Evaluating the Effects of Temperature and Ozone on Particulate Matter Levels in Southeastern Michigan

Student Researchers:
Yasmine Ahmad, Jenna Charara, and Nadine Mazeh

School:
Crestwood High School

Dearborn Heights, MI 48127

High School Teacher:

Diana Johns

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Table of Contents

Abstract:

Understanding **particulate matter** (PM) levels in the researcher's community is critical for informing public health decisions and raising public awareness regarding potential threats to personal lung health. This research was conducted during the Summer and Fall of 2022. Data was collected daily during this period on **ground-level ozone, particulate matter ($PM_{2.5}$), surface temperature**, and air temperature. Crestwood's **PurpleAir** device and the handheld **PocketLab Air** was used to determine particulate matter levels. Ground-level ozone was also collected using the **Pocketlab Air** sensor. **Surface temperature** taken with an infrared thermometer and air temperature was recorded using Crestwood's WeatherBug weather station. PM data was collected with the **Pocketlab Air** sensor to compare data with the **PurpleAir** device. This allowed the researchers to test the reliability of the **PocketLab Air** device. In addition, the researchers recorded real-time data from three different locations in Michigan, all less than 25 minutes from each other, using **PurpleAir** levels online. This enabled the community's results to be compared to places nearby. These locations included Detroit, Livonia, and Oak Park. The objective of this research was to analyze how $PM_{2.5}$ levels might be affected as temperature and ozone levels change. PM levels were taken from each location and compared with the other atmospheric data collected. Observing the results through different seasons allowed the researchers to conclude that $PM_{2.5}$ data from **PocketLab Air** and **PurpleAir** appear to positively correlate with changes in temperature and ozone. As $PM_{2.5}$ in the air can damage gas exchange in lungs at the alveoli level, it is crucial that citizens in the community be aware when high levels exist so they can reduce outdoor activity so as to avoid respiratory distress. Reducing **ground-level ozone** and **particulate matter** levels can reduce potential health risks to lungs and permit athletes to continue playing without adverse health complications.

Key Words: Particulate Matter, PocketLab Air, PurpleAir, Ground-Level Ozone, Surface Temperature

Research Questions:

1. What effect does air temperature have on a $PM_{2.5}$ data collected from the PurpleAir device?
2. How does $PM_{2.5}$ vary across different locations in Michigan that are in close proximity?

3. To what extent does ground-level impact $PM_{2.5}$ levels?

4. How does $PM_{2.5}$ levels taken from the Pocketlab device correlate to the measurements of $PM_{2.5}$ that PurpleAir collected?

Null hypothesis:

1. There is no significant correlation between $PM_{2.5}$ with air and surface temperature.

2. There is no significant difference in $PM_{2.5}$ across a variety of locations in Michigan.

3. There is no significant correlation between ozone and $PM_{2.5}$ levels.

4. There is no significant difference between $PM_{2.5}$ taken from the PocketLab Air device and the PurpleAir device.

Introduction and Review of Literature:

The location of this research was on Crestwood High School's band practice field (Dearborn Heights, MI). This is where many summer, spring, and fall outdoor sports are practiced. As many students do heavy breathing exercises in high temperatures, the potential effects of high $PM_{2.5}$ and ground-level ozone become increasingly concerning. Smaller $PM_{2.5}$ particles are even more dangerous than larger PM particles known as PM_{10}. Examples of these according to the CDC are dust, tobacco smoke, soot, and industrial emissions (National Center for Environmental Health 2023). Studying ground-level ozone at is a critical piece of information for students' wellbeing. The researchers used a PocketLab Air for approximate values. Previous email discussions with Dr. Margaret Pippen of NASA indicated that the current GLOBE protocol for ozone is not very reliable and she suggested not using it. The PocketLab Air was additionally tested by her office and found to be not as accurate either. Current outdoor ozone monitors are expensive and not affordable to use in school research. PurpleAir is currently working on pairing an ozone sensor with its particulate sensor and when and if available, it may become a reliable method of measuring two ambient criteria air pollutants: ground-level ozone and particulate matter. Because the researcher's study site is situated near a major road in the community, many cars are passing by every minute, emitting nitrogen oxides, one of the key atmospheric chemicals essential to the creation of ozone. Many people mow their grass, fuel their cars, barbecue and produce VOCs (volatile organic

