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Inequality of Air Quality?: A Study of Air Quality within Housing Price Brackets in Gettysburg, PA

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Abstract

With the rise of cars and other motorized vehicles has come the rise of air pollution, which tends to have disproportionate environmental and health impacts on low-income and communities of color. This study analyzes car presence and air quality on a transect within Gettysburg, PA to determine if there is a relationship between air pollution and vehicle presence, and if there is a difference in air quality between higher price bracket housing compared to campus, commercial, and lower price bracket housing. To test our research questions, we identified nine sampling locations along a transect where we measured air pollutants, including particulate matter (2.5 um and 10 um), VOCs, and NO2, with Flow by Plume Labs and Atmotube Pro air quality monitors. Our hypotheses that car activity will increase the amount of air pollution in Gettysburg and that there will be a greater environmental justice disparity within lower housing price brackets were not supported. The air quality along the transect was not greatly affected by vehicle presence and was consistent with regional conditions, and while measurements of different pollutants changed with location, there was not one clear trend between these two variables. However, there were consistently higher levels of vehicle traffic in the commercial and low-income areas than in the high-income and campus areas. The main limitations of our study were the lack of functionality and accuracy of our air monitors, which reduced the sample size of our data. These results provide room for further study of racial and child health disparities caused by cars and air pollution, as well as the impact of higher traffic levels on the risk of car and pedestrian accidents.

Keywords

air quality, air pollution, transportation, environmental justice, socioeconomic status

Disciplines

Environmental Health | Environmental Indicators and Impact Assessment | Environmental Sciences

Comments

Written for ES 400: The Automobile and its Effects on Environment and Culture.

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December 12, 2023

I affirm that I have upheld the highest principles of honesty and integrity in my academic work and have not witnessed a violation of the Honor Code. We have not used AI for this project.

Arden H. Dowd Alexis Jones Jess Schaefer

ABSTRACT:

With the rise of cars and other motorized vehicles has come the rise of air pollution, which tends to have disproportionate environmental and health impacts on low-income and communities of color. This study analyzes car presence and air quality on a transect within Gettysburg, PA to determine if there is a relationship between air pollution and vehicle presence, and if there is a difference in air quality between higher price bracket housing compared to campus, commercial, and lower price bracket housing. To test our research questions, we identified nine sampling locations along a transect where we measured air pollutants, including particulate matter (2.5 um and 10 um), VOCs, and NO_2, with Flow by Plume Labs and Atmotube Pro air quality monitors. Our hypotheses that car activity will increase the amount of air pollution in Gettysburg and that there will be a greater environmental justice disparity within lower housing price brackets were not supported. The air quality along the transect was not greatly affected by vehicle presence and was consistent with regional conditions, and while measurements of different pollutants changed with location, there was not one clear trend between these two variables. However, there were consistently higher levels of vehicle traffic in the commercial and low-income areas than in the high-income and campus areas. The main limitations of our study were the lack of functionality and accuracy of our air monitors, which reduced the sample size of our data. These results provide room for further study of racial and child health disparities caused by cars and air pollution, as well as the impact of higher traffic levels on the risk of car and pedestrian accidents.

INTRODUCTION:

Significance and Rationale

In the 21st century, over 1 billion cars have been manufactured, and with the increase of cars on the roads comes an increase in pollutants such as particulate matter (pm) pollution, nitrogen dioxide (NO_2), and the formation of ozone as well as an increase in health issues caused by these pollutants (Johansson et al., 2017) (Jarvis et al., 2010). Particulate matter pollution, as defined by the EPA, is “a mixture of solid particles and liquid droplets” in the air (USA, 2023). Particulate matter can be emitted directly from a given source, such as construction sites, fires, or unpaved roads (USA, 2023). Most pm is formed in the atmosphere through chemical reactions between elements and compounds released from sources like power plants and cars, including sulfur, nitrogen oxides, and carbon (USA, 2023).

NO_2 is formed through combustion reactions and, similarly to pm, can be emitted from traffic emissions and burning fuel. It is a highly reactive chemical and can be used as an indicator for other nitrogen oxides, (EPA, 2023) (Jarvis et al., 2010). NO_2 is the most commonly occurring oxide in the atmosphere, and when these oxides interact with each other, they promote the creation of ozone (Erickson et al., 2020). Ozone is not emitted by cars, but its formation can occur rapidly, as it is formed by the interaction of volatile organic compounds (VOCs), nitrogen oxides, and solar radiation (Erikson et al., 2020). Ozone is the cause of over 8 million hospitalizations and 400,000 premature deaths in the US annually. Furthermore, Ozone is linked to a reduction in photosynthetic productivity and general plant health (Erickson et al., 2020).

Both pm and NO_2 have the potential to be detrimental to environmental and human health. Particulate matter can alter fresh bodies of water and make them acidic, change nutrient balances in water bodies and soil, and ultimately alter biodiversity and ecosystem health. (USA, 2023). NO_2 has been shown to dramatically decrease plant productivity in a range of vegetation types from forests to croplands, along with indirect impacts through associated ozone formation (California, 2023) (Lobell et al., 2022).

In regard to human health, small particulates, especially particles under 10 um, may pass from the lungs into the bloodstream (USA, 2023). Resulting human health complications can include heart attacks, premature deaths, and worsened lung function. Exposure to NO_2 also leads to a variety of health issues including asthma, increased sensitivity to allergens, and similarly to pm, can lead to premature death and heart issues (California, 2023).

