | 1.962990915 | 1.133333333 |
| | Temperature | 25.66666667 | 0.3055050463 | 0.1763834207 |
| | Wind Speed | 1.833333333 | 0.5686240703 | 0.3282952601 |
| Rose Bathroom | Relative Humidity | N/A | N/A | N/A |
| | Temperature | N/A | N/A | N/A |
| | Wind Speed | N/A | N/A | N/A |

| | | | | |
|---|---|---|---|---|
| Rose first floor (near the heater) | Relative Humidity | N/A | N/A | N/A |
| | Temperature | N/A | N/A | N/A |
| | Wind Speed | N/A | N/A | N/A |
| Outside RKC | Relative Humidity | N/A | N/A | N/A |
| | Temperature | N/A | N/A | N/A |
| | Wind Speed | N/A | N/A | N/A |
| Inside RKC | Relative Humidity | N/A | N/A | N/A |
| | Temperature | N/A | N/A | N/A |
| | Wind Speed | N/A | N/A | N/A |

**Table 2. Meteorological Parameters Relative humidity, Temperature, Wind speed (Mean, Standard Deviation, Standard Error)**

| Sites | Particulate Matter | Mean | Standard Deviation | Standard Error |
|---|---|---|---|---|
| Outside Rose Lab | PM 0.5 | 901,212 | 4690.393587 | 2708 |
| Outside Rose (Hegmen Triangle) | PM 0.5 | 930,334 | 42392.9031 | 24475.55401 |

| | | | | |
|---|---|---|---|---|
| Rose first floor hallway | PM 0.5 | 516,425 | 18969.53906 | 10952.06849 |
| Rose entryway | PM 0.5 | 542,445 | 331447.5967 | 191361.3592 |
| Rose Bathroom | PM 0.5 | 702,460 | 24943.10354 | 14400.90754 |
| Rose first floor (near the heater) | PM 0.5 | 990,815 | 254683.4316 | 147041.5478 |
| Outside RKC | PM 0.5 | 581,159 | 271475.8614 | 156736.6616 |
| Inside RKC | PM 0.5 | 799,852 | 278830.6062 | 160982.9255 |

