2018

Predictors of PM 2.5 and Radon Concentrations in Residences of Central Kentucky: A Cross Sectional Study

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Predictors of PM 2.5 and Radon Concentrations in Residences of Central Kentucky: A Cross Sectional Study

Capstone Project Paper

A paper submitted in partial fulfillment of the requirement for the degree of Master of Public Health in the University of Kentucky College of Public Health

By

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April 18, 2018

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ABSTRACT

Aim: To measure levels of respirable particles (PM 2.5) and radon in homes in Central Kentucky and assess modifiable risk factors that could reduce the morbidity and mortality of cardiovascular and respiratory disease.

Methods: PM 2.5 and radon samples were taken in homes (n=21) in Central Kentucky. An in-home checklist was completed for each home that assessed a variety of potential environmental respiratory exposures.

Results: The geometric mean of PM 2.5 for all 21 homes was 8.4 $\mu g/m^3$ which was well below the EPA air quality standard of 35 $\mu g/m^3$. Smoking status, burning candles, and general cleanliness were statistically significant ($P \leq 0.05$) variables in determining elevated PM 2.5 levels. General cleanliness was determined through assessing the amount of dust, animal hair and clutter. Number of pets was statistically significant ($P \leq 0.10$) for PM 2.5 as well. None of the variables assessed for radon were statistically significant.

Conclusion: Improving general cleanliness, reducing the number of candles burned, regularly grooming pets, and eliminating smoking in the home could reduce the amount of PM 2.5 in a home. This may be particularly important for people at risk of or who already have a respiratory disease. Prediction of radon levels based on home characteristics may be difficult due to the highly variable levels from home to home. All homeowners, especially those in regions where high levels of radon are known, should test their homes to determine if mitigation is needed. Although more research is needed to look at the association between PM 2.5 exposure and health outcomes in Central Kentucky, there are modifiable factors that may reduce the amount of PM 2.5 in homes.

INTRODUCTION

Over half of the body's intake of air during a lifetime occurs within the home (Sundell, 2004). Furthermore, in some regions of the world, especially the developed world, people spend up to 90% of their time indoors (Klepeis et al., 2001, Sundell, 2004). Therefore, the indoor environment is extremely important in relation to our health because of the overwhelming amount of time that we spend in it and the potential for substantial long-term exposures. Indoor air quality has been considered a major environmental factor since the beginning of the "hygienic revolution" around 1850, but has lost some emphasis since the boom of outdoor environmental issues in the 1960's (Sundell, 2004). In the developing world, exposure to solid biomass fuel is a major concern for indoor air quality which may have led to 1.6 million cases of premature mortality in 2000 alone (Po, FitzGerald, & Carlsten, 2011). In the developed world, the concerns about indoor air quality revolve more around the increased air tightness of buildings, new construction materials, and a variety of lifestyle choices (Jones, 1999). Many potential contaminants degrade the quality of indoor air, especially particulate matter and toxic gases. This study focused on measuring respirable particulate matter less than 2.5 micrometers (μm) in diameter (PM 2.5) and radon gas, which is a known carcinogen (National Research Council, 1999).

PM 2.5 is a potential health concern at certain concentrations because of its size alone, not necessarily its chemical makeup. Particles that are under 2.5μm in diameter can penetrate deep into the lungs causing irritation and degradation of the alveolar walls, which can ultimately lead to inflammation and decreased lung function (Kim, Kabir, & Kabir, 2015). Exposure to particles of this size has been shown through a number of toxicological and epidemiological studies to be closely related to increased incidence of human disease and mortality rate. One of the most well-known studies, “The Harvard Six Cities Study,” showed that outdoor concentrations of PM 2.5 were positively related to human mortality, especially among the elderly, in central and eastern United States (Schwartz, Dockery, & Neas, 1996). Further studies showed that outdoor and indoor sources of PM 2.5 may adversely impact respiratory health (Karottki et al., 2014). Long-term exposure to fine particulate matter may be associated with small but measureable increases of lung cancer mortality among non-smokers (Turner et al., 2011). PM 2.5 exposure can impact lung development in children as well as decrease lung function among both children and adults with and without existing lung disease (Paulin & Hansel, 2016). A wide range of people may be adversely affected by high levels of PM 2.5, but certain populations are at greater risk. Characteristics such as life stage (children and older adults), genetic polymorphisms, preexisting cardiovascular and respiratory disease, low socio-economic status (SES), high body mass index (BMI), and diabetes may increase a person’s susceptibility to PM health effects (Sacks et al., 2011).

Common sources of indoor particulates include combustion of tobacco products, stoves, heaters, fireplaces, candles, pet dander, volatile organic compounds (VOCs), dust mites, and mold/bacteria from water damage. Tobacco smoke is a major contributor of PM 2.5 and can lead to in-home levels several times greater than that found in homes of non-smokers, no matter the location within the home (Van Deusen et al., 2009). Non-smoking homes may experience greater levels of PM 2.5 if they live in multi-unit housing where smoking is allowed in adjacent units (King et al., 2010). Cooking in the home is also a major contributor for increased PM 2.5 levels. While cooking, PM 2.5 can increase 20-40 fold in the kitchen and 10 fold in bordering rooms (Wan et al., 2011). Other factors such as the type of flooring, number of people, and pets in the home may contribute to PM 2.5 levels because of resuspension of aerosols (Ferro, Kopperud, &

Hildemann, 2004). Lifestyle factors may be important in reducing the amount of PM 2.5 in homes. For example, regular cleaning of homes, using an exhaust fan while cooking, reducing clutter, and changing central air system filters may prove effective when trying to reduce PM 2.5 levels (Laumbach et al., 2015; Brook et al., 2010).

Radon exposure is considered the second leading cause of lung cancer among smokers and the leading cause among lifetime non-smokers, or "never smokers" (WHO, 2010). It is estimated that 10% – 25 % of all lung cancer cases occur among never smokers and that 30% of those cases could be attributed to radon exposure (Torres-Duran et al., 2014). Many studies have concluded that radon is associated with lung cancer, but few, if any, have identified potential risk factors for radon exposures. Identification of these risk factors could help guide testing and remediation.

METHODS

Participants for this study were selected through convenience sampling of family and friends who currently live in the Central Kentucky area. Equipment for the collection of radon and PM 2.5 samples was left in each home for a minimum of four days and an in-home checklist was completed for each residence. The in-home checklist assessed a variety of in-home respiratory exposures and was administered both through observation and verbal questioning. Each home was sent a letter that detailed the results of the radon and PM 2.5 in-home testing shortly after the testing was completed.

Indoor PM 2.5 Sampling

Indoor air was sampled utilizing an occupational sampling protocol adapted for indoor air (Pavilonis et al., 2013). Over a four-day period, a BGI OMNI 400 sampling pump (BGI Waltham, MA) with a SKC PM 2.5 sampler (SKC, Eighty Four, PA) was used to sample respirable dust (PM 2.5) at a rate of 4 liters per minute. The device was placed at least one meter above the floor in the area of the house where the family reported spending the most time. The samples were collected on a 37 mm polyvinyl chloride (PVC) filter with a 5.0 µm pore size (SKC Inc., Eighty Four, PA). The filters were weighed with an electrical microbalance (Mettler MTS, Columbus, OH) before and after sample collection with a sensitivity of ± 2 µg. The microbalance was calibrated before each weighing session. Before weighing both times, the filters were stored in a temperature and humidity controlled chamber for at least 48 hours to allow for acclimatization to a standard temperature (68° F) and relative humidity (50%). The difference in weight was divided by the average flow rate and multiplied by the number of sampling minutes to estimate the PM 2.5 concentration over the four-day sampling period in micrograms per cubic meter of air ($\mu g/m^3$).

