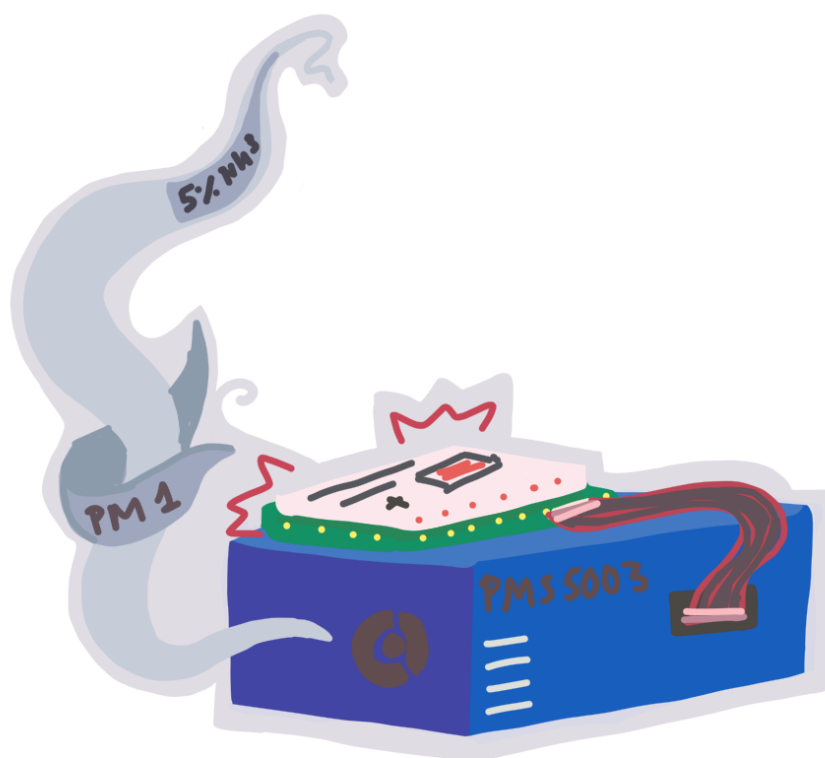


Comprehensive Analysis of Particulate Matter, Volatile Organic Compounds and Anthropogenic Aerosols using Raspberry Pi Technology



Shreya Halbe | Jasper High School | 10th Grade

Acknowledgement of Major Assistance

This project was possible because of the support of my parents, and my sponsors Ms.Vashka Desai and Ms.Teresa Walls, who helped submit this project. The school's support of the science fair program is what made it possible for me to take part in this amazing process.

TABLE OF CONTENTS

1: Introduction	3
1.1: Introduction to Research Paper	3
1.2: Particulate Matter	3
1.3: Background Information	4
1.4: Purpose	4
1.5 Hypothesis	4
2: Materials	5
2.1 For the Raspberry Pi Monitor	5
2.2 Tests	5
2.3 Softwares Used	5
3: Procedure	6
3.1 Assembly	6
3.2 Conneciton to Wi-fi	7
3.3 Setting-up Software	7
3.4 Monitor: Adding the python library for the enviro-plus	8
3.5 Data Analysis:	8
4: Methods	9
4.1 Coding	9
4.2 Graphing	9
5: Results	10
5.1 Control Test	10
5.2 VOCs	10
5.3: Aerosols	12
5.4 Cumulative Effect	13
6: Data Analysis	14
6.1 Observations	14
6.2 VOCs vs. Aerosols	14
6.3 Time Pie-Charts	15
6.4 Chemicals as VOCs and Aerosols	16
6.5 Regression Graphs	17
7: Discussion and Conclusions	19
7.1 Solutions	19
7.2 Error Analysis	19
7.3 Future Applications	19
7.4 Conclusion	19
Bibliography	19-20
Statement on Outisde Assistance	20

Introduction

1.1: Introduction to Research Paper

Air Pollution is a product of human activities involving the disposal of harmful gases in abnormal amounts that the atmosphere cannot handle. Indoor Air Pollution, though less recognized, is an extremely potent problem. According to the WHO¹, indoor smoke is a serious health risk for some 3 billion people and ambient air pollution also causes 1.6 million deaths annually. Indoor air quality is of utmost importance as it affects respiratory health and more so in the current situation of a respiratory disease pandemic.²

This project focuses on indoor air quality as little research has been done on the issue, and rising research indicates that indoor air has worse effects than outdoor air depending on the indoor exposures³. The experimenter has always been interested in anthropocene events and has been doing science fair projects relating to air pollution. Several indoor activities like cooking, cleaning, and disinfecting result in the exposure of potent chemicals to indoor air. Two specific categories of such chemicals were studied mainly because of their common usage in indoor environments, the Volatile Organic Compounds (VOCs) and Aerosols.

1.2: Particulate Matter

Particulate Matter is defined as microscopic particles of solid or liquid matter suspended in the air. There are three magnitudes or diameter sizes of PM. These are PM₁, PM_{2.5}, and PM₁₀. These can also be represented as PM 1, PM 2.5, and PM 10. The negative health impacts of the three magnitudes are shown in the diagram below⁴. Part of this research project was to find any differences in the magnitude of effect on different particle sizes as a result of exposure to VOCs and aerosols.



1.3: Background Information

Volatile Organic Compounds (VOCs) can be defined as organic chemicals that have a high vapor pressure at ordinary room temperature. This means that chemicals used in processes like wood furnishing or polishing, over time can turn into fumes and then be inhaled. Some VOCs, toxic in nature like Formaldehyde, are becoming a part of our daily lives. Some extremely common, and potentially hazardous VOCs include Alcohol, Butanal, Ethanol and Acetic Acid. Aerosols, that cover a wide range of chemicals, are any suspension of fine solid or liquid particles in air. These aerosols can be natural, like fog and mist, or anthropogenic like dust.

1.4: Purpose

The purpose of this project was to identify correlations between different indoor air pollutants and study more about PM particles using Raspberry Pi. **This research focused on investigating correlations between Particulate Matter (PM) content in response to exposure to common aerosols and VOCs in an indoor setting, to help find solutions to reduce PM concentrations.** VOCs and aerosols can cause respiratory diseases and this research focuses on its impact on PM particles. This research was done with the overall aim to contribute towards increasing awareness and being helpful in developing recommendations for indoor air quality.

