Lower Eastern Shore Air Quality Monitoring Project

April 2020 – March 2021

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Executive Summary

Through the collective efforts of the Maryland Department of the Environment (Department or MDE), the Keith Campbell Foundation for the Environment, and the Delmarva Chicken Association, an air monitoring project was undertaken on Maryland's Lower Eastern Shore to collect data on ambient air quality to learn more about how air quality near poultry houses compares to other areas of Maryland. Ambient air quality monitoring equipment for ammonia (NH_3) and particulate matter was purchased and installed at two new monitoring sites – one near a higher-than-average density of poultry houses and one near a lower density of poultry houses. Additional NH_3 monitoring equipment was purchased and installed in two existing monitoring sites operated by the Department – one, an urban site at Oldtown in Baltimore City and the other, an isolated rural site at Horn Point in Dorchester County. These existing sites were in locations that allowed them to serve as background monitors for both NH_3 and particulate matter. Ambient air quality data collection for this project officially began on April 1, 2020.

According to U.S. Environmental Protection Agency's (EPA) environmental mapping and screening tool (EJ Screen), about one-third of the population within the portion of the study area that includes a higher-than-average density of poultry houses is considered low income and one-quarter of the population is above the age of 64. Both measures are higher than the statewide average. About 10% of the population has less than a high school education, which is equal to the statewide average. Thirty-four percent of the population are people of color, which is less than the statewide average of 49%.

After the completion of one full year of data collection, there were no measured violations of federal air quality standards for particulate matter and no exceedances of a conservative health benchmark for NH_3. Concentrations of all parameters remained quite low overall throughout the year. Summaries of monitoring results for April 2020-March 2021 are presented in Table 1 below.

To protect public health, MDE uses the National Ambient Air Quality Standards (NAAQS). As NH_3 does not have a health based national ambient standard, MDE scientists chose a conservative comparison metric. NAAQS exists for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$, or fine particulate) and particulate matter less than 10 microns in diameter (PM_{10}). For the purposes of this project, the health benchmark selected for NH_3 comparison is the Department's one-hour air toxics screening level of 350 parts per billion (ppb).

Table 1. Monitoring Results Summaries.

April 2020 – March 2021 Data Summary for NH_3 MDE 1-hour screening level = 350 ppb

Parameter	Site	Average hourly value (ppb)	Median hourly value (ppb)	Maximum hourly value (ppb)	Minimum hourly value (ppb)
NH_3	Oldtown (Urban, no poultry operations)	6.5	6.4	26.9	-0.1
	Horn Point (Rural, no poultry operations)	2.2	2.1	9.4	0.3
	Princess Anne (Low poultry operation density)	6.3	5.5	123.6	0
	Pocomoke City (High poultry operation density)	11.3	8.1	218.7	0.2

April 2020 – March 2021 Data Summary for $PM_{2.5}$ NAAQS $PM_{2.5}$ 24-hour standard = 35 µg/m^3

Parameter	Site	Average 24-hr value (µg/m^3)	Median 24-hr value (µg/m^3)	Maximum 24-hr value (µg/m^3)	Minimum 24-hr value (µg/m^3)
$PM_{2.5}$	Oldtown (Urban, no poultry operations)	6.7	6	25.1	0.8
	Horn Point (Rural, no poultry operations)	4.9	4.6	16.7	-1
	Princess Anne (Low poultry operation density)	7.2	6.6	24.6	2
	Pocomoke City (High poultry operation density)	7	6.4	22.6	2

April 2020 – March 2021 Data Summary for PM_{10} NAAQS PM_{10} 24-hour standard = 150 µg/m^3

Parameter	Site	Average 24-hr value (µg/m^3)	Median 24-hr value (µg/m^3)	Maximum 24-hr value (µg/m^3)	Minimum 24-hr value (µg/m^3)
PM_{10}	Oldtown* (Urban, no poultry operations)	14.2	12.2	36.5	2.6
	Horn Point* (Rural, no poultry operations)	7.9	7	19.9	1.2
	Princess Anne (Low poultry operation density)	13.5	12.9	35.8	4
	Pocomoke City (High poultry operation density)	13.7	13.1	40.8	4.5

Concentrations of both $PM_{2.5}$ and PM_{10} for the two Lower Eastern Shore sites were comparable, on average, with those measured at the urban Oldtown site in Baltimore City, but the Oldtown site did show greater variability. The isolated rural Horn Point site was consistently much lower.

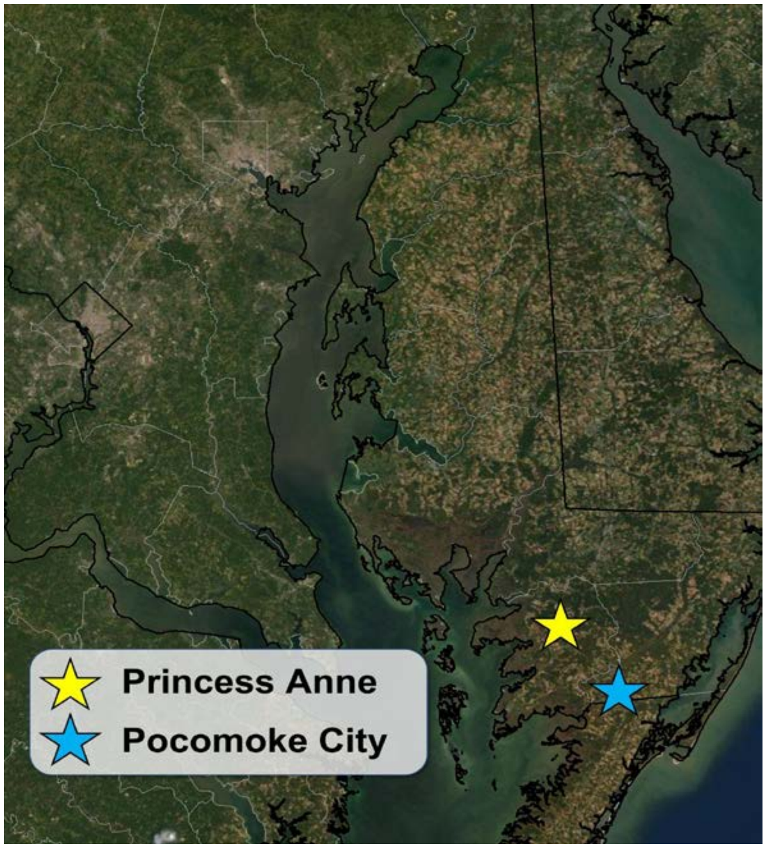
Transient hourly spikes in NH_3 concentrations were frequently observed at the Pocomoke City site, but these never approached the MDE 1-hour screening level, and the majority of the 24-hour NH_3 concentrations rarely exceeded 50 ppb. Average NH_3 concentrations were comparable for the Princess Anne (6.5 ppb) and Oldtown (6.3 ppb) sites while the Pocomoke City site average was almost twice as high (11.3 ppb), with the Horn Point site averaging much lower at 2.2 ppb.

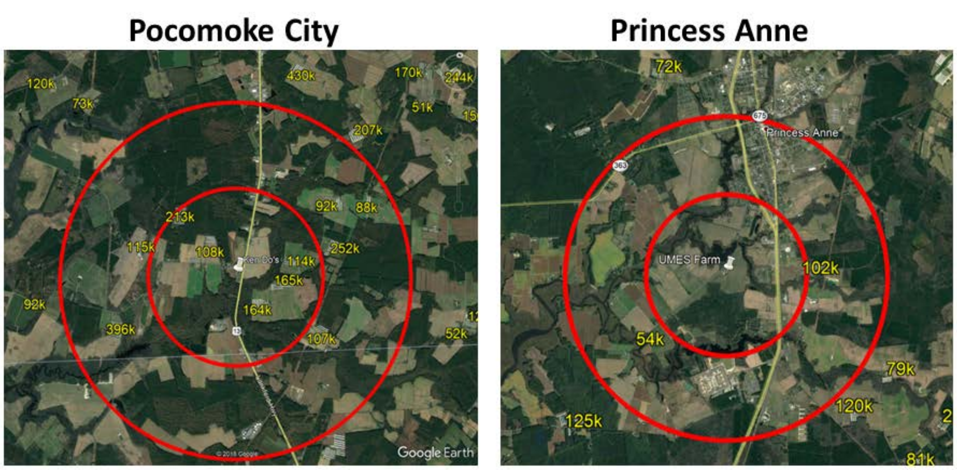
The density of poultry operations within the 2-mile radius surrounding the Pocomoke City site is much greater than the majority of residents of the Eastern Shore would experience within 2 miles of their individual residences. Therefore, these results indicate that the majority of Lower Eastern Shore residents are not being exposed to harmful levels of NH_3, $PM_{2.5}$, or PM_{10} from poultry operations. We welcome additional information about exposure of residents who live even closer to poultry operations.

This project is a first step in determining the quality of the air breathed by the residents of the Lower Eastern Shore who live in the vicinity of a concentration of poultry houses. Monitoring remains ongoing at the two Lower Eastern Shore sites and an urban background site.