Indoor Radon Sampling

Radon testing was conducted using the E-PERM Radon Measurement System (Rad Elec Inc., Frederick, MD). The electret passive environmental radon/radiation monitor (E-PERM) is an electret ion chamber composed of two components, an electret and a special chamber. Specifically, the short-term electret and s-chamber were used to form the SST configuration. Before testing, the electret voltage was measured using the electret voltage reader. The E-PERMs were opened and then placed in different locations in the home depending on the type of home. If there was a basement, one was placed in the basement and one on the main floor. If not, one was placed on each level of the home or opposite sides of the homes. After at least four days, the E-PERMs were closed and then shortly after the voltage was measured again using the electret voltage reader. The reduction in voltage and the amount of time the chamber was open were used to calculate the amount of radon in the home.

In-Home Checklist

The in-home checklist examined indoor risk factors that might influence the degree of respiratory exposures. This checklist was completed by both observation from the researcher and verbally questioning the participants. Common in-home respiratory exposure sources were assessed. The age of the home and approximate square footage were collected through the local property valuation administrator website and recorded as a continuous variable. The distance to the street was approximated by the researcher and recorded as <75 feet and >75 feet. Attached garage was recorded as yes/no. The home construction type was recorded as single family or apartment. Participants were asked if there was a smoker in the home. They were also asked about number and types of pets in the home. Participants were asked if in the last year they experienced (yes/no): water damage, mold or bacterial growth, and pest (insect or rodent) problems. Candle usage was assessed as a yes/no and the frequency was recorded as several times per week, once a week, or never. The flooring type in the primary living space was recorded and later collapsed into whether the flooring in the primary living area was carpet, an area rug, or other. Participants were also asked about alternate heating sources used, including wood burning stove, gas fireplace, and space heaters. Their use was recorded as yes/no. Finally, general cleanliness was scored by four variables: dust on objects, floors, walls, baseboards, or furniture in the home (yes/no); animal hair on objects, floors, walls, baseboards, or furniture in the home (yes/no); dirt on objects, floors, walls, baseboards, or furniture in the home (yes/no); clutter, such as objects blocking walking paths or objects covering generally clear surfaces such as tables, bookshelves, or the floor, and piles of objects in corners or on beds in the home (yes/no). The scores were summed, with a minimum value of 0 and a maximum value of 4, and then later divided into two groups for analysis. Scores of 0 and 1 represented high cleanliness and a score of 2, 3, or 4 represented low cleanliness.

Statistical Analysis

Initially, all variables were plotted on a histogram to assess the normality of distribution. It was found that the PM 2.5 and radon measurements were not normally distributed. Most of the measurements were clustered together on the left side of the distribution with a few much higher measurements to the right side of the distribution (right skewed distribution). The measurements were log-transformed in order to create a more nearly normal distribution (log-normal distribution). To find means, the log of all PM 2.5 and radon measurements was taken and then the mean of the logs was calculated. The means of the logs were then exponentiated in order to calculate the geometric mean. The same process was completed in order to find the geometric standard deviation.

The log-transformed data were normally distributed which allowed the application of normal distribution statistics. Both outcomes, PM 2.5 and radon, were continuous variables. Therefore, either a t-test or an analysis of variance analysis (ANOVA) was used for statistical analysis, depending on the number of groups in the independent exposure variable. For the multi-level variables, an ANOVA was completed including Tukey and Duncan multiple range tests to look at significance between groups. All analyses were completed in SAS version 9.4 for Windows (2013, SAS Institute Inc., Cary, NC).

RESULTS

Data were collected for PM 2.5 and radon levels in 21 homes. The average age of the homes was 43 years old (built in 1975) and the average size was 1,707 ft^2. Of these homes, 15 (71%) were built before 1980 and 6 (29%) were built in 1980 or after. Also, 9 (43%) were smaller than or equal to 1,500 ft^2 while 12 (57%) were larger than 1,500 ft^2. There were 15 (71%) single family homes and 6 (29%) apartments (Tables 1 & 2).

In-home particulate sources were fairly common among these 21 homes (Tables 1 & 2). Two participants reported smoking indoors or having an in-home smoker (9%) and there were 9 homes with cats or dogs (43%). Thirteen homes burned candles at least once per week (62%) and 4 homes used either a wood burning stove or gas logs as an alternate heating source (19%). Ten homes had a low level of cleanliness (48%) based on dust, animal hair, and clutter seen throughout the home.

For radon, two samples were taken per home (except one home) for a total of 41 samples at the same homes as the PM 2.5 sampling. Therefore, the average age and size were the same. Several potential home characteristics were assessed to look at their association with radon levels. Seven homes were either apartments that had other residents beneath them or were built on a concrete slab (33%), three had a crawl space (14%), and 11 had a basement (53%). Fifteen homes did not have a sump pump (71%) and six did have a sump pump (29%). Seven of the homes had visible cracks in their basement or along the foundation (33%) and 14 did not have visible cracks (67%).

Among the 21 samples of PM 2.5, 1.04 μg/m^3 was the lowest sample and 58.72 μg/m^3 was the highest sample. Only two samples (10%) were above the EPA air quality standard of 35 μg/m^3. Fourteen samples were less than 10 μg/m^3. The geometric mean of PM 2.5 concentrations was significantly higher ($p<0.05$) in homes that had a smoker, regularly burned candles, and had a general low cleanliness. The PM 2.5 levels in homes that had one or more pets were also significantly higher than levels in homes that had no pets. There was no significant difference in the PM 2.5 levels in homes with one pet versus homes with two or more pets. No other variables were significantly associated with the PM 2.5 levels.

Among the 41 samples, the lowest measurement of radon was 0.6 pCi/L and the highest measurement was 21 pCi/L. Twenty-six samples were above the EPA standard of 4 pCi/L and 5 samples were above 10 pCi/L. The geometric mean for the radon samples was 4.24 pCi/L. None of the variables for radon were found to be statically significant. Homes that were built on a concrete slab and homes that had visible cracks in the basement or along the foundation tended to have higher amounts of radon, but the difference was not statistically significant.

DISCUSSION

This study examined the relationship between home characteristics and in-home exposures to PM 2.5 and radon in Central Kentucky. The data showed that smoking, burning candles, having pets, and general cleanliness were significant contributors to higher PM 2.5 levels in the home. In homes where smoking was present, the PM 2.5 levels were approximately four times higher than non-smoking homes. Similarly, for the other variables, the homes that regularly burned candles, had pets, or had a low cleanliness level had PM 2.5 levels that were approximately three times higher than homes that did not have these qualities. These findings are supported by previous studies that found regularly cleaning the home, changing the air filter, and reducing clutter could reduce the amount of PM 2.5 in a home (Laumbach et al., 2015; Brook et al., 2010). Although the sources identified are fairly common in homes, they are also modifiable. Cleaning the home on a regular basis, grooming pets on a regular basis outside of the home, burning fewer candles, and reducing clutter are all changes that can be easily implemented.

None of the variables tested for were found to be significantly associated with radon levels. Previous studies have shown a strong association between residential radon and lung cancer (Krewski et al., 2005). Most studies have looked at the health effects of radon exposure, but few, if any, have focused on home characteristics that effect the rate of exposure to radon. Residential radon can be highly variable in that one home may have extremely high levels of radon while the home next to it is under the EPA recommendation. Residential radon is higher in some regions than others, but home to home variability may be based solely on the type of geology underneath a home.

Limitations

The findings of this study should be viewed in the context of our limitations. First, a small sample size (n=21) limited the type of statistical analysis that could be done. Simple statistical tests, like the t-test and ANOVA had to be used to interpret our findings instead of something more complex like linear regression. With such a small sample size the study suffers from low power to detect significant differences in PM 2.5 and radon levels by independent variable categories. The assessment of PM 2.5 levels was based on a four-day sampling period. This may not be representative of the typical home levels that could vary with seasons or other behavioral factors. Lastly, the sample came from a convenience sampling of family and friends.

Therefore, this study is unlikely to be representative of the entire population of Kentucky. While demographic information was not collected, this sample is certainly not representative across education levels and SES. A more diverse sample would allow for greater representation of the general population and allow for stratification based on other factors.