This study impacts the environmental (air quality) and human (circulatory health and respiratory health) aspects of sustainability. It is important to note that there is scarcity of research specific to correlation between different pollutants, or about the pollutants themselves making it an emerging subject that warrants great attention. Research aimed at day-to-day activities can help yield simple yet effective solutions that can be easily implemented. Often environmental change calls for big commitments that average citizens cannot make, and thus it is important to remember that even a small change with a substantial impact, is a fitting solution to indoor air pollution.

1.5: Hypothesis

The hypothesis of this research is, 'If aerosols and volatile organic compounds (VOCs) increase in quantity in air, then the particulate matter will increase in concentration ($\mu\text{g}/\text{m}^3$) exponentially'. The aim of this project was to find the trends and correlations between particulate matter and VOCs and aerosols, and to record the various interactions that particulate matter has with the environment and other pollutants. Using the data collected, reasonable solutions and systems will be drafted to help mitigate the impact of the problem.

1- <https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health>

2- <https://seetheair.wordpress.com/?s=covid19+particulate+matter>

3- <https://www.scmp.com/lifestyle/health/article/1820604/why-indoor-air-pollution-may-be-worse-it-outdoors>

4 -PM Magnitude Diagram - https://www.jing.fm/clipimg/full/98-989703_particulate-matter-human-lungs.png

Materials

2.1 For the Raspberry Pi monitor

- Enviro+ pHAT(helps measure air quality (pollutant gases and particulates), temperature, pressure, humidity, light, and noise level.)
- PMS5003 particulate matter sensor (with cable)
- Raspberry Pi Zero W
- Micro-SD card
- SD card adapter
- 5V, 1A+ USB power supply
- A long USB A to micro-B cable
- 4 hex standoffs (4-40 X 3/8)
- 4 screws (4-40)
- Display, keyboard, and mouse, in this case, a laptop is being used
- Mini-HDMI and micro-USB adapter
- Protective sheet or butter paper for covering sensitive exposed hardware

2.2 Tests (150ml)

- Closed area or container
- Alcohol
- Butanal
- Acetic Acid
- Sodium Hyperchlorite
- Acetone
- Paint (contains traces of formaldehyde)
- Beaker (250 ml)
- SDS sheets⁵, gloves, goggles, laboratory mask, apron

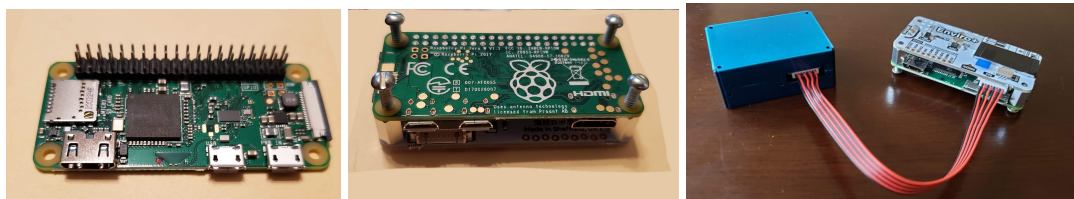
2.3 Softwares Used

- Graphing: Excel[®] Spreadsheets
- Program Coding: VScode
- Code Language: Python 3.8.2
- Mobaxterm
- Powerpoint for presenting and labelling graphs

Procedure

3.1 Assembly

1. To attach the two boards, align them so that the two headers will attach and connect each other. Placing them on top of each other, insert the male headers of the Raspberry Pi W Board into the female headers of the enviro+.
2. When it is half-way inserted screw in the standoffs to assure sturdiness. Then insert the female headers entirely, as much as possible.
3. Now attach the PMS5003 air monitor sensor to the Raspberry Pi Board using a picoblade cable system. Secure in place.



Images taken by Experimenter

(left): Raspberry Pi Board

(middle): Raspberry Board attached to pHAT using screws

(right): All parts connected

-
4. The SD Card is necessary for coding the Raspberry Pi W Board monitor. In this case, download and format the SD card.
 5. Using an adaptor, insert the SD card into the adaptor, which goes in the computer slot.
 6. Go to the Raspberry Pi OS site and go to Downloads⁵, and retrieve the original download for the Raspberry Pi W Board imager.
 7. Then choose the version of the download. In this case, 64-bit is chosen. (information in computer). Choose the SD card.
 8. Click write, and wait. Remove the SD card when the system tells the user to do so.

3.2 Connection to Wi-fi

9. Insert the SD card into the computer and go to the folder in which the user has stored the raspberry imager code and systems.
10. Add a new document to the folder titled: `wpa_supplicant.conf`. Open in Notepad.
11. When it opens type the following:

```
country=AU
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
network={ssid="MyWiFiNetwork" (add the wifi username)}
```

```
psk="aVeryStrongPassword"      (add the wifi password)
key_mgmt=WPA-PSK }
```

12. Now add the SSH file. To add, add a file with no extension named ssh. The connection will then be established after the SD card is completely formatted and inserted into the Raspberry Pi W Board.
13. Now remove the SD card adaptor and SD card. Insert the SD card into the Raspberry Pi W Board and boot the monitor. This is represented by a green blinking light.
14. To establish a wifi connection, type: This is called a ping message.

```
PS C:\WINDOWS\system32> ping raspberrypi.local
```

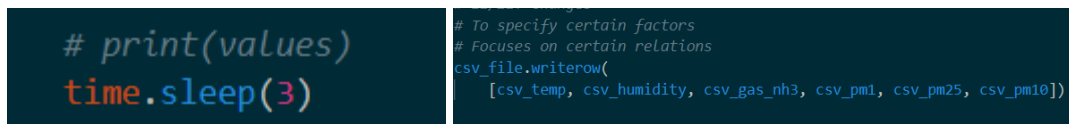
15. Enter the password, which by default is **raspberrypi**.
16. Then wait for the ping messages to be received from the Raspberry Pi W Board. Once the messages are received, the connection is established and the Raspberry Pi W Board is connected to the local wi-fi!
17. For the SSH connection, download the right-bit puTTY service⁶. In this case, it is 64-bit.
18. Now complete the puTTY configuration after the download and add the hostname of the raspberrypi monitor.
19. The Raspberry Pi W Board is connected to wifi and SSH, and booted!

3.3 Setting-up Software

20. To download the python library, open a command prompt terminal and type the following:

```
git clone https://github.com/pimoroni//enviro-plus-python cd
enviroplus-python Sudo ./install.sh
```

21. Use 'ls' (list) to navigate further lists, and cd (change directory) to navigate to that part of the list.
22. Try examples by navigating to examples.
23. The code pulls libraries from this file. *The code is detailed in the Method Section.*
24. The coding was done using python 3.8.2⁷ and drafted using VSCode⁸.



