# How Do Various $PM_{2.5}$ Pollutants Affect Indoor Air Pollution?

## Introduction/Background

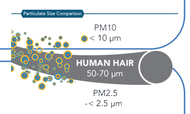
### Increased Awareness Post-COVID-19

- Since COVID-19, awareness around air pollution has increased drastically.
- A recent Boston Consulting Group survey of around 3,000 people from 8 different countries showed that 70% of people were more aware of pollution since COVID-19.
- Furthermore, 75% said that environmental issues were just as dangerous as health issues.

- This project identifies various $PM_{2.5}$ pollutants in day-to-day activities and analyzes their effects on indoor air quality.
- Poor indoor air quality affects not only the health of many but also the economy of a multitude of countries.
- In the United States, because of poor indoor air quality, adults in the United States miss around 14.5 million workdays due to asthma. Due to the IAQ (Indoor Air Quality) being 3-7% higher, productivity has been shown to lower by 33%.
- Economic loss: $168 billion annually.

### $PM_{2.5}$ – What it is & Why it's dangerous

- Fine particulate matter (≤2.5 microns in diameter) is 20x smaller than a human hair.
- It can be inhaled deep into the lungs, causing respiratory diseases.
- Linked to influenza.




### Indoor vs. Outdoor Air Pollution

- Indoor air can be 2-5 times more polluted than outdoor air.
- 90% of time spent indoors (on average, for Americans).
- Household air pollution caused 3.2 million deaths in 2021, including 237,000 children under age 5.

## Experimental Details

### Experiment Question

How do different sources of $PM_{2.5}$ pollution affect indoor air quality?

### Experiment Hypothesis

If I measure $PM_{2.5}$ levels in the air before and after introducing various pollution sources for 50 minutes, I predict that the air fryer will cause the greatest increase in $PM_{2.5}$ levels.

### Experimental Variables

Dependent: The $PM_{2.5}$ levels in the indoor air.
Independent: Various sources of $PM_{2.5}$ pollutants.
Controlled: 1. The type of $PM_{2.5}$ detector.
2. The amount of time the pollutant is exposed to the air.
3. Room the $PM_{2.5}$ is measured in.

### Materials:

1.Temtop S1 $PM_{2.5}$ AQI monitor
2. Timer
3. $PM_{2.5}$ pollutant Sources:
Natural Gas
Candles
Incense Sticks
Air Fryer
Humidifier

## Experimental Procedures

Turn on the $PM_{2.5}$ monitor (Temtop S1).
→ Place it in the test area, at least 2 ft from walls/objects.
→ Set to Real-Time mode and record a 5-second baseline reading (µg/m³).
→ Introduce the chosen pollutant for 50 minutes.
→ Stop exposure and record the new $PM_{2.5}$ level.
→ Log Data ID, pollutant type, baseline, and post-exposure values.
→ Analyze results to accept or reject the hypothesis.

## Experimental Results & Data Analysis

- In this study, I evaluated the impact of five distinct pollutant sources on $PM_{2.5}$ concentrations.
- To ensure accurate measurement, I first established a baseline $PM_{2.5}$ level for each source under controlled conditions. Subsequently, each pollutant source was introduced individually, and changes in $PM_{2.5}$ levels were monitored and recorded.
- This systematic approach allowed for a clear assessment of the effect each pollutant had on ambient $PM_{2.5}$ concentrations.