Conclusions

The findings of this study show that there are modifiable factors that can be changed in order to reduce the amount of PM 2.5. This may be very important for people that are at risk of or already have a respiratory disease. Suggestions include improving home cleanliness, eliminating in-home smoking, reduction of burning candles, grooming pets often, and improving home ventilation in order to reduce the PM 2.5 levels. Predicting if a residence will have high levels of radon based on home characteristics is difficult. Research has shown that radon levels are highly variable between homes that are close together. Ultimately, all homeowners, especially those that live in regions where high radon is known to be prevalent, should test for radon. Central Kentucky is known to have high levels of radon and homeowners should take action to determine if remediation is required. Future research should look at in-home PM 2.5 levels as well as specific particulates and their association with respiratory diseases in Central Kentucky across a socially diverse population. Researchers should also seek to identify home characteristics that are associated with high radon levels in order to target specific homes for testing and remediation.

ACKNOWLEDGEMENTS

First, I would like to extend my gratitude to my chair, Dr. Wayne Sanderson, for his support throughout the process. Several topic changes occurred, but Dr. Sanderson was always encouraging and expressed confidence in me. I would also like to thank my other committee members, Drs. David Mannino and W. Jay Christian for their support in this endeavor. I would like to acknowledge and thank John Flunker for teaching me the process of collecting samples and for allowing me to adapt my methods from one of his previous studies. I most certainly should thank family and friends who allowed me to take samples in their homes without hesitation. Without them, this project would have not come to fruition. Finally, I would like to thank my wife and parents for supporting me in innumerable ways throughout the capstone process, my academic career, and my life.

Table 1: PM 2.5 levels by home characteristics and in-home exposures

Measure	N	Geometric Mean ($\mu g/m^3$)	Geometric Std. Dev.	P-Value
PM 2.5	21	8.40	2.48	
YEAR BUILT				
BEFORE 1980	15	7.11	2.57	.192
1980 OR AFTER	6	12.72	2.06	
SIZE OF HOME				
< OR EQUAL TO 1500 FT^2	9	8.64	2.21	.902
>1500 FT^2	12	8.21	2.78	
# OF PEOPLE				
1	5	6.83	4.25	.683
2	9	7.78	1.92	
3 OR MORE	7	10.73	2.27	
DISTANCE TO STREET				
<75 FT	14	8.83	2.91	.728
>75 FT	7	7.59	1.68	
HOME TYPE				
SINGLE FAMILY	15	7.79	2.54	.561
APARTMENT	6	10.14	2.45	
SMOKING STATUS*				
NO	19	7.39	2.54	**.044**
YES	2	28.25	2.45	
# OF PETS^				
0	12	5.88^{A}	2.64	**.104**
1	4	15.20^{B}	2.36	
2 OR MORE	5	12.29^{B}	1.31	
ATTACHED GARAGE				
NO	13	7.80	2.23	.648
YES	8	9.46	3.02	
BURN CANDLES*				
NO	8	4.80	2.33	**.023**
YES	13	11.84	2.20	
ALTERNATE HEATING				
NO	17	8.11	2.71	.729
YES	4	9.72	1.51	
FLOORING				
NO CARPET	7	9.66	2.32	.827
CARPET	8	7.18	3.53	
AREA RUG	6	8.77	1.49	
CLEANLINESS*				
LOW	10	13.56	2.28	**.017**
HIGH	11	5.43	2.17	

* = $P \leq 0.05$ for t-test
^ = $P \leq 0.10$ for t-test
A & B = statistically significant different groups using Duncan's Multiple Range Test

Table 2: Radon levels by home characteristics

Measure	N	Geometric Mean (pCi/L)	Geometric Std. Dev.	P-Value
RADON	41	4.24	2.48	
YEAR				
BEFORE 1980	30	4.36	2.56	.747
1980 OR AFTER	11	3.92	2.33	
SIZE OF HOME				
< OR EQUAL TO 1500 FT^2	19	4.27	2.61	.954
>1500 FT^2	22	4.20	2.42	
HOME STRUCTURE				
NOTHING/SLAB	13	5.61	2.57	.396
CRAWL SPACE	6	3.42	2.43	
BASEMENT	22	3.80	2.48	
HOME TYPE				
SINGLE FAMILY	30	4.17	2.62	.857
APARTMENT	11	4.42	2.18	
SUMP PUMP				
NO	29	4.46	2.50	.569
YES	12	3.73	2.49	
COUNTY				
FRANKLIN	8	3.25	2.63	.473
SCOTT	16	4.79	2.58	
FAYETTE	16	4.58	2.33	
CRACKS				
NO	27	3.66	2.47	.156
YES	14	5.61	2.40	

* $P \leq 0.05$ for t-test
^ $P \leq 0.10$ for t-test

REFERENCES

Brook, R. D., Rajagopalan, S., Pope, C. A., Brook, J. R., Bhatnagar, A., Diez-Roux, A. V., ... & Peters, A. (2010). Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association. *Circulation*, *121*(21), 2331-2378.

Ferro, A. R., Kopperud, R. J., & Hildemann, L. M. (2004). Source strengths for indoor human activities that resuspend particulate matter. *Environmental science & technology*, *38*(6), 1759-1764.

Jones, A. P. (1999). Indoor air quality and health. *Atmospheric environment*, *33*(28), 4535-4564.

Karottki D.G., Beko G, Clausen G, Madsen AM, Andersen ZJ, Massling A, Ketzel M, Ellermann T, Lund R, Sigsgaard T, et al. Cardiovascular and lung function in relation to outdoor and indoor exposure to fine and ultrafine particulate matter in middle-aged subjects. *Environ Int*. 2014;73:372–81

Kim, K. H., Kabir, E., & Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Environment international*, *74*, 136-143.

King, B. A., Travers, M. J., Cummings, K. M., Mahoney, M. C., & Hyland, A. J. (2010). Secondhand smoke transfer in multiunit housing. *Nicotine & tobacco research*, *12*(11), 1133-1141.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., ... & Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of Exposure Science and Environmental Epidemiology*, *11*(3), 231.

Krewski, D., Lubin, J. H., Zielinski, J. M., Alavanja, M., Catalan, V. S., Field, R. W., ... & Sandler, D. P. (2005). Residential radon and risk of lung cancer: a combined analysis of 7 North American case-control studies. *Epidemiology*, *16*(2), 137-145.

Laumbach, R., Meng, Q., & Kipen, H. (2015). What can individuals do to reduce personal health risks from air pollution?. *Journal of thoracic disease*, *7*(1), 96.

National Research Council. (1999). *Health effects of exposure to radon: BEIR VI* (Vol. 6). National Academies Press.

Paulin, L., & Hansel, N. (2016). Particulate air pollution and impaired lung function. *F1000Research*, *5*.

Pavilonis B.T., Anthony TR, O'Shaughnessy PT, Humann MJ, Merchant JA, Moore G, Thorne PS, Weisel CP, Sanderson WT. Indoor and outdoor particulate matter and endotoxin concentrations in an intensely agricultural county. *J Expo Sci Environ Epidemiol.* 2013; 23:299–305.

Po, J. Y., FitzGerald, J. M., & Carlsten, C. (2011). Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. *Thorax*, *66*(3), 232-239.

Sacks, J. D., Stanek, L. W., Luben, T. J., Johns, D. O., Buckley, B. J., Brown, J. S., & Ross, M. (2011). Particulate matter–induced health effects: Who is susceptible?. *Environmental health perspectives*, *119*(4), 446.

SAS Institute Inc., SAS. 2013, SAS Institute Inc.,: Cary, NC.

Schwartz, J., Dockery, D. W., & Neas, L. M. (1996). Is daily mortality associated specifically with fine particles?. *Journal of the Air & Waste Management Association*, *46*(10), 927-939.