Repeat every 3 seconds.

| Exports certain parameters to the CSV file.

3.4 For testing: VOCs and Aerosols

25. Using the closed container, and the monitor, the temperature and initial air quality index were measured for 10 minutes or 600 seconds. This was the base test.

26. Then the pollutant was introduced, or activity (vacuuming etc) was conducted for the remaining hour. Tests were taken for longer in case there was any further change, but since the data was consistent, all trials were graphed for 60-90 minutes.
27. Hundred milliliters of chemicals were taken in a beaker.
28. Various confounding factors like area, temperature, initial PM reading and weather were considered and kept as consistent as possible.
29. These readings showed up on the programming application, and were exported to CSV file, where they were later graphed. This was done for efficiency since there were thousands of data points. The readings were graphed. Same steps were repeated for all chemicals.
30. A 24 hour control test was taken to compare. This included time, temperature, pressure, PM counts, and humidity.
31. Aerosols were tested using a similar process as for VOCs.
32. The monitor was placed at a height of 2 feet or above in cases of diffusion as this was observed to be more accurate.

3.5 Data Analysis:

33. The averages were calculated for VOCs and Aerosols, as well as average data columns were created for PM 1, PM 2.5 and PM 10 (three different magnitudes of PM particles).
34. Bar graphs were used that contrasted average VOC readings and average PM readings.
35. The time-pie chart, which displayed how much data readings changed in installments of 10 minutes, were graphed using the data of individual readings through 10 minutes. This was done by taking the first reading of the start of 10 minutes, and then the last reading of those 10 minutes. $[\text{Last reading}] - [\text{First reading}] = [\text{difference in those 10 minutes}]$
36. Lastly, regression analysis or a correlation chart was graphed to show the coefficient correlations between the different PM particle magnitudes, that helped see which magnitudes were impacted the most. This regression chart helped in finding the correlation equation and coefficient as well.
37. This process was done for the VOCs and aerosols separately.

5- Raspberry Pi Downloads: <https://www.raspberrypi.org/software/>

6 -PuTTY (0.76): <https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html>

7- VSCode: <https://code.visualstudio.com/>

8- Python 3.8.2: <https://www.python.org/downloads/release/python-382/>

Pie Chart: Graphed by Exprimenter, example of data analysis

Methods

4.1 Coding:

The code for this project was over 12-13 pages long, and thus could not be attached in this research paper. Here were the main steps:

1. Coded the Raspberry Pi board to detect the various parameters: humidity, time, temperature, PM readings, and pressure. While there were other options, these parameters were included as they were most likely to affect Indoor Air Quality.⁹
2. The spec sheet for the monitor ensured the accuracy of the PMS5003 monitor.
3. The 3 different magnitudes of PM were displayed separately on the display board of the monitor. The display section of the code was written so that the color of the readings shows whether or not the reading is good. **Green** suggests a healthy reading, **yellow** is slightly polluted, while **red** is dangerous. The temperature, humidity, and ammonia/pressure was also displayed.
4. The loop was written which would repeat this process every 3 seconds.
5. The data returned was exported to a CSV file, which organizes the data in rows and columns, which aids in the graphing process.

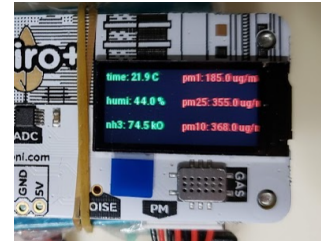
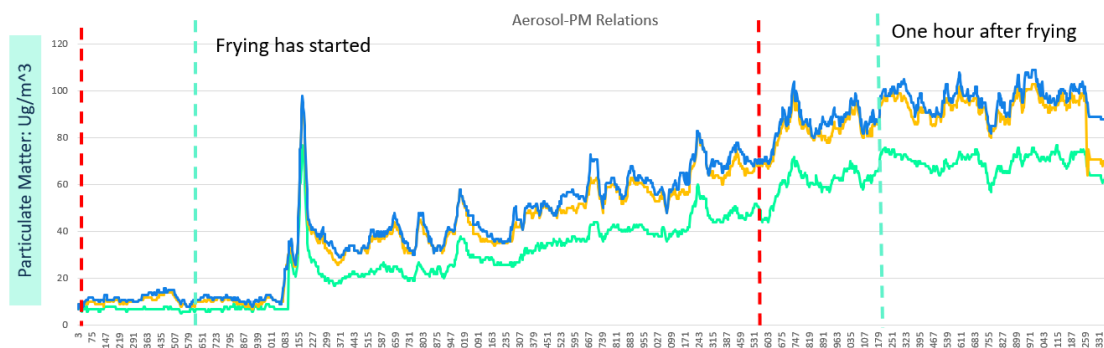


Image (top) - taken by Experimenter, shows the various colors of readings

Image (bottom) - taken by Experimenter, final monitor.

9- https://www.epa.gov/sites/default/files/2014-08/documents/sec_2.pdf

4.2 Graphing:



Here is an example of a PM reading graph. The first red line shows the start reading of the base test, and the second, an hour after the first. The blue lines show the beginning and end of the activity or introduction of pollutants. The three different colors in graphed lines represent separate PM particles. X- axis: Time | Y-axis: PM readings (micrograms/meter cube)

Results

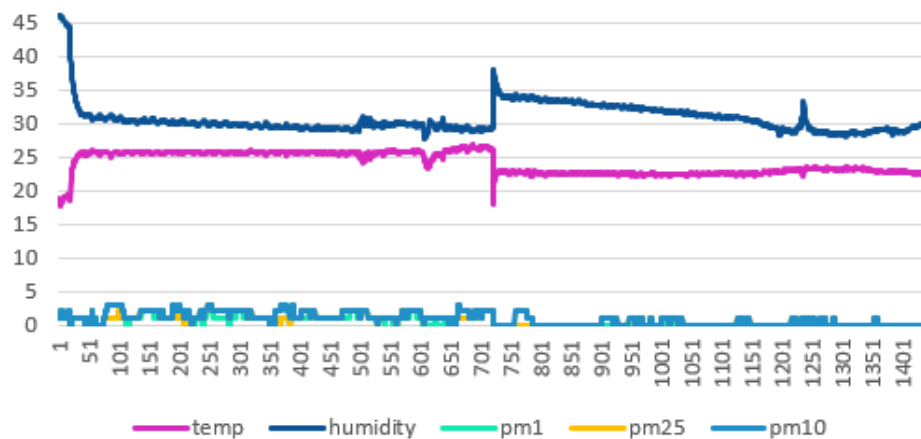
Graphing Legend:

PM 1 | PM 25 | PM 10 |

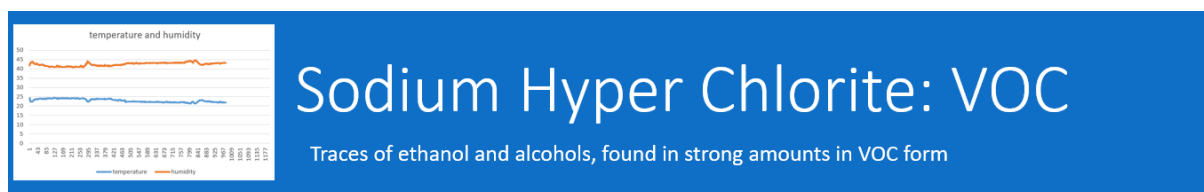
The graph on the top-left shows humidity and temperature for comparison.

