A Longitudinal Study Comparing Select Atmospheric Parameters with Air Pollutant Levels in Southeastern Michigan

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Abstract:

The relationship between various atmospheric parameters and air pollutants is essential for schools that value outdoor activities to understand fully. This research used GLOBE protocols to measure weather parameters such as air temperature, humidity, pressure, and dew point. Researchers compared their GLOBE data with ground-level ozone, particulate matter ($PM_{2.5}$), and Volatile Organic Compounds (VOCs) measured using consumer-grade instruments known as PurpleAir, PocketLab Air, and ATMO Tube. Data collected from each device was compared with data reported by local professional-grade devices when available. This data allowed researchers to assess the accuracy of each device. This research aimed to analyze some of the atmospheric factors contributing to high $PM_{2.5}$ levels. All measurements were taken at or near solar noon to maintain reporting consistency. The data collected and analyzed in this research showed that high $PM_{2.5}$ levels do appear to correlate with high ozone levels and high air temperatures. Researchers found that the PocketLab Air and ATMO Tube had measurements typically below locally reported data, but they constantly varied with professional devices. Reducing the intense, long-term effects of ground-level ozone, particulate matter ($PM_{2.5}$), and Volatile Organic Compounds (VOCs) is crucial for student health and safety during recess and when practicing and performing athletic outdoor-based sporting activities. This longitudinal research extended a project conducted previously to include data taken during two different seasons and years. Air quality data collected at schools is vital as atmospheric conditions can vary considerably on a microscale level.

Key Words: ground-level ozone, particulate matter ($PM_{2.5}$), Volatile Organic Compounds (VOCs), ATMO tube device, EPA ozone

Research Questions:

1. How do $PM_{2.5}$ levels taken from a Pocketlab Air correlate to the measurements of $PM_{2.5}$ taken from a permanently installed PurpleAir device?
2. To what extent does ground-level ozone correlate with $PM_{2.5}$ and VOC levels?
3. How does air temperature affect VOC data collected with the ATMO Tube?
4. How does $PM_{2.5}$ data taken from the ATMO Tube vary with values obtained from the Pocketlab Air device and PurpleAir?
5. How do locally reported ground-level ozone data from the EPA and Pocketlab Air devices vary?

Null Hypothesis:

1. There is no significant correlation between $PM_{2.5}$ data collected from the Pocketlab Air device and data collected from the PurpleAir instrument.
2. There is no significant correlation between the ground-level ozone, $PM_{2.5,}$ and VOCs.
3. There is no significant correlation between VOC data collected from the ATMO tube and air temperature.
4. There is no significant difference between the variety of $PM_{2.5}$ data collected from the ATMO tube, Pocketlab Air, and the PurpleAir instrument.
5. There is no significant correlation between EPA-reported ozone levels and the Pocketlab Air ground-level ozone readings.

Introduction and Review of Literature

Researchers collected atmospheric data daily on the Crestwood High School's band practice field, located in front of Crestwood High School in Dearborn Heights, MI. Multiple students used this location for many activities, such as bands, sports, and clubs. It also borders a road with heavy daily traffic. With more students spending time outdoors during the summer and fall, increasing levels of VOCs, $PM_{2.5}$, and ground-level ozone levels are becoming increasingly alarming (Panyacosit). The tiny particles known as $PM_{2.5}$ are the most dangerous since, when inhaled, they embed themselves deep within the lungs' alveoli, interfering with gas exchange (Yu-Fei Xing). The Summer of 2023 also consisted of multiple Ozone Action Days, where high air temperatures combined with VOCs, particulate matter, and NOx resulted in substantial ground-level ozone levels in the Dearborn Heights community. The researchers could not collect data on nitrogen oxides due to the lack of affordable and available consumer-grade instrumentation. High levels of VOCs were detected, which have become increasingly alarming in the Dearborn Heights community due to local active oil refineries like Marathon Oil. The large number of nearby industrial and manufacturing sites has even resulted in the introduction of a new suite of air quality monitors to Dearborn, Michigan - next to the studied city. Ali Abazeed, the inaugural director of the newly launched Dearborn Department of Public Health, explained that Dearborn is an industrial and car-oriented city, leaving air concerns that other cities may not have (Laster). The work of local agencies was essential in helping the researchers decide what data to collect and to help them frame their findings within local air quality initiatives. It is essential to continue testing at schools because students' lungs are still developing and are, therefore, more likely to be adversely affected by poor air quality. To do so, the researchers utilized their school's PurpleAir device to obtain near professional grade $PM_{2.5}$ data,

which is automatically published online and can inform citizens and students of potentially hazardous air conditions. The data recorded from the PocketLab Air and ATMO Tube were collected even though the researchers realized that this data would likely vary from more sophisticated research-grade instruments. While Dr. Margaret Pippin of NASA Langley indicated that the current GLOBE protocol for ozone and the PocketLab Air is not as accurate as professional equipment, the results mirror trends seen with more sophisticated equipment. With record-high summer temperatures in Michigan, the researchers' study site measured high ground-level ozone readings. Nitrogen oxides (one of the components of ozone development) are released by vehicles or industries and can aggravate respiratory diseases, such as asthma (Cofala et. al).

Similarly, VOCs also lead to the formation of ground-level ozone, especially in the summer months, from gas lighters and lawn mower evaporators. The research study site of Crestwood High School brings in multiple pollutants because of its proximity to roads and industries, such as the Ford Motor Company factories and steel mills. As previously described by Ali Abazeed in his research, air emissions in nearby areas can pick up in the prevailing winds, causing potential health risks to citizens. While ground-level ozone and particulate matter are EPA criteria pollutants, they continue to pose harmful health effects and can lead to dangerous outdoor conditions. VOCs are a primary factor in ozone formation, making it critical to analyze the release of these compounds. According to the Arab American News, over 40% of Americans live in polluted counties, with an unhealthy level of smoke or soot, and the Dearborn-Detroit-Warren area was ranked 13th in air pollution (Jassem).

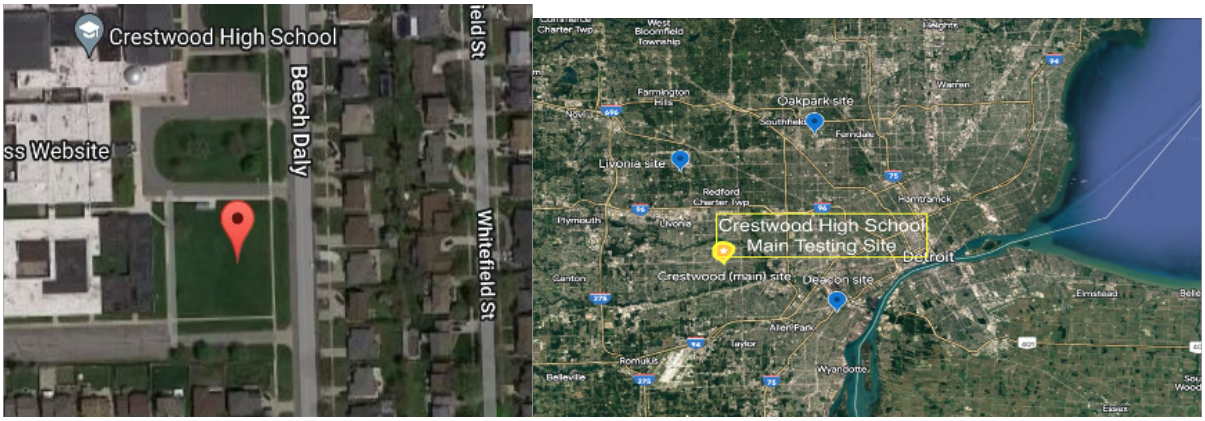


Figure 1 (left) and 2 (right). Site Visualization. The location (on the left) displays the main testing site, Crestwood High School's march band practice field. The next image (on the right) captures the school on a larger-scale map featuring its precise location in Southeast Michigan.

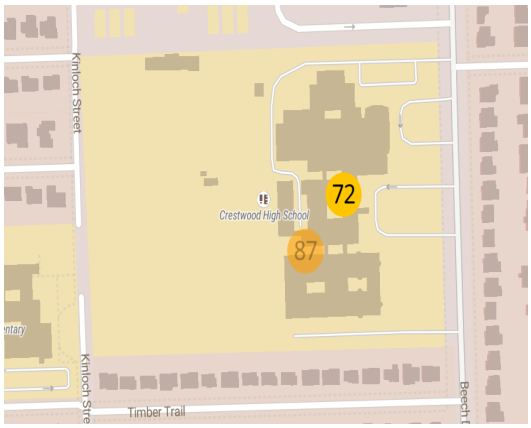


Figure 3: PurpleAir. The PurpleAir website (shown above), depicts the site the researchers used to confirm $PM_{2.5}$ and ozone data were accurate. The map is a visualization of the two device locations located in the courtyards at Crestwood High School. The PurpleAir showing a reading of "87" is currently in need of repair and its values are not being recorded.

Methodology:

The researchers used the Pocketlab, Purple Air, and ATMO Tube from July through late October to measure $PM_{2.5}$, air temperature, VOCs, and ozone. Furthermore, the researchers used WeatherBug to measure wind speed, barometric pressure, dew point, and humidity. The researchers graphed the data here to investigate relationships between the various atmospheric parameters collected. The researchers used the ATMO Tube device by switching on the front

button and holding it up to shoulder length for about 3-5 minutes. At the same time, the data was displayed on the ATMO Tube Pro app, which displayed the $PM_{2.5}$ and VOCs on the associated cell phone. The Pocketlab Air was held up to arms-length to gather information on the ozone and $PM_{2.5}$. The researchers followed this protocol for about 3-5 minutes until the number stopped fluctuating.

Figure 4-6. Pocketlab Air is a device that the researchers used at shoulder length for about 3-5 minutes for 96 consecutive days (first). A researcher held up and then read the ozone and $PM_{2.5}$ off the associated mobile app. After the researcher waited 3-5 minutes, the ozone data (right) stabilized and leveled off.

For each GLOBE parameter measured, the researchers entered the temperature, wind speed, barometric pressure, and humidity on the GLOBE Program- Science data entry.

Figure 7-9. The **ATMO Tube** was operated by a researcher who pressed the front button, holding it upwards. As VOCs and $PM_{2.5}$ were recorded, the researcher then inputted data onto a sheet to keep the information organized (middle). The photo on the right shows how the $PM_{2.5}$ data was rated by the ATMO device, displaying an 8.2 showing that the air was nonhazardous.

Results:

During the seasonal change between summer and fall, the data collected was analyzed and compared with more complex, research-grade instruments to compare accuracy. The $PM_{2.5}$ data collected from the Pocketlab Air device and data collected from the PurpleAir are positively correlated, causing the researchers to reject the null hypothesis. This means the data collected demonstrates that PocketLab Air and PurpleAir are different, but they follow similar trends. The PurpleAir is assumed to be more accurate because it is near the research grade, but the values determined by the PocketLab Air are lower. Furthermore, the null hypothesis of ground-level ozone's correlation to $PM_{2.5}$ and VOCs must also be rejected, as they were shown to be positively correlated. This demonstrates that ground-level ozone, $PM_{2.5}$, and VOCs have identical trends. The relationship between VOC data collected with the ATMO tube and air temperature appears to exist, allowing us to accept the null hypothesis. This means there is no relationship between air temperature and VOC levels. The $PM_{2.5}$ data collected from the handheld ATMO tube and Pocketlab device has shown a positive correlation with the research-grade PurpleAir, again accepting the researchers' null hypothesis. Accepting this null hypothesis means that the $PM_{2.5}$ data, ATMO tube, and PocketLab Air devices all do not show a significant similarity. In contrast, the researchers reject the null hypothesis of a distinct correlation between EPA and PocketLab ground-level ozone, meaning that EPA ozone and PocketLab Air ground-level ozone have similar trends. This conclusion proved the consumer Pocketlab ozone protocol can be compared to the higher-value device used by the AirNow EPA ozone site.

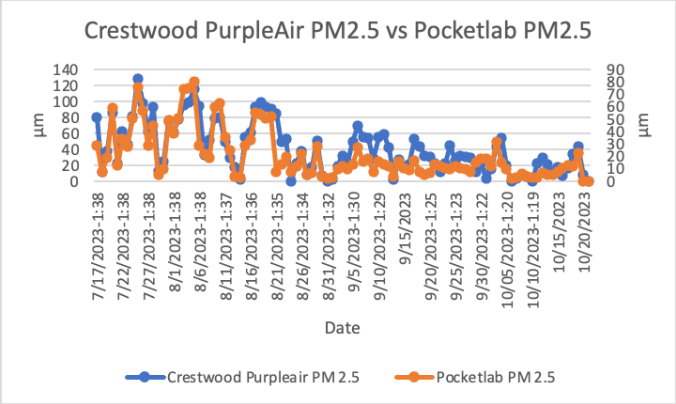


Figure 10. $PM_{2.5}$ data was obtained with Crestwood High School's PurpleAir device vs the Pocketlab device. Data collected from both devices was taken within an hour of solar noon. However, the Pocketlab device is a consumer-grade device held by the researchers, in contrast to the PurpleAir device being placed in a stable environment. Despite this, both devices appear to be positively correlated throughout the four study months.

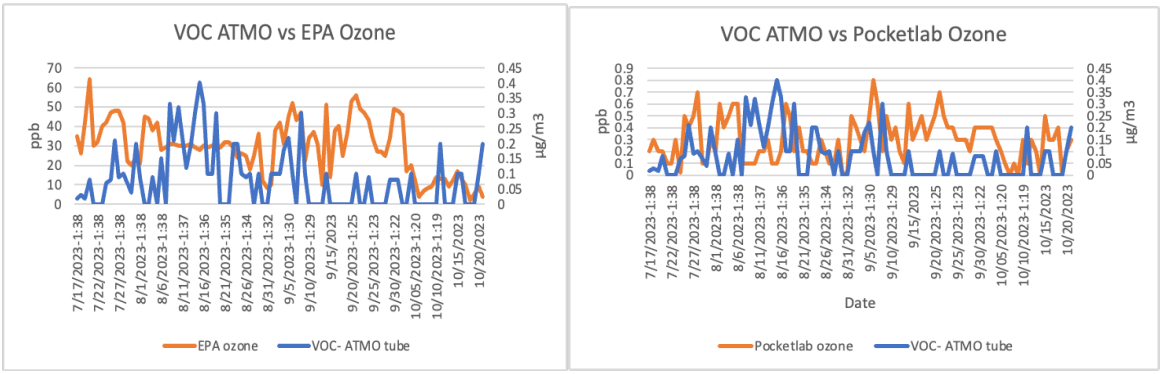


Figure 11-12. VOC ATMO data vs EPA ozone (on the left) and Pocketlab Ozone (on the right). The researchers compared the VOC data from the ATMO device to the EPA ozone reported on the AirNow website. It was found that VOC data, although typically below ozone levels, displayed a strong correlation. The relationship is further displayed to the left, as VOC and Pocketlab ozone are positively correlated. As the number of VOCs in the atmosphere increases, they form with other pollutants, such as nitrogen oxides, to also increase ground-level ozone levels.

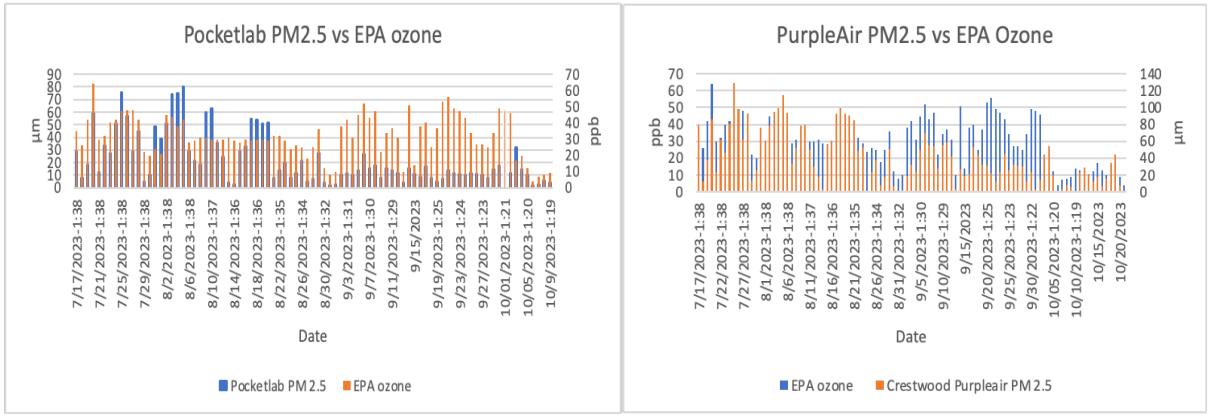


Figure 13-14. Particulate Matter data from PurpleAir and Pocketlab compared to EPA ozone. The researchers used the high-quality PurpleAir data from their school's sensor to monitor the fluctuations of $PM_{2.5}$ over the various months. When comparing this data to EPA ozone, there is a significant correlation. This can also be concluded when comparing AirNow's EPA ozone to the Pocketlab device (on the left).

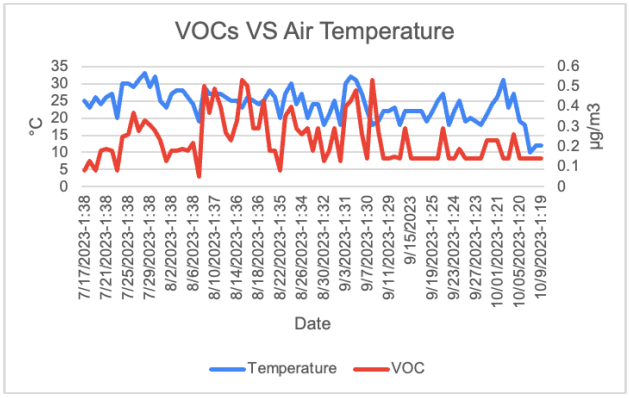


Figure 15. Temperature and VOC levels. Air Temperature recorded from the WeatherBug app in comparison to VOCs throughout the summer to fall months. The researchers used the ATMO tube device to collect VOC data at solar noon. They then compared this to the WeatherBug temperature in Celsius at the same time. The two parameters demonstrated a positive correlation. As the temperature increased throughout the summer months, the number of VOCs also grew as more toxic components of VOC, such as oil and gas, evaporated in the hot air.

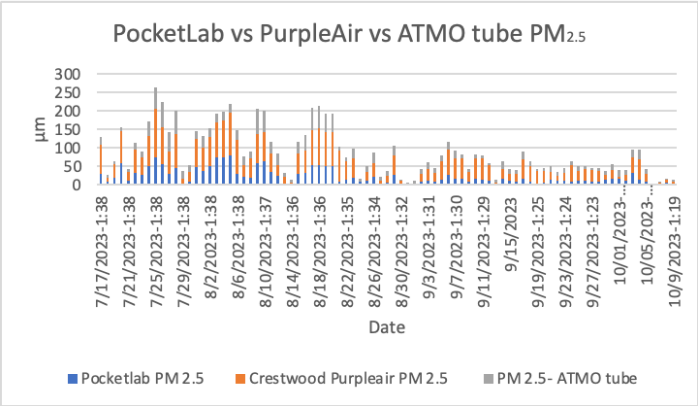


Figure 16. PocketLab, PurpleAir, and ATMO Tube $PM_{2.5}$ data were compared throughout four months at or near solar noon. The three data devices were used simultaneously to compare their accuracy. It was found that as the dates change into different seasons, such as July to October, the $PM_{2.5}$ levels begin to decrease with each device. This is because of the temperature decrease. The positive correlation between PM and temperature can be identified on the bar of each device, despite two being handheld and only the PurpleAir being research-grade. Each device positively correlates with one another as they fluctuate similarly.

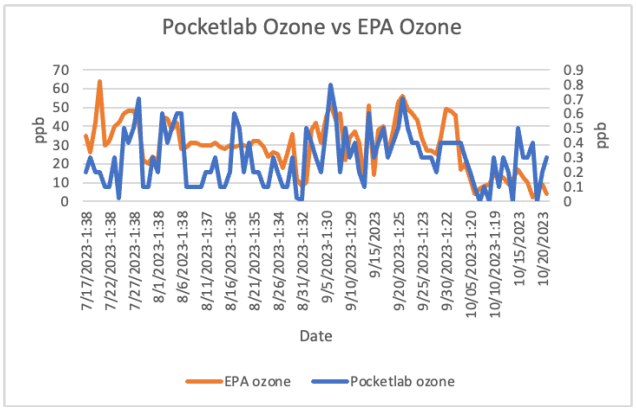


Figure 17. The Pocketlab ozone data compared to the EPA ozone data from the AirNow site. The Pocketlab ozone is a consumer-grade handheld device, as the EPA ozone is an official U.S. protocol. Despite this, the two ozone data sites were significantly similar as they fluctuate throughout the summer and fall. The devices appeared to peak and fall similarly throughout the researched period. Ozone action days in Southeastern Michigan, such as July 27, 2023, proved to have significant ground-level ozone concentration on both the Pocketlab and EPA devices.

Discussion:

$PM_{2.5}$ data from the PurpleAir device and PocketLab Air were closely correlated, but the

PocketLab Air values were always consistently lower than the PurpleAir device by the same

amount. This demonstrates that a more research-grade device like the PurpleAir measures particulate matter values consistently higher and likely more accurately than the handheld PocketLab Air. Also, the data collected indicates that ozone levels are positively correlated with days when the $PM_{2.5}$ levels were higher. The relationship between the two implies that ozone levels depend on weather conditions as they correlate on days with high temperatures and high relative humidity. The summer-long study determined the $PM_{2.5}$ data collected from each device PurpleAir, PocketLab Air, and ATMO Tube were closely related, although each measured somewhat different values. For $PM_{2.5}$ the PurpleAir had the highest readings, with the other two consumer devices each recording lower values. Although the values were inconsistent, the variation with which they deviated from the PurpleAir was always similar. When the researchers analyzed the level of $PM_{2.5}$ from each device and made comparisons of all of them, they concluded that they had similar results. The positively correlated graph comparing all devices indicates that higher air temperatures increase the levels of PM and ozone. These results are likely because higher temperatures worsen air quality by increasing ground-level ozone and $PM_{2.5}$ counts. With the increasing effects of climate change, Crestwood High School was directly affected by the infamous wildfires from Canada during the late spring and summer of 2023. In the researcher's community, there were days when the researchers visibly saw gray air, which caused a sudden change in PM and ozone levels as ozone action days were implemented soon after.

For more precise data, the researchers would like to raise money or write a grant to obtain research-grade, higher-quality equipment. Having better tools will allow researchers to collect more accurate data resulting in more meaningful results. In this investigation, the researchers used an ATMO tube device, which we found was a great tool due to its ability to be easily

transported and clipped onto bags or backpacks. However, it could have been more accurate. The researchers hope to raise money for similar devices so students can track air quality on a more personal level. To get the most accurate results, the researchers collected data from July to October, including the seasonal temperature changes from summer to autumn. One possible source of error in the researchers' investigation is that the ATMO Tube device is a relatively new instrument, and it took some time for the researchers to achieve the best, more precise results from it. Since this is a continuous study, the researchers have experience using the other devices mentioned. Another possible source of error is the unknown time the ozone was picked up on EPA ozone. The website never mentions explicitly that the ozone was taken at solar noon so it may differ from the other devices used. A final variable that may affect the results is that the PurpleAir device is located within one of Crestwood's courtyards. However, the researchers could not access the courtyards as the school was closed in the summer. The researchers measured near the courtyard, known as the band practice field.

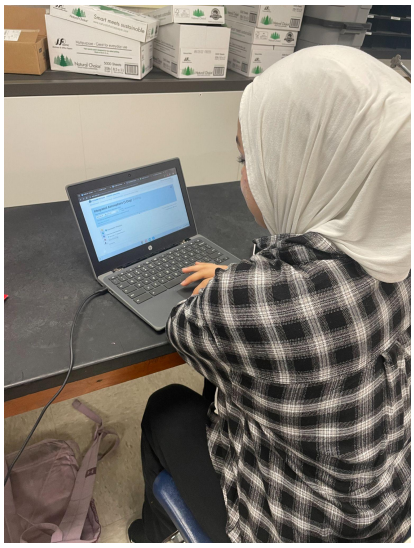
Conclusion:

The researchers concluded that air temperature and VOC levels positively correlate throughout the summer and fall. Despite differences in the measurement of $PM_{2.5}$ devices, the PurpleAir, handheld PocketLab Air, and ATMO tube devices showed significant similarities. The PocketLab and ATMO devices are easily accessible and simple to use, allowing the researchers to gather VOC, $PM_{2.5}$, and ground-level ozone data. These devices allow for a transportable data source that students can use at all times. The PurpleAir device, conversely, is a research-grade device in a stable location, allowing the researchers to compare the three databases for accurate results. Furthermore, the PurpleAir is a sensitive device that can pick up far more microscopic

particles than the handheld devices. Previous emails the researchers' teacher had with Dr. Margaret Pippen allowed the researchers to understand that the PocketLab Air device was consumer-rated and not necessarily research-grade. Despite this, the researchers found a consistent, positively correlated trend of the three particulate matter devices. Ozone Action days reported by the state of Michigan's EGLE's Air Quality Division (AQD) Clean Air Action Day Program matched the Ozone days collected by the Pocketlab Air and EPA ozone devices. However, most days, the Pocketlab ozone seemed lower than the EPA ozone. This data results from the inadequate device design, proving that the Pocketlab may be better utilized for collecting $PM_{2.5}$ rather than ground-level ozone data. The data collected also revealed a positive correlation between VOC and ground-level ozone. The VOCs in sunlight result in the formation of ozone in the sunlight. This also accounted for the VOC rise with higher temperatures. The research location is home to nearby schools, activities, businesses, and parks used by many adults and children throughout the day, making the study essential. $PM_{2.5}$ devices, such as the ATMO tube and Pocketlab device, can quickly warn citizens of threatening pollutant levels. When coaches and athletes are aware of the warnings, they can adjust their practice times throughout the year to accommodate participants' health. The researchers hope to access devices of higher quality, like the PurpleAir, to have the ability to collect substantial ground-level ozone and VOC data to alert their community. In addition, a NOx research grade protocol will allow for more research following ground-level ozone trends. The investigated variables of VOCs, $PM_{2.5}$, and ozone have been stated to cause cardiovascular disease, asthma, and heart attacks and are even some of the Clean Air Act criteria pollutants (Schmalensee). Since 1970, the United States has practiced implementing and reducing these pollutants. It is necessary to study the regulated pollutants and install more PurpleAir devices around Southeastern Michigan to protect citizens'

health. As a result of the GLOBE research conducted this year and last year with Crestwood's PurpleAir instrument, the district was able to write a grant to purchase four more PurpleAir devices to install at each of the other district schools. It will be interesting to see how Particulate Matter varies microscale within the Crestwood School district and how it is compared to other locally and regionally reporting PurpleAir devices.

Submitting GLOBE Data Verification:



Alaa Selman, a student researcher, submitting data for GLOBE verification.

Citations:

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Badges:

I Am A Data Scientist: The researchers worked to pursue the “I Am A Data Scientist” badge, collecting and analyzing a significant amount of atmospheric data, including ground-level ozone, air temperature, $PM_{2.5}$, and VOC, and various other weather-related data, from July to October. This data was gathered through devices such as PocketLab Air, PurpleAir, ATMO Tube, and WeatherBug.

I Make An Impact: The researchers worked to achieve the "I Make An Impact" badge with their primary objective being to inform locals, individuals who work outdoors, and student-athletes who practice outdoors. The researchers concluded that elevated levels of particulate matter, volatile organic compounds, and ozone can have long-term effects on respiratory health. The researchers also used their data to advocate for PurpleAir $PM_{2.5}$ monitors to be installed at their districts' elementary schools. Having these monitors can inform adults and children of hazardous conditions in their community to prevent them from performing lengthy outdoor activities.

I Am A Problem Solver: The researchers used their data, from the summer and fall months of 2022 and 2023 to conclude high levels of threatening $PM_{2.5}$ near their study site and high school, Crestwood High School. Because of how effective the PurpleAir device was in warning school administration of poor air quality during last year's Canadian wildfires, the researchers were able to encourage their community to invest in these instruments for each of Crestwood's other district schools.