compounds) which are also essential to the formation of ground-level ozone. Ground-level ozone can also be created in communities upwind and then brought to the community via variable prevailing Southwesterlies. Ground-level ozone pollution is formed from photochemical reactions between nitrogen oxides and volatile organic compounds. This happens in the presence of sunlight and heat. This makes the summer months especially susceptible to high ozone levels as lawn mowers, factories, and gas-powered motors are in active use. Crestwood's study site is also very close to industries such as the Ford Motor Company and Marathon oil refinery just to name a couple. Depending on the wind direction, air emissions from these and other local industries can move harmful emissions towards the school. Although both ground-level ozone and particulate matter are criteria air pollutants monitored by the Environmental Protection Agency, levels often reach concerning rates in the community. These two pollutants have strong evidence for public health concerns making them guilty for causing dangerous conditions. Those with health issues, such as lung problems or hypertension, can be most at risk (Sinkemani, Li, and Chen). Unlike larger pollution, the tiny $PM_{2.5}$ can easily make their way into deep parts of the lungs or blood. These issues include, "irregular heartbeat, aggravated asthma, decreased lung function, and irritation of the airways" (Environmental Protection Agency 2022).

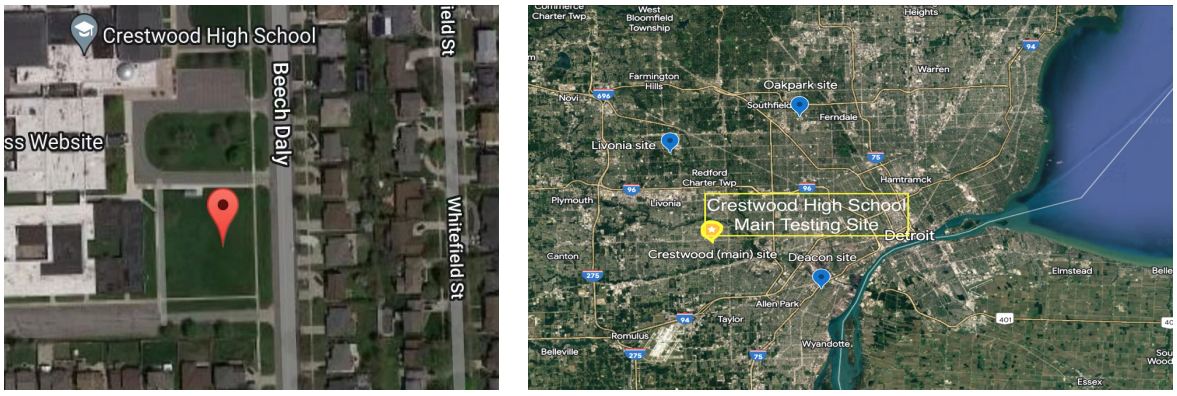


Figure 1 (left) and 2 (right). Site visualization. The location on the satellite image (on the left) shows Site 1 (Crestwood High School's marching band practice field). The image on the right captures Crestwood High School (42.3221° N, 83.2932° W) on a larger scale map to indicate where the school is located in Southeastern Michigan.

