Air Pollution With 2.5 Micron Particulate Matters and Testing the Decay of the Aerosol Concentration as a Function of Time to Compare the Efficiency of AHPCO® and Bi-Polar Units in Reducing the Indoor Particle Counts

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Abstract

One of the top environmental concerns of the world today is air pollution, which is affecting our health every day (Bickerstaff & Walker, 2001). Studies have shown that air pollution has a major effect in human health by increasing sickness and death (Dockery, & Pope III, 1994). A major form of air pollution is aerosol; scientists describe it as tiny, airborne solid and liquid particles that are released by Earth's surface both naturally and as a product of human activities (Simmon, & Voiland, 2010; NOAA Earth System Research Laboratory [NOAA], 2017). Our biggest problem with air pollution is the aerosols in the form of Particulate Matter (PM), also known as particulate pollution. The most dangerous particulate matters are those which

are less than 10 micrometers, because when inhaled, they can reach deep down into our lungs and even into our bloodstreams (U.S Environmental Protection Agency [EPA], "Particulate Matter (PM) Basic," 2017). The purpose of this study was to test a new kind of air purifier, and help the public make the right choice for their health. In this research several experiments were conducted using the Air Oasis filter-less air purifier with Advanced Hydrated Photo Catalytic Oxidation (AHPCO) and Bi-polar units inside the fiberglass chambers to estimate the decay of aerosol concentration as function of time. In higher concentration a prominent rate of decay was measured when using the Air Oasis units however, there has not been any significant change at the lower concentration.

Keywords: Particulate Matter (PM), PM 2.5, Aerosol, AHPCO, Bi-Polar

Introduction

One of the top environmental concerns of the world today is air pollution, which is seriously affecting our health every day (Bickerstaff & Walker, 2001). Air pollution is increasing and is an ongoing problem due to growing population, growing industries, an exponential increase in the number of motor vehicles in cities, power plants, trade, and burning of fossil fuels. Bigger cities such as Beijing in China, Delhi in India, Los Angeles, Houston, and New York in the U.S. are affected by air pollution more than other cities (Feng, Wang, Wu, & Yan, 2016). Studies have shown that air pollution has a major effect on human health by increasing sickness and mortality (Dockery, & Pope III, 1994).

A major form of air pollution is aerosol; described as tiny, airborne solid and liquid particles that are released by the Earth's surface both naturally and as a product of human activities (Simmon, & Voiland, 2010; NOAA, 2017). Ninety percent of aerosol mass is from volcanic ash, smoke, gases and most abundantly sea salt and dust; the other ten percent are man-made (Simmon, & Voiland, 2010). Aerosols have an effect on the energy balance of the atmosphere by absorbing radiation, or acting as condensation nuclei during cloud formation and by setting off precipitation (NOAA, 2017). Not only do aerosols have an effect on climate, but also impact photosynthesis, agricultural production, and the quality of air we breathe, which affects the health of all living organisms (NOAA, 2017). The biggest problem with air pollution are the aerosols in the form of Particulate Matter (PM), also known as particulate pollution. These are mixtures of particles and liquid droplets found in the air around us (EPA, "Particulate Matter (PM) Basic," 2017). They vary in size and shape and are made of hundreds of different chemicals. Most PM are large enough that they are visible, such as dust, dirt and smoke. Others are so small that they require an electron microscope to be seen. These particulate matters

are called the PM 2.5, or particulate matters with a size of 2.5 micrometers in diameter. Generally, these are combustion particles, organic compounds, metals, and etc., normally less than or equal to 2.5 micrometers (EPA, "Particulate Matter (PM) Basic," 2017). Particulate matters are found all around us such as construction sites, unpaved roads, fields, smokestacks, or fires. The particles that are formed in our atmosphere are results of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides; these are pollutants that are generally released from power plants, industries, and automobiles (NOAA, 2017). The most dangerous particulate matters are those which are less than 10 micrometers, because when inhaled, they can reach deep down into our lungs and even into our bloodstreams (EPA, "Particulate Matter (PM) Basic," 2017).