**Table 3. Particulate Matter (Mean, Standard Deviation, Standard Error)**


**Figure 1. Map for the sites**

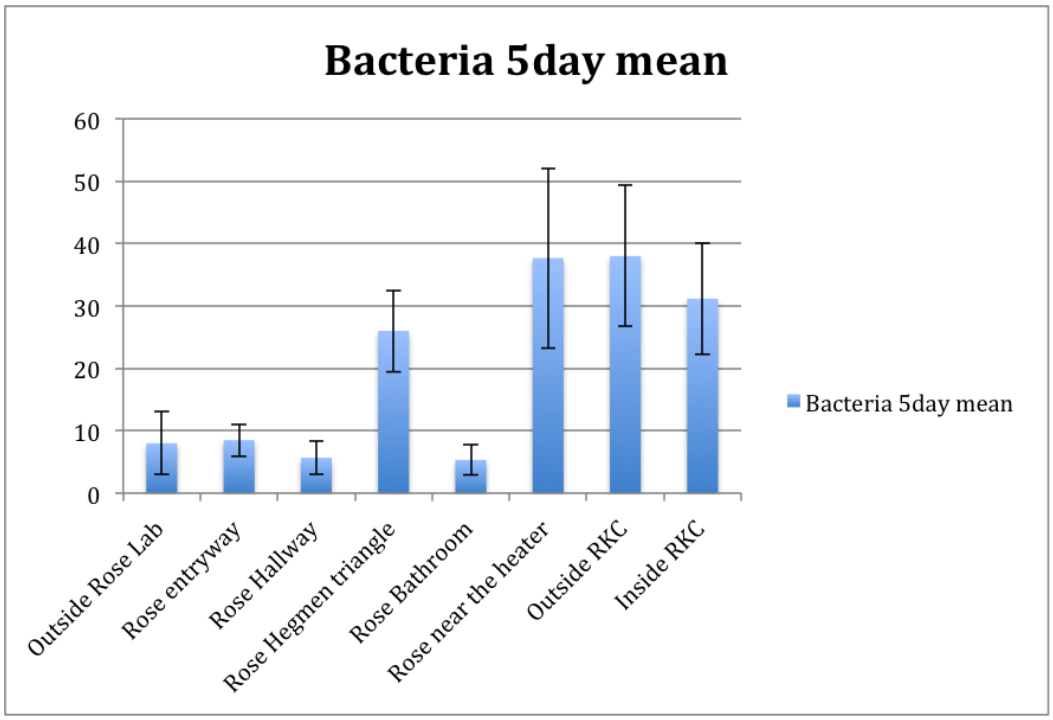


**Figure 2. Bacteria 5 day**

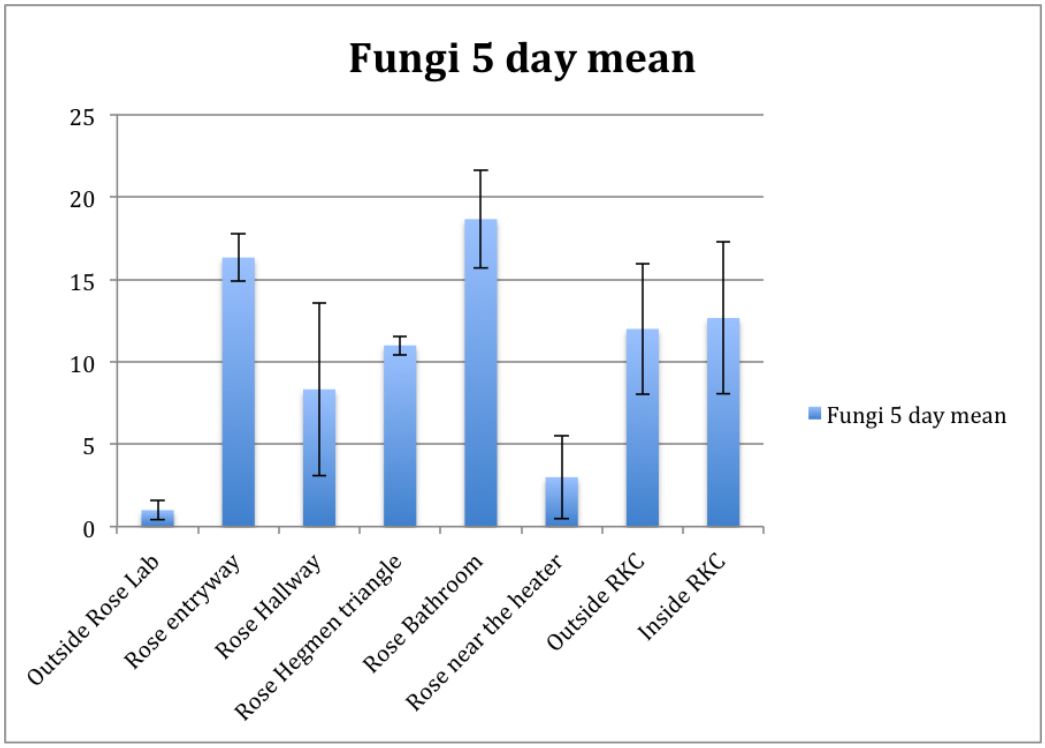