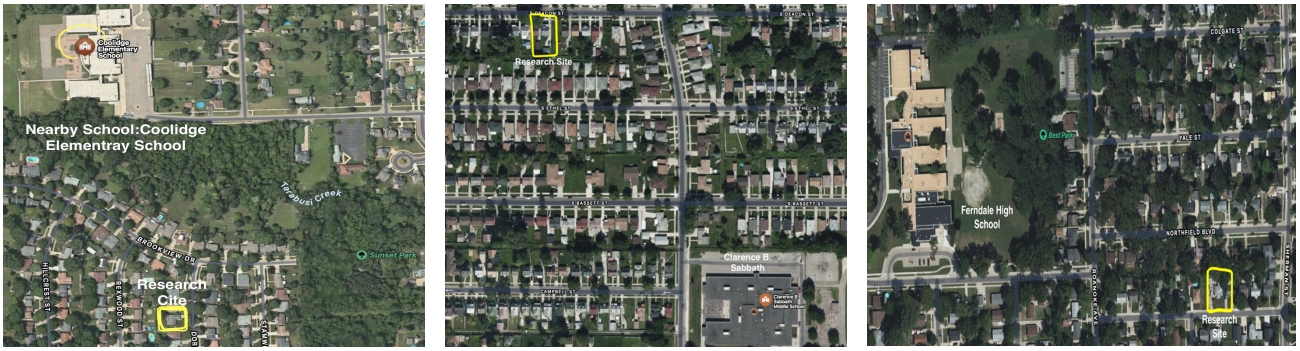


Figure 3-5: Site Visualization. The location on the satellite image shows Site 2, Livonia (left). This location is surrounded by multiple parks and an elementary school. The location on the left shows the satellite image of Site 3, Deacon (middle). This location is right in the middle of a local neighborhood and small businesses. The location on the right displays the satellite image of site 4, Oakpark (right). This location is near an Elementary School.

Methodology:

Using data from PocketLab Air, the researchers collected the $PM_{2.5}$ along with ozone at Solar Noon once a day for a total 84 days of data collection from August through October. Using GLOBE protocols were used to determine air temperature, surface temperature, wind speed, and barometric pressure. The PocketLab was held at arms-length to collect both the ozone and $PM_{2.5}$ data, waiting about 3-5 minutes every day until the data stopped fluctuating. In the meantime, using the GLOBE Observer app, the students collected cloud data alongside surface temperature and recorded it on the GLOBE Program- Science data entry. The researchers then went on the PurpleAir websute to collect the $PM_{2.5}$ at the different locations around Metro Detroit. Also, to measure the accuracy of each of these devices, researchers collected data from PurpleAir at the Crestwood High School band practice field. Over the course of about three months, including one seasonal change, this process was followed daily. All the data was put in Microsoft Excel where the researchers then created graphs looking for comparisons across all data collected. In the meantime, using the GLOBE Observer App, students collected cloud data alongside surface temperature and entered it on the GLOBE Program data entry portal. The researchers then went on PurpleAir website to collect the $PM_{2.5}$ at the different locations around Metro Detroit.

Figure 6-7. PurpleAir is one of the websites the researcher used to make sure that the $PM_{2.5}$ and ozone data is accurate at the research site by comparison (right). The map is a visualization of what the researchers dealt with when looking at the 4 locations all together. (left)

Figure 8-10. PocketLab Air was collected by one of the researchers waiting 3-5 minutes at shoulder length, while the other used a mobile device to collect the data of PM2.5 and Ozone (middle). The green sensor (left) is what was used to gather this data on the PocketLab app. After this time period you can see that the data starts to become constant (right), at this point the researchers added this to the spreadsheet.

Figure 9-11. Surface Temperature, was taken with an infrared thermometer (middle). When the device is adjusted to the correct units, in this case degrees Celsius, it is ready to take the surface temperature. The researchers made sure to avoid shadows (right). We took nine random measurements around the study site and inserted the data into the GLOBE Data science entry (left).

Results:

During the research period, temperature, location, ozone, and $PM_{2.5}$ data were always collected within an hour of Solar Noon. Research proved the correlation between $PM_{2.5}$ with air and surface temperature was shown to be evidently positively correlated so the researchers can reject the null hypothesis. The relationship null hypothesis of ozone and $PM_{2.5}$ must also be rejected as they were also proven to be positively correlated. However, the data fails to reject the null hypothesis of $PM_{2.5}$ varying across Southeast Michigan and from the PocketLab versus PurpleAir device.