Long term particle pollution, especially PM 2.5 has been previously linked with a lot of different health issues. These problems include increased respiratory symptoms, decreased lung function, aggravated asthma, development of chronic respiratory disease in children, development of chronic bronchitis or chronic obstructive lung disease, irregular heartbeat, nonfatal heart attacks and premature death in people with heart or lung disease (Sacramento Region Spare the Air [Sacramento], 2017). Short term exposure to particulate matter can aggravate individuals with lung disease by causing asthma attacks, acute bronchitis, increase susceptibility to respiratory infections, as well as cause heart attacks and arrhythmias in people with heart disease. Healthy individuals can also experience symptoms such as nose and eye irritation, coughing, chest tightness and shortness of breath (Sacramento, 2017).

We may presume that we are safe from air pollution when we are inside, however unfortunately there is such a thing as indoor air pollution; we breathe polluted air while we are in the comfort of our homes and work places. While the primary source of outdoor PM 2.5 is fuel combustion during transportation and energy production, indoor PM 2.5 sources include cooking, smoking and cleaning activities (Biswas et al., 2008). Air pollutants encountered indoors include particulate matter, gases such as ozone, nitrogen dioxide, carbon monoxide and sulfur dioxide, microbial and chemical volatile organic compounds, passive smoke, and outdoor ambient air (Alexis et al., 2008). The sources for indoor air pollutions are appliances, heaters, household cleaners, pesticides, radioactive gas and environmental tobacco smoke. Other pollutants make their way in through windows, doors, cracks and ventilation (Psr, 2017). In 1989, Ott estimated the amount of time people spent outdoors and indoors in 44 cities in the U.S.; individuals that were employed spent about 2% of their time outdoors, 6% in transit, and 92% indoors (Behar et al., 2001). This indicates that most of our time is spent indoors.

Due to growing concerns of indoor air quality, demand for air purifiers has risen, and attempts to invent a high quality air purifier has increased as well. There are many air purifiers out in the market; the focus of this study is on the unique filter-less air purifiers, Air Oasis 3000 G3 Advanced Hydrated Photo Catalytic Oxidation (AHPCO) and the Bi-polar 2400-24V units. The purpose of this study was to test the effectiveness and efficiency of the air purifiers, and help the public make the right choice for their health.

Objective

The objective of this study was to look at the decay of aerosol concentration as function of time when using and when not using the AHPCO and Bi-Polar units. The plan was to inject the aerosols in the chamber without any units running for the first run. Ideally, 10 mg/m3 of aerosols would be inject to see the decay of aerosols and repeated three times to get some background knowledge in how the aerosols behave in the chamber. The aerosol would be dispersed and the decay would be recorded. The next experiment involving ventilation using a small fan to circulate the air in the chamber. Observations were carried out on the experimental decay of particles and compared that to the first experiment. The third experiment was done with the AHPCO unit to see any changes in the decay of the particles.

Experimental Chamber & DustTrak

The experiments were conducted in a chamber with a height of 29.5-inch, 16-inch width and 46-inch length. On one end of the chamber there was an inlet, where the aerosols were dispersed and the other end was an outlet. On the inlet there was a T connector that split the flow, one end goes in the chamber that brings the aerosols into the chamber, the other end has the safety pass of air. At the outlet, everything is linear, meaning there is a straight and constant number of particles coming out. The outlet was attached to the DustTrak 8520 spectrometer that sucked the aerosols in, to take the concentration in mg/m^3. On top of the chamber is a safety filter that captures the aerosols and lets air out. There is no need to know how much of the particle is coming in, just have to measure how much of the particles are in the chamber as a function of time.

Dry-dispersed Illite NX Dust

For this experiment the illite NX dust was used as aerosols. Illite NX dust is an illite rich powder that has a similar mineralogical composition to atmospheric mineral dust that is found in remote areas. The reason for the use of illite NX dust for this study was due to its similar characteristics to the natural earth mineral and dust (Hiranuma et al., 2015). However, the illite NX dust does not represent volatile organic compounds (VOC), bioaerosols, or

aeroallergens. Illite NX dust is a mixture of different types of clay minerals such as: illite, kaolinite, quartz, calcite/carbonate and feldspar (Hiranuma et al., 2015). Illite is a clay mineral found in marine shales and is poorly crystallized (Encyclopedia Britannica, 2017.). Kaolinite clay mineral is soft, easily molded or shaped, and is used in a lot of commercial products (Minerals.net, 2017). Quartz is one of the most durable minerals, its chemical compound is one-part silicon and two parts oxygen (SiO_2). Quartz is the dominant mineral of mountaintops and mostly found in beaches, rivers, and desert sands (Geoscience News, "Quartz," 2005-2017). Calcite is a mineral that forms rocks and is found everywhere, its chemical formula is $CaCO_3$ (Geoscience News, "Calcite," 2005-2017). Feldspar is another mineral found in illite NX dust, it is a given name to a group of minerals with alumina and silica (Minerals Education Coalition, 2017).

