APPLIED MATHEMATICS & STATISTICS

Exposure to Particulate Matter in Commercial Kitchens

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Abstract

Air pollution is known to be correlated with neurological diseases such as Alzheimer's, dementia, and stroke. One common place where people are exposed to high levels of air pollution is kitchens. The main pollutant of interest is particulate matter with a size of 2.5 microns in width (PM 2.5). This pollutant is absorbed into the bloodstream through respiration and can damage neurons when the pollutant is stuck in capillaries that feed them. This study aims to demonstrate the high levels of these pollutants in kitchens and the ability of masks to reduce pollution exposure.

The study found that there is significant exposure to particulate matter in commercial kitchens. This exposure can be reduced to a safe level with a surgical mask or N95 mask. The study also found that a cloth mask can significantly reduce pollution exposure, but not enough to be considered safe. The study also found a statistically significant improvement in pollution reduction depending on the mask; N95 being the best, followed by the surgical mask, and a cloth mask being the least effective.

Introduction & Methods

The Homewood kitchen is a commercial kitchen that is likely very similar to other commercial kitchens. This study aimed to gain insight into what the levels of air pollution were inside a commercial kitchen and what could be done to reduce exposure to pollutants.

In order to do this 4 different air pollutants were tracked using Purple Air sensors: PM 2.5, PM 1.0, PM 10.0, and volatile gases. Purple Air sensors are low-cost sensors that take measurements of the amount of a pollutant present in the air every two minutes using a laser. Four of these sensors are set up in the Homewood kitchen next to each other. One sensor is blocked by a surgical mask, another by an n95 mask, another by a cloth mask, and the final sensor is unobstructed. The final sensor acts as the control. These sensors simultaneously collect data for 10 days.

The sensors were initially calibrated in my home kitchen. The sensors are connected to a Wi-Fi source to ensure that they are all working on the same universal clock. The sensors are also plugged in at the same time to ensure they have the same start time and take measurements at the same time.

Since the Purple Air sensors are reduced-price sensors, a formula is used to collocate them to what would be an expected reading on the Gold Standard EPA air pollution machine reading. This formula is:

$$Adjusted\ Value = 0.52 * PM\ 2.5 - 0.086 * Humidity - 5.75$$

The data is collected, and a Riemann sum is used to calculate the number of pollutants exposed to the sensor over the entire day. The percentage of pollution reduction is calculated using the formula:

$$\%\ Reduction = 1 - \frac{Masked\ Reading}{Unmasked\ Reading}$$

Methods Cont.

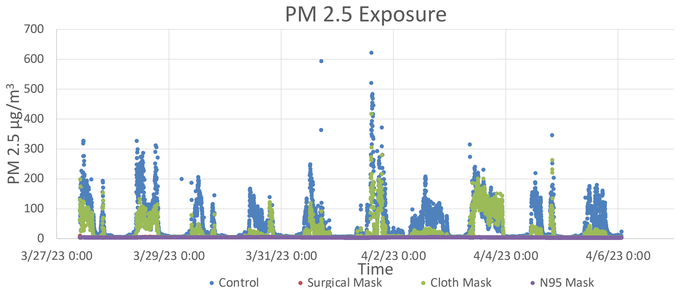
An average percent reduction is calculated for the 10 days observed. A standard deviation is also calculated. The two populations are compared with a Z-score to test for a significant difference in percent reduction. The formula for this is:

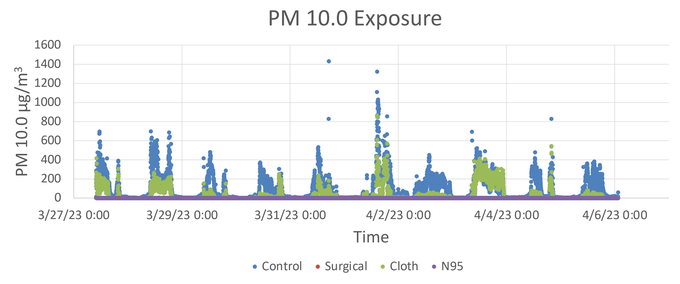
$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{{\sigma_1}^2}{n_1} + \frac{{\sigma_2}^2}{n_2}}}$$

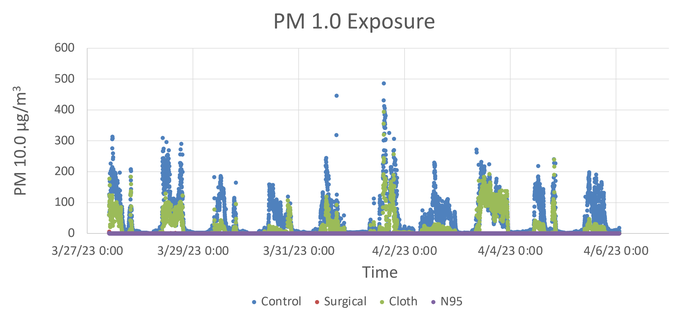
This Z-score is translated to a p-value and a significance level of .05 must be achieved for there to be sufficient evidence that one mask provides superior protection.

Results

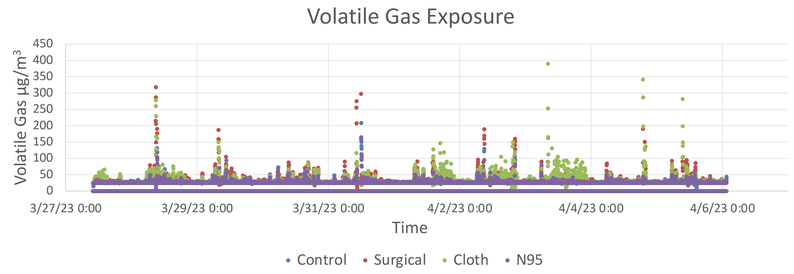
Below are the measurements of each air pollutant taken every two minutes for 10 days. What is immediately noticeable is that the surgical and N95 masks reduce pollutant exposure to almost zero for all pollutants except volatile gases. Volatile gases were not protected against by any of the masks. It was also clear that without a mask, exposure to all air pollutants was above safe levels.







Results Cont.



Analysis

The analysis of the averages reveals that the N95 mask provides statistically significant improved protection over the surgical mask and the cloth mask in all categories. The surgical mask is also statistically significantly better than the cloth mask in all categories.

Z-Scores	PM 2.5	PM 10.0	PM 1.0	gas
Cloth v Surgical	13.70409 09	13.08441 56	13.86725 12	2.608846 72
Cloth v N95	14.73378 08	13.73290 91	14.58186 86	13.96917 58
Surgical v N95	3.219611 95	3.302929 47	3.266645 37	27.60170 97

p values	PM 2.5	PM 10.0	PM 1.0	gas
Cloth v Surgical	0	0	0	0.004554
Cloth v N95	0	0	0	0
Surgical v N95	0.000643	0.000478	0.000545	0

Cloth Reduction Averages			
PM 2.5	PM 10.0	PM 1.0	gas
0.557993149	0.645045055	0.643593534	-0.092053305
std dev			
0.227796449	0.253295327	0.238481097	0.077062151

Surgical Reduction Averages			
PM 2.5	PM 10.0	PM 1.0	gas
0.884506471	0.983045975	0.982510408	-0.070644243
std dev			
0.069831832	0.050718792	0.053465584	0.028210153

N95 Reduction Averages			
PM 2.5	PM 10.0	PM 1.0	gas
0.909039838	0.999798071	0.999975722	0.022582385
std dev			
0.030494577	0.000106659	3.2056E-05	0.018573724

Conclusions

This study concludes that there is significant exposure to particulate matter in commercial kitchens. Air with under 12 µg/m^3 of PM 2.5 is considered safe and prolonged exposure to over 50 µg/m^3 can lead to serious health risks. Levels of PM 2.5 exceeded over 100 µg/m^3 for significant periods of time indicating that there is a serious health risk. Sensors that were protected by a cloth mask saw a significant, but not sufficient, reduction in PM 2.5 exposure. The surgical and N95 masks were both able to reduce exposure to healthy levels.

Additional Questions?

Feel free to contact the Brain Signatures Laboratory with any additional questions via the QR Code to the right, or if you would like to contact me directly, I can be reached at blorin3@jhu.edu.