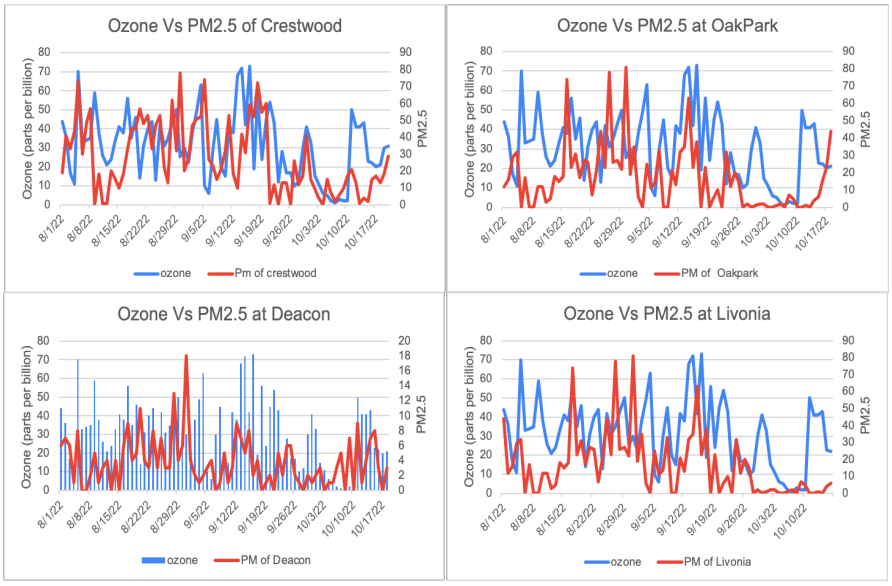


Figure 12-15. $PM_{2.5}$ and ozone were compared during the research period at various locations around Metro Detroit. The first location is the researchers test site, Crestwood High School, (top left). The next location is OakPark (top right). The third location is Deacon (bottom left). The fourth and final location is Livonia (bottom right). Each graph indicates a positive correlation with ozone levels around Metro Detroit and the $PM_{2.5}$ of these locations. In other words, as ozone levels rise, so do particulate matter levels.

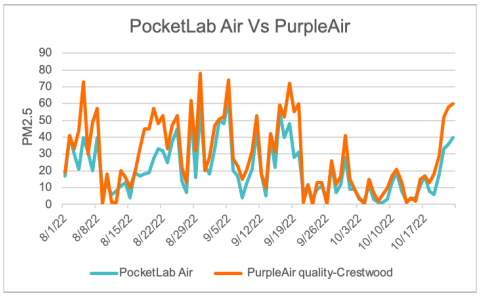


Figure 16. $PM_{2.5}$ at Crestwood on PurpleAir device vs. the PocketLab device during the research time. Data obtained from these two devices were both taken at the same time (solar noon). Although the Pocketlab

device is consumer grade and isn't in a stable location, unlike the PurpleAir device, they seem to have a very close relationship.

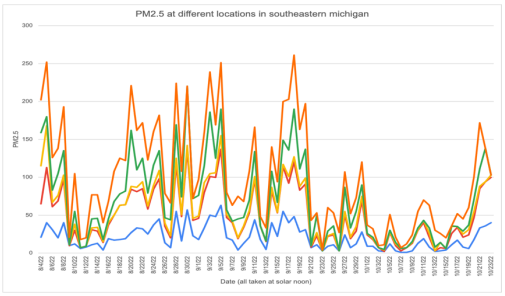


Figure 17. $PM_{2.5}$ data at the four (4) researched sites taken from PurpleAir and Pocketlab Air being compared on the same dates at solar noon. The sites being only about twenty-five minutes from each other creates very similar results. As the dates change into different seasons, such as August to October, the $PM_{2.5}$ levels begin to decrease. This is because of the temperature decrease. The positive correlation between PM and temperature can be identified on the graph in each location.