Section 1 – Background and Introduction

Through the collective efforts of MDE, the Keith Campbell Foundation, and the Delmarva Chicken Association, an air monitoring project was undertaken on Maryland's Lower Eastern Shore to collect data on ambient air quality to learn more about how air quality near poultry houses compares to other areas of Maryland. Ambient air quality monitoring equipment for NH_3 and particulate matter (both $PM_{2.5}$ and PM_{10}) was purchased and installed at two new monitoring sites (Fig. 2) – one near Pocomoke City and the other south of Princess Anne (on a farm owned by the University of Maryland Eastern Shore (UMES)). Additional NH_3 monitoring equipment was purchased and installed at two existing monitoring sites owned by the Department – one, an urban site at Oldtown in Baltimore City and the other, an isolated rural site at Horn Point in Dorchester County. These existing sites, which already contained fine particulate matter monitors, were in locations that allowed them to serve as background monitors for both NH_3 and particulate matter. Ambient air quality data collection for this project officially began on April 1, 2020.





- Almost 900,000 chickens within a 2 mile radius and about half that number within 1 mile.
- Impacted from multiple directions.
- Many more chicken houses outside of 2 mile radius.
- 29 broiler houses within a 1 mile radius and 70 houses within a 2 mile radius.

- Much less impacted by poultry operations within a 2 mile radius.
- Approximately 14 miles to the NE of Pocomoke City site.
- No broiler houses within a 1 mile radius and 7 houses within a 2 mile radius.

Figure 1. Eastern Shore monitoring locations.

The Pocomoke City monitoring location was chosen due to its proximity to a higher-than-average density of poultry houses. Proximity to poultry houses was the location parameter that drove the decision on site placement. The Princess Anne monitoring location was chosen due to its similar general topography as the Pocomoke City station, but near a lower density of poultry houses. The maps in Figure 1 show the monitoring locations and the poultry houses within a 1- and a 2-mile radius of the monitoring locations. The number of birds within such houses is also shown on the maps. Detailed site descriptions are presented in Appendix C.

This report summarizes the ambient air quality monitoring data collected at the two Lower Eastern Shore sites and the two background sites for the period April 1, 2020 through March 31, 2021, and describes the monitoring methods utilized for the project. Monitoring is still ongoing at the Pocomoke City, Princess Anne, and an urban background site. Monitoring for NH_3 at Horn Point was discontinued on May 14, 2021 due to the measured concentrations continually being extremely low.

The data are available as near real-time on the Department's webpage at: mde.maryland.gov/programs/Air/AirQualityMonitoring/Pages/Lower-Eastern-Shore-Monitoring-Project.aspx. The historical data are also downloadable through links presented on the same webpage.

Section 2 - Monitoring Results Summaries

In evaluating the results of the first year of the Lower Eastern Shore Monitoring Project, $PM_{2.5}$ and PM_{10} concentrations will be compared to their respective NAAQS. For $PM_{2.5,}$ the applicable NAAQS are a 24-hour average of 35 micrograms/cubic meter ($\mu g/m^3$), and an annual average of 12 $\mu g/m^3$. For $PM_{10,}$ the applicable NAAQS is a 24-hour average of 150 $\mu g/m^3$. There is no annual NAAQS for PM_{10}.

No ambient NAAQS have been established for NH_3; however, risk-based residential and worker air concentration screening levels have been issued by various federal and state agencies. Among the available exposure levels that exist, the three that are shown in Table 2 below reflect those that best fit the objective of this project – to provide data on residential air quality in the vicinity of poultry operations. The first is EPA's residential lifetime exposure concentration, which assumes an exposure concentration reflective of a residential setting, where an individual would be exposed 24 hours a day, 350 days a year, and over a 30-year duration.

Table 2. NH_3 screening levels.

Source	NH_3 Concentration (ppbv)	Explanation
EPA (residential)	748	EPA residential lifetime exposure concentration assuming 24 hours a day, 350 days a year, and 30-year exposure duration. Concentrations are derived from the 2016 Integrated Risk Information System Toxicological Review for NH_3.
MDE 8-hour air toxics screening level	250	One one-hundredth of the Threshold Limit Values (TLVs) set by the American Conference of Governmental Industrial Hygienists for an 8-hour exposure period. TLVs refer to the airborne concentrations of a substance that represents conditions to which nearly all workers may be exposed without adverse health effects.
MDE 1-hour air toxics screening level	350	One one-hundredth of the TLVs set by the American Conference of Governmental Industrial Hygienists for a 1-hour exposure period.

The second and third values in the chart are MDE's air toxics screening levels. These screening levels are used during the permitting of pollution point sources to determine whether the emissions from an individual source would pose a threat to public health. The screening levels are conservative in nature, as they represent the worker protection exposure levels developed by the American Conference of Governmental Industrial Hygienists divided by a safety factor of 100.

There is no universally accepted level for when NH_3 can be detected through smelling. An odor threshold for NH_3 has been documented in different studies to be as low as 0.04 parts per million (40 ppb), and sensitivity to odors can vary among individuals. This threshold is below the levels shown above that are being used to determine impacts to public health, which means that an odor can be detected before the concentration reaches a level where public health is being impacted.

$PM_{2.5}$ Data Summaries

A summary of $PM_{2.5}$ data from April 1, 2020 through March 31, 2021 is presented below in Table 3. Throughout the course of the year, $PM_{2.5}$ concentrations remained relatively low and did not approach levels of either the 24-hour or annual NAAQS. Annual averages for the two Lower Eastern Shore sites and Oldtown were fairly comparable, with the Princess Anne and Pocomoke City sites registering slightly higher values than the Oldtown site in Baltimore City, (7.2 $\mu g/m^3$ and 7.0 $\mu g/m^3$ vs. 6.7 $\mu g/m^3$, respectively) and the rural Horn Point site demonstrating the lowest $PM_{2.5}$ annual average (4.9 $\mu g/m^3$).

Among the sites in this project, the maximum observed 24-hour $PM_{2.5}$ concentration throughout the year was 25.1 µg/m^3, which occurred at the Oldtown site on Dec. 11, 2020**.** On Feb. 10, 2021, Princess Anne and Pocomoke City experienced similar maximums at 24.6 µg/m^3 and 22.6 µg/m^3, respectively. The maximum at Horn Point, also on Feb. 10, 2021, was considerably lower at 16.7 µg/m^3, likely due to the isolated rural location. This is not definitive, but elevated concentrations over an area this large most likely indicate a regional air mass, not an event influenced by local sources. It could be due to an inversion over the Lower Eastern Shore. All sites exhibited excellent 24-hour data completeness, the lowest being 89% at the Oldtown site.

Table 3. $PM_{2.5}$ data summary, April 2020 – March 2021.

Parameter	Site	Average 24-hr value (µg/m^3)	Median 24-hr value (µg/m^3)	Maximum 24-hr value (µg/m^3)	Minimum 24-hr value (µg/m^3)	% Complete
$PM_{2.5}$	Oldtown (Urban, no poultry operations)	6.7	6	25.1	0.8	89
	Horn Point (Rural, no poultry operations)	4.9	4.6	16.7	-1	96
	Princess Anne (Low poultry operation density)	7.2	6.6	24.6	2	100
	Pocomoke City (High poultry operation density)	7	6.4	22.6	2	100

NAAQS 24-hr standard = 35 µg/m^3; Annual Average standard = 12 µg/m^3.

$PM_{2.5}$ Time Series Plots

Daily concentrations of $PM_{2.5}$ are color coded according to their corresponding Air Quality Index colors (Fig. 2), and never exceed the moderate range. The time series plots presented below in Figures 3 through 6 illustrate the daily 24-hour $PM_{2.5}$ concentration from April 1, 2020, through March 31,2021.

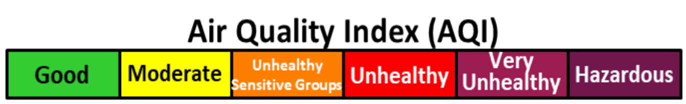


Figure 2. The Air Quality Index.

Concentrations tended to track well across all the sites on the Eastern Shore, rising and lowering on the same days. Although the magnitude was considerably lower at the more isolated and rural Horn Point site. This is indicative of $PM_{2.5}$ concentrations being primarily driven by a regional air mass. Concentrations at Oldtown did not track as well with the other sites and were more variable and generally higher due to local influences in the urban environment. Oldtown did experience an operational interruption from Aug. 24 to Sept. 17, 2020.

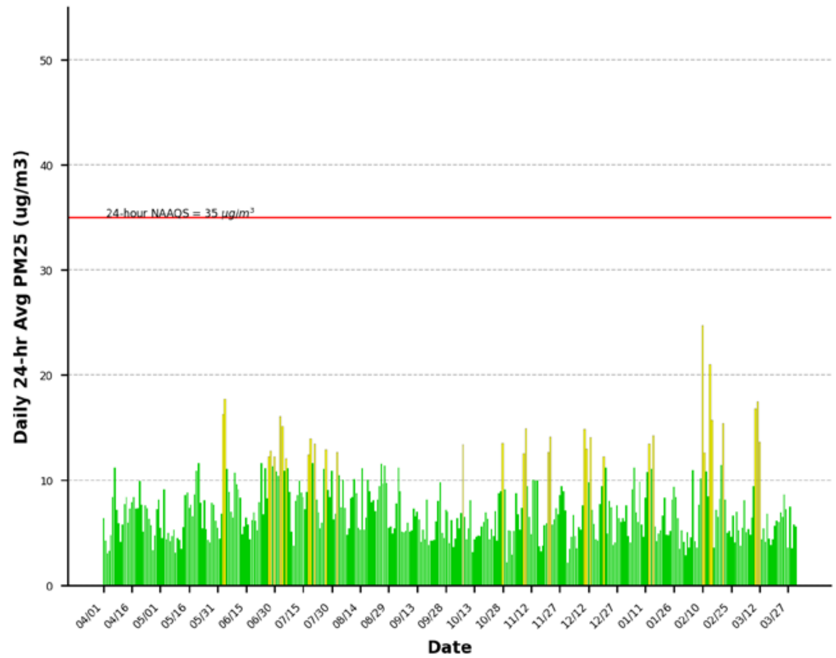


Figure 3. $PM_{2.5}$ at Princess Anne, April 2020 through March 2021.