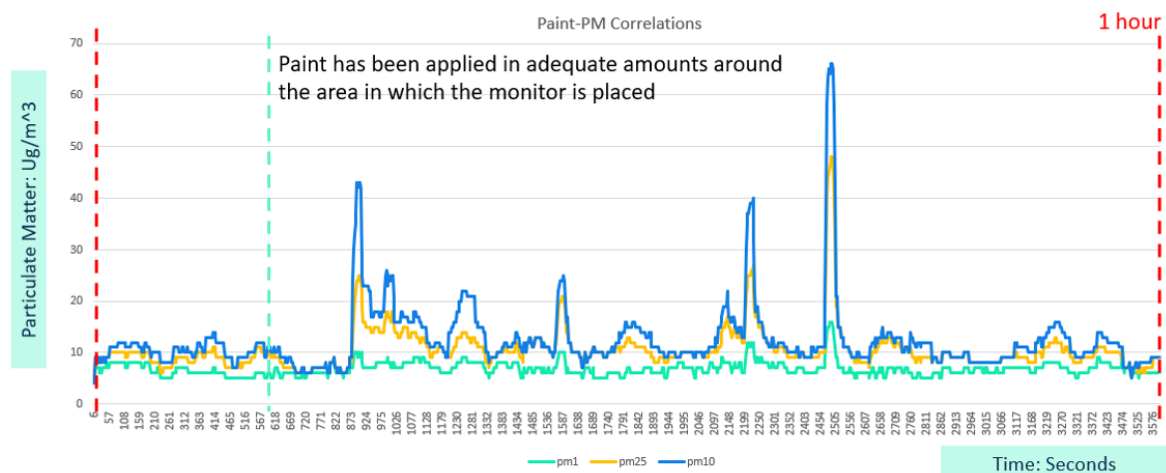
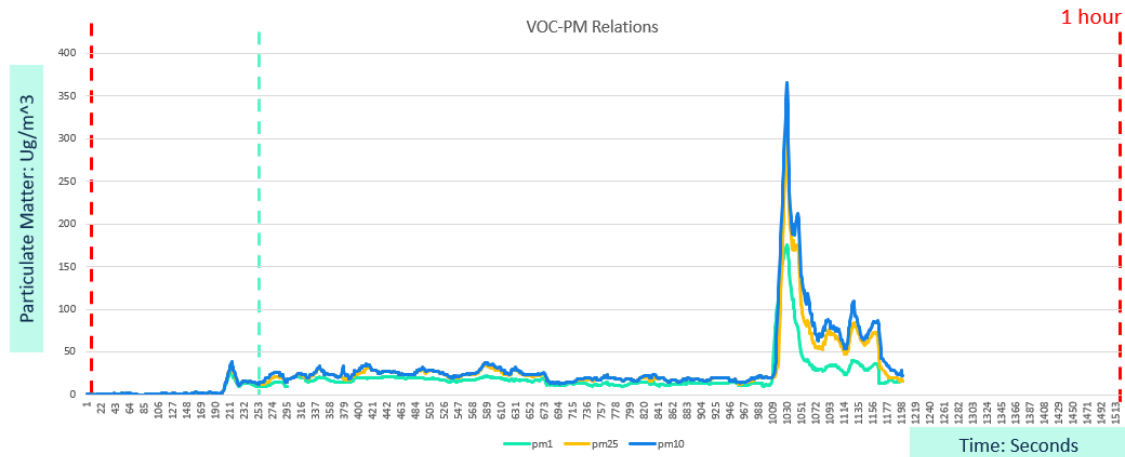
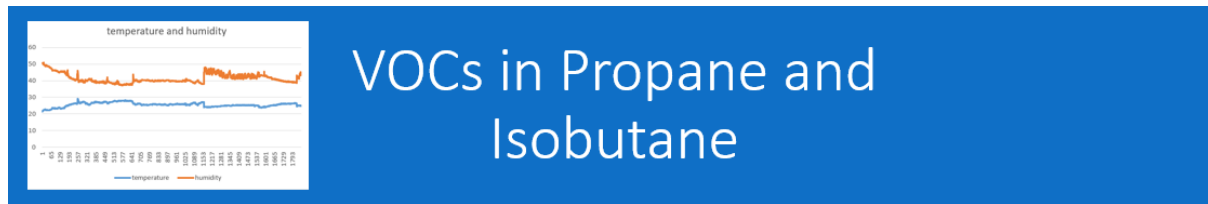
5.1 Control Test

This graph represents the control sample for the research. It demonstrates the nature of Indoor Air on a normal day in the controlled setting where the experimentation took place. The graph was taken over 24 hours in intervals, and the X-axis represents time in minutes, whereas the Y-axis represents the PM concentration readings. It can be observed that the humidity and temperature were very consistent. The PM readings are low and at certain points PM 25 and PM 1 are so low, they do not show consistently on the graph.



5.2 VOCs



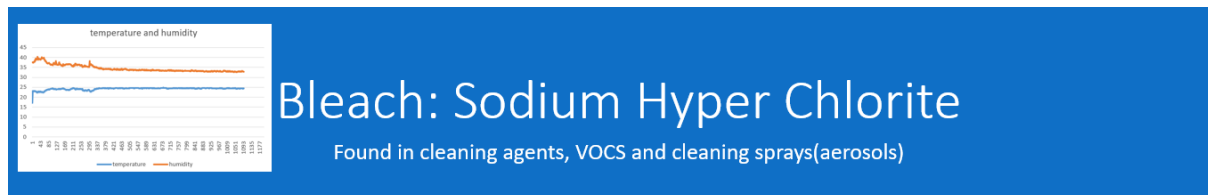


The above three graphs are tests of VOCs that were conducted. The first one was the most significant and had the most impact on PM concentrations. The chemical name is Sodium Hypochlorite and is used extensively as an ingredient in cleaning supplies. The second graph shows PM concentrations in the presence of Propane and Isobutane chemicals or VOCs, that are used in candles and incense. They are very potent as they spread and turn into vapor very quickly.