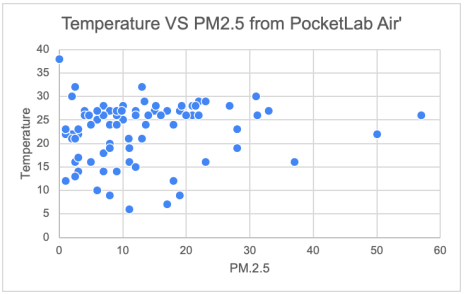


Figure 18. Temperature in comparison to $PM_{2.5}$ using a PocketLab Air. These characteristics are positively correlated, as the temperature increases so does the $PM_{2.5}$ that was collected from the PocketLab Air.

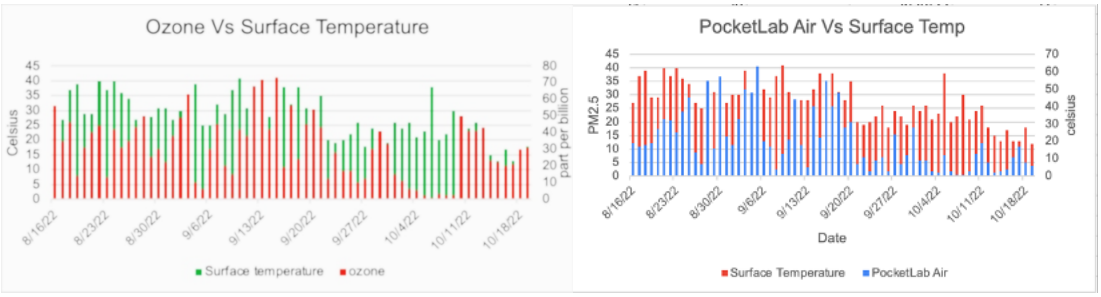


Figure 19-20. Surface Temperature in comparison to ozone and $PM_{2.5}$ from the PocketLab Air. The surface temperature taken from an infrared thermometer in comparison to ozone (to the left) shows a positive correlation. As the surface temperature increases, so does the ozone levels. The same thing happens in the PocketLab and Surface temperature graph (to the right). This graph also has a positive correlation. As the $PM_{2.5}$ levels taken from the PocketLab go up, so does the surface temperature.

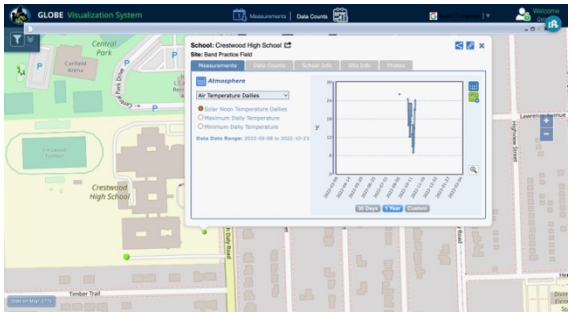


Figure 21. Globe Site Visualization. This is a sample page of the researchers' site on the GLOBE visualization system.

Discussion:

Data from the PurpleAir device and PocketLab were consistent with data obtained through Weather Bug and the Michigan Department of Environmental Quality. The ozone levels were also constant on days of high ground-level ozone, and PM levels rose. The relationship between the two implies that they fluctuate according to similar weather phenomena, such as ambient air and surface temperature. The amount of $PM_{2.5}$ collected from the PurpleAir device compared to the PocketLab Air data shows positive correlation. However, the PocketLab Air device tends to have lower results. These results may be because of the height the researchers held it from or the high fluctuations that occurred with the consumer-grade device. The PurpleAir device is in a stable location, making it much more accurate and quality. When the researchers analyzed the level of $PM_{2.5}$ from each site, side-by-side comparisons concluded that the locations had similar results. The positively correlated graph comparing all areas indicates that atmospheric conditions affect PM. This result may be because higher temperatures worsen air quality, increasing ground-level ozone and smaller PM counts.