**Figure 3. Fungi 5 day**

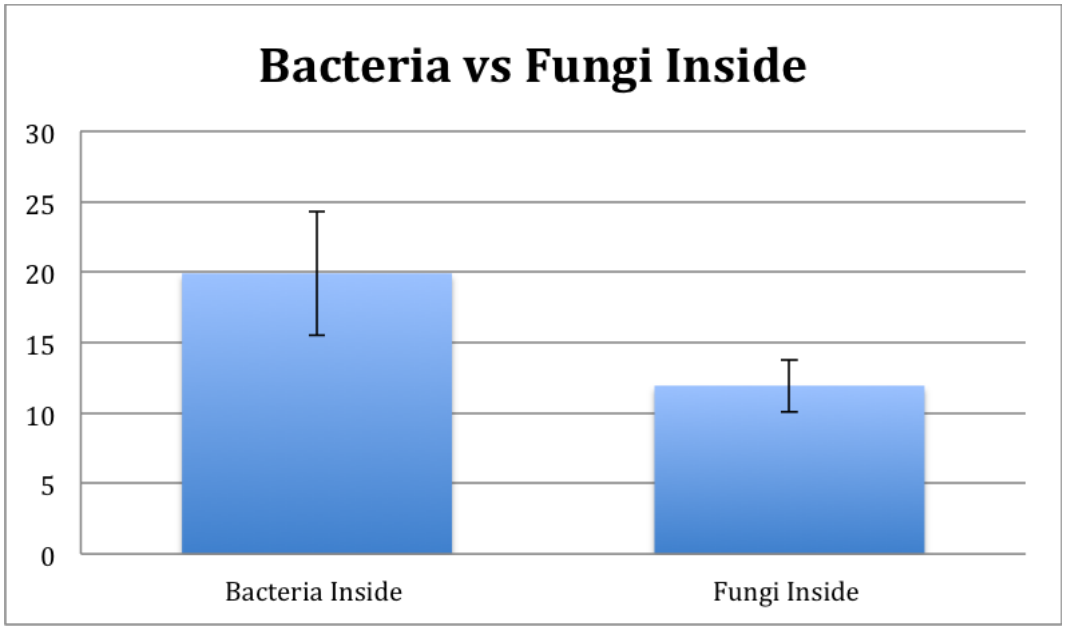


**Figure 4. Bacteria vs Fungi Inside**

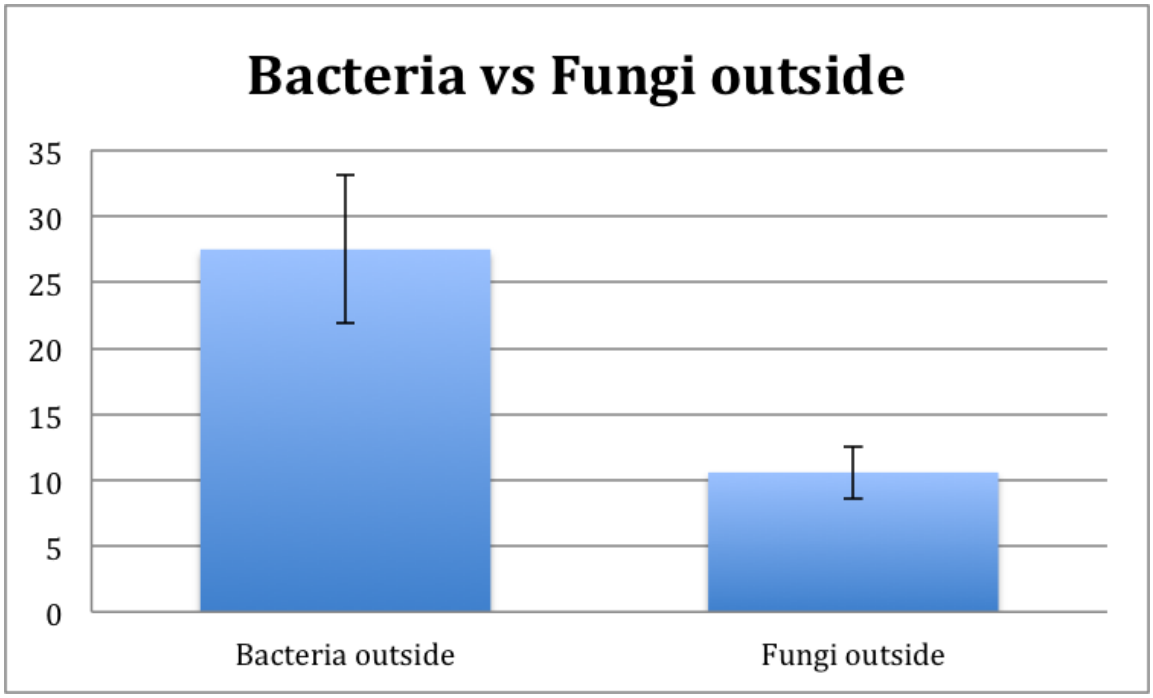


**Figure 5. Bacteria vs Fungi