Previous studies that demonstrated the effects of pm on the temperature and health of urban areas have focused mainly on larger particulate pollution (Kittelson et al., 2003). We will be focusing on car emissions, meaning we are looking at molecules ranging from 35 to 65 nm, compared to larger, more often studied particulate pollutants of 10um (Yang et al., 2020). NO_2 has been studied in depth in regard to its health effects at one-hour exposure times while our study aims to examine NO_2 levels across a variety of locations over time (California, 2023).

As established in the EPA analysis and previous literature reviews, air pollutants are dangerous to human and environmental health. Although air pollutants do not purposefully discriminate, humans tend to discriminate through structural racism, causing pockets of higher-density pollutants in low-income and communities of color (Bramble et al., 2023). Low-income and communities of color are chosen as the neighborhoods to place polluting power plants, major highways, waste facilities, and other hazardous waste sites that harm human health. The placement of these sites is purposeful as these communities are less likely to be able to fight back against large polluting corporations due to a lack of time, economic, political, and social resources. However, this is extremely dangerous as poor air quality is more detrimental to socially vulnerable communities who are less likely to be able to cope, adapt, and resist (Shrestha et al., 2016).

Due to past discriminatory housing policies, low-income families tend to face greater impacts of unsafe environmental conditions compared to high-income families. The Home Owners' Loan Corporation (HOLC) mortgage evaluations in the 1950s led to low-income and communities of color being purposefully labeled as high-risk and denied loans, resulting in housing and economic decline of these neighborhoods (Mitchell & Franco, 2018). HOLC policy led to redlining and destruction of communities through highways, which resulted in dangerous air pollutants and health hazards correlating with low housing incomes (Popovich et al., 2021). Communities with household incomes lower than $20k, racial minorities, and neighborhoods with the lowest rating of D on the redlining scale had the largest pollutant concentrations and disparities (Bramble et al., 2023). Children are among the most vulnerable in these populations, as their bodies are more susceptible to short and long-term health damage due to their age and biological differences (Grineski & Collins, 2019). Children with parents who fall into the category of low-income and racial minorities face greater contaminants and dangerous health effects from air pollution due to their homes and schools being in hot-spot neighborhoods (Grineski & Collins, 2019). Hot spots are areas with high cumulative environmental burdens and high social vulnerability. They are especially dangerous, as exposure is not limited to one type of contaminant. Low-income housing and affordable housing programs are more likely to be in hot spots and have higher levels of industrial pollution (Goplerud et al., 2022).

Statement of Purpose, Research Questions, and Objectives

We wish to understand how much air pollution in Gettysburg is caused by cars compared to regional conditions. We will have a dual focus on levels of pollutants in various locations around Gettysburg, PA, and the impact of this pollution on residents of varying housing categories within the Gettysburg community. It is crucial to evaluate the health and environmental justice implications of air pollution on low-income and minority communities. These issues are particularly relevant in Gettysburg, PA because the area has a high number of cars and roads due to its rural location, spread-out configuration, and lack of reliable public transportation. Therefore, our research questions are: How much air pollution, specifically levels of pm, VOCs, and NO_2 in Gettysburg is caused by cars compared to regional conditions? And, does this air pollution have disproportionate effects on low-income areas compared to other housing areas in Gettysburg?

We hypothesize that car activity will increase the amount of air pollution in Gettysburg. A previous study found that during quick accelerations, vehicles that use gasoline emit more exhaust particles than during steady movement (Kittelson et al., 2003). Another study shows that car drivers' exposure to pm increases during peak traffic hours, exposing them to higher levels of car exhaust (Abbass et al., 2020).

As for exploring disproportionate effects on various income levels, we hypothesize that there will be a greater environmental justice disparity within lower housing price brackets versus higher price brackets. A past study concluded that areas with a median household income of less than $20,000 have a 40% higher concentration of ultrafine particles than the national average, while areas with a median household income of over $110,000 have a 16% lower concentration of ultrafine particles than the national average (Bramble et al., 2023). We believe that these trends are likely to continue in Gettysburg.

METHODS:

Study Area

To explore these questions, we sampled along a transect of Gettysburg borough based on the housing price bracket (Figure 1). Our transect began along Washington Street, starting at the intersection with Broadway Street and ending at Breckenridge Street (Figure 2). We chose Washington Street as our transect based on its range of housing types and price brackets, and we selected 9 intersections along it as our sampling locations. The homes on W Broadway have the highest cost, typically $450,000 and above according to Zillow (*Gettysburg PA Recently Sold Homes*, n.d.). The next four intersections are on the Gettysburg College campus, but the fourth and fifth intersections also include some residential houses. The sixth location, on the intersection with Chambersburg Street, is primarily commercial. The final three locations are in either mixed-use or completely residential areas. The average housing prices at these intersections are $350,000 and lower and represent the lower-income category (*Gettysburg PA Recently Sold Homes*, n.d.). As the intersections are farther from Chambersburg Street, the quality of the homes generally decreases, with the lowest housing price bracket at Breckenridge St. (*Gettysburg PA Recently Sold Homes*, n.d.).

Data Collection

We collected air quality data with two Flow air quality sensors by Plume Lab and one Atmotube Pro sensor. The sensors are simplified for general public use and connect to smart devices via Bluetooth to describe what airborne particles and compounds are present and in what quantities through an app. They detect both indoor and outdoor air quality and were made to help people track the air quality around them. The Flow sensors detect NO_2, volatile organic compounds (VOCs) such as ozone in parts per billion (ppb), and particulate matter at 1, < 2.5, and 2.5 - 10 ug/m^3. The Atmotube Pro measures the same pollutants except NO_2. Each brand of sensor rated pollutants according to its air quality index (AQI). Although the numbers each brand used for AQI values varied, they were split into similar overarching categories that we could compare. These categories corresponded to health effects associated with exposure to the amount of pollution detected. In a test run of the sensor, it takes around 60 seconds to detect changes in air quality. Then, it organizes the data into a graph with each pollutant's AQI rating by time of measurement, and finally, it assigns a hazard value (Low, Fair, Moderate, High, Very High, Hazardous).

For five weeks from October 3rd to November 3rd, we took samples at each of the 9 selected intersections at 4pm on Tuesdays and Fridays, resulting in 10 samples from each location and 90 samples total. We chose this collection time because the areas are likely to have more vehicle traffic due to rush hour. We used regional air quality levels from the EPA's AQI as a baseline to compare the detected pollutants in given areas (*Interactive Map of Air Quality*, n.d.).

In addition to air quality, we recorded temperature, weather, and traffic levels. Temperature and weather could potentially affect levels of air pollution, so it was useful to consult data during analysis. We used weather data from the Apple Weather App using data from Apple-specific collection and forecasts (*Feature availability and data sources in the Weather app*, n.d.). At the beginning of the data collection period, we found humidity, cloud cover (no cloud cover, minimal cover, medium cover, full cover), and precipitation over the past 24 hours. Traffic data provides context for the air quality readings and whether they are affected by car activity. We calculated the amount of traffic per sample location by tracking the number of vehicles that passed through each intersection within the four minutes we were there and calculating the average per minute.

Analysis

To answer our first research question of how much atmospheric pm, NO_2 and VOCs in Gettysburg are caused by cars compared to regional conditions, we compiled the Flow and Atmotube Pro sensor data into an Excel spreadsheet. Using the sum, average, and maximum Excel functions, we created total pollutant levels per day and averaged the levels from all 10 sampling days as collected from the sensors. After finding these values for each location, we compiled the pollutant level, traffic, temperature, and weather data from each location in a shared spreadsheet. With this data, we made figures and examined whether there were patterns within the data we collected and how it compared to regional AQI. We utilized an online database on AQI data called Air Now. Air Now is associated with the EPA and contains an archive of regional past AQI data, which we used for our comparison (*Interactive Map of Air Quality*, n.d.).

To answer our second research question about the impacts of this pollution on low-income areas within the Gettysburg community, we compared the measured AQI categories across each of the four housing categories: high-income, campus, commercial, and low-income. From these results, we can conclude whether there are air pollutant differences based on socioeconomic trends in Gettysburg.

RESULTS:

AQI Trends

Both Flow and Atmotube AQI ratings remained constant along our transect and did not differ between streets regardless of the housing bracket (Table 1) (Figure 2) and regardless of traffic level (Figure 4). The commercial bracket had the highest average of cars per sample at 84.4 and had the same AQI ratings as every other price bracket (Figure 4). AQI did change over the sampling days with the Flow monitor data whereas the Atmotube AQI readings remained the same, matching the regional AQI at "Low" as seen in Figure 3.

Flow Monitor Data

According to the Flow monitors, the lowest measures of pm 10 and 2.5 were found at the commercial intersection which also recorded the highest levels of traffic (Figure 5) (Figure 6). Furthermore, the Flow monitors measured mostly stable levels of NO_2 and VOCs, with high levels of VOCs in the high-income intersection as seen in Figure 7, and a spike in NO_2 levels in the commercial intersection as seen in Figure 8 .

Atmotube Monitor Data

When looking at the Atmotube pollutant trends, pm 10 levels stay very consistent through the different price brackets (Figure 5). Particulate matter 2.5 levels have an increasing trend from high-income to campus, commercial, and low-income price brackets as seen in Figure 6. Inversely, Figure 7 demonstrates a high level of VOCs in high-income intersections when compared to campus, commercial, and low-income bracket intersections, with a slight uptick in detected VOCs in the low-income intersections when compared to the commercial intersection.

Comparing Monitors

The Flow monitors and Atmotube monitors collected pm 10 and pm 2.5. When the data for pm 2.5 from each monitor was compared with the average observed vehicles, the Atmotube had a higher overall average with each point falling above its respective Flow measurement (Figure 9). The inverse was true for the pm 10 comparison of the two air monitors and the average observed vehicles, with the Flow monitor measuring higher pm 10 levels at every point, with two close points at 84.4 average vehicles (Figure 10).

DISCUSSION:

Interpretation of Results

Based on our results, we did not find a clear relationship between vehicle traffic and air pollution nor a constant trend between housing category and amount of pollution. The overall AQI from the Atmotube Pro and the regional AQI were in the least-polluted category consistently. The overall Flow AQI varied day-to-day and recorded seemingly random spikes in pollution that did not clearly correlate with outdoor conditions or with the other Flow monitor recording data at the same time. AQI is based on the greatest value recorded per pollutant, so these spikes in pollution made the overall Flow AQI value much higher than the majority of the pollutant levels recorded. Therefore, we decided not to include the Flow AQI when determining a relationship between overall AQI regionally and locally. We were not yet using the Atmotube Pro during the first three days of data collection, so we cannot confidently determine whether vehicle traffic affected overall air quality in Gettysburg. The consistent readings between the Atmotube Pro and regional conditions show that there is not a strong relationship between vehicle traffic and air pollution in Gettysburg within the scope of our study.

As for our second research question, we found no consistent trend between housing category and air pollution. While there is a variance between the average amount of each type of pollution and housing category, there were no patterns constant enough to determine a clear relationship between the two. The Atmotube Pro's pm 2.5 measurements, exhibited a gradual increase from high income to campus to commercial to low income. Conversely, as seen in the VOC measurements from both instruments, the opposite pattern occurs: the pollutant levels are highest in the high-income bracket, decrease in the campus bracket, and are lowest in commercial and low-income. As these patterns do not seem to have a consistent trend, we cannot conclude that there are disproportionate effects of air pollution on areas of lower socioeconomic status. There were consistently higher levels of vehicle traffic in the commercial and low-income areas than in the high-income and campus areas. As a result, lower-income areas may face other environmental justice effects caused by higher traffic levels.

Due to the continued inconsistencies and lack of functionality with our air monitor readings, we find that our results are likely impacted by instrumental error. There may still be a relationship between pollutant levels, traffic, and socioeconomic status, but we did not find data within the confines of our study to support any clear trends. However, our study did show a higher presence of vehicles in commercial and lower housing price brackets, which could lead to different types of environmental justice issues in these areas, such as increased traffic accidents, noise pollution, and reduced pedestrian safety.

Results in Relation to Other Studies

Concerning socio-economic factors regarding air pollution, Shrestha et al. found in their study that there was a limited degree of inequality among those with higher social vulnerability with 95% confidence intervals when considering environmental factors including NO_2, pm 10, and benefits and burdens associated with proximity to green spaces and lack thereof respectively (2016). These findings align with our study as we found differences in transportation levels between low and high-value property areas, although, there was a limited degree of inequality found by the study.

Our results found that there were higher traffic levels in commercial intersections and low-price bracket housing. Previous research has been consistent in finding that a higher presence of automobiles increases air pollution (California, 2023). Although our study did not find a relationship between pollution levels and vehicle presence, it is reasonable to assume that Gettysburg follows the same patterns as found in prior studies. Specific to residential area pollution, Bramble et al. found median household incomes of less than $20k had the largest pollutant concentrations and disparities, with concentrations 40% higher than the average. Neighborhoods with household incomes greater than $110k had ultrafine particle [UFP] concentrations 16% lower than the region average found in the study (2023). Another study focused on low-income housing tax credit (LIHTC) properties and found that pollution levels in LIHTC properties were found to be 10% higher compared to neighborhoods without LIHTCs (Goplerud et al., 2022). This is consistent with our studies' high and low breakdowns of over $450k and below $350k respectively whereas in our lower residential breakdowns, we found a higher concentration of automobiles.

Limitations

The largest limitation of our study was the functionality of our air monitors. Our study began using three Flow air quality sensors by Plume Labs. After the first day of data collection, we found that one of the air quality monitor readings was highly inconsistent compared to the other two Flow monitors, leading us to believe it was broken or dysfunctional. We submitted a request to the department for a new air monitor, resulting in three sampling days of missing data for one of our monitor readings**.** Although the two Flow sensors we continued to use seemed more accurate, studies on the Flow monitors and customer reviews agree that this sensor is not entirely reliable. A study by the South Coast Air Quality Management District found no to weak correlations between Flow monitors measuring NO_2, pm 2.5, and pm 10 and reference instruments measuring the same pollutants. The correlations were especially weak for measurements taken after 5 minutes, suggesting that our measurements from a period of 4 minutes also may not be reliable (*Field Evaluation Plume Labs Flow 2*, 2020). Additionally, consumer reviews frequently report inaccurate readings and large spikes in pollutant levels that quickly drop back to previous levels (*Customer Reviews: Plume Labs Flow 2*, n.d.).

An Atmotube Pro monitor replaced the faulty Flow monitor, and although the Atmotube Pro appeared to be more accurate, having different monitors reduced the comparability of our data. The South Coast Air Quality Management District performed a similar study on Atmotube Pro air monitors as it did on Flow air monitors. The Atmotube Pro monitors do not collect NO_2 data, so the study was not fully consistent with the study on the Flow monitors. This study found a strong correlation between the Atmotube Pro's pm 2.5 readings and the pm 2.5 readings of the reference instruments and a very weak correlation between the Atmotube Pro's pm 10 readings and the pm 10 readings of the reference instruments (*Field Evaluation Atmotube Pro*, 2020). These results suggest that the Atmotube Pro is reliable when measuring pm 2.5. The lack of reliability for pm 10 measurements was still stronger than the Flow monitor's rating (*Field Evaluation Plume Labs Flow 2*, 2020). Consumer reviews of the Atmotube Pro reflect the study results, with generally positive reviews. Negative reviews included some reports of inaccurate readings, but less frequently than reviews of the Flow (*Customer Reviews: Atmotube Battery Powered Pro*, n.d.).

All three monitors also had some issues exporting data into spreadsheets. In several separate instances, there was a range of minutes missing from the data we exported from the monitors' apps, which was supposed to report air quality measurements per minute. We had to report as n/a in our datasheet. There was not enough missing data to null our results completely, but the missing data likely affected our averages and the overall consistency in our data projections.

The exported Flow data did not record AQI, so all Flow AQI data had to be calculated by hand. As previously mentioned, the Flow AQI values were not taken into account due to inaccurate readings from the instruments. The regional database we used to measure AQI, the Flow monitor, and the Atmotube Pro monitor all used different number ranges to represent AQI, which made it difficult to compare and interpret the AQI scores. The database, Flow AQI, and Atmotube Pro AQI all categorized their numerical scores based on health effects associated with exposure to specific amounts of air pollutants. The descriptions of each of the categories were similar and thus comparable across the three AQI systems. However, the numeric values would have been a more accurate representation of AQI, and the categorical organization of the data may have resulted in generalizations.

Furthermore, we were limited in the amount of time we had to collect data. We collected data twice a week for 5 weeks, but each collection day lasted slightly over an hour because that was the only time commonly available amongst all three of us. The data collected from our study does not pull from a large enough sample size to make clear conclusions. Also, because of the time limit and trying to gather the most amount of data in a small window, we had to redesign and reduce the range of our transect. As a result, our transect only accounted for a small variation in housing prices and did not include diverse racial demographics, which reduced our environmental justice evaluation.

Future Research

Collecting data on racially diverse areas can be difficult due to the limited racial diversity in Gettysburg, but there are still pockets of diversity that could be purposefully selected for future research. A continuation of our study could focus on these pockets, specifically African American, Latinx, and Asian demographic groups. An environmental justice evaluation could be made to compare air pollution levels in racially diverse neighborhoods to see if they face disproportionate pollution levels.

Another vulnerable population that these research questions could focus on is children. An initial idea for our study was to monitor air pollution at a local elementary school. To evaluate the impact of transportation on this population, air pollution data could be collected in the pick-up and drop-off areas which tend to have high numbers of idling cars. Apart from idling cars being a concern for the general air quality, these pick-up and drop-off areas may be close to school playgrounds, which would increase the risk of developing health issues due to the student's young age and developing brains.

Though our hypothesis that car activity will increase the amount of air pollution in Gettysburg and that there will be a greater environmental justice disparity within lower housing price brackets was not supported, our study demonstrates the higher presence of cars in commercial and low-price bracket housing areas. Therefore, future research could evaluate the disproportionate effects of higher traffic levels in low-income areas, such as increased traffic accidents, increased noise pollution, and reduced pedestrian safety.

REFERENCES

Tables, Figures, and Appendices:

Tables and figures:

Table 1. AQI classifications by Flow and Atmotube air monitors by street and price bracket

Location	Price Bracket	Flow AQI	Atmotube AQI
Broadway	High	Moderate	Good
Pizza House	Campus	Moderate	Good
Stevens Street	Campus	Moderate	Good
Water Street	Campus	Moderate	Good
Constitution	Campus	Moderate	Good
Chambersburg	Commercial	Moderate	Good
Middle Street	Low	Moderate	Good
High Street	Low	Moderate	Good
Breckenridge	Low	Moderate	Good

Figure 1. Locator map of the study area with a red pin representing Gettysburg, PA.

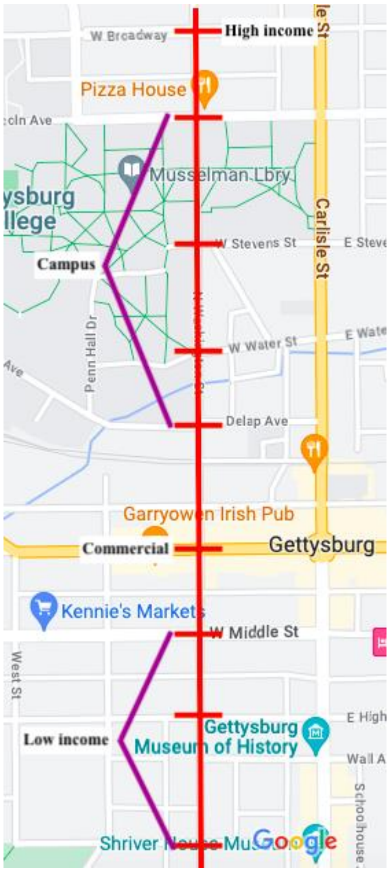

Figure 2. Map of Washington Street transect with collection intersections and housing categories labeled.

Figure 3. Overall AQI levels from the Flow and Atmotube air quality monitors compared to regional AQI levels for each day of data collection. Categories 1-6 represent the categorization of AQI scores based on health risks from exposure to that amount of air pollution. Beginning with 1, the categories are titled low, fair, moderate, high, very high, and hazardous.

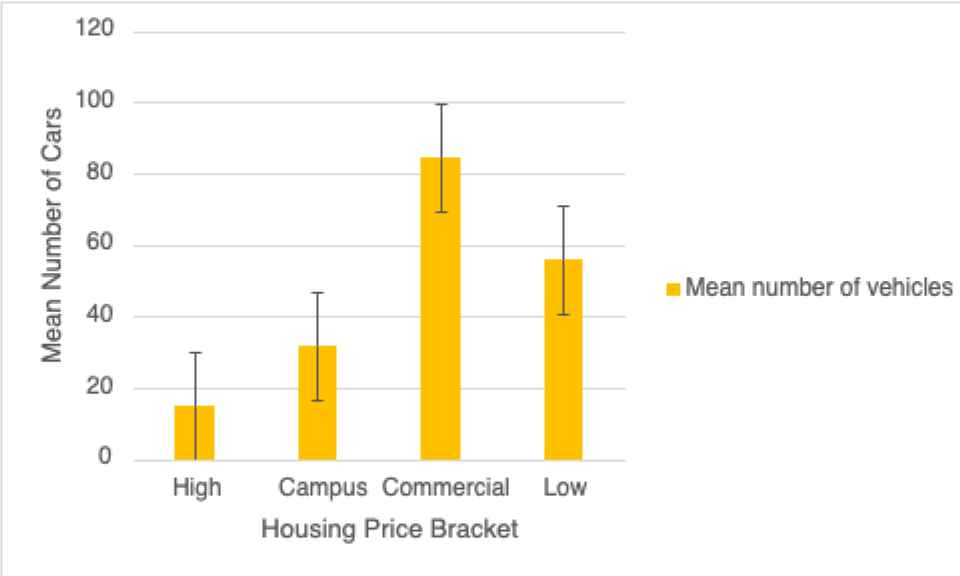

Figure 4. The average number of vehicles based on average per minute by housing price bracket (high price, campus, commercial, low price).

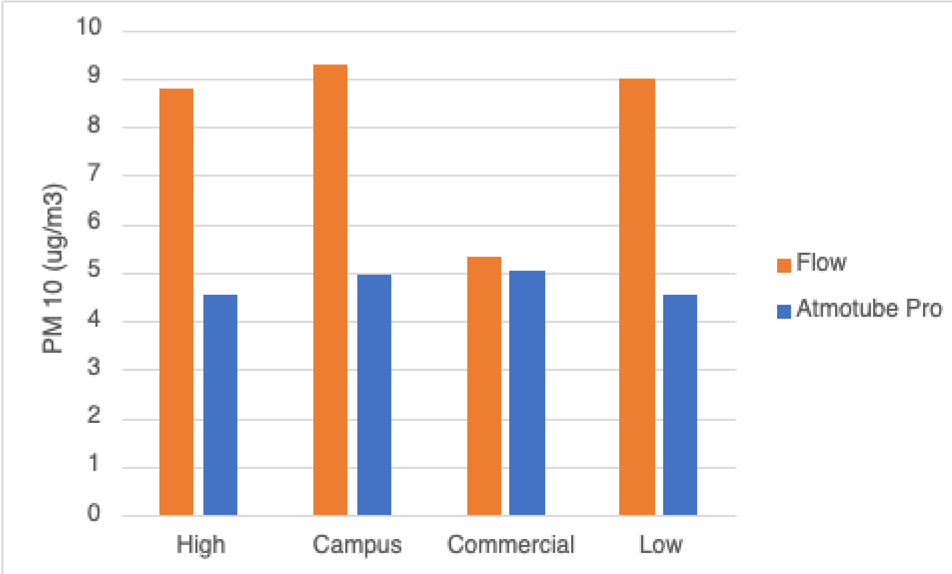

Figure 5. Average pm 10 air pollution levels by price bracket along our Gettysburg transect using Plume and Atmotube Pro air quality monitors

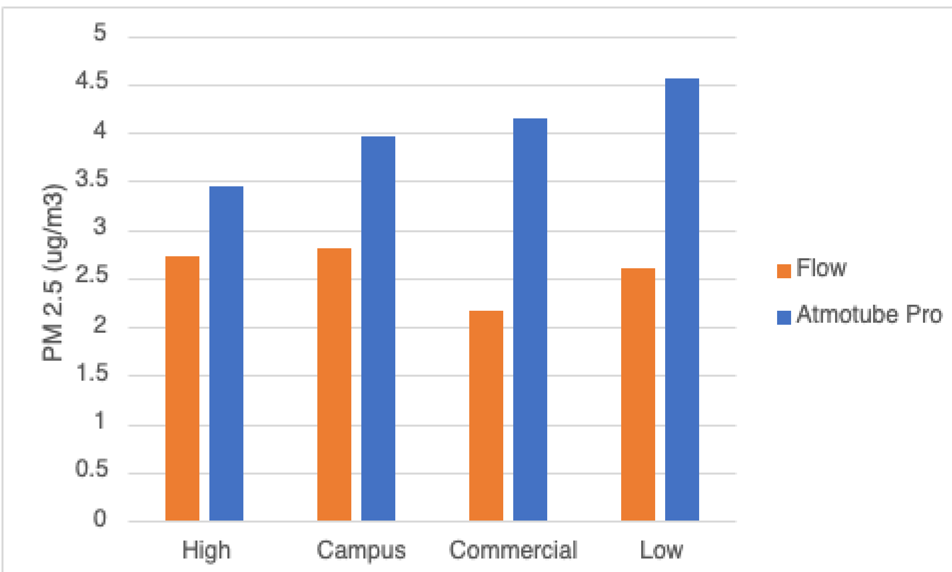

Figure 6. Average pm 2.5 air pollution levels by price bracket along our Gettysburg transect using Plume and Atmotube Pro air quality monitor.

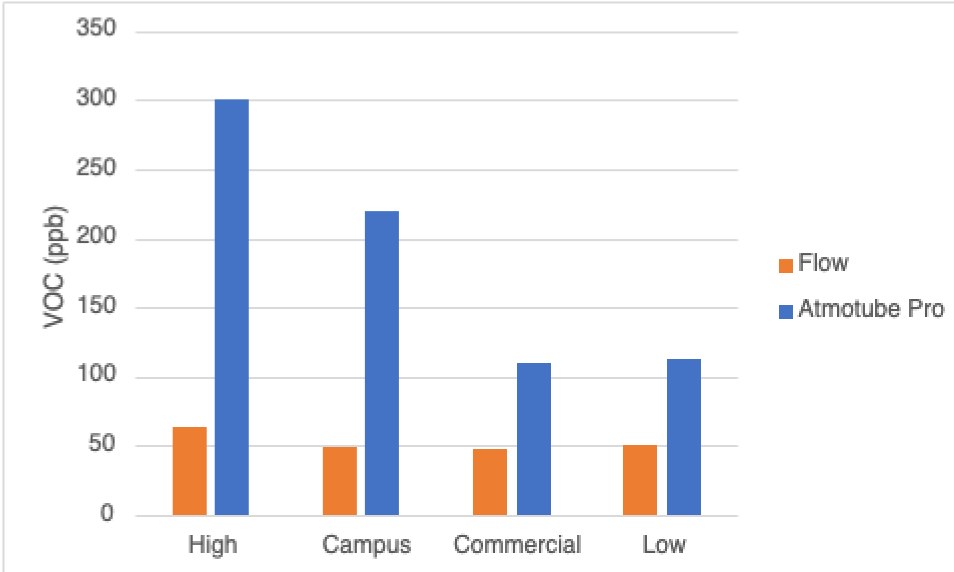

Figure 7. Average VOC air pollution levels by price bracket along our Gettysburg transect using Flow and Atmotube Pro air quality monitors

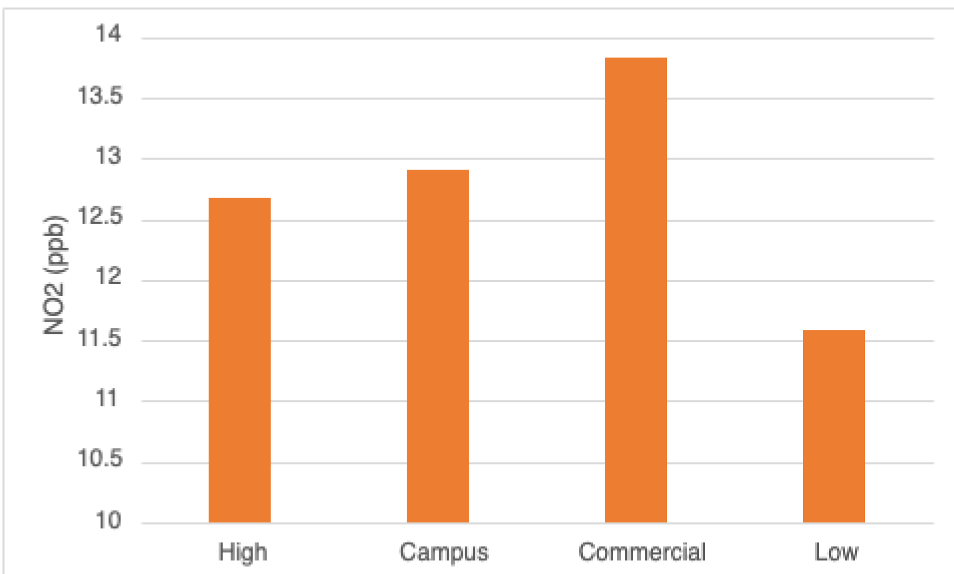

Figure 8. Average NO_2 air pollution levels by price bracket along our Gettysburg transect using the Flow air quality monitor.

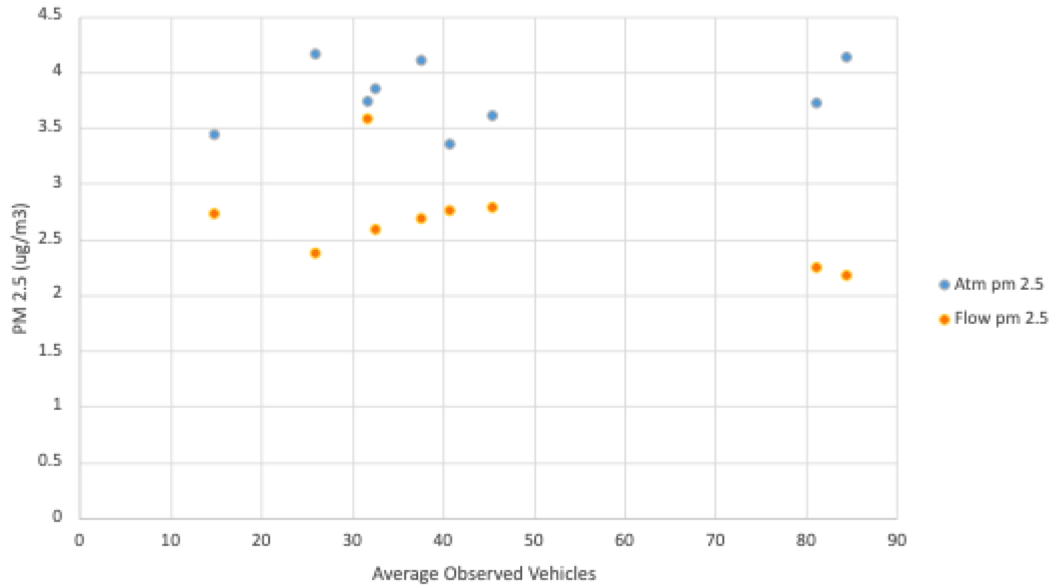

Figure 9. Scatter plot of pm 2.5 (particulate matter) in ug/m3 by the Atmotube Air Monitor and the Flow Air Monitor by the average number of observed vehicles.