The researchers collected data for over three months to find more accurate results. Conducting research with few human and mobile errors is challenging. One possible source of error in the researcher's investigation was the update on the PocketLab app on the mobile device. In the middle of the study, an update on PocketLab caused some confusion. The app's format was modified, resulting in some days of understanding the new structure. During this time, it was necessary to collect data from PurpleAir and Weatherbug. Another possible source of error is the unknown conditions at each research location. Different circumstances can affect the sensor's ability

to provide accurate results. A final possible source of error in this investigation is not allowing the PocketLab Air to acclimate long enough to the outside weather conditions. This error prevents the PocketLab from being in the air long enough to stop fluctuation.

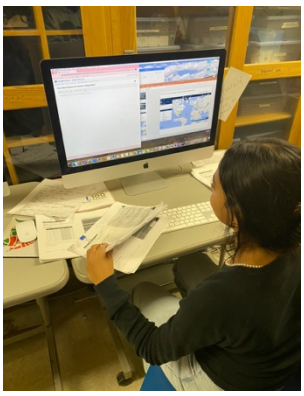
Conclusion:

The data collected at the research locations revealed that surface and air temperature are positively correlated to ozone and $PM_{2.5}$ levels. Despite differences in the two measurement devices, the PurpleAir and handheld PocketLab Air showed significant similarities. The PocketLab measured $PM_{2.5}$, PM_{10}, and ground-level ozone quickly with an app installed on the researcher's phone. The device is easy to use and transport. The researchers were able to compare two datasets because they had PocketLab data in addition to PurpleAir. Previous emails our teacher had with Dr. Margaret Pippen allowed the researchers to understand that the PocketLab Air device was consumer-rated and not necessarily research-grade. Although our particulate values did vary between the PocketLab and PurpleAir devices, the differences were consistent. The PM trends were similar and gave the researchers a valuable comparison. The PocketLab Air device is still beneficial for observing trends in particulate matter, although the researchers believe that $PM_{2.5}$ counts taken by the PurpleAir are more accurate and precise. When ozone action days were not present, the PocketLab reported high ground-level ozone. While this was not always the case, it led the researchers to conclude that the PocketLab Air device is better suited for PM rather than ozone measurements. This could be due to large fluctuations or an inadequate device design.

It is essential to research PM and ozone as they are two of the six criteria for air pollutants regulated by the Clean Air Act. Because all four study sites are near schools and public parks, it was critical to monitor $PM_{2.5}$ levels. Students attending schools near the PurpleAir device should be aware of the high levels to protect them from potential respiratory issues. Workouts and practice times can be adjusted or canceled by informing coaches of health risks. According to research on ground-level ozone and particulate matter health impacts, “exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma,” and other respiratory illness (Kristie L.Ebi and Glenn McGregor). These potentially life-threatening risks make it even more important to inform nearby areas. Installing more

PurpleAir devices near schools and outdoor recreational centers can achieve accurate PM levels and protect the health of citizens. In the future, the researchers hope to work with multiple cities around Michigan to bring awareness and understand the causes of PM and ground-level ozone. It would also be more accurate if ozone levels were measured using a more precise device geared toward ground-level ozone.

Submitting GLOBE Data Verification:



Student researcher, Yasmine Ahmad, sits at the computer to submit our data for GLOBE verification.

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Badges:

I Am A Data Scientist: The researchers worked to achieve the "I Am A Data Scientist." During the months of August to October surface temperature, ozone, $PM_{2.5}$, a great deal of atmospheric weather and associated data was collected and analyzed using collection devices such as PurpleAir, PocketLab Air, and WeatherBug.

I Am A STEM Professional: The researchers worked to achieve the "I Am A STEM Professional" badge as we first became interested in air quality (particulate matter and ozone) by our involvement in the GLOBE Air Quality campaign sponsored by a STEM professional, Dr. Margaret Pippen of NASA. The researchers' advisor, Mrs. Diana Johns also shared some of her previous emails with Dr. Pippen that helped guide the direction our research took.

I Make An Impact: The researchers worked to achieve the "I Make An Impact" badge as the main goal behind their research is to inform student athletes, staff, and other local people who work who actively work in outdoor environments. The researchers came to the conclusion that high particulate matter levels and high levels of ozone can have long term effects on the respiratory system. Being aware of this can ensure the safety of both children and adults.