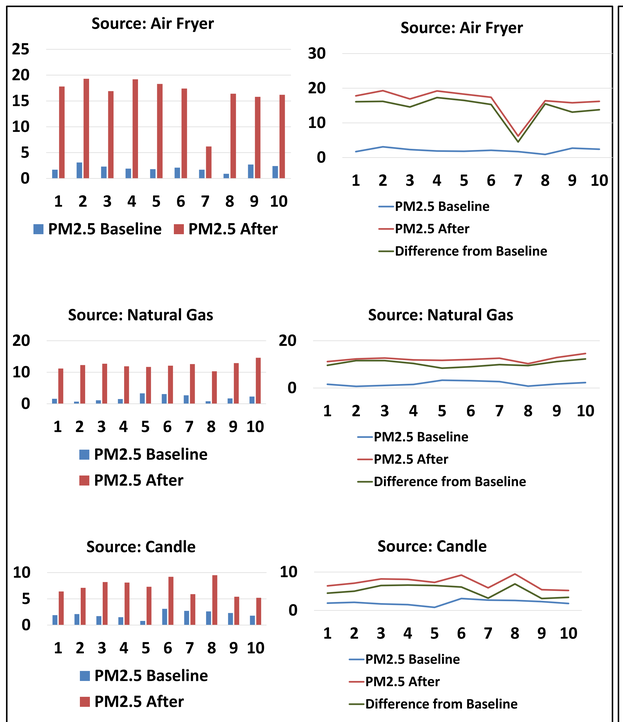



*Figure 1. Left panel: Bar plot to compare the $PM_{2.5}$ measurements after exposure to the sources from the Baseline $PM_{2.5}$ observation over ten different data collection time points. Right Panel: A line chart displays the trend over the replication of the data collection.*

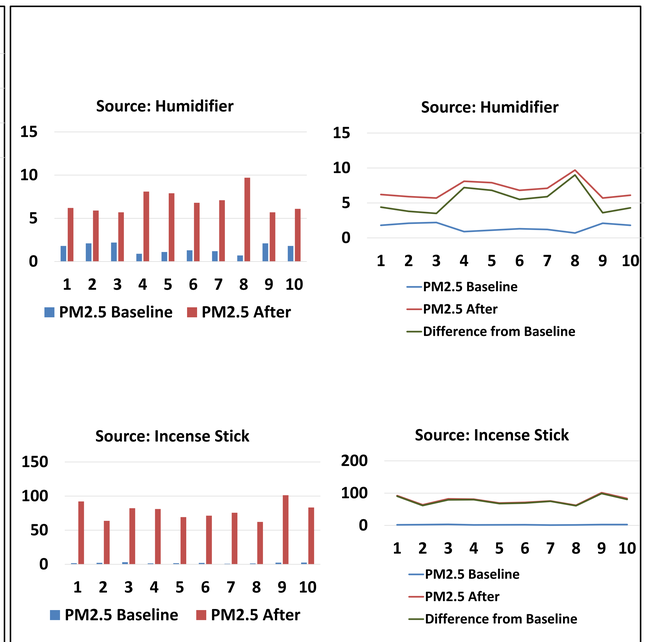



*Figure 2. Left panel: Bar plot to compare the $PM_{2.5}$ measurements after exposure to the sources from the Baseline $PM_{2.5}$ observation over ten different data collection time points. Right Panel: A line chart displays the trend over the replication of the data collection.*

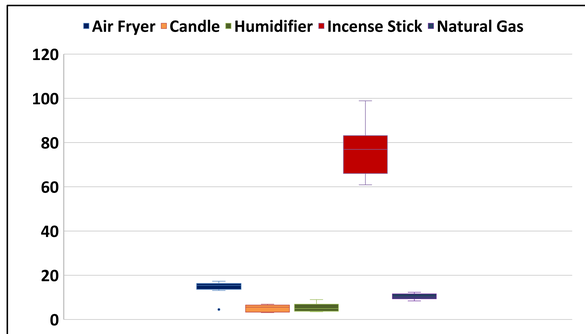



*Figure 3. Comparison of **Exposure-Adjusted $PM_{2.5}$** Values relative to baseline across all sources. A box-and-whisker plot is used to provide a clearer view of the distribution of values for each pollutant source after accounting for baseline differences.*