AHPCO and Bi-Polar Air Purifiers

As air pollution has increased, may it be outdoors or indoors, the need for clean air has risen; and companies are coming up with new products to meet public demands. A new technology has hit the market that can be the answer to a lot of indoor air pollution. To test this theory, we have decided to do an experiment with the Advanced Hydrated Photo Catalytic Oxidation (AHPCO) nanotechnology and Bi-polar unit a new filter-less air purifier by Air Oasis. The AHPCO technology does not need a filter or air purifier for the air to pass through (Air Oasis, 2018). "The AHPCO operates by creating ions from the UV light the UVC lamp destroys germs that pass by. Redundant air cleansing ions are then formed from water vapor when rays of light from the UVC lamp excite the AHPCO catalyst… Bacteria, viruses, VOCs and other pollutants are destroyed: Redundant ions actively seek out pollutants and break them down. They are neutralized as the contaminants are destroyed… Harmless By-products of Water Vapor: Ions revert back to harmless water vapor and the cycle repeats, thereby reducing additional contaminants" (Air Oasis, 2018).

The Bi-polar unit works by dispersing positive and negative ions. This unit uses the water vapor that is already in the air by splitting water vapor and producing positive and negative ions while constantly dispersing ions throughout the ambient air (Air Oasis, 2018). We have been analyzing the air quality of Texas Panhandle in terms of aeroallergen concentrations for more than seventeen years (Ghosh et al., 2017). Other successful research projects have been done through West Texas A&M University with the Air Oasis units, that has shown reduction in aeroallergens, mold, bacteria, fungus, and volatile organic compounds (VOC's) (Ghosh, Aranda, Bennert, & Chudasama. 2011; Ghosh, Saadeh, Gaylor, & Aurora. 2006; Ghosh et al., 2017).

Methods

During this study a total of 24 experimental runs were done in the fiberglass chambers. For precision, 18 of the experiments were done specifically to compare the effects of the AHPCO and Bi-Polar air purifiers. Ten experiments were done with high aerosol concentration and eight experiments were done with low aerosol concentration. The other six experiments were conducted on various different filters and air purifiers. The initial experiments were conducted by dispersing high aerosol concentration of approximately 10 mg/m^3 to 13 mg/m^3 into the chamber. For each experiment, about 10 mg/m^3 illite NX dust was injected into the chamber. Then, the DustTrak (DT) spectrometer was turned on to measure and record the decrease in the aerosol concentration over time. The DT spectrometer was set in five second intervals to record the change in aerosol concentration. For the control, no units were run inside the chamber. The duration of these experiments varied around 30 minutes to 2 hours. More experiments were performed the same way; another control experiment was conducted including a running ventilation. The following experiment included running ventilation and the AHPCO inside the chamber and the next experiment included a running ventilation and the Bi-polar unit. The experiments continued with more trials using the same procedure. Lower aerosol concentration experiments began with dispersing approximately 1 to 2mg/m^3 aerosols. Eight more experiments were conducted following the same protocol for the Control run, AHPCO, and for Bi-Polar.

The majority of previous research done with the Air Oasis units had a time frame of a few days to a week or two for each experiment. For this research, each experiment was held for an hour or two max.

Formula number 1 was used to find the exponential decay rate (*R*):

$$\mathrm{f(m)} = [\mathrm{m}]\mathrm{t} = [\mathrm{m}]_\mathrm{o}\mathrm{e}^{-\mathrm{rt}} \quad (1)$$

$$\mathrm{m} = [\mathrm{m}]_\mathrm{o}\mathrm{e}^{-\mathrm{rt}}$$

$$\mathrm{m} = \text{final concentration}$$

$$[\mathrm{m}]_\mathrm{o} = \text{intial concentration}$$

$$\mathrm{e} = \text{exponential}$$

$$\mathrm{r} = \text{rate}$$

$$\mathrm{t} = \text{time}$$

R can be used to differentiate between the exponential decay rate of the control and the Oasis unit. The area in between the control and the Oasis units' slope was calculated using the formula number 2 to determine the total amount of decay by the Oasis unit:

$$\int [\mathrm{m}]_\mathrm{o}\mathrm{e}^{-\mathrm{rt}} \text{ with the unit} - \int [\mathrm{m}]_\mathrm{o}\mathrm{e}^{-\mathrm{rt}} \text{ without the unit} \quad (2)$$