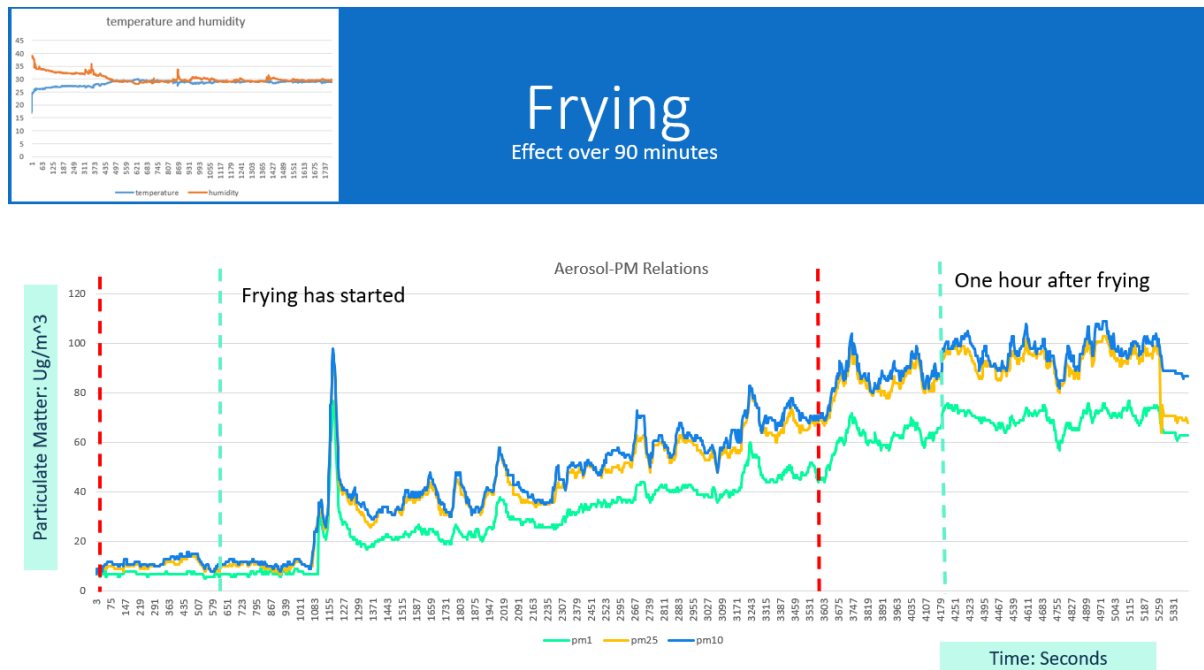
The third graph, VOCs in paint, had the next most impactful effect, although it is important to remember that the amount of paint could have an impact on PM readings. Another important observation of paint is how it quickly fades and rises, which shows that PM readings are

mostly impacted in certain intervals, and reducing exposure to paint while it is wet is a practical solution.

5.3: Aerosols



The above graph tests Isobutane and Propane propellants which was also tested for VOCs in the form of candles and incense. This can help us analyze the difference between Aerosol-PM correlations and PM-VOC correlations, similar to Sodium Hypochlorite.



Multiple aerosols are produced while frying, including water aerosols and gas. Excessive frying can be harmful. The above graph shows an increase in PM readings due to the increase in surrounding aerosol concentration. Aerosols tend to carry particles that attach to them easily. Throughout all the trials taken, frying presented the same conclusion, that aerosols carry PM particles and can increase PM concentrations. This confirms the hypothesis.

5.4 Cumulative Effect

It is very important to note that these chemicals and exposures are all part of daily activities. Over a period of time, there can be a cumulative effect of these key pollutants in indoor spaces and this makes indoor air pollution of great concern to public health. The USEPA guidelines¹⁰ to the right indicate the PM levels in safe limits over 24 hour or yearly basis. Interestingly, some of the tests in the current project indicated PM levels way higher than these safe limits for just one exposure. This indicates that day-to-day activities and exposures can very well pass these safe limits and can have a cumulative detrimental effect.

Table 2

Indoor air quality guidelines for major indoor air pollutants.

Pollutants	Concentration Levels (mg/m ³)	Exposure Time	Organization
CO	100	15 min	WHO
	60	30 min	
	30	1 h	
	10	8 h	
	29	1 h	USEPA
	10	8 h	
CO ₂	1800	1 h	WHO
NO ₂	0.4	1 h	WHO
	0.15	24 h	
	0.1	1 year	USEPA
PM	0.15	24 h	USEPA
	0.05	1 year	

10- <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7215772/>

Data Analysis

The data analysis will help understand the various correlations between the pollutants and effects on indoor air quality. This data can be used to devise potential future applications or solutions.

6.1 Observations

These are the observations that were noted during the research process, and were used to determine the key points for Data Analysis.

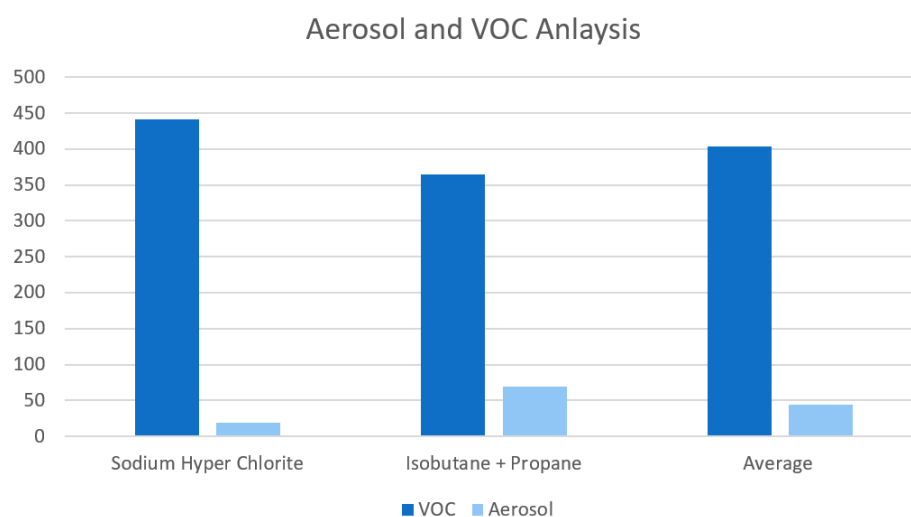
Monitor:

1. The Monitor must be placed at a height ~ 2 feet to capture accurate readings as dust and PM particles rise

Testing:

1. VOCs had an overall greater impact than aerosols
2. PM 10, followed by PM25 increased the most and showed the most change in response to pollutant exposure.
3. Substances that had VOCs that would emit PM particles (like candles) had a more sudden increase and decrease.
4. Aerosols had lesser effect on PM content and hence appeared to be safer to use than VOCs (shown in graph below).