Sundell, J. (2004). On the history of indoor air quality and health. *Indoor air*, *14*(s7), 51-58.
Torres-Durán, M., Barros-Dios, J. M., Fernández-Villar, A., & Ruano-Ravina, A. (2014). Residential radon and lung cancer in never smokers. A systematic review. *Cancer letters*, *345*(1), 21-26.
Turner, M. C., Krewski, D., Pope III, C. A., Chen, Y., Gapstur, S. M., & Thun, M. J. (2011). Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers. *American journal of respiratory and critical care medicine*, *184*(12), 1374-1381.
Van Deusen, A., Hyland, A., Travers, M. J., Wang, C., Higbee, C., King, B. A., ... & Cummings, K. M. (2009). Secondhand smoke and particulate matter exposure in the home. *Nicotine & Tobacco Research*, *11*(6), 635-641.
Wan, M. P., Wu, C. L., To, G. N. S., Chan, T. C., & Chao, C. Y. (2011). Ultrafine particles, and PM2. 5 generated from cooking in homes. *Atmospheric environment*, *45*(34), 6141-6148.
World Health Organization (WHO. (2010). WHO guidelines for indoor air quality: selected pollutants.

BIOSKETCH

Kyle Hancock was born and raised in Frankfort, Kentucky. He attended the University of Kentucky for undergrad and earned a Bachelor of Public Health as a part of the first graduating class for this degree. Currently, he is completing his MPH degree with a primary concentration in environmental health, a secondary concentration in epidemiology, and a graduate certificate in public health management. He also works as a teaching assistant at PresentationU, a centralized communication center at the University of Kentucky that seeks to support efforts to graduate competent communicators.

The research presented in this capstone was developed through collaboration with Dr. Wayne Sanderson and John Flunker. Kyle has been working on this study since January 2018 and hopes that the identification of environmental factors that contribute to PM 2.5 levels will help their research in Eastern Kentucky.

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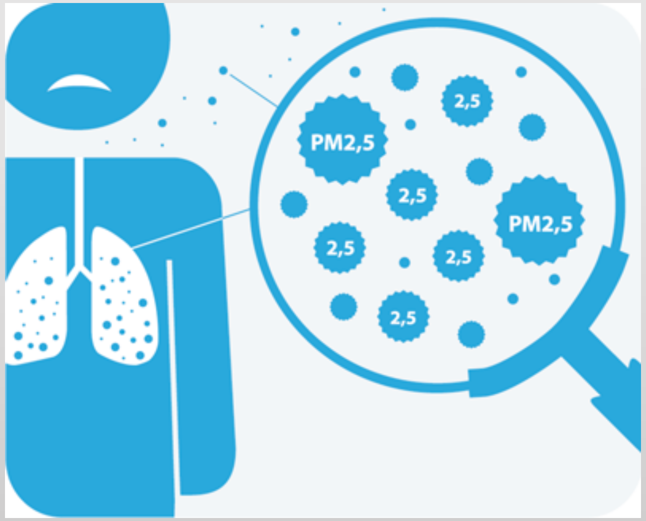
Risk Factors for PM 2.5 and Radon Concentrations in Residences of Central Kentucky: A Cross Sectional Study



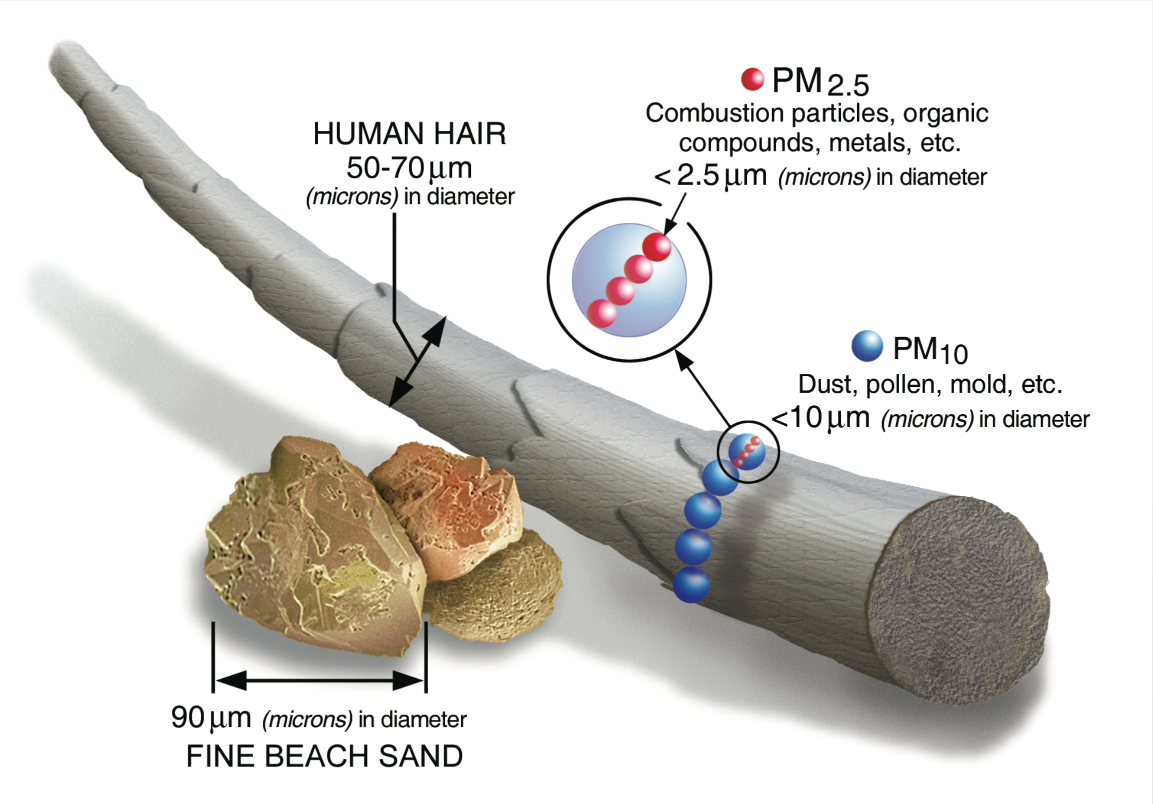
Kyle Hancock

Capstone Presentation

April 18, 2018

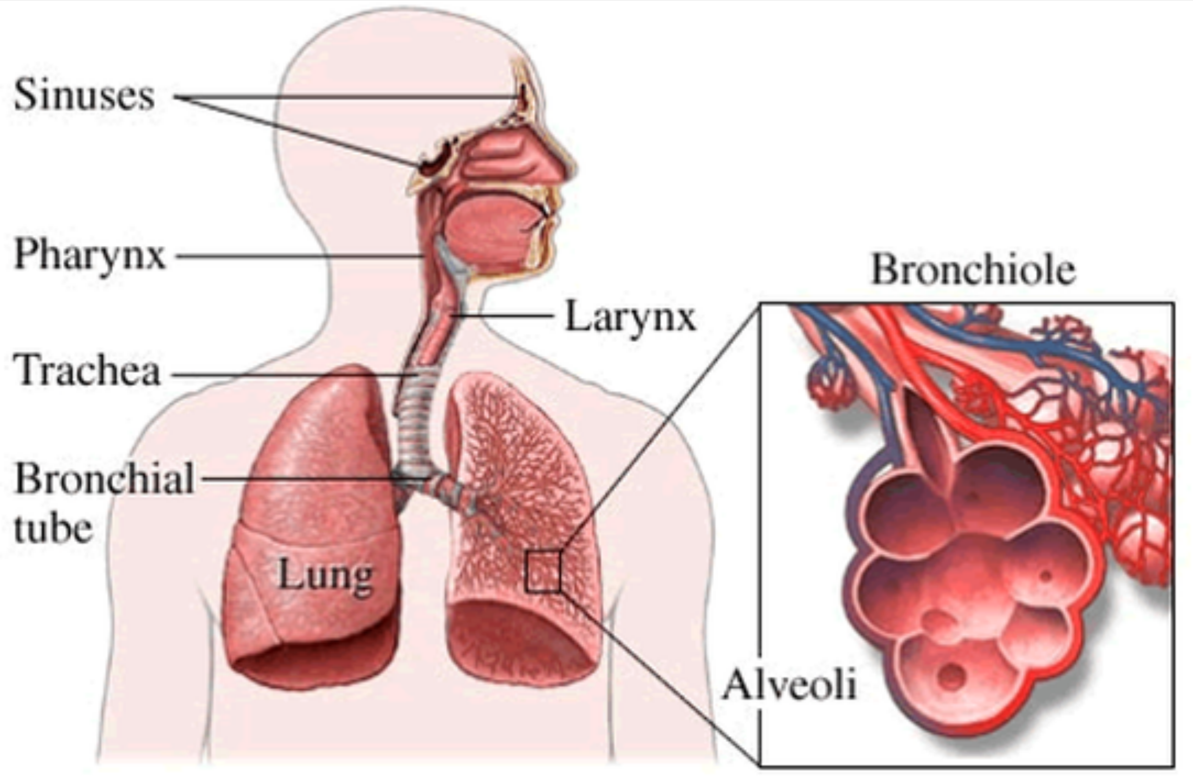
Background – PM 2.5

- Potential Sources:
  - Combustion Particles
  - Organic Compounds
  - Dust
  - Pollen
  - Mold
- "The Harvard Six Cities Study"
- Deep lung penetration