Results: Descriptive & Calculated Analysis

A representative graph for three of the high aerosol concentration experiments including the Control, AHPCO, and Bi-Polar has been shown in Figure 2a. Figures 2b, 2c, and 2d show the measured concentration with a calculated exponential line of best fit. Figure 2a shows the series of Bi-Polar constantly decreasing with time. The steeper the slope, the faster decay of aerosols. The Bi-Polar unit shows the steepest slope, followed by the AHPCO unit. The control slope is not as steep compared to the slopes of the two units, meaning the Air Oasis units were significant in the decay rate of aerosols as a function of time compared to the control.

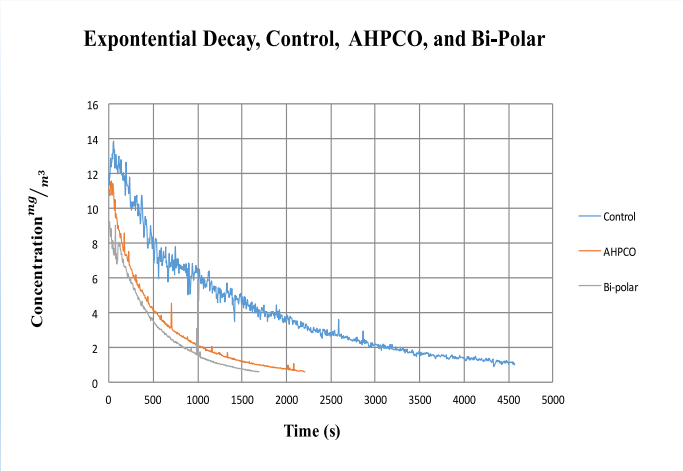

Figure 2a. High aerosol concentration decay for control and when using AHPCO, and Bi-Polar units.

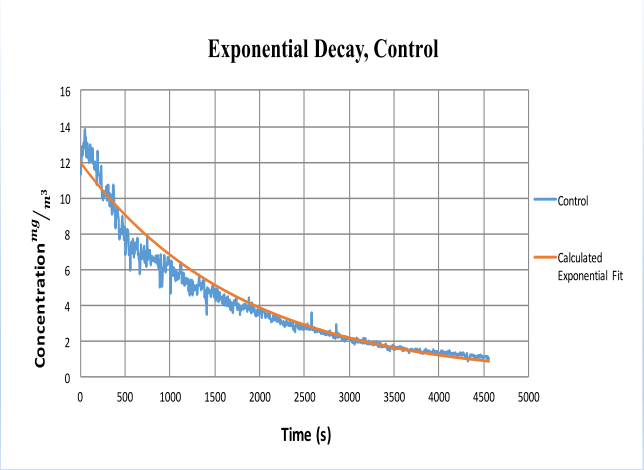

Fig.2b High aerosol concentration control trial with a calculated exponential line of best fit.

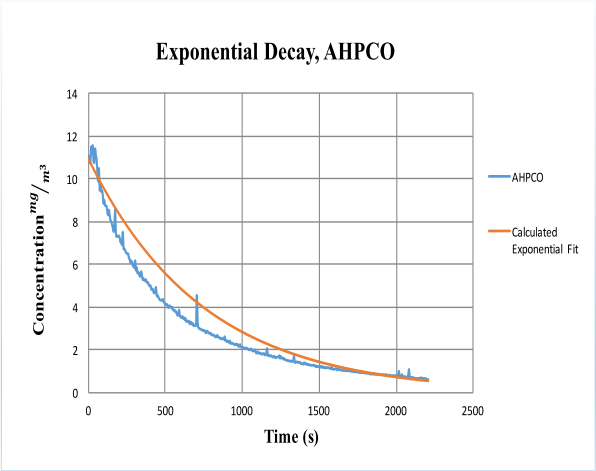

Fig.2c High aerosol concentration with a calculated exponential line of best fit when using AHPCO.