6.2 VOCs vs. Aerosols



This bar graph shows one of the main observations of the testing, which is the difference between aerosols and VOC when it comes to the interaction with PM in the air. In all the three cases, VOCs had a greater impact on PM concentrations. The first bar shows Sodium

Hypochlorite. The second represents the Isobute and Propane (commonly used together) chemicals, and the last bar shows the average of all the trials taken. VOCs had an overall greater impact than aerosols, on an average $359 \mu/m^3$ more for PM10.

6.3 Time Pie-Charts

The pie charts below show when the most change in PM concentrations happened in response to the pollutant exposure. These charts display the PM readings over time and the change in percentage. There are 6 divisions, each representing 10 minutes. The bigger they are, the more they change. This can help us understand the periods of change to minimize exposure during those periods. We can see that the least change happens in the beginning, while more change happens in the middle.

These are the charts. The most change happened:

VOC: Sodium Hypochlorite - middle 20 minutes

Frying: middle 40 minutes

Bleach: Aerosol Sodium HYperchlorite - middle 20-30 minutes

Paint: first 20 minutes

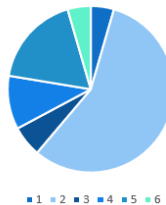
VOC Butane+Propane: after the first 10 minutes

Aerosol Butane+Propane: after the first 20-30 minutes

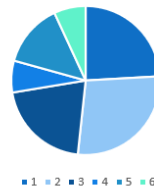
Sodium Hyper Chlorite effects over an hour in 10 minute installments



Frying effects over an hour in 15 minute installments



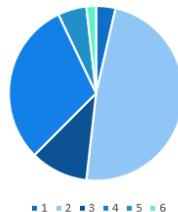
Effects of bleach over an hour in 10 minute installments



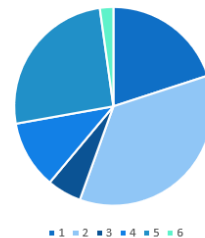
Effects of paint over an hour in 10 minute installments



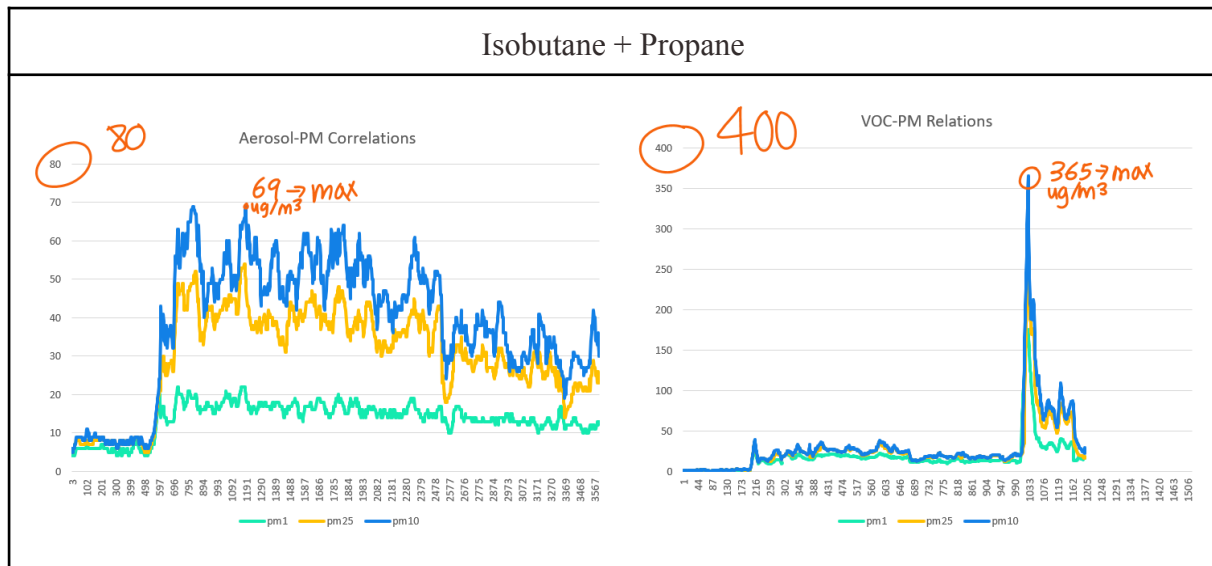
Effects of VOC butane and propane over an hour, in 10 minute instalments