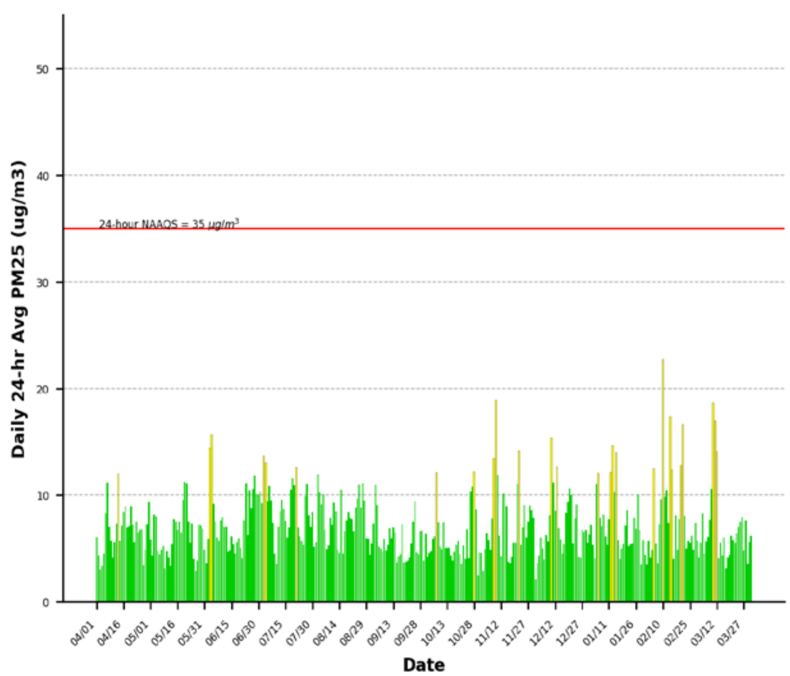


Figure 4. $PM_{2.5}$ at Pocomoke City, April 2020 through March 2021.

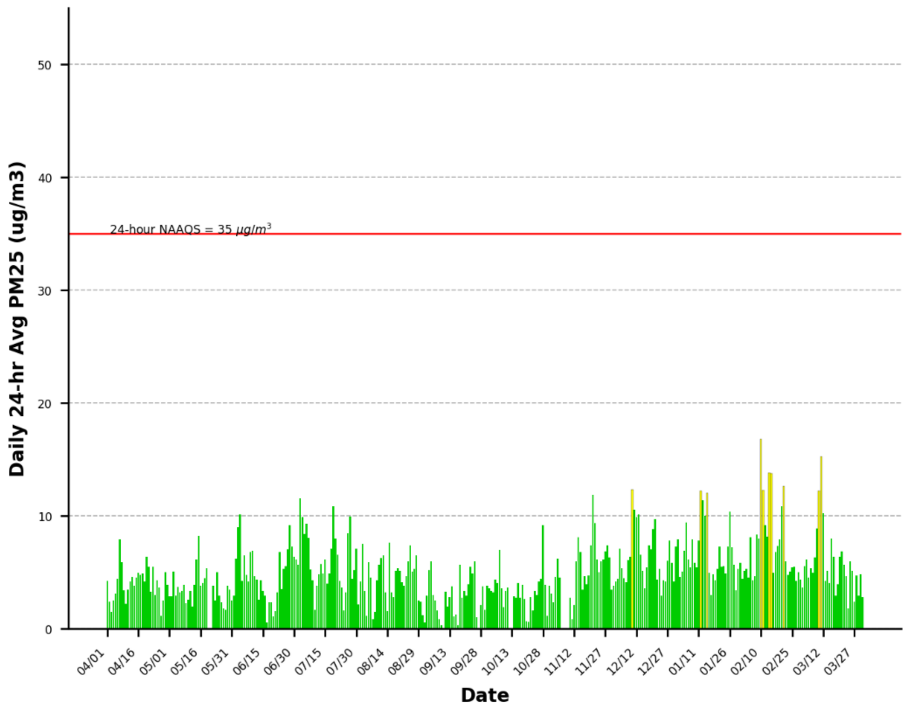


Figure 5. $PM_{2.5}$ at Horn Point, April 2020 through March 2021.

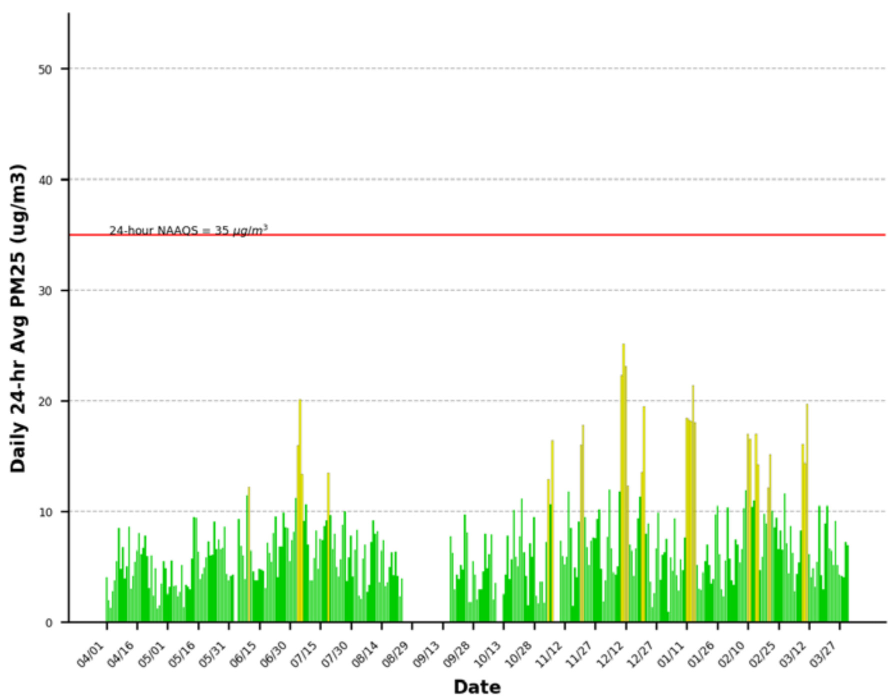


Figure 6. $PM_{2.5}$ at Oldtown, April 2020 through March 2021.

$PM_{2.5}$ Box and Whisker Plots

A box and whisker plot is a visual tool used to graphically display the center, range, distribution, and variance of values within a set of data. A typical representation of a 95/5 box and whisker plot is shown in Figure 7 below. In this example, the ends of the box represent the 75th and 25th percentiles, or the interquartile range, with 50% of the data points falling within the box. The interquartile range is a standard way of expressing variability as this is where most of the values lie. The median is represented by the orange horizontal line in the box with 50% of the data points falling above and below the line. The whiskers are the lines that extend above the box to the 95th percentile, and below to the 5th percentile with 90% of the data points bounded within this range.

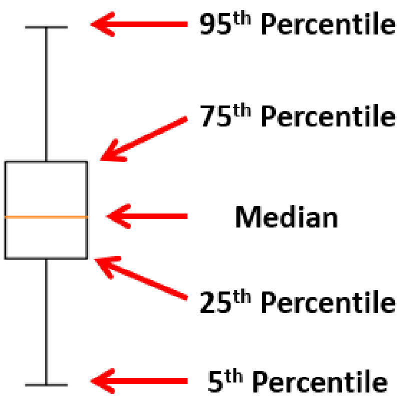


Figure 7. Typical 95/5 Box and Whisker Plot.

A 95/5 box and whisker plot for hourly concentrations of $PM_{2.5}$ from April 1, 2020, through March 31, 2021, is presented below in Figure 8. The Oldtown site exhibits the greatest overall and interquartile range, which is expected from an urban street corner environment compared to the more rural Eastern Shore sites. The Pocomoke City and Princess Anne sites are similar to one another with a slightly tighter overall and interquartile range versus Oldtown. The similarity in these two sites helps demonstrate that $PM_{2.5}$ concentrations are not unduly influenced by the proximity and density of chicken houses. The Horn Point site shows the tightest overall and interquartile range as expected due to its isolated rural location. For all sites, 95% of the 24-hour $PM_{2.5}$ concentrations were less than 16 µg/m^3. For the Eastern Shore sites, 95% were below 13.4 µg/m^3.