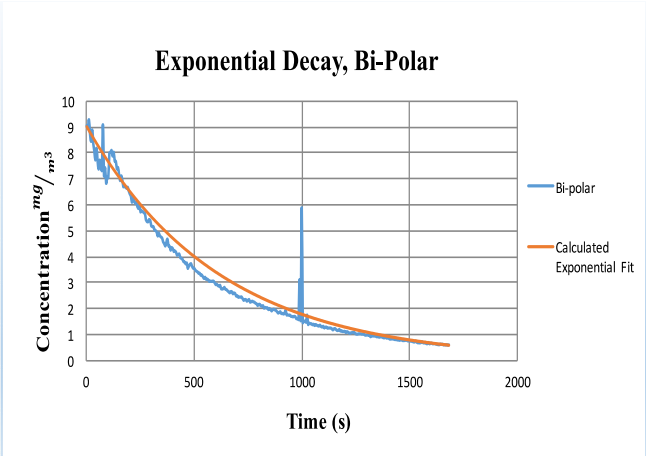

Fig.2d High aerosol concentration with a calculated exponential line of best fit when using Bi-Polar.

Table 1 shows the calculated rate of decay, the area under each curve, and the area between each curve of all three high concentration experiments. The results of Table 1 suggest that the area between the control and Bi-Polar is the greatest, followed by the area between the control and AHPCO. The area between Bi-Polar and AHPCO is not that significant. By looking at the graph and the table, it can be seen that aerosol decay rate was faster when using the Air Oasis units than when not using the units. For every run of the ten high aerosol concentration experiments, the degradation stayed consistent with the results shown.

Table 1. Calculated rate of decay, the area under each curve, and the area between each curve of all three high concentration experiments.

Experiments in high concentration	**Rate of decay** (mg/m^3*s)	**Area under the curve** (mg/m^3*s)	**Area between the Control and AHPCO curves** (mg/m^3*s)	**Area between the AHPCO and Bi-Polar curves** (mg/m^3*s)	**Area between the Control and Bi-Polar curves** (mg/m^3*s)
Control	0.00056	22769.93	14641.325	2929.32	17560.645
AHPCO	0.00135	8128.605			
Bi-Polar	0.00162	5209.285			

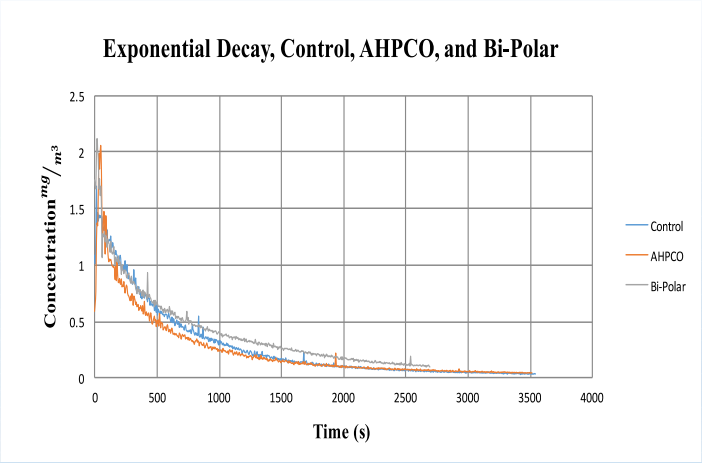

Fig.3a Low aerosol concentration decay for control and when using AHPCO, and Bi-Polar units.

Figure 3a shows the slope for the low aerosol concentration rate of decay as a function of time. This graph does not show an immense difference in between the three slopes, but the slope of AHPCO shows a slightly steeper curve than the control and Bi-Polar experiment. Figures 3b, 3c, and 3d show the exponential decay for low aerosol concentration with a calculated exponential line of best fit of control, and when using AHPCO and Bi-Polar units.

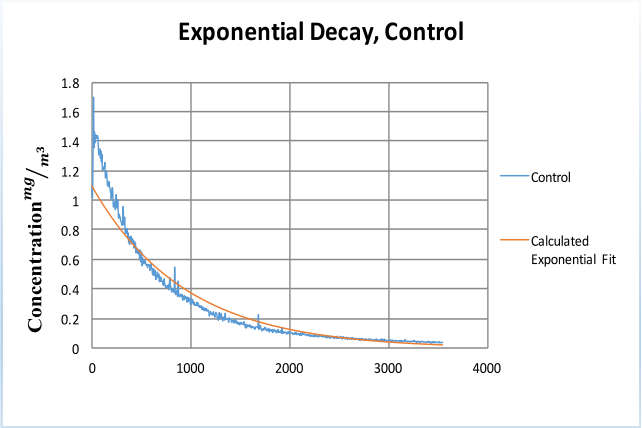

Fig.3b Exponential decay for low aerosol concentration control trial with a calculated exponential line of best fit.