Effects of Aerosol butane and propane over an hour, in 10 minute instalments



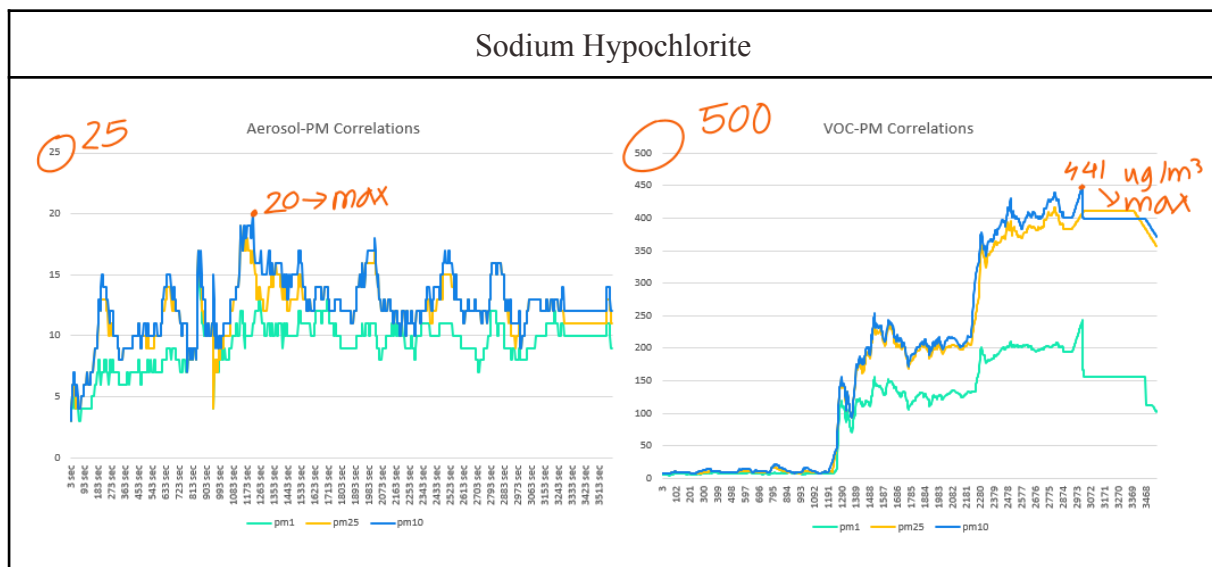
6.4 Chemicals as VOCs and Aerosols



Left - Aerosols

Right- VOCs

The maximum point on the Aerosol graph is at (831, 69) which is the reading at the 831st second or at the 13th minute. This contrasted to (1030, 365), the maximum point for the VOC graph, shows that VOCs had a greater impact on the PM concentrations when tested for an hour each.



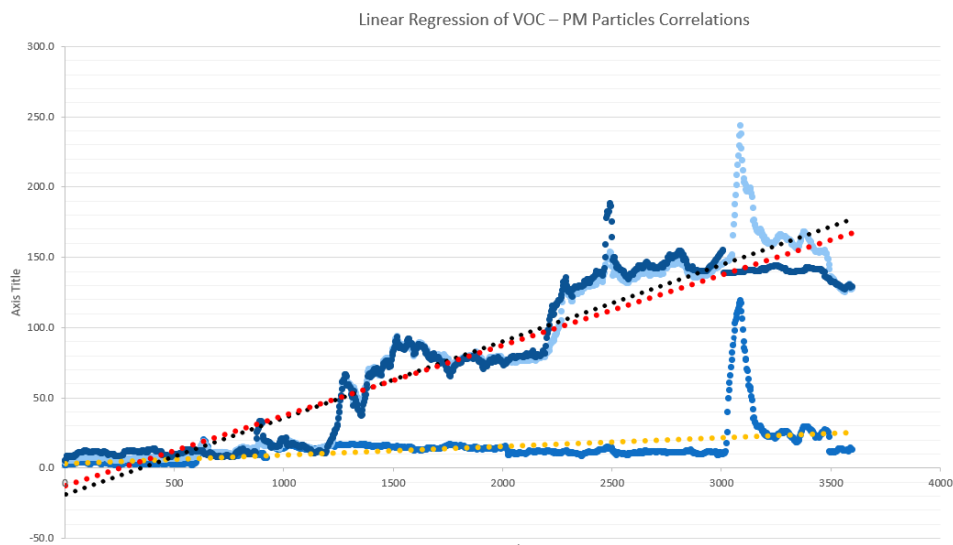
Left - Aerosols

Right- VOCs

The maximum point on the Aerosol graph is at (1212, 20) which is the reading at the 1,212nd second or at the 20th minute. This contrasted to (3006, 44), the maximum point for the VOC graph, shows that VOCs had a greater impact on the PM concentrations when tested for an hour each.

6.5 Regression Graphs

Legend: PM1 | PM25 | PM10 | Graphs by Experimenter

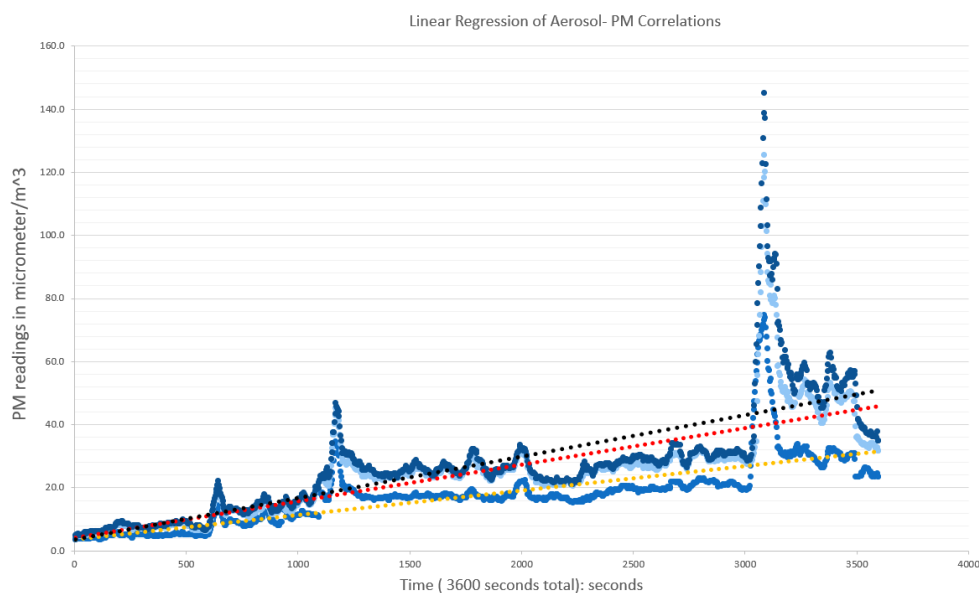


PM 1 $y = 0.0062x + 2.8914$
 $R^2 = 0.2013$

PM 25 $y = 0.0545x - 18.664$
 $R^2 = 0.9037$

PM 10 $y = 0.05x - 12.488$
 $R^2 = 0.8882$

This graph shows which PM particle was impacted the most. VOCs impacted PM 10 and PM 25 the most.



PM 1 $y = 0.0078x + 3.5784$
 $R^2 = 0.5963$

PM 25 $y = 0.0116x + 4.2418$
 $R^2 = 0.5984$

PM 10 $y = 0.0132x + 3.5808$
 $R^2 = 0.5692$

Aerosols impacted all the PM particles pretty similarly, suggesting aerosols interact with any other suspended particles, compared to VOCs that tend to interact with larger suspended particles. Even in this, PM 10 was impacted the most along with PM 25. The regression equations helped to find out which particle was the most consistent, and thus the R coefficient was closer to 1, as the line was more accurate. In both cases it was PM25 and PM10.

Discussion and Conclusions

7.1 Solutions

Effective solutions are drafted based on factors like feasibility, economical value, public awareness of the issue, urgency of the issue at stake and impact factor of the solutions. This research can be effectively applied in following areas:

- Formulating safer cleaning products that emit no VOCs.
- Designing better Aerosol sprays or products.
- Innovations in home planning and designing to reduce the possibility of PM build up in indoor air (taller ceilings).
- Designing innovative and affordable Air monitoring systems as an in-built feature for all homes and indoor places (especially schools, hospitals and offices).
- Most importantly, increasing public awareness related to quality and safety of indoor air.

7.2 Error Analysis

Like any research, there were errors encountered in the project too. These have been described below along with their solutions.

- The PM sensor was kept at a height of 2 feet + height to capture the results.
- Errors in code: redundancy, bugs, monitor readings and library modules not present
- Unsteady program: fixed using loop-debugging methods

7.3 Future Applications

Future applications will include using collected data and applying it to help mitigate the problem. One solution includes installing in-built air quality systems in indoor spaces like homes, schools, offices and hospitals. Another solution could include developing a mobile app that provides real time readings of indoor PM concentrations and uses correlations to enhance features. Most importantly, this research can be applied to increase public awareness on this crucial public health issue!

7.4 Conclusion

Indoor Air Pollution is defined as the chemical, biological, and physical contamination of indoor air. Indoor Air Pollution is a relatively new field of research and is recently being explored more deeply due to the COVID-19 pandemic. The current project specifically aimed to find the trends and correlations between two anthropogenic and potent pollutant categories commonly found indoors, Volatile Organic Compounds(VOCs) and Aerosols, with Particulate Matter in air.

The hypothesis was 'If aerosols and Volatile Organic Compounds increase in quantity in air, then the particulate matter will increase in concentration ($\mu\text{g}/\text{m}^3$) exponentially'. The

independent variables were the VOC and Aerosols introduced, and time. The dependent variables were the pm1, pm25, and pm10 (magnitudes of PM) particles. The control was a 24 hour reading of pm1, pm25, and pm10, and lastly, the constants were humidity and temperature. It was repeatedly observed that PM content indeed increased exponentially over time in response to VOCs and not as much in response to the aerosols. Another prominent observation was that an increase in PM10 prevailed throughout all testing scenarios. The use of aerosol related chemicals can lead to less particulate matter concentrations, and depending on the chemical, aerosols also act as a reflector of UV rays and sunlight. VOCs and Aerosols differ in the ways they affect and react with the environment. These observations can augment development of suitable home cleaning products and agents. The direct applications of this project include safe product designing, safe home designing to avoid PM buildup and most importantly to increase public awareness related to quality and safety of indoor air!

Bibliography

Anthes, E. (2020, June 1). Coronavirus Lockdowns May Raise Exposure to Indoor Air Pollution. Scientific American.

<https://www.scientificamerican.com/article/coronavirus-lockdowns-may-raise-exposure-to-indoor-air-pollution>

Chillingsworth, J., & Flower, A. (2019). Live green?: 52 steps for a more sustainable life. Quadrille, An Imprint Of Hardie Grant Publishing. (Original work published 2019)

Ching-Boon, K. (2016, June 10). Why indoor air pollution may be worse than it is outdoors. South China Morning Post.

<https://www.scmp.com/lifestyle/health/article/1820604/why-indoor-air-pollution-may-be-worse-it-outdoors>

Farmer, S. A., Nelin, T. D., Falvo, M. J., & Wold, L. E. (2014). Ambient and household air pollution: complex triggers of disease. American Journal of Physiology - Heart and Circulatory Physiology, 307(4), H467%u2013H476. <https://doi.org/10.1152/ajpheart.00235.2014>

Flatow, I. (2007, December 14). Toxins in the Home: Indoor Air Can Be Polluted Too [Radio]. NPR. <https://www.npr.org/templates/story/story.php?storyId=17243171>

Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality. (2020, April 1). PubMed Central (PMC).

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7215772/>

Papathanasiou, S., Papathanasiou, S., Papathanasiou, S., Papathanasiou, S., & Papathanasiou, S. (2021, September 6). Search Results for “covid19 particulate matter” –. See The Air.

<https://seetheair.wordpress.com/?s=covid19+particulate+matter>

Raspberry Pi. (n.d.). Setting up your Raspberry Pi. Raspberry Pi.Org.

<https://projects.raspberrypi.org/en/projects/raspberry-pi-setting-up>

US EPA. (2019, February 7). Indoor Pollutants and Sources | US EPA. US EPA; Environmental Protection Agency, US. <https://www.epa.gov/indoor-air-quality-iaq/indoor-pollutants-and-sources>

United States Environmental Protection Agency. (2014, August). Factors Affecting Indoor Air Quality. EPA.Gov. https://www.epa.gov/sites/default/files/2014-08/documents/sec_2.pdf

World Health Organization: WHO. (2018, May 2). Ambient (outdoor) air quality and health. Who.Int; World Health Organization: WHO.
[https://www.who.int/en/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-eaalth](https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-eaalth)

Statement on Outside Assistance
Researchers Name: Shreya Halbe
Title of Paper: Comprehensive Analysis of Particulate Matter, Volatile Organic Compounds and Anthropogenic Aerosols using Raspberry Pi Technology
What steps led you to formulate your hypothesis? (Where did you get the idea for your research?) Please be specific. I got the idea from many different articles and just a concern for indoor air pollution. It was mainly because of the COVID-19 and the different chemicals we were using to sanitize our households. I formulated my hypothesis after lots of research and by understanding the nature of chemicals and particulate matter.
Where did you conduct the major part of your work? (i.e. home, school, or other institutional setting, university lab, medical center, etc.) I conducted all of my research at home in a designated spot.
If you worked in an institutional setting, did you work on your project as part of a team or group? If so, how large was the team and who was on the team (students, adult researchers, etc.)? Describe your role on the team. N/A
Describe what parts of the research you did on your own and what parts you received help (i.e. literature search, hypothesis, experimental design, use of special equipment, gathering data, evaluation of data, statistical analysis, conclusions, and preparation of written report (abstract and/or paper)). I did most of my work on my own and borrowed some coding knowledge from my father. I used websites like EPA and research publishing websites to learn about the nature of the chemicals I was using so I could choose the perfect trails and chemicals. I used the assistance of my school LASER (science fair) program to conduct my research process, making sure I have my logbook and data.
Is your research current or a continuation of previous research? If a continuation, please describe the current work and advancement(s) of this research in comparison to the prior work and results. It is a current project.