Outside**

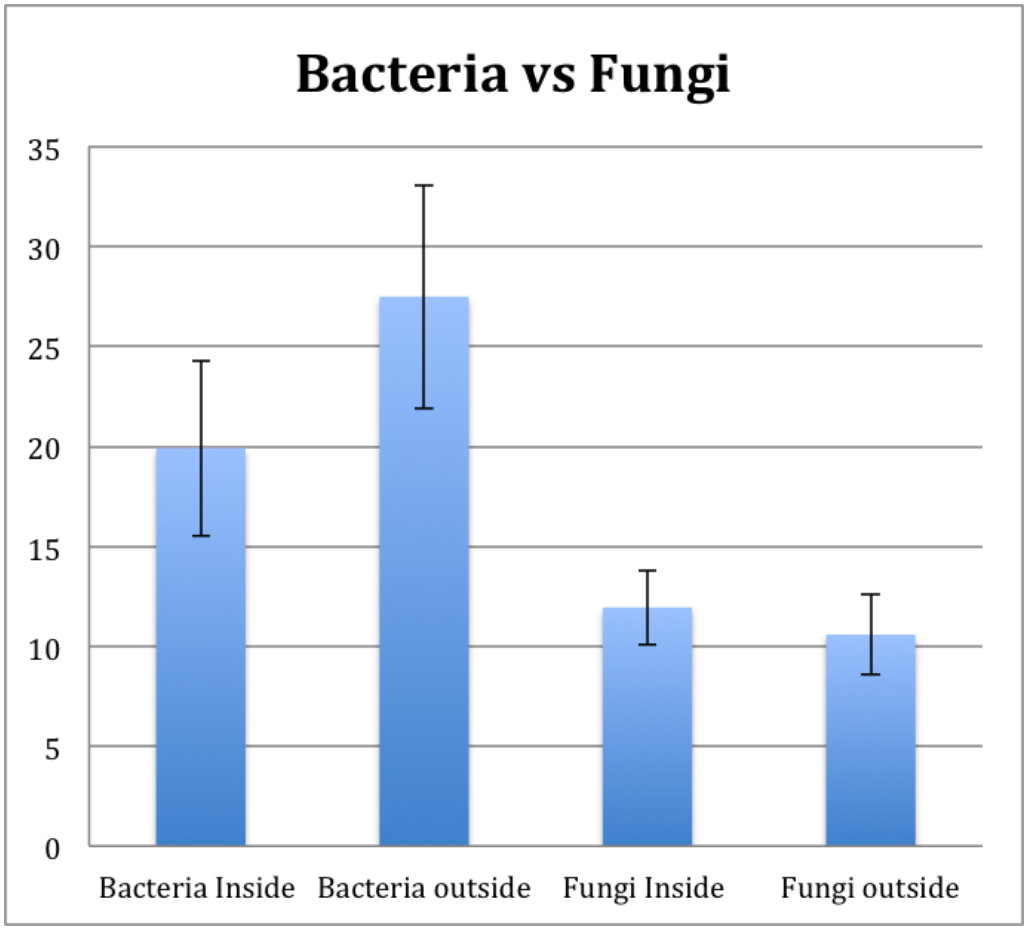


**Figure 6. Bacteria vs Fungi**

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**Appendix**

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