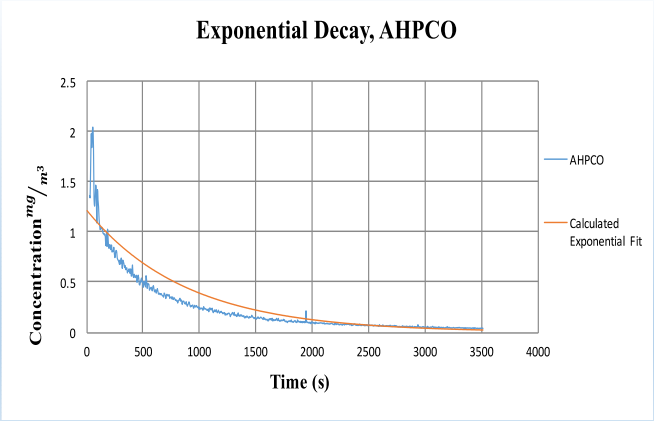

Fig.3c Exponential decay for low aerosol concentration with a calculated exponential line of best fit using AHPCO.

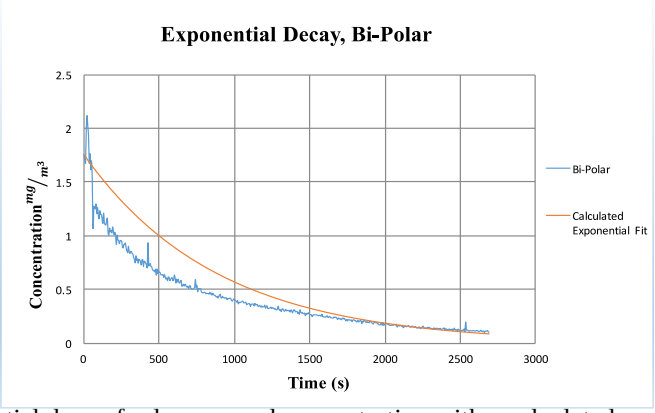

Fig.3d Exponential decay for low aerosol concentration with a calculated exponential line of best fit using Bi-Polar.

Table 2 shows the calculated rate of decay, the area under each curve, and the area between each curve of all three low concentration experiments. From this table, it can be determined that there is not much of a change in the rate of decay in low concentration aerosols when using the Air Oasis units and when not using them. When comparing the rate of decay in Table 1 and Table 2, it can be seen that the decay rate for the units in both of the experiments, low and high aerosol concentration, did not change dramatically while the control decay rate was a lot slower in Table 1.

Table 2. Calculated rate of decay, the area under each curve, and the area between each curve of all three low concentration experiments.

Experiments in low concentration	**Rate of decay** (mg/m^3*s)	**Area under the curve** (mg/m^3*s)	**Area between the Control and AHPCO curves** (mg/m^3*s)	**Area between the AHPCO and Bi-Polar curves** (mg/m^3*s)	**Area between the Control and Bi-Polar curves** (mg/m^3*s)
Control	0.00107	1558.62	168.93	59.434	228.37
AHPCO	0.00114	1727.55			
Bi-Polar	0.00113	1786.98			

Conclusion

As today's concern for better air quality rises, the demand for better air purifiers is increasing. This research is the first known study to test the decay of aerosol concentration as a function of time in a closed chamber, testing the effects of using Air Oasis filter-less air purifiers: AHPCO and Bi-polar units. The decay of aerosol concentration as function of time when using the AHPCO and Bi-Polar units was positive in the high concentrations; there was a decline in the slope of the graph after using both units. The aerosol concentration decay at lower level aerosol concentrations while using the air purifier units was not significant to the control rate of decay. AHPCO and Bi-Polar units degraded high and low concentrations of aerosol at approximately the same rate of decay, with the high concentration rate of decay being faster by .00049mg/m3*s between the experiments with Bi-Polar, and .0001mg/m3*s with AHPCO. Air Oasis units help sanitize and reduce aeroallergens, mold, bacteria, fungus, and volatile organic compounds (VOC's) according to other researches (Ghosh, Aranda, Bennert, & Chudasama. 2011; Ghosh, Saadeh, Gaylor, & Aurora. 2006; Ghosh et al., 2017).