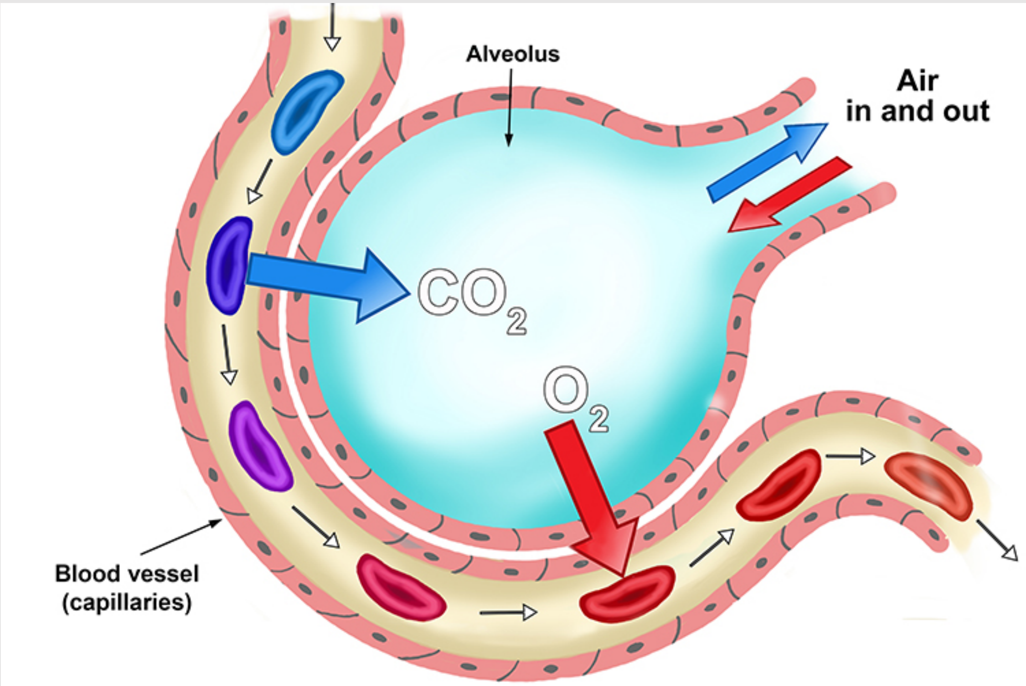


https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

Background – PM 2.5



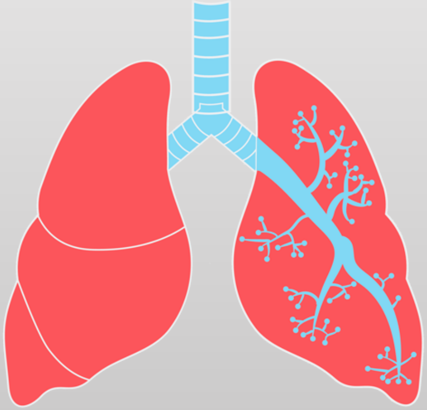
https://www.energysolutionsnc.com/pollutants



http://www.mammothmemory.net/biology/organs-and-systems/the-pulmonary-system/alveolus.html

Background – PM 2.5

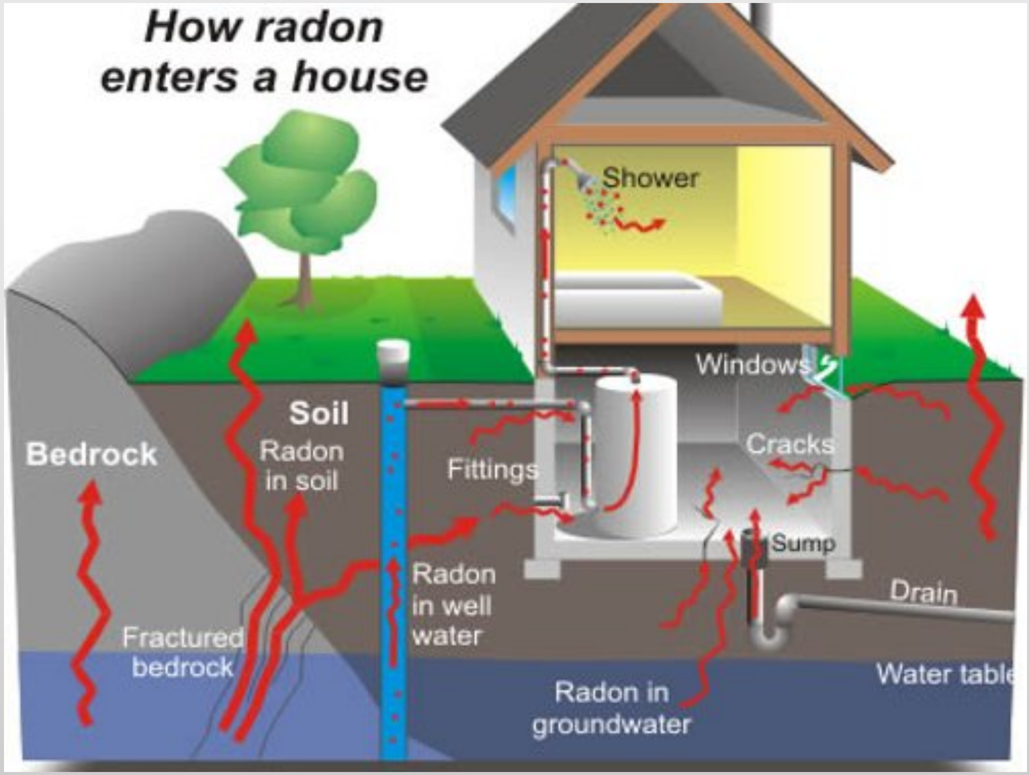
- Potential Health Concerns:
  - Decreased Lung Function (Karottki et al., 2014)
  - Cardiovascular Disease (Brook et al., 2010)
  - Lung Cancer (Turner et al., 2011)
  - Lung Development (Paulin & Hansel, 2016)



- At-Risk Populations (Sacks et al., 2011):
  - Children and Older Adults
  - Pre-existing Disease
  - Low SES
  - High BMI
  - Diabetes

Background - Radon

- Breakdown of Uranium
- Highly Variable
- Main Health Concern – Lung Cancer
  - 30% of cases among never smokers (Torres-Duran et al., 2014)
  - 1st leading cause among never smokers (Torres-Duran et al., 2014)



http://coloradobenchmarkhomes.com/radon-gas/

Primary Purpose

To measure levels of respirable particles (PM 2.5) and radon in homes in Central Kentucky to assess modifiable risk factors that could reduce the morbidity and mortality of cardiovascular and respiratory disease.