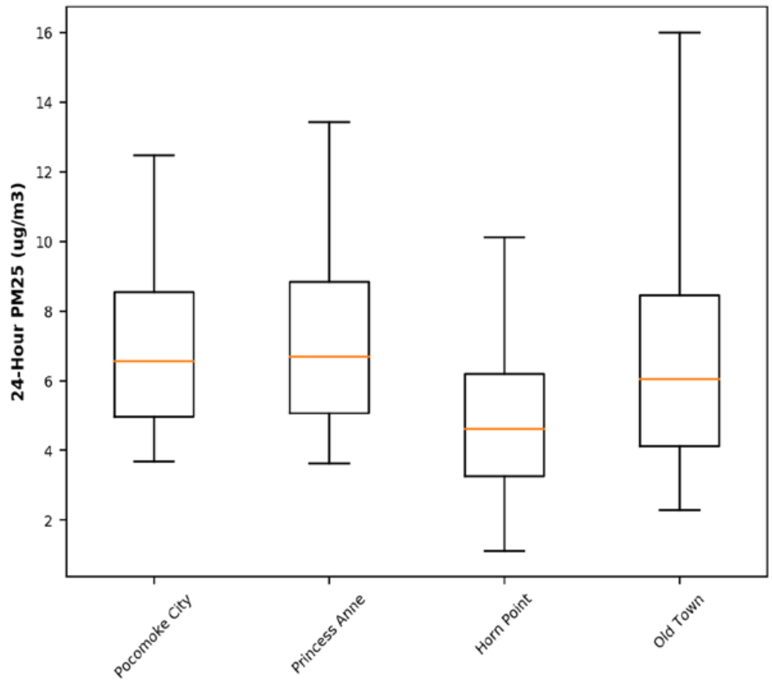


Figure 8. Box and whisker plots of 24-hour $PM_{2.5}$ data at all four study locations, April 2020 through March 2021.

It is also instructive to examine the range of hourly $PM_{2.5}$ concentrations across the sites. Wide disparities among the plots point to the likelihood of local sources impacting a site. A 95/5 box and whisker plot for hourly concentrations of $PM_{2.5}$ from April 1, 2020, through March 2021 is presented below in Figure 9. As with the 24-hour concentration plots, the Oldtown site exhibits the greatest overall and interquartile range (a standard way of expressing variability as this is where most of the values lie), which is expected from an urban street corner environment compared to the more rural Eastern Shore sites.

The Pocomoke City and Princess Anne sites again are similar; $PM_{2.5}$ concentrations seem not unduly influenced by the proximity of the Pocomoke City site to a higher than average density of chicken houses. The Horn Point site shows the lowest overall range as expected from the isolated rural location. For all sites, 95% of the hourly $PM_{2.5}$ concentrations measured throughout the year were below 17.0 $\mu g/m^3$. For the Eastern Shore sites, 95% were below 14.8 $\mu g/m^3$. The overall maximum hourly $PM_{2.5}$ concentration was 69.0 $\mu g/m^3$, which occurred at Oldtown on July 5, 2020. The maximums at the other sites are as follows: Pocomoke City was 49.4 $\mu g/m^3$ on May 4, 2020, Princess Anne was 37.7 on February 10, 2021, and Horn Point was 33.0 on April 8, 2020.

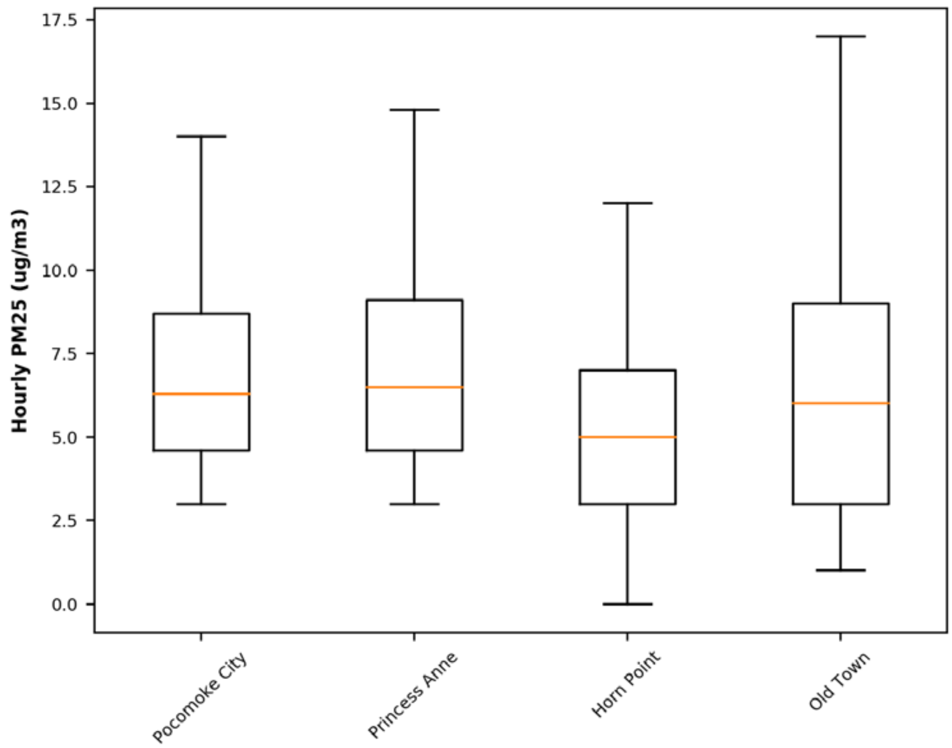


Figure 9. Box and Whisker plots of hourly $PM_{2.5}$ data at all four study locations, April 2021 through March 2021.

PM_{10} Data Summaries

Throughout the course of the year, PM_{10} concentrations remained extremely low and did not approach anywhere near the level of the 24-hour NAAQS. It is important to note that the Oldtown and Horn Point sites utilized different instrumentation. These sites used a manual filter-based Federal Reference Method (FRM) that gave a discreet 24-hour concentration and samples were collected on a once every 6-day frequency, while the Lower Eastern Shore sites had continuous monitors that measured hourly concentrations. A summary of PM_{10} data from April 1, 2020, through March 31, 2021, is presented below in Table 4.

Annual averages were comparable at Pocomoke City, Princess Anne, and Oldtown at 13.7 µg/m^3, 13.5 µg/m^3, and 13.5 µg/m^3, respectively. The more isolated and rural Horn Point was considerably lower at 8.0 µg/m^3. On average, a little over half of PM_{10} is composed of $PM_{2.5}$ at all of the sites.

The maximum observed 24-hour PM_{10} concentration throughout the year was 40.8 µg/m^{3,} and occurred at the Pocomoke City site on March 10, 2021. Oldtown experienced a similar maximum of 40.0 µg/m^3 March 11, 2021. The maximum at Princess Anne was 35.8 µg/m^3 (August 18, 2020). The maximum at Horn Point was considerably lower at 20.0 µg/m^3 March 11, 2021, likely due to the isolated rural location.

All sites exhibited excellent 24-hour data completeness at 100%.

Table 4. PM_{10} data summary, April 2020 – March 2021.

Parameter	Site	Average 24-hr value (µg/m^3)	Median 24-hr value (µg/m^3)	Maximum 24-hr value (µg/m^3)	Minimum 24-hr value (µg/m^3)	% Complete
PM_{10}	Oldtown* (Urban, no poultry operations)	13.5	12.1	40.0	2.6	100
	Horn Point* (Rural, no poultry operations)	8.0	7	20.0	1.2	100
	Princess Anne (Low poultry operation density)	13.5	12.9	35.8	4	100
	Pocomoke City (High poultry operation density)	13.7	13.1	40.8	4.5	100

*Oldtown and Horn Point stations measure PM_{10} with an FRM manual filter method. Values shown are through April 1, 2021. NAAQS 24-hr standard = 150 µg/m^3.

PM_{10} Time Series Plots

The time series plots presented below in Figures 10 through 13 illustrate the daily 24-hour PM_{10} concentration (every sixth day for Horn Point and Oldtown) from April 1, 2020, through March 31, 2021. These daily concentrations are color coded according to their corresponding Air Quality Index colors and never exceed the good range.

PM_{10} concentrations tended to track well across all the sites, rising and lowering on the same days. Although the magnitude was considerably lower at the more isolated and rural Horn Point site. The Lower Eastern Shore and Oldtown sites did exhibit spikes on different days occasionally, likely due to local influences like windblown road and agricultural dust due to nearby farming activities and possibly construction work at the Princess Anne site (PM_{10} is composed of larger particles that do not stay in the atmosphere as long).

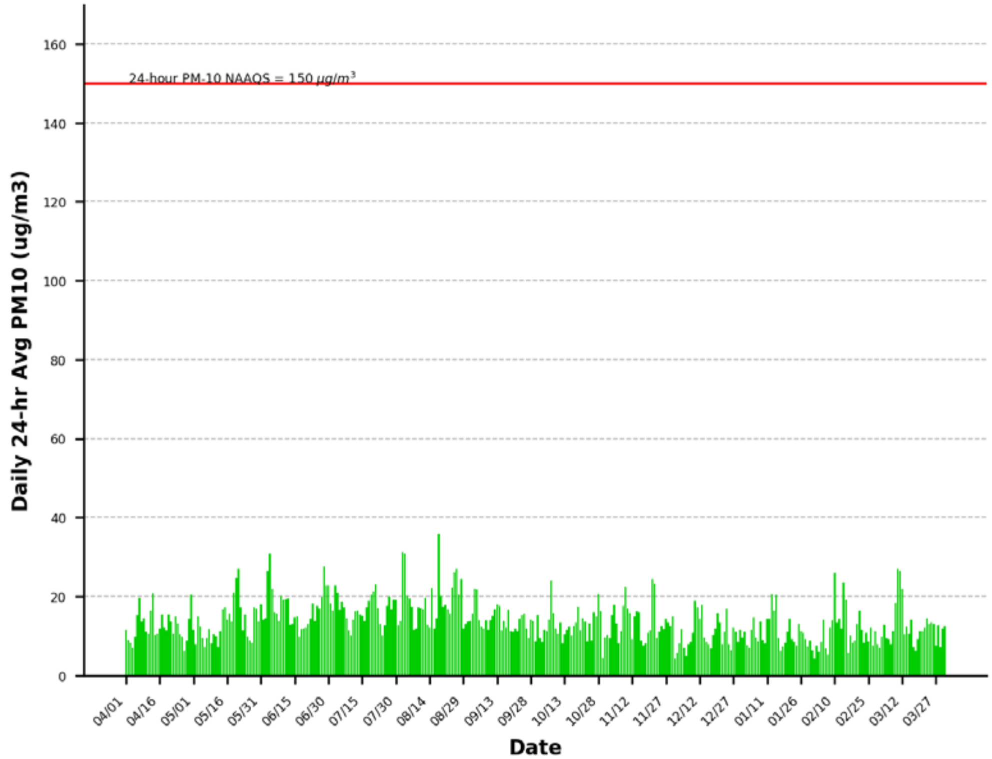


Figure 10. 24-hour PM_{10} data from Princess Anne, April 2020 through March 2021.

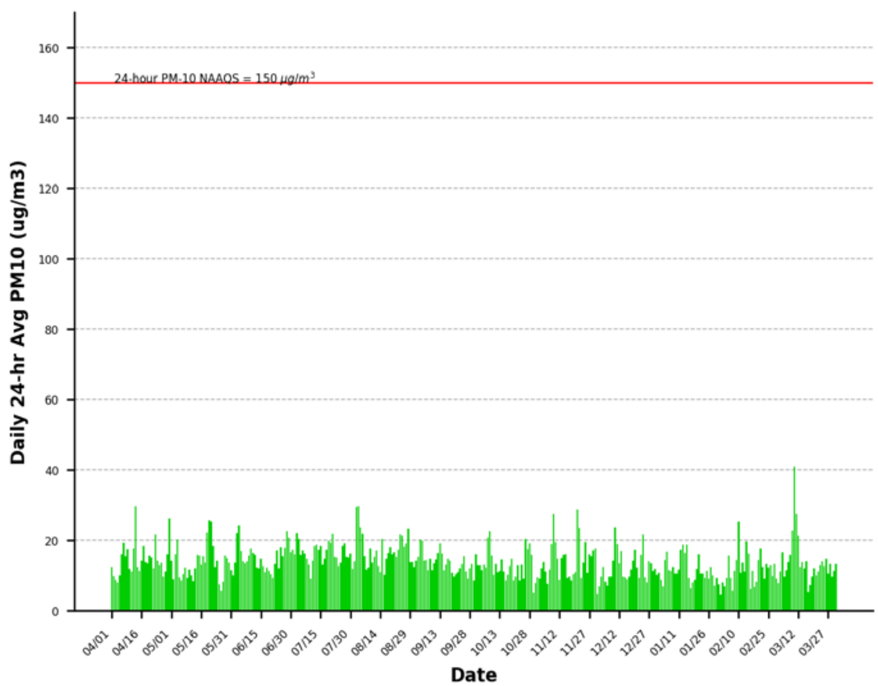


Figure 11. 24-hour PM_{10} data from Pocomoke City, April 2020 through March 2021.

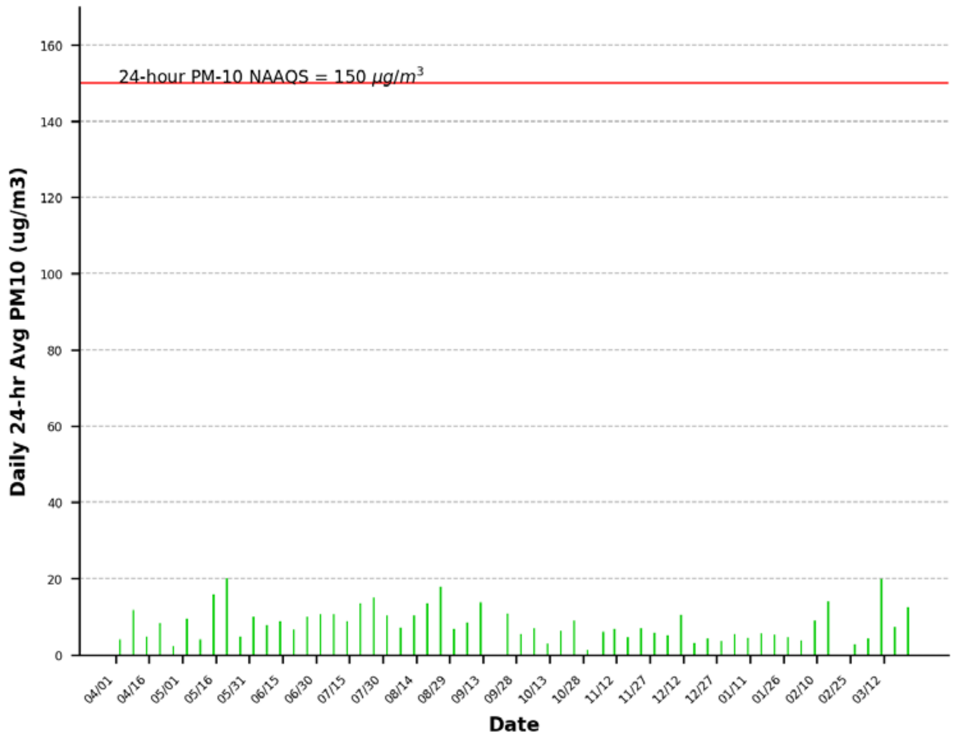


Figure 12. 24-hour PM_{10} data from Horn Point, April 2020 through March 2021.

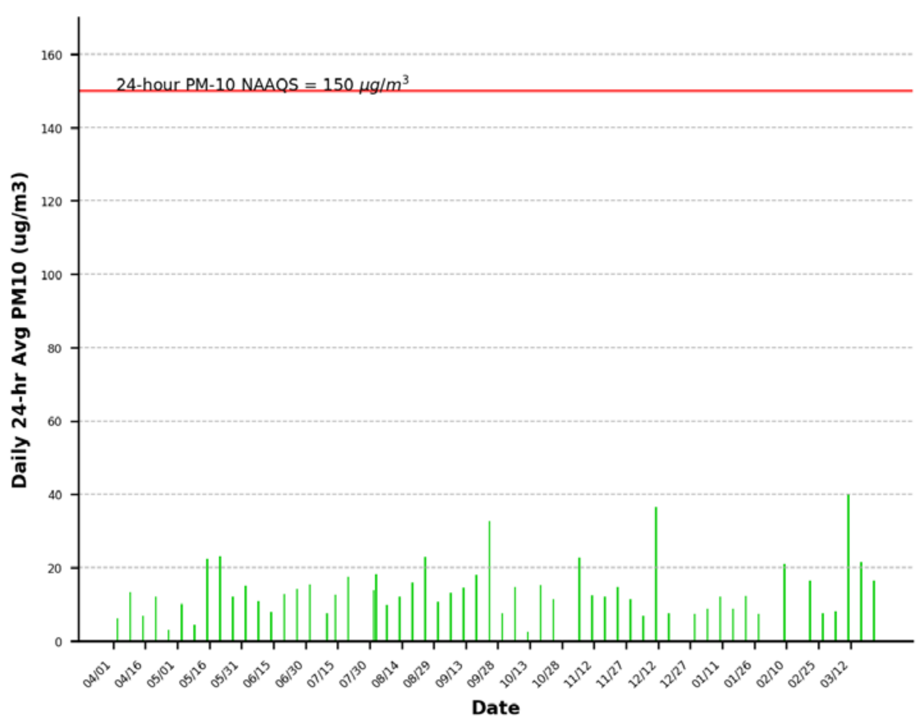


Figure 13. 24-hour PM_{10} data from Oldtown, April 2020 through March 2021.

PM_{10} Box and Whisker Plots

A 95/5 box and whisker plot for 24-hour concentrations of PM_{10} from April 1, 2020, through March 31, 2021, is presented below in Figure 14. The plots for Oldtown and the Lower Eastern Shore sites all exhibit similar overall and interquartile ranges, with Oldtown ranges being slightly larger than Pocomoke City, and Pocomoke City being slightly larger than Princess Anne. Horn Point again shows the lowest overall range consistent with its isolated location.

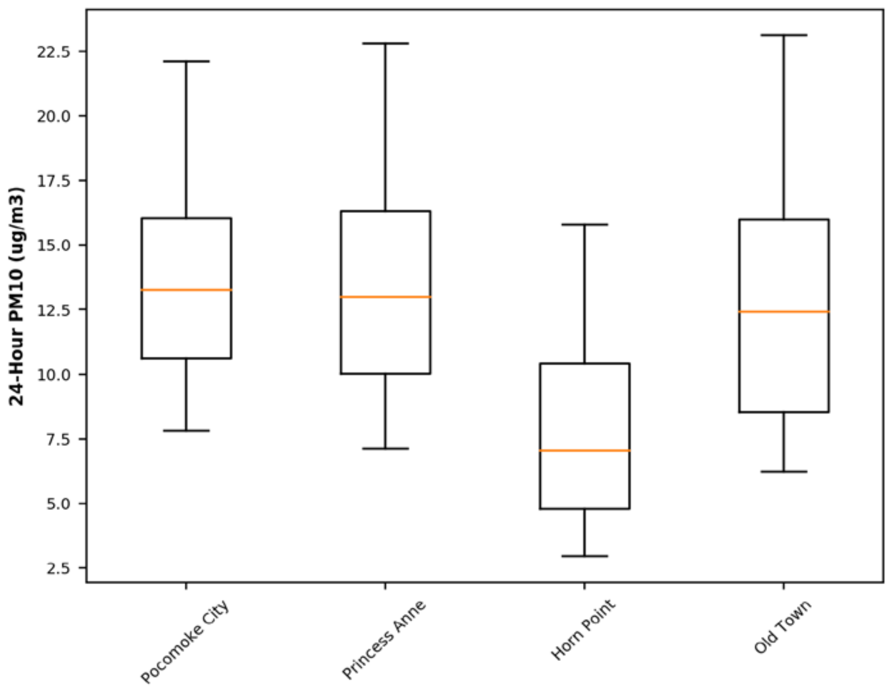


Figure 14. Box and whisker plots of 24-hour PM_{10} data at all four study sites, April 2020 through March 2021.

A 95/5 box and whisker plot for hourly concentrations of PM_{10} from April 1, 2020, through March 31, 2021, is presented below in Figure 15 (there were no hourly concentrations available for Oldtown or Horn Point because different instrumentation was used.) As with $PM_{2.5}$, the Pocomoke City and Princess Anne sites are nearly identical, indicating that PM_{10} concentrations are not unduly influenced by the proximity of the Pocomoke City site with a higher than average density of chicken houses. Overall, 95% of the hourly PM_{10} concentrations measured throughout the year at the Lower Eastern Shore sites were below 25.5 µg/m^3. The overall maximum hourly PM_{10} was 231.3 µg/m^3 and occurred at Princess Anne on August 18, 2020. The Pocomoke City maximum was 156.4 µg/m^3 on November 21, 2020. Construction activities at a building located less than 100 feet from the shelter at Princess Anne are believed to be responsible for the maximum value there. The construction crew was observed cutting concrete blocks for placement on the outside walls of the building, and a lot of visible dust was observed coming off of the saw itself. At Pocomoke City, the field operator observed, and later confirmed, that crop harvesting on fields adjacent to the shelter had occurred at the time of the maximum value at that site.

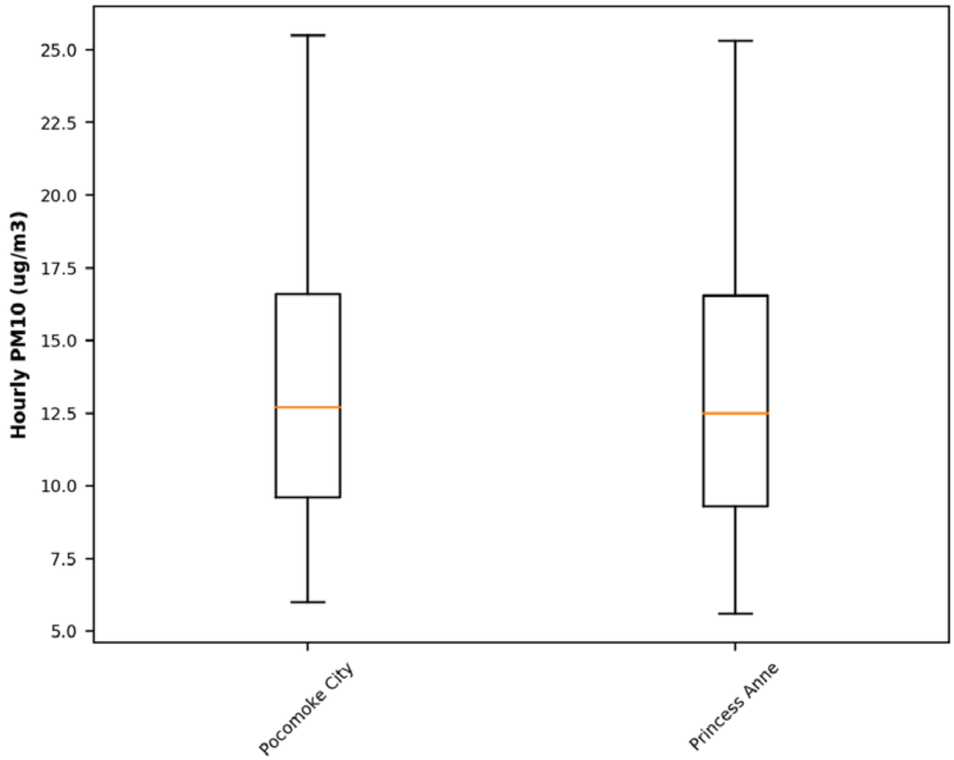


Figure 15. Box and whisker plots of hourly PM_{10} data at Pocomoke City and Princess Anne, April 2020 through March 2021.

NH_3 Data Summaries

Throughout the course of the year, hourly NH_3 concentrations remained very low and did not approach the level of the MDE 1-hour screening level of 350 ppb. The Pocomoke City site had the highest annual hourly average at 11.3 ppb. The Oldtown and Princess Anne sites were nearly identical at 6.5 ppb and 6.3 ppb, respectively. The more isolated and rural Horn Point site registered the lowest annual hourly average of 2.2 ppb. A summary of NH_3 data, from April 1, 2020, through March 31, 2021, is presented below in Table 5.

The wide variation in the magnitude of the maximums registered at each site can be attributed to the presence and type of potential NH_3 sources and meteorological influences near each location. The Pocomoke City site is located in an area with a higher than average density of poultry operations. Even in this area, other sources of NH_3 exist, including episodic application of manure or fertilizer along with vehicle emissions. Poultry operations will contribute NH_3 at different levels depending on the activities in the house and the weather during those operations. If the house does not actively house a flock, then emissions would be lower, unless cleanout is underway in which case both particle and NH_3 pollution may be episodically higher. Younger flocks will emit smaller amounts of NH_3 than older and larger birds. The Princess Anne site is in an area with a lower density of poultry operations but is located on the UMES Integrated Crop Farm where there are various agricultural activities occurring onsite and throughout the immediate surrounding area.

Urban sources of NH_3 likely to impact the Oldtown site include vehicle emissions, electric generating units equipped with Selective Catalytic Reduction systems, sewage, water treatment plants, incineration, and other industrial processes.

Table 5. NH_3 data summary, April 2020 – March 2021.

Parameter	Site	Average hourly value (ppb)	Median hourly value (ppb)	Maximum hourly value (ppb)	Minimum hourly value (ppb)	% Complete
NH_3	Oldtown (Urban, no poultry operations)	6.5	6.4	26.9	-0.1	91
	Horn Point (Rural, no poultry operations)	2.2	2.1	9.4	0.3	91
	Princess Anne (Low poultry operation density)	6.3	5.5	123.6	0	92
	Pocomoke City (High poultry operation density)	11.3	8.1	218.7	0.2	93

MDE 1-hour screening level = 350 ppb.

NH_3 Time Series Plots

The Princess Anne site only had one episode of elevated NH_3 concentrations while the Pocomoke City site exhibited frequent spikes in NH_3, thus we conclude that the Pocomoke City site is influenced by poultry operations. Unlike the time series plots for $PM_{2.5}$ and PM_{10}, NH_3 concentrations did not track as well across the sites and do show large differences in magnitude. The time series plot presented below in Figure 16 illustrates the hourly NH_3 concentrations from April 1, 2020 through March 31, 2021 for all four sites. Hourly concentrations at the Pocomoke City site clearly stand out as the most variable and exhibit more frequent spikes with greater magnitude than any of the other sites. The Princess Anne site did experience one multi-day episode of elevated hourly concentrations from July 2-5, 2020. This episode can most likely be attributed to the application of nitrogen liquid fertilizers on June 25, 26, and 27, 2020 to the front fields next to the monitoring station and subsequent volatilization over the following week (per communication from the UMES Farm Manager).

The primary differences in surrounding land use between the Pocomoke City and Princess Anne sites are the amount of agricultural area, forested area, and the density of poultry operations. Agricultural area is greater for the Princess Anne site while both forested area and density of poultry operations are greater for the Pocomoke City site.

The rural Horn Point site and the urban Oldtown site did not exhibit any significant spikes in NH_3 concentrations.

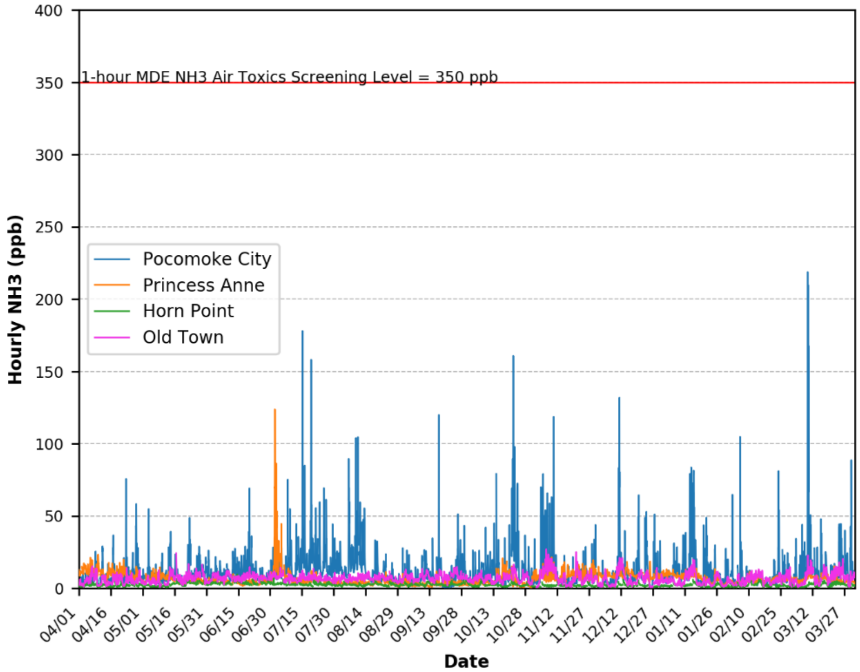


Figure 16. Hourly NH_3 concentrations, April 2020 through March 2021.

A time series plot of 24-hour NH_3 concentrations is presented below in Figure 17. In this figure, it is much easier to discern the difference in daily concentrations across the sites without focusing on the extreme one-hour excursions. The majority of the 24-hour concentrations fall well below 20 ppb with the higher values corresponding to the periods where hourly values spiked at the Pocomoke City and Princess Anne sites, as discussed above. Both the Oldtown and Princess Anne sites experience a bump in daily NH_3 concentrations during the winter months while the Pocomoke City site had a string of higher daily averages during July.

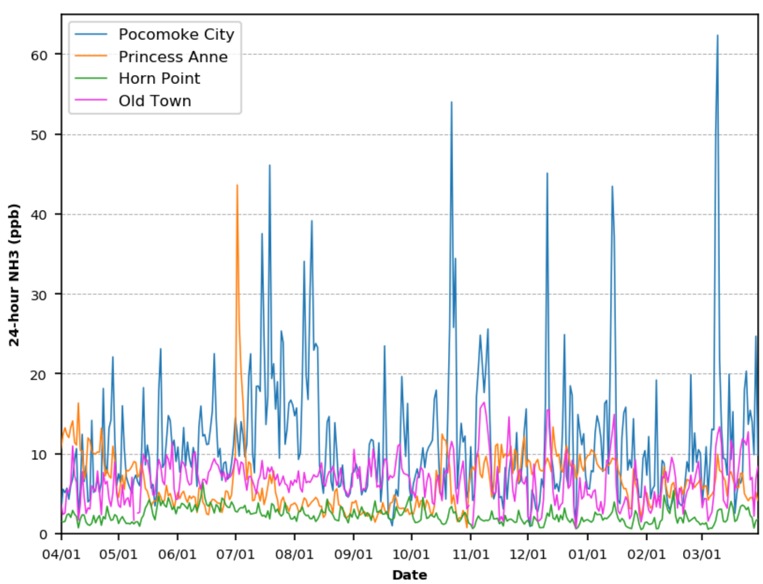


Figure 17. 24-hour NH_3 concentrations, April 2020 through March 2021.

NH_3 Box and Whisker Plots

A 95/5 box and whisker plot for hourly concentrations of NH_3 from April 1, 2020 through March 31, 2021, is presented below in Figure 18. Unlike the box and whisker plots for $PM_{2.5}$ and PM_{10}, the Pocomoke City site exhibits both a much greater overall and interquartile range. This is indicative of the influence of local sources of NH_3 and is consistent with the much greater density of poultry operations surrounding this location. The Princess Anne and Oldtown sites are again similar, with Oldtown having a somewhat higher median due the urban location. Once again, the Horn Point site shows the tightest and lowest range as expected given the isolated rural location. For all sites, 95% of the hourly NH_3 concentrations were below 29.6 ppb. Excluding the Pocomoke City site, 95% of the hourly NH_3 concentrations were below 12.5 ppb.

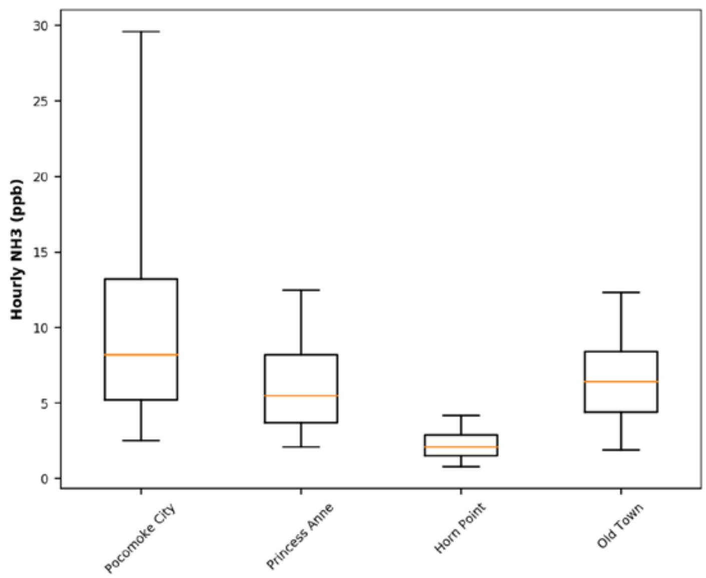


Figure 18. Box and whisker plots showing hourly NH_3 concentrations, April 2020 through March 2021.

Section 3 - Conclusions and Next Steps

The focus of this project was to characterize the air quality that the majority of residents of the Lower Eastern Shore experience and compare the data to the air quality at a more isolated rural location and an urban location in Baltimore City. Concentrations of both $PM_{2.5}$ and PM_{10} for the two Lower Eastern Shore sites were comparable, on average, with those measured at the urban Oldtown site in Baltimore City, but the Oldtown site did show greater variability. The isolated rural Horn Point site was consistently much lower.

Average NH_3 concentrations were comparable for the Princess Anne (6.5 ppb) and Oldtown (6.3 ppb) sites while the Pocomoke City site average was almost twice as high (11.3 ppb), with the Horn Point site averaging much lower at 2.2 ppb. Transient hourly spikes in NH_3 concentrations were frequently observed at the Pocomoke City site, but these never approached the MDE 1-

hour screening level and the majority of the 24-hour NH_3 concentrations rarely exceeded 50 ppb.

After the completion of one full year of data collection, there were no measured violations of the $PM_{2.5}$ and PM_{10} NAAQS and no measured NH_3 concentrations approaching the MDE 1-hour air toxics screening level at any of the four monitoring locations. Concentrations of all parameters remained quite low overall throughout the year.

The density of poultry operations within the 2-mile radius surrounding the Pocomoke City site is much greater than the majority of residents of the Eastern Shore would experience within 2 miles of their individual residences. Therefore, it is reasonable to conclude that the majority of Lower Eastern Shore residents are not being exposed to harmful levels of NH_3, $PM_{2.5}$, or PM_{10} from poultry operations. Since fence line analysis of ammonia concentrations were not completed in this study, MDE encourages review and analysis by academic partners of existing research and/or further study, if needed.

Monitoring remains ongoing at the two Lower Eastern Shore sites and in the Baltimore area. Monitoring for NH_3 at Horn Point was discontinued on May 14, 2021 because measured concentrations were extremely low and there was limited value in continuing operating the site. The NH_3 monitor was moved from Oldtown to Baltimore County on Nov.19, 2021 as the Oldtown site was discontinued.

This project is a first step in determining the quality of the air of the Lower Eastern Shore who live in the vicinity of a concentration of poultry houses. This project will evolve to include additional monitoring sites aimed at furthering our understanding of the health impacts from poultry operations. MDE encourages the scientific community, academia, environmental advocate groups, and the general public to use the data to conduct independent evaluations of the public health impacts from poultry operations. This project was developed in response to public concerns about the health impacts in rural agricultural communities and continued engagement by the public will guide policies.

The following Appendices to this report are available online at the Department's web page at: mde.maryland.gov/programs/Air/AirQualityMonitoring/Pages/Lower-Eastern-Shore-Monitoring-Project.aspx.