This study showed approximately the same rate of decay in high and low aerosol concentrations as functions of time. In higher concentrations, a prominent rate of decay was measured when using the Air Oasis units; however, there has not been any notable effect in using the units in lower concentrations. This research was intended to help individuals suffering with indoor air pollution make a better decision for an air purifier that fits best to

their demands. The aerosols used in this study did not represent volatile organic compounds (VOC's), bioaerosol, or aeroallergens; future research may consider the usage of different aerosols containing these substances.

References:

1. Air Oasis web site: http://www.airoasis.com/
2. Alexis, N., Bacchus, H. , Bernstein, J. A. , Bernstein, L. , Fritz, P. , Homer, E. , . . . & Li, N. (2008) . The health effects of nonindustrial indoor air pollution. *Journal of Allergy and Clinical Immunology, 121*(3), 585-59. https://doi.org/10.1016/j.jaci.2007.10.045
3. Behar, V. J., Klepeis, E. N., Nelson, C. W., Ott, R. W., Robinson, P. J., Tsang, M. A., . . . & Switzer, P. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Science & Environmental Epidemiology*, 11, 231-252. Retrieved from: http://www.nature.com/jes/journal/v11/n3/full/7500165a.html?foxtrotcallback=true#bib50
4. Bickerstaff, K. Walker, G., (2001). Public understandings of air polluting: The 'localisation' of environmental risk. *Global Environmental change*, *11*(2), 133-145. https://doi.org/10.1016/S0959-3780(00)00063-7
5. Biswas, P., Grinshpun, A. S., Hu, S., Lee, T., LeMasters, G., Martuzevicius . . . & D. Reponen, T. (2008). Traffic-related $PM_{2.5}$ aerosol in residential houses located near major highways: Indoor versus outdoor concentration. *Atmospheric Environment*, 42(27), 6575-6585. https://doi.org/10.1016/j.atmosenv.2008.05.009
6. Dockery, D. W., & Pope III, C. A. (1994). *Acute Respiratory Effects of Particulate Air Pollution*. Environmental Epidemiology Program, Harvard School of Public Health, Boston, Massachusetts 02115-6096, 107-109. Retrieved from: http://www.annualreviews.org/doi/pdf/10.1146/annurev.pu.15.050194.000543
7. Encyclopedia Britannica. *Illite Mineral.* (2017). Retrieved from: https://www.britannica.com/science/illite
8. Environmental Pollution Centers. *What Is Air Pollution?*. (2017). Retrieved from: https://www.environmentalpollutioncenters.org/air/
9. Feng, J., Wang, J., Wu, Q., & Yan, Z., (2016). Impact of Anthropogenic aerosols on summer precipitation in the Beijing-Tianjin-Hebei urban agglomeration in China: *Regional climate modeling using WRF-Chem*: Advances in Atmospheric Sciences, 33, 753-766. Retrieved from:

https://search.proquest.com/openview/32ab6c6634d212e5c29dfa6fdb97f4a0/1?pq-origsite=gscholar&cbl=54452