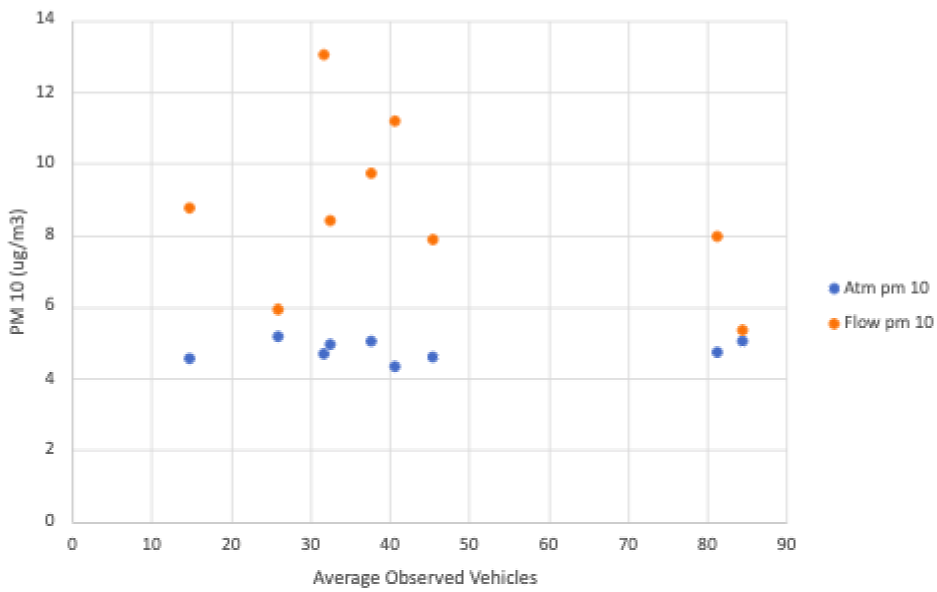

Figure 10. Scatter plot of pm 10 (particulate matter) in ug/m3 by the Atmotube Air Monitor and the Flow Air Monitor by the average number of observed vehicles.

Appendices:

Instrument

Location

- Transect through Gettysburg Borough along Washington Street
- Begin at the intersection of Washington St. and W Broadway
- Take measurements at specified intersections
- Take last measurement at the intersection of Washington St. and Breckenridge St.

Micro-location/setting up the monitor

1. Turn on Flow sensor and wait 10 minutes for the monitor to acclimate, Turn on Atmotube sensor which is ready immediately
2. Set the sensor up on the sidewalk along the intersection
3. Wait 4 minutes for the sensor to complete the air quality reading

Recording

1. We will be recording variables that may have an effect on air quality in the area in chart format:

Week#	Day #	Weather	Temp. (C)	Cloud cover	Humidity (%)	Rain recently?	Traffic levels (cars per minute)
1	1	Breeze, sunny	29	minimal	56%	This morning Yest. afternoon	3 cars avg (low)
	2						
2	1						
	2						

2. We will record the time we started collecting data

Week#	Day #	Location	Time (24:00hr)
1	1	a	12:00 - 12:07
		b	12:09 - 12:15
		…etc	…

3. Transfer the data into a usable format

timestamp	date (UTC)	NO2 (ppb)	VOC (ppb)	pm 10 (ug/m3)	pm 2.5 (ug/m3)	NO2 (Plume AQI)	VOC (Plume AQI)	pm 10 (Plume AQI)	pm 2.5 (Plume AQI)	pm 1 (ug/m3)	pm 1 (Plume AQI)
1695744517	2023-09-26 16:08:37	0	134	3	2	0	11	3	4	1	3
1695744577	2023-09-26 16:09:37	0	117	3	2	0	9	3	4	1	3
1695744637	2023-09-26 16:10:37	0	107	3	2	0	9	3	4	1	3
1695744697	2023-09-26 16:11:37	0	102	3	2	0	8	3	4	1	3
1695744757	2023-09-26 16:12:37	0	95	3	2	0	8	3	4	1	3
1695744817	2023-09-26 16:13:37	0	93	3	2	0	7	3	4	1	3
1695744877	2023-09-26 16:14:37	0	92	3	2	0	7	3	4	1	3

   a. The app shows the potential pollutants, and they are accessed by scrolling through an automatically generated graph on the phone connected to the device used.
   b. The data can be exported and opened in numbers where it is given the above format
   c. We will then transfer the data into Excel where we will work with the data

Changing sites

1. Record the time data was stopped being collected
2. Go to the next location
3. Record the time data started to be collected at the next location
4. Repeat the data entry process

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