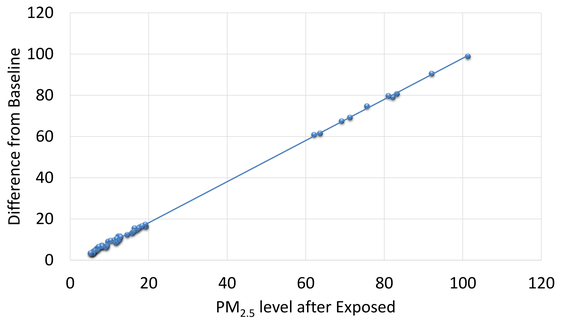



*Figure 4. The scatter plot with a linear fit displays **"after-exposure" $PM_{2.5}$ values** (x-axis) against the **difference from baseline** (y-axis). Because baseline $PM_{2.5}$ is essentially constant, the strong correlation you observe between the difference and the "after" value is expected and valid.*

| Sources / $PM_{2.5}$ | Air Fryer (N=10) | Candle (N=10) | Humidifier (N=10) | Incense Stick (N=10) | Natural Gas (N=10) |
|---|---|---|---|---|---|
| [min, max] | [4.50, 17.30] | [3.10, 6.90] | [3.50, 9.00] | [60.90, 98.90] | [8.40, 12.30] |
| [mean, SD] | [14.29, 3.67] | [5.18, 1.54] | [5.40, 1.83] | [76.27, 12.19] | [10.35, 1.28] |
| Median [Q1, Q3] | 15.40 [14.00, 16.17] | 5.55 [3.67, 6.50] | 4.95 [3.92, 6.57] | 76.90 [67.92, 80.45] | 10.15 [9.53, 11.50] |
| IQR | 2.17 | 2.83 | 2.65 | 12.53 | 1.97 |

**Table 1.** *Summary Statistics for each pollutant source for the $PM_{2.5}$ value difference between baseline and after-exposed values. In the Table, min = minimum value of the pollutant. max = maximum value of the pollutant. mean = average value of the pollutant. SD = standard deviation of the value of the pollutant. Median = median value of the pollutant. Q1 = first quartile value of the pollutant. Q3 = third quartile value of the pollutant. Interquartile Range (IQR) = (Q3 – Q1) value of the pollutant.*

**Further Statistical Analysis: A Deeper Comparison Across Sources:**

To determine whether changes in $PM_{2.5}$ levels differed across pollutant sources, a one-way Analysis of Variance (ANOVA) was performed using the differences between baseline and post-exposure values (Table 1).

**Hypothesis Test:**
Null Hypothesis ($H_0$): The mean change in $PM_{2.5}$ is the same for all five pollutant sources.
Alternative Hypothesis ($H_a$): At least one pollutant source produces a significantly different mean change in $PM_{2.5}$.

**Table 2A: SUMMARY Table**

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Air Fryer | 10 | 142.9 | 14.29 | 13.43 |
| Humidifier | 10 | 54 | 5.4 | 3.34 |
| Natural Gas | 10 | 103.5 | 10.35 | 1.64 |
| Candle | 10 | 51.8 | 5.18 | 2.36 |
| Incense Stick | 10 | 762.7 | 76.27 | 148.64 |

**Table 2B: ANOVA Table**

| *Source of Variation* | *SS (sum of squares)* | *DF (degrees of freedom)* | *MS (Mean square)* | *F-value* | *P-value* | *F critical* |
|---|---|---|---|---|---|---|
| Between Groups | 36984.28 | 4 | 9246.07 | 272.88 | <0.0001 | 2.58 |
| Within Groups | 1524.731 | 45 | 33.88 | | | |
| Total | 38509.01 | 49 | | | | |

**Conclusion:** Based on the F-distribution, statistical significance is determined by the p-value. If **F > F-critical**, the null hypothesis ($H_0$) is rejected.

In this analysis, the ANOVA p-value was very small, so we reject $H_0$ and conclude that at least one pollutant source produced a significantly different change in $PM_{2.5}$ levels.