10. Geoscience News and Information Geology.com. *Calcite.* (2005-2017). Retrieved from http://geology.com/minerals/calcite.shtml
11. Geoscience News and Information Geology.com. *Quartz A ubiquitous mineral with an enormous number of uses.* (2005-2017). Retrieved from: http://geology.com/minerals/quartz.shtml
12. Ghosh, N., G. Estrada, Veloz, M., Bouyi, D., Bennert, J. Bennert, J., Saadeh, C. and Revanna, C. Meteorological and clinical analysis of aeroallergen data: Increase in allergy and asthma cases in Texas Panhandle. ALLERGY AND ALLERGEN IMMUNOTHERAPY: New Mechanisms and Strategies (2017):101-124. Book Chapter, Apple, CRC Press, New York.
13. Ghosh, N., Aranda, A., Bennert, J., & Chudasama, J. (2011). Photo-Catalytic Oxidation Nanotechnology Used in Luna improved the air quality by reducing volatile organic compounds and airborne pathogens. *International Journal of the Computer, the Internet and Management, (19)*
14. Ghosh, N., C. Saadeh, M. Gaylor, N. Aurora. (2006). Seasonal and Diurnal Variation in the Aeroallergen Concentration in the Atmosphere of Texas Panhandle. *Journal of Allergy and Clinical Immunology*:117(2); February 2006
15. Ghosh, N., A. Howard, N. Sherali, C. Revanna, C. Pratt, C. Saadeh, J. Bennert, J. Bennert, K. Mullan and J. Rogers. (2017). Reduction of MRSA populations and Aeroallergens on using AHPCO® and Plasma Nanotechnology for Air Purification. International Journal of Advances in Science, Engineering and Technology, ISSN: 2321-9009, Vol-5, Issue-3-1, Aug.-2017:10-12.
16. Hiranuma, N., Augustin-Bauditz, S., Bingemer, H., Boose, Y., Budke, C., Curtius, J., Danelczok, A. . . . & Diehl, K., (2015). A comprehensive laboratory study on the immersion freezing behavior of illite NX particles: A comparison of 17 ice nucleationmeasurement techniques: *Atmospheric Chemistry and Physics*. doi:10.5194/acp-15-2489-2015
17. Minerals Education Coalition. *Feldspar.* (2017). Retrieved from: https://mineralseducationcoalition.org/minerals-database/feldspar/
18. Minerals.net The Mineral & Gemstone Kingdom. *The Mineral Kaolinte.* (2017). Retrieved from: http://www.minerals.net/mineral/kaolinite.aspx
19. NOAA Earth System Research Laboratory. *Aerosols: Climate and Air Quality.* (2017). Retrieved from: https://www.esrl.noaa.gov/research/themes/aerosols/

20. Psr. *Indoor Air Pollutants Examples.* (2017). Retrieved from: http://action.psr.org/toolkit/refguide/refguide-indoor-air-pollutants-examples.htm
21. Sacramento Region Spare the Air. (2017). *Air Quality Information for the Sacramento Region.* Retrieved from: http://www.sparetheair.com/health.cfm?page=healthoverall
22. Simmon, R., & Voiland, A., (2010) . Aerosols: Tiny Particles, Big Impact: *NASA Earth Observatory.* Retrieved from: https://earthobservatory.nasa.gov/Features/Aerosols/
23. U.S Environmental Protection Agency. *Asbestos' Impact on Indoor Air Quality.* (2017). Indoor Air Quality (IAQ): Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/asbestos-impact-indoor-air-quality
24. U.S Environmental Protection Agency. *Basic Information about Mercury.* (2017). Retrieved from: https://www.epa.gov/mercury/basic-information-about-mercury
25. U.S Environmental Protection Agency. *Biological Pollutants' Impact on Indoor Air Quality.* (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/biological-pollutants-impact-indoor-air-quality
26. U.S Environmental Protection Agency. *Carbon Monoxide's Impact on Indoor Air Quality.* (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/carbon-monoxides-impact-indoor-air-quality
27. U.S Environmental Protection Agency. *Clean Air Act Overview*. (2017). Air Pollution: Current and Future Challenges. Retrieved from: https://www.epa.gov/clean-air-act-overview/air-pollution-current-and-future-challenges
28. U.S Environmental Protection Agency. *Facts About Formaldehyde.* (2017). Retrieved from: https://www.epa.gov/formaldehyde/facts-about-formaldehyde#whatisformaldehyde
29. U.S Environmental Protection Agency. *Indoor Particulate Matter.* (2016). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter
30. U.S Environmental Protection Agency. *Introduction to Indoor Air Quality*. (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality
31. U.S Environmental Protection Agency. *Learn About Asbestos.* (2017). Retrieved from: https://www.epa.gov/asbestos/learn-about-asbestos#effects

32. U.S Environmental Protection Agency. *Nitrogen dioxide's Impact on Indoor Air Quality*. (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/nitrogen-dioxides-impact-indoor-air-quality
33. U.S Environmental Protection Agency. *Particulate Matter (PM) Basic*. (2016). Particulate Matter (PM) Pollution. Retrieved from: https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
34. U.S Environmental Protection Agency. *Pesticides' Impact on Indoor Air Quality*. (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/pesticides-impact-indoor-air-quality
35. U.S Environmental Protection Agency. *Volatile Organic Compound Impact on Indoor Air Quality*. (2017). Indoor Air Quality (IAQ). Retrieved from: https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality