Improving Indoor Air Quality in Bethlehem, PA Through Optimized Phytopurifiers

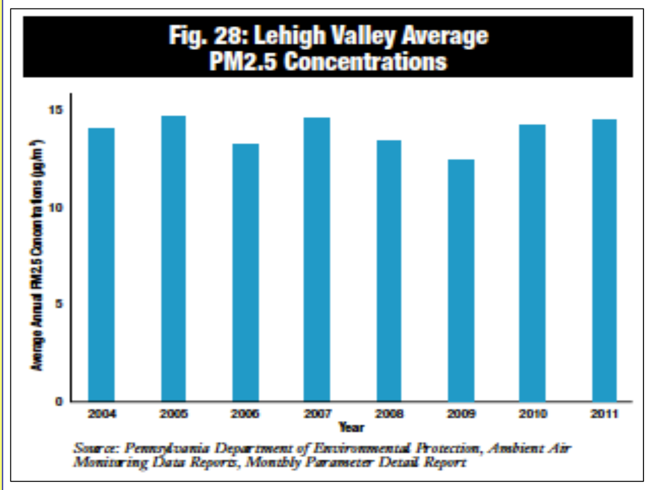
Maria Cuenca, Carlie Skellington & Erin Sowell
Sustainable Development Mountaintop Project, Lehigh University

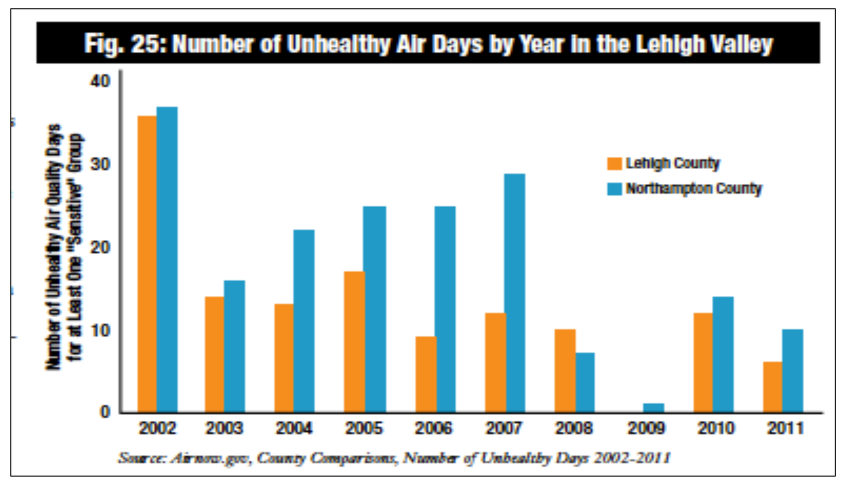
Introduction

- The average person spends approximately 80-90% of time indoors (EPA 2015).
- Air pollution is commonly two to five times more concentrated indoors than outdoors (EPA 2015)
- While the 1990 Clean Air Act requires the EPA to set National Ambient Air Quality Standards for particular harmful pollutants, many areas do not meet the air qualifications required to pass
- Air pollution influences lung and neurological function, causing asthma, respiratory disorders, and headaches
- Air pollution effects people of lower socioeconomic status at higher rates
- We developed a plant-based air filter prototype named Phytopurifier that has potential to be affordable for all socioeconomic statuses, but specifically lower socioeconomic status
- We use residents of Bethlehem as a potential consumer population

Bethlehem's Air Pollution

- Pennsylvania is the 4th ranked state in the nation for ground level ozone
- Bethlehem currently fails to meet the annual particle pollution standard and has exceeded the average number of high ozone days
- The EPA declared the Lehigh Valley as a nonattainment area in April of 2012 due to unmet ground level ozone standards (Hoke 2012)
- The topography as a valley and the area's moist climate have been a primary cause for the trapping of pollutants





Prototype Specifications

- Plant: *Spathiphyllum* (Peace Lily) or *Epipremnum aureum* (Golden Pothos)
- Medium: Plant clay pebbles, Ladybug Natural expanded shale, and water phase granular activated carbon (1.68mm-2.00mm)
- Wet Scrubber & Microbes
- Additions: Aquagarden fountain pump, sprinkler nozzle, 12V Delta Electronics fan, PVC pipe
- Container: A five-gallon Encore Plastics HDPE commercial bucket

Figure 1: Putting together the first prototype

Figure 2: Putting together the first prototype

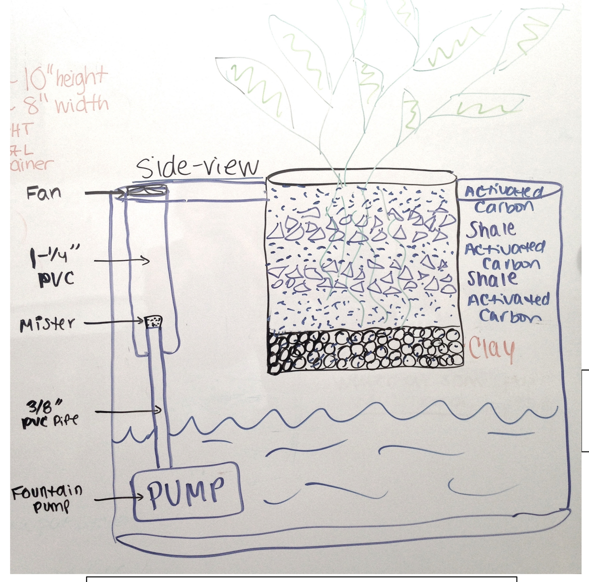


Figure 3: Side-view drawing of prototype

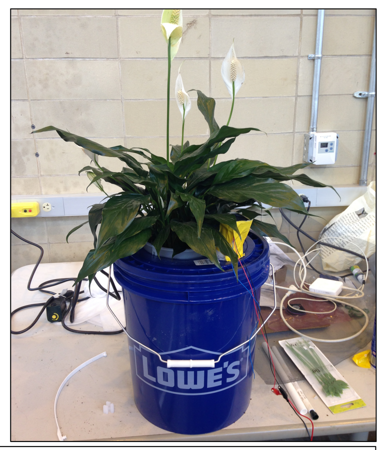


Figure 4: First completed testing prototype

Figure 5: First completed aesthetic prototype

Testing Chamber

- A 275-gallon, 1m x1m x 1m IBC container represents a sealed, contained environment.
- A 0.5m x 0.5m opening serves as an entryway for the prototype and testing materials. During testing, the entryway was sealed with a 0.55m x 0.55m OPTIX clear acrylic sheet and secured with duct tape
- A separate 0.05m x 0.05m opening allows for entry of the extension cords.
- Components Inside Chamber:
  1. Small personal fan for continuous airflow
  2. Three extension cords
  3. TekPower output DC power supply regulator

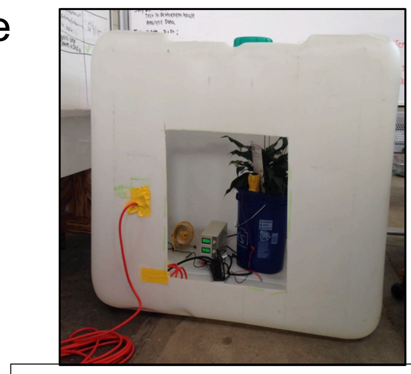


Figure 6: IBC Testing Chamber

Testing Methods

Control Test

- Performed with each monitoring device to collect starting concentrations of pollutants before experimental testing

Prototype Test

- Performed with each monitoring device to measure the pollution adsorption capacity of the entire prototype, which includes the plant, medium, and microbes

Carbon Monoxide (CO) Testing

- Situated CO Monitor securely on the inside of the Optix clear acrylic sheet with duct tape
- Completely sealed the IBC chamber using duct tape
- Delivered pollutant by inserting smoke from one cigarette using a turkey baster
- Allowed the test to run over an appropriate length of time, while recording the reading on the CO Monitor at 30 minute intervals

Figure 7: Preparation of cigarette using Chefmate baster

Figure 8: Cigarette smoke pumping technique

Figure 9: Draeger Safety Pac 3500 CO Monitor

Carbon Black (CB) Testing

- The microAeth Model AE51 black carbon aerisol monitor was utilized to carry out tests
- Carbon black pollutant was delivered using two cigarettes in five minute intervals using a turkey baster
- Two tests were performed in 24 hour intervals including a controlled test and a test with a Golden Pothos prototype
- Allowed the test to run for ~1 hour

Figure 10: microAeth Model AE51 black carbon monitor

Carbon Black Test Results

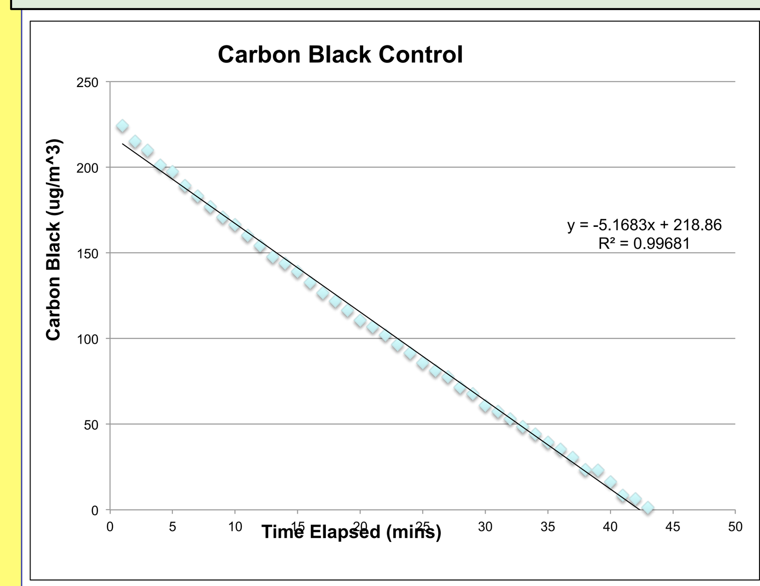


Figure 11: CB Control Analysis

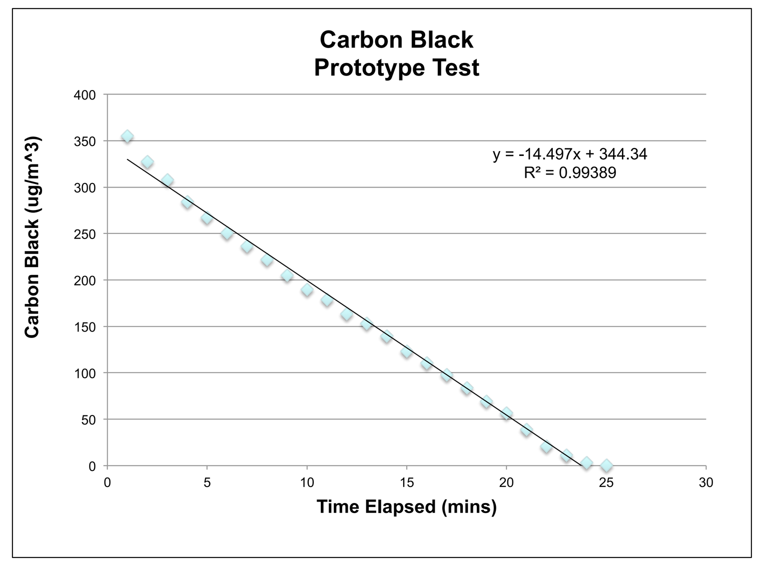


Figure 12: CB Prototype Test Analysis

Rate of Decrease: 312 μg/m^3 per hour

Rate of Decrease: 852 μg/m^3 per hour

CO Test Results

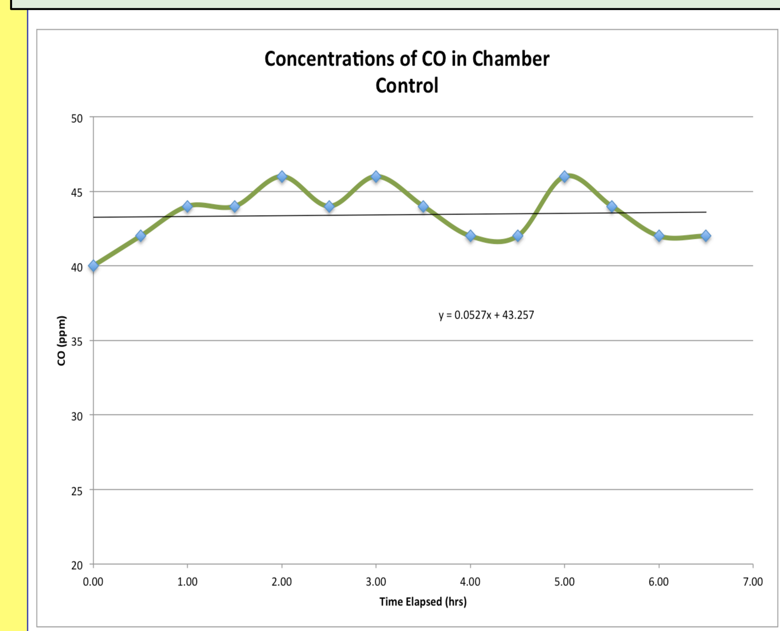


Figure 13: CO Control Analysis

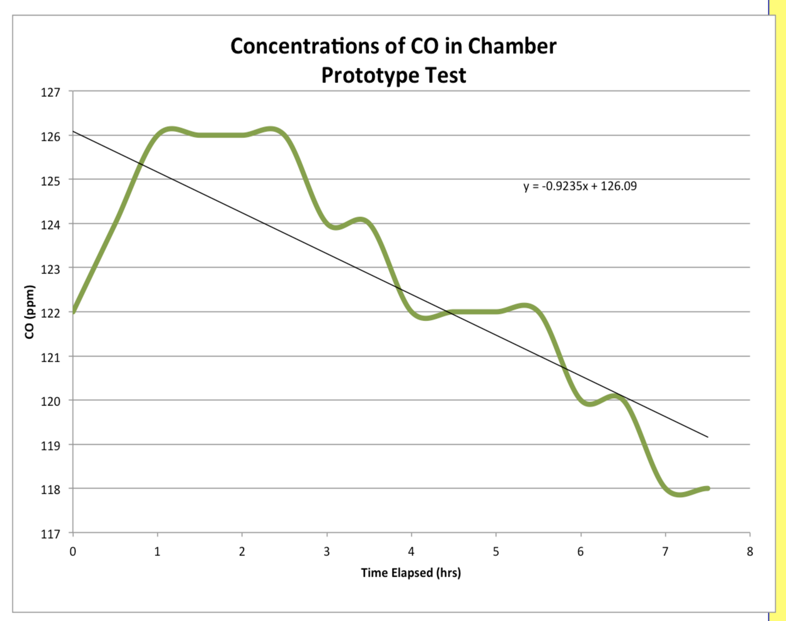


Figure 14: CO Prototype Test Analysis

Rate of Decrease: 0.0 ppm per hour

Rate of Decrease: 0.9 ppm per hour

Conclusions

The Phytopurifier team aimed to create an affordable plant-based air purification system available to people of all backgrounds. Through our experimentation the team learned the prototype was able to reduce target pollutants at a more rapid rate than the control environment where no Phytopurifier was utilized. The Phytopurifier is capable of removing 852 μg/m^3 per hour of CB and 0.9 ppm of CO per hour. These numbers are significant. The Occupational Safety and Health Administration (OSHA) permissible exposure limit for carbon black is 3500 μg/m^3 over a 10 hour period. A Phytopurifier could considerably reduce the total concentration of CB in the air. According to the EPA, natural levels of CO in the air are 0.5 ppm and homes with gas stoves have from 5 to 15 ppm of CO in its air. At a CO removal rate of 0.9 ppm per hour, a purifier would reduce CO levels considerably. By removing CO and CB from homes, it is possible to decrease air pollution related heath problems. A low-cost filter makes air filtering more accessible to everyone.

Figure 15: Preparation of aesthetic prototypes

Works Referenced

Hoke, Scoll., et al., "State of the Lehigh Valley: Community Trends at a Glance."*Lehigh Valley Research Consortium* (2012): 22-25. *Lehigh Valley Research*.

Unknown Author. 2015. "Health Effects of Air Pollution." *United States Environmental Protection Agency.* http://www.epa.gov/region07/air/quality/health.htm

Zhang, J., Wang, Z., Ren, D. 2010. "Botanical Air Filtration." *ASHRAE Journal.* (Dec): 138-140.

Acknowledgements

Thank you to Dr. Orrs and Dr. Weisman for the constant support throughout the project. Thank you to Dr. Holland and Dr. Fox for guidance, assistance and supplies. Thank you to the Lehigh University Mountaintop Program for providing funding and giving us this opportunity.