## Conclusion & Recommendation

- This experiment showed that common indoor activities (statistically) significantly elevate $PM_{2.5}$ levels, impacting air quality and health.
- Incense burning had the highest increase (mean: 78.20 µg/m³, IQR: 13.3 µg/m³), posing potential health risks and leading to the rejection of our hypothesis. The air fryer also raised $PM_{2.5}$ levels (mean: 16.35 µg/m³) but with lower variability.
- Candle and humidifier use had moderate effects (mean: 6.92–7.23 µg/m³), while natural gas showed the most stable levels (IQR: 0.93 µg/m³).
- Overall, incense and air fryers had the greatest impact, emphasizing the need for proper ventilation and air quality monitoring.

**Future Research:**
- Test a wider range of household sources (e.g., gas stoves, toasters).
- Study long-term health impacts of repeated indoor $PM_{2.5}$ exposure on cognitive, respiratory and cardiac function.
- Study the chemical composition of $PM_{2.5}$ pollutants.

**Industry & Policy:**
- Develop guidelines for household products that raise $PM_{2.5}$ levels.
- Improve designs of air fryers, candles, and incense to cut emissions.
- Promote awareness and encourage air purifiers or better ventilation.
- Public awareness campaigns should educate consumers on the risks of these sources, promoting the use of enhanced ventilation to reduce exposure.

### Citations:


1. American Lung Association. (n.d.). Clean air indoors. Lung.org. https://www.lung.org/clean-air/indoor-air.
2. California Air Resources Board. (2015). Inhalable particulate matter and health (PM2.5 and PM10). https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
3. Dominici, F., Wang, Y., Correia, A. W., Ezzati, M., Pope, C. A., III, & Dockery, D. W. (2015). Chemical composition of fine particulate matter and life expectancy: In 95 US counties between 2002 and 2007. *Epidemiology*, *26*(4), 556–564.
4. Fowler, D., Brimblecombe, P., Burrows, J., Heal, M. R., Grennfelt, P., Stevenson, D. S., Jowett, A., Nemitz, E., Coyle, M., Liu, X., Chang, Y., Fuller, G. W., Sutton, M. A., Klimont, Z., Unsworth, M. H., & Vieno, M. (2020). A chronology of global air quality. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *378*(2183), 20190314.
5. Hu, S. (2022, October 21). The Clean Air Act 101. Natural Resources Defense Council. https://www.nrdc.org/stories/clean-air-act-101
6. Indoor Air Hygiene Institute. (2021, April 6). PM2.5 explained. https://www.indoorairhygiene.org/pm2-5-explained
7. Sundell, J. (2004). On the history of indoor air quality and health. Indoor Air, 14(s7), 51–58.
8. U.S. Environmental Protection Agency. (2019, January 18). Introduction to indoor air quality. https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality
9. Xing, Y. F., Xu, Y. H., Shi, M. H., & Lian, Y. X. (2016). The impact of PM2.5 on the human respiratory system. Journal of Thoracic Disease, 8(1), E69–E74.


### Photo Credits:

1. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
2. https://environmentalhealth.ucdavis.edu/air-pollution/out-frying-pan-and-fire-gas-stove-toxicity-debate
3. https://www.vecteezy.com/png/49216588-burning-candle-isolated
4. https://www.vecteezy.com/png/52574909-incense-stick-with-golden-stand-icon-or-agarbatti-illustration
5. https://www.vecteezy.com/png/54484724-modern-humidifier-with-transparent-dome-and-orange-led-light
6. https://www.vecteezy.com/png/55061961-an-air-fryer-with-the-digital-timer-on
7. https://temtopus.com/products/temtop-s1-air-quality-monitor
8. Figures 1–4, Table 1 created by Archishman Dey using Microsoft Excel, 2025.
9. Table 2A and 2B created by Archishman Dey from statistical analysis in Microsoft Excel, 2025.