Methodology

- Convenience sampling
- Minimum 4-day sampling period
- In-home checklist (respiratory exposures)

http://bgadd.org/about-us/

Sampling Equipment

https://www.skcinc.com/catalog/advanced_search_result.php?keywords=%2C&search_in_description=1&sort=3a&page=67

https://bgi.mesalabs.com/2017/10/24/omni-400-end-of-life/

http://www.safehousepa.com/radon.html

In-Home Checklist

- Observation and verbal questioning

- Common respiratory exposures:
  - Smoking
  - Pets
  - Candles
  - Dust
  - Mold
  - Alt Heating
  - Home Characteristics

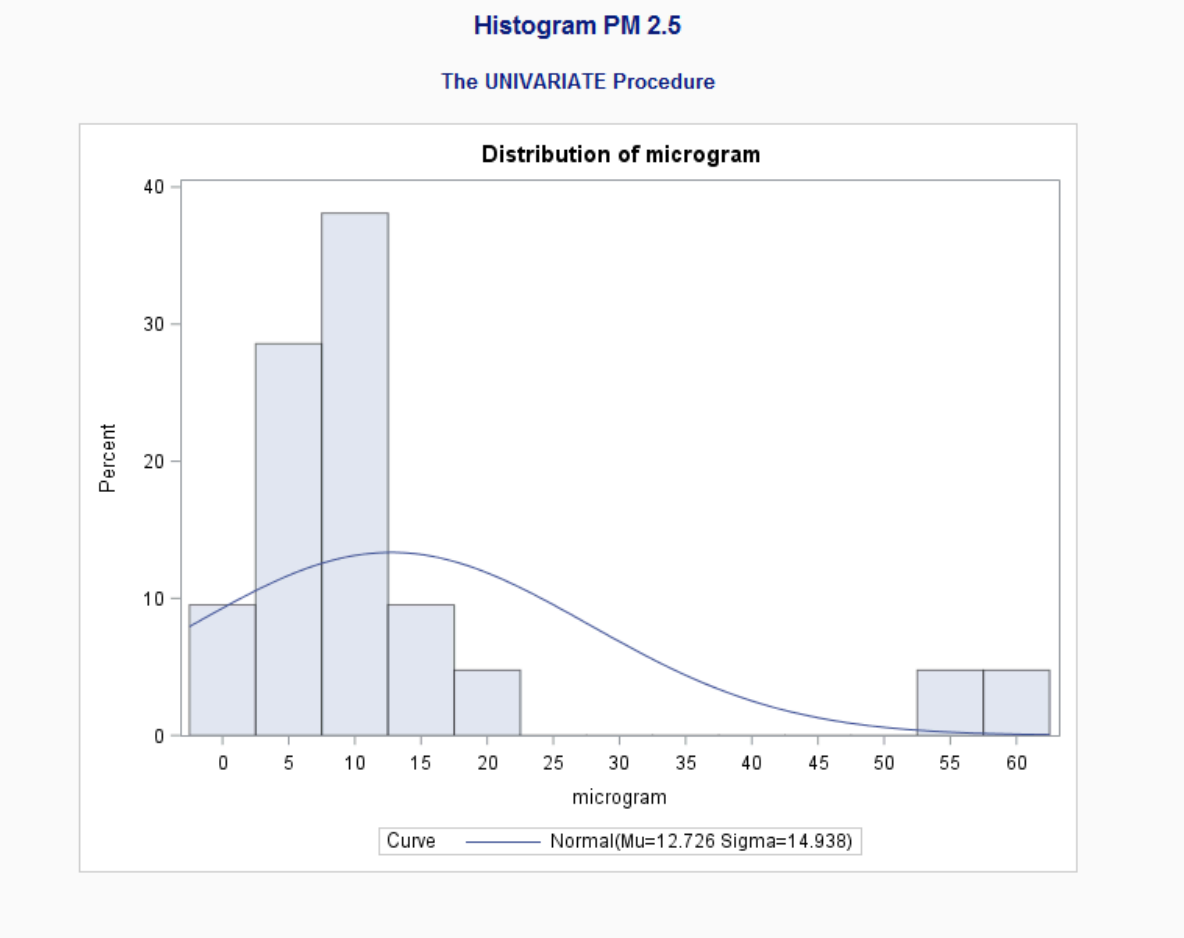
Home address________________ Date/time___________ GPS coordinates (lat)___________(long)____

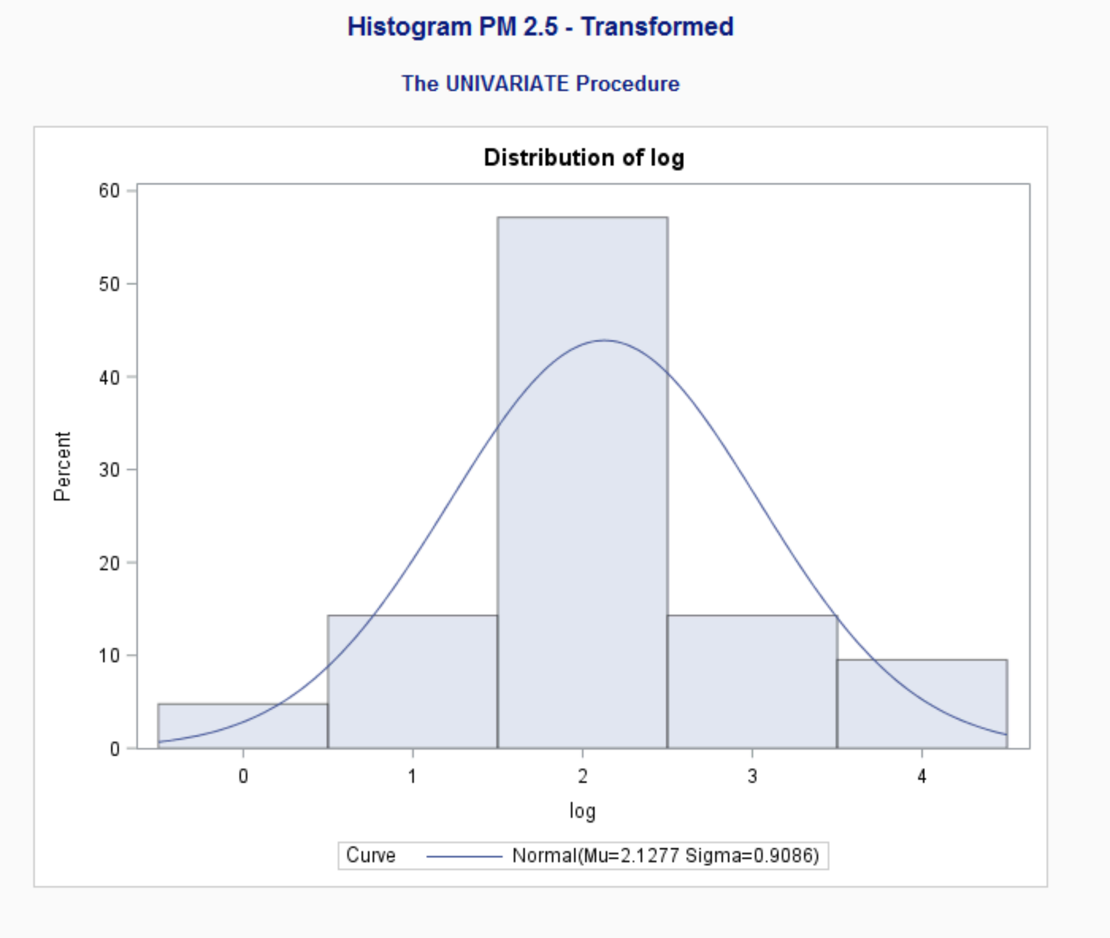
1. Distance to street (feet)			
2. Dust on outside of home/plants	Yes (1)	No (2)	(L, M, H)
3. Driveway material	Gravel (1), Dirt (2), Blacktop (3), Asphalt (4), Other:		
4. Home construction	Single fam (1), Mobile (2), Apt (3), Duplex/townhome (4), Other (5)		
5. Water damage (**Outside**)	Yes (1)	No (2)	(L, M, H)
6. Mold (**Outside**)	Yes (1)	No (2)	(L, M, H)
7. Smoking in home	Yes (1)	No (2)	# cigs/day (avg):
8. Live in smoker	Yes (1)	No (2)	# cigs/day (avg):
9. Visiting smoker	Yes (1)	No (2)	# cigs/day (avg):
10. Pets in home	Yes (1)	No (2)	Type (#):
11. Pest problem in last year	Yes (1)	No (2)	Type (#):
12. Water problem in last year	Yes (1)	No (2)	Location:

Data Analysis

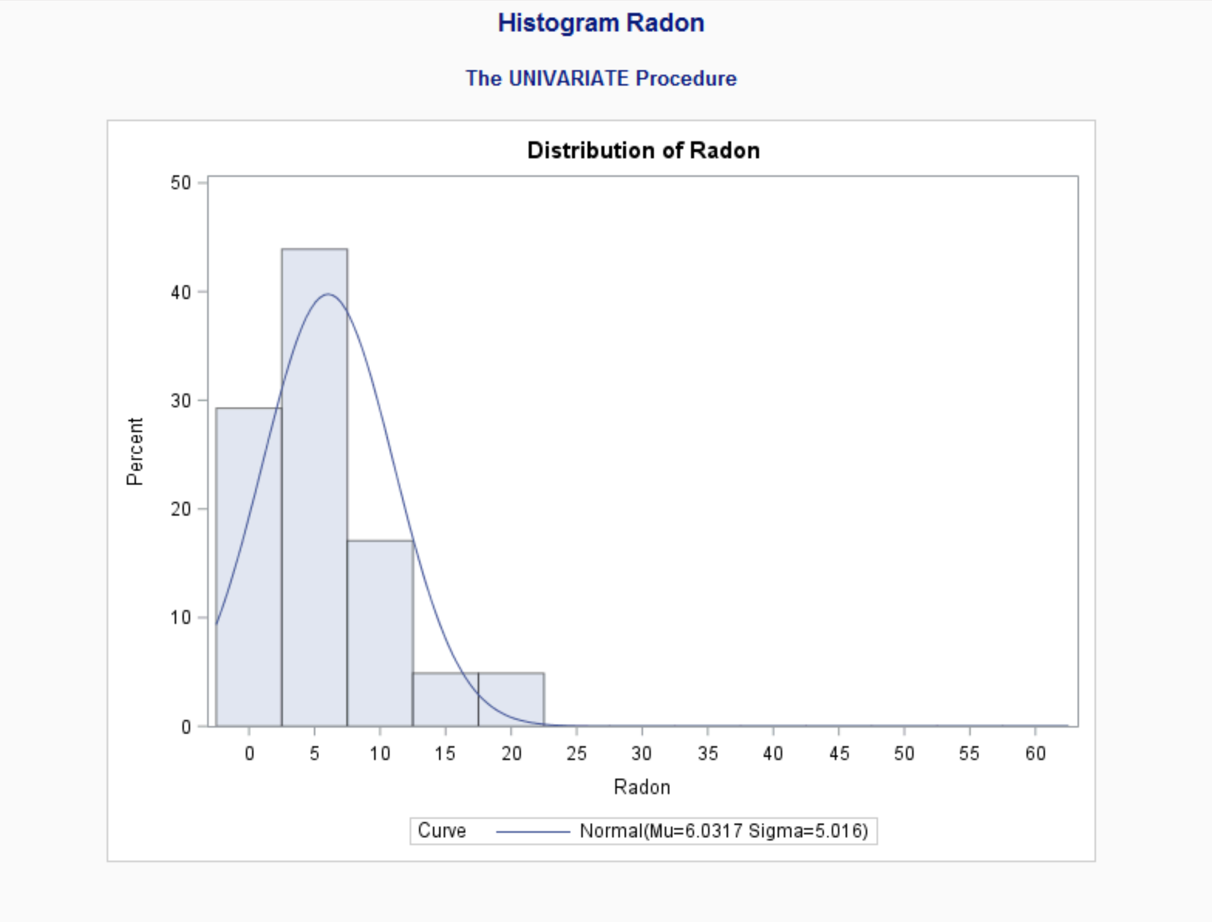
- Not normally distributed data
- Log-transformation
- Continuous outcome variables – PM 2.5 and radon
- T-test and ANOVA(with multiple range tests)

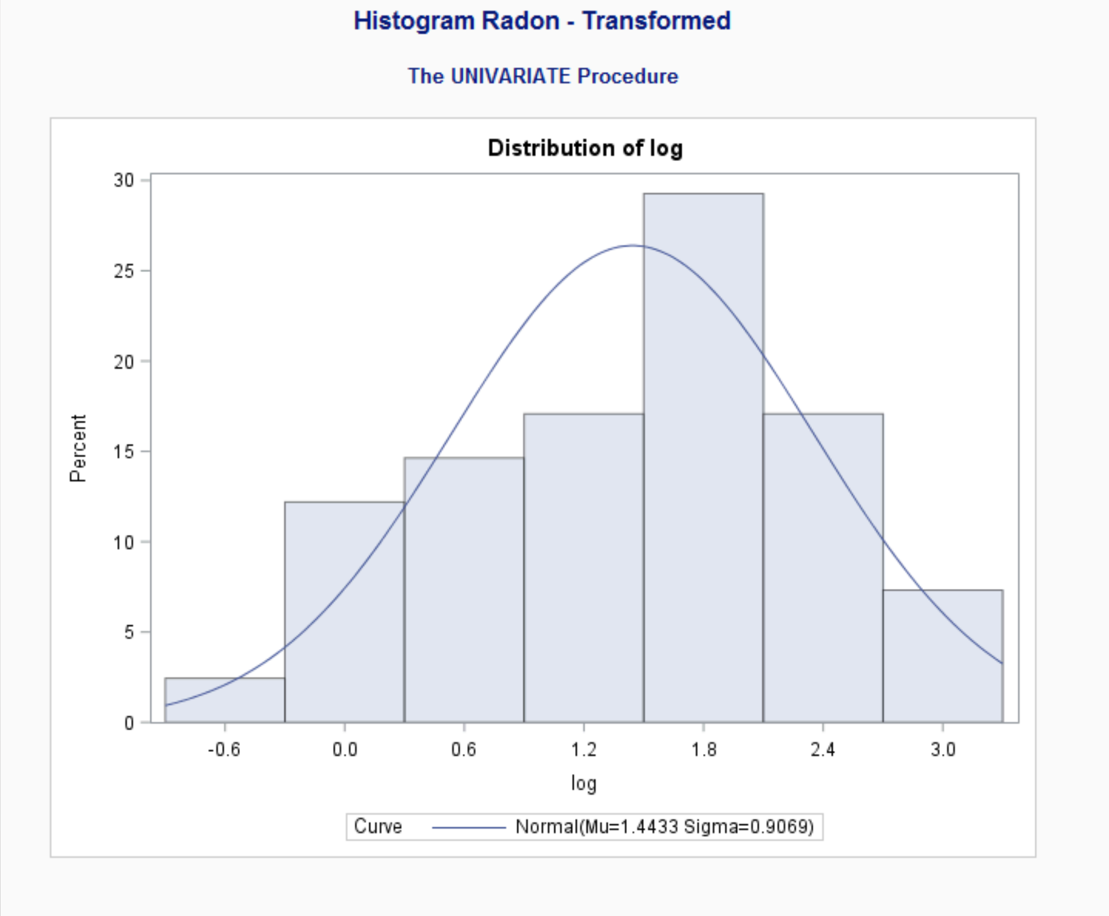
Data Analysis – PM 2.5 Log Transformation





Data Analysis – Radon Log Transformation





Results – PM 2.5 and Radon

- PM 2.5 = 21 samples
- Radon = 41 samples (two samples at each home except for one)
- Average age of homes = 43 years (built in 1975)
- Average size of homes = 1,707 ft^2
- 15 single-family homes (71%) and 6 apartments (29%)
- Respiratory exposures were fairly common

Results – PM 2.5

Table 1: PM 2.5 levels by home characteristics and in-home exposures

MEASURE	N	GEOMETRIC MEAN (µg/m³)	GEOMETRIC STD. DEV.	P-VALUE
PM 2.5	21	8.40	2.48	
YEAR BUILT				.192
BEFORE 1980	15	7.11	2.57	
1980 OR AFTER	6	12.72	2.06	
SIZE OF HOME				.902
< OR EQUAL TO 1500 FT²	9	8.64	2.21	
>1500 FT²	12	8.21	2.78	
# OF PEOPLE				.683
1	5	6.83	4.25	
2	9	7.78	1.92	
3 OR MORE	7	10.73	2.27	
DISTANCE TO STREET				.728
<75 FT	14	8.83	2.91	
>75 FT	7	7.59	1.68	
HOME TYPE				.561
SINGLE FAMILY	15	7.79	2.54	
APARTMENT	6	10.14	2.45	
SMOKING STATUS*				**.044**
NO	19	7.39	2.54	
YES	2	28.25	2.45	
# OF PETS^				.104
0	12	5.88[A]	2.64	
1	4	15.20[B]	2.36	
2 OR MORE	5	12.29[B]	1.31	
ATTACHED GARAGE				.648
NO	13	7.80	2.23	
YES	8	9.46	3.02	
BURN CANDLES*				**.023**
NO	8	4.80	2.33	
YES	13	11.84	2.20	
ALTERNATE HEATING				.729
NO	17	8.11	2.71	
YES	4	9.72	1.51	
FLOORING				.827
NO CARPET	7	9.66	2.32	
CARPET	8	7.18	3.53	
AREA RUG	6	8.77	1.49	
CLEANLINESS*				**.017**
LOW	10	13.56	2.28	
HIGH	11	5.43	2.17	

* = P≤0.05 for t-test
^ = P≤0.10 for t-test

Results - Radon

Table 2: Radon levels by home characteristics

MEASURE	N	GEOMETRIC MEAN	GEOMETRIC STD. DEV.	P-VALUE
RADON	41	4.24	2.48	
YEAR				.747
BEFORE 1980	30	4.36	2.56	
1980 OR AFTER	11	3.92	2.33	
SIZE OF HOME				.954
< OR EQUAL TO 1500 FT^2	19	4.27	2.61	
>1500 FT^2	22	4.20	2.42	
HOME STRUCTURE				.396
NOTHING/SLAB	13	5.61	2.57	
CRAWL SPACE	6	3.42	2.43	
BASEMENT	22	3.80	2.48	
HOME TYPE				.857
SINGLE FAMILY	30	4.17	2.62	
APARTMENT	11	4.42	2.18	
SUMP PUMP				.569
NO	29	4.46	2.50	
YES	12	3.73	2.49	
COUNTY				.473
FRANKLIN	8	3.25	2.63	
SCOTT	16	4.79	2.58	
FAYETTE	16	4.58	2.33	
CRACKS				.156
NO	27	3.66	2.47	
YES	14	5.61	2.40	

* $P \leq 0.05$ for t-test
^ $P \leq 0.10$ for t-test

Results – PM 2.5 and Radon

- Statistically significant variables (PM 2.5):
  - Smoking
  - Burning candles
  - Having pets
  - General cleanliness

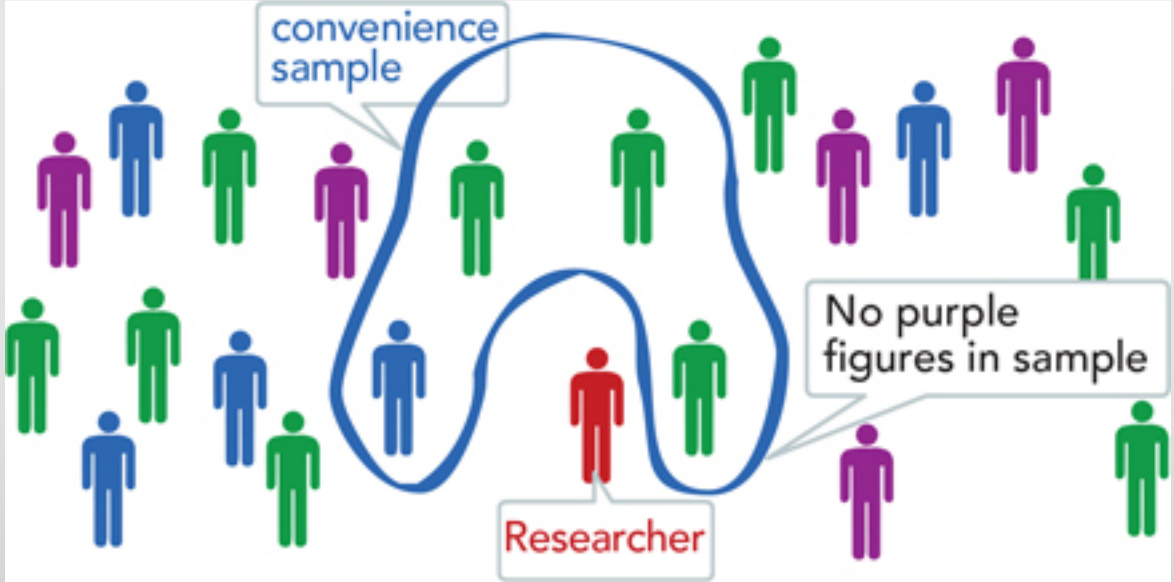
- Statistically significant variables (Radon):
  - None
  - Potentially home structure type and cracks

Discussion

- Smoking = 4X greater levels of PM 2.5
- Candles, pets, and cleanliness = 3X greater levels of PM 2.5
- Modifiable factors:
  - Cleaning home on regular basis
  - Regularly grooming pets outside of home
  - Burning fewer candles
  - Reducing clutter
- Radon = Highly variable based on geography

Limitations

- Small sample size (n=21)
- 4-day sampling period
- Convenience sampling
  - Non-representative sample



http://assets.pearsonschool.com/file-vault/flipbooks/texasreview/mathematics/digits/TX_Digits_HomeworkHelper_HTML_Files/Grade%207/Volume%202/page_368.html

Future Research

- Specific particulates
- Lung function testing
- More diverse population
  - Stratify for SES
- Mountain Air Project (MAP) Study

https://greenbookblog.org/2011/05/19/the-futuress-of-research-a-slew-of-views/

Acknowledgements

- Committee Members:
  - Dr. Sanderson
  - Dr. Mannino
  - Dr. Christian
- John Flunker
- UK CPH
- Family & Friends

References

- Brook, R. D., Rajagopalan, S., Pope, C. A., Brook, J. R., Bhatnagar, A., Diez-Roux, A. V., ... & Peters, A. (2010). Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association. *Circulation*, *121*(21), 2331-2378.
- Karottki D.G., Beko G, Clausen G, Madsen AM, Andersen ZJ, Massling A, Ketzel M, Ellerman T, Lund R, Sigsgaard T, et al. Cardiovascular and lung function in relation to outdoor and indoor exposure to fine and ultrafine particulate matter in middle-aged subjects. *Environ Int*. 2014;73:372–81.
- Paulin, L., & Hansel, N. (2016). Particulate air pollution and impaired lungfunction. *F1000Research*, *5*.
- Sacks, J. D., Stanek, L. W., Luben, T. J., Johns, D. O., Buckley, B. J., Brown, J. S., & Ross, M. (2011). Particulate matter–induced health effects: Who is susceptible?. *Environmental health perspectives*, *119*(4), 446.
- Schwartz, J., Dockery, D. W., & Neas, L. M. (1996). Is daily mortality associated specifically with fine particles?. *Journal of the Air & Waste Management Association*, *46*(10), 927-939.
- Sundell, J. (2004). On the history of indoor air quality and health. *Indoor air*, *14*(s7), 51-58.
- Torres-Durán, M., Barros-Dios, J. M., Fernández-Villar, A., & Ruano-Ravina, A. (2014). Residential radon and lung cancer in never smokers. A systematic review. *Cancer letters*, *345*(1), 21-26.
- Turner, M. C., Krewski, D., Pope III, C. A., Chen, Y., Gapstur, S. M., & Thun, M. J. (2011). Long-term ambient fine particulate matter air pollution and lung cancer in a large cohort of never-smokers. *American journal of respiratory and critical care medicine*, *184*(12), 1374-1381.

QUESTIONS