- Appendix A - Quality Assurance and Data Validation Standard Operating Procedures
- Appendix B - Field Data Collection Methods
- Appendix C - Monitoring Site Descriptions and Maps

Appendix A –
Quality Assurance and Data Validation SOP
for the Lower Eastern Shore Air Quality Study

Quality Assurance Overview

Hourly ammonia (NH_3) and particulate matter ($PM_{2.5}$ and PM_{10}) data were collected at two stations on the Lower Eastern Shore: Princess Anne and Pocomoke City. For comparison purposes, hourly concentrations of NH_3 and $PM_{2.5}$ were also measured at the Oldtown station, in downtown Baltimore City, and at the Horn Point station, a rural site on the Eastern Shore. PM_{10} is not measured continuously at Oldtown or Horn Point, but manual (FRM) PM_{10} data were collected there every sixth day. Real-time data were observed as they report in to the MDE's Envidas Data Acquisition System and were subsequently transferred out to AirNow Tech and ultimately posted to MDE's website.

Real-time data were observed by Quality Assurance staff throughout each business day to ensure that data were reporting in a timely manner, as well as to ensure that anomalous data were evaluated quickly. In addition to observing real-time data on a virtually 24-7 basis, field quality control checks are performed regularly to verify the quality of data being collected. Please see Appendix B for detailed information about field quality control activities. The quality control checks performed by Field Operations staff allow the precision and validity of the ambient air monitors to be quantified. This is done by testing the monitor's response to known inputs in order to assess the measurement error.

Data Quality Objectives (DQO's) are qualitative and quantitative statements that clarify the purpose of the project, define the most appropriate type of information to collect, determine the most appropriate conditions from which to collect that information, and specify tolerable levels of potential decision errors. DQO's have been developed by EPA to support the primary regulatory objectives for each of the criteria pollutants. However, the purpose of this project is simply to collect information on ammonia and particulate matter near poultry houses for comparison with air quality in other parts of Maryland. The priority objective is to ensure that decision makers can make comparisons to data collected at the non-agricultural sites, within a specified degree of certainty. By meeting this data quality standard for comparison, additional goals for supporting both timely data reporting and research goals is achieved. Tolerable levels of potential decision errors have been specified in the DQO's established by the EPA for the criteria pollutants are as follows:

Table A-1 Quality check performance limits.

Parameter	Precision*	Bias	Minimum Data Completeness Goal	
			Hourly	Quarterly/Annually
NO_2	15%	15%	75%	80%
$PM_{2.5}$	10%	10%	N/A	80%

* 90 percent confidence limit for the coefficient of variation, calculated in accordance with 40 CFR 58, App. A.

Measurement Quality Objectives (MQO's) are designed to evaluate and control for various phases of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQO's. MQO's can be defined in terms of the following data quality indicators: precision, bias, representativeness, detection limit, completeness, and comparability. Precision is measure of the agreement among repeated measurements of the same property under identical, or substantially similar, conditions. For this project, precision will be calculated using the weekly 1-point Quality Control (QC) checks. Bias is the systematic or persistent distortion of a measurement process which causes error in one direction. Bias will be calculated for each daily instrument verification check and the multi-point calibrations.

Quality Assurance Activities

If a quality check produces results outside of the target limits, corrective actions will be taken.

Field Quality Checks

- Manual remote zero/span checks were conducted approximately once every 14 days on the NH_3 instruments, starting at different times of day to avoid missing any diurnal patterns.
- One-point precision checks were performed approximately once within every 14 days on the NH_3 instruments and approximately once per month on the PM monitors.
- Multi-point calibrations were conducted once per calendar quarter.

Evaluating the Field Quality Checks

- If the analyzers exceed the limits in Table A-1, then the site operator initiates a manual re-check and further corrective actions, if needed.
- If the comparison reflects that an instrument may be malfunctioning, a 1-pt QC check and subsequent recalibration were conducted, followed by another 1-pt QC check.
- The zero/span checks, bi-weekly 1-point QC checks, calibration records, and maintenance records were also used by the data management team to verify the validity of the data.

Evaluating the Raw Data

- Hourly data records were edited to reflect the nature of any ‘missing’ data, or hours that do not reflect raw data. Specific instructions for editing data can be found in MDE’s Data Validation SOP for Gas NAAQS (approved 2018), under the Monthly Review and Editing heading.
- After log notes have been reviewed and the correct Quality Assurance codes have been applied, the data were then summarized before being published to MDE’s website. At the end of each month, data were summarized and reported to MDE’s website as downloadable summaries.

Summarizing the Data for the Public

- For each NH_3 monitor, hourly average, median, minimum, and maximum values were determined for the previous month, as well as for the entire period of record to date.
- For each PM monitor, 24-hour (daily) average, median, minimum, and maximum values were determined for the previous month, as well as for the entire period of record to date.
- PM gravimetric filter data take longer to process, so there is often a bit of a time gap before the manual PM data were available. Specific activities associated with handling PM data can be found in MDE’s 2018 PM QAPP.
- Summary data are available on MDE’s Lower Eastern Shore Project webpage:

https://mde.maryland.gov/programs/Air/AirQualityMonitoring/Pages/Lower-Eastern-Shore-Monitoring-Project.aspx

Appendix B –
Field Data Collection Methods
for the Lower Eastern Shore Air Quality Study

Contents:

A. NH3 - Teledyne API T201 Continuous Ammonia (NH3) Analyzer (All four sites)

B. PM2.5 / 10 - Teledyne API T640X PM Mass Monitor (Princess Anne and Pocomoke City)

C. PM2.5 - Met One BAM 1020 (Oldtown and Horn Point)

D. PM10 - Thermo Fisher Partisol-Plus 2025i Sequential Sampler (Oldtown and Horn Point)

E. Meteorology - Vaisala WXT 536 Weather Transmitter (Horn Point, Princess Anne, and Pocomoke City)

Ammonia Measurement Method – Teledyne API (TAPI) T201 Continuous Ammonia (NH3) Analyzer

Theory of Operation:

The TAPI T201 Ammonia analyzer method is based off the federally approved method (RFNA-1194-009) for measuring nitrogen dioxide using the chemiluminescence method. The analyzer measures ammonia by oxidizing it to nitric oxide by the following reaction:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

The resulting nitric oxide is then measured by the chemiluminescent reaction with ozone. The process uses two converters to oxidize the different sample gases. A high temperature catalytic converter, the 501 NH_3, converts NH_3 and NOx into NO creating the TNx channel. A second converter, housed inside the T201 analyzer and consisting of heated molybdenum, converts all of the NOx in the sample to NO producing the NOx channel. The nitric oxide channel is measured while bypassing both the 501 NH_3 and molybdenum converter. The calculated gas concentrations, ammonia, and nitrogen dioxide, are computed from the differences between the measured channels, as outlined in the following concentrations:

NO (Nitric Oxide) Concentration = Measured

TN_x (Total Nitrogen) Concentration = Measured (NH_3 + NO_2 + NO)

NO_x (Total Nitrogen – Ammonia) Concentration = Measured (NO_2 + NO)

NH_3 (Ammonia) Concentration = Calculated as follows:

[(TNx - NOx) / (NH_3_CE_FACTOR1)]

NO_2 (Nitrogen Dioxide) Concentration = Calculated as follows:

[(NOx – NO) / (NO_2_CE_FACTOR1)]

The TAPI T201 Ammonia analyzers were operated at all four project sites, Pocomoke City, Princess Anne, Oldtown, and Horn Point.

Instrument Specifications:

The TAPI T201 analyzer specifications are listed below:

Ranges	Min: 0-50 ppb Full scale Max: 0-2000 ppb Full scale (selectable, independent NH_3, NO, NO_2, NOx, TNx ranges supported)	
Measurement Units	ppb, ppm, µm/m³, mg/m³ (user selectable)	
Noise at Zero[1]	≤ 0.5 ppb (RMS)	
Noise at Span[1]	≤ 1.0% of reading (RMS) above 50 ppb	
Lower Detectable Limit[2]	< 1 ppb	
Zero Drift[3, 5]	< 0.5 ppb / 24 hours (NO, NOx)	
Span Drift[5]	≤ 1.0% of full scale / 24 hours	
Response Time[4]	< 340 seconds to 90%	
Linearity	NO calibration 1% of full scale NH_3 calibration 2% of full scale	
Precision	0.5% of reading above 50 ppb	
Sample Flow Rate	1000 cc/min ± 10% (500 cm³/min bypass to vacuum manifold, 500 cm³/min to reaction cell)	
Temp Range	15-40 ºC	
Dimensions H x W x D	7" x 17" x 23.6" (18cm x 43cm x 61cm)	
Weight, Analyzer	43 lbs (20 kg)	
Weight, Converter	22 lbs (10 kg)	
Power, Analyzer	Power Rating	Typical Power Consumption
	100-120 V, 220-240 V ~50/60 Hz	125 W
Power, Converter	100-120 V, 220-24- V ~50-60 Hz	480 W
Environmental	Installation Category Pollution Degree 2, Over-voltage Category II, Indoor use only	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)	
Standard I/O	(1) Ethernet: 10/100Base-T; (2) RS-232 (300 – 115,200 baud) (2) USB device ports; (8) opto-isolated digital outputs; (6) opto-isolated digital inputs; (4) analog outputs	
Optional I/O	(1) USB com port; (1) RS485 (300 – 115,200 baud); (4) digital alarm outputs; Multidrop RS232; (3) 4-20mA current outputs	

1 As defined by USEPA
2 Defined as twice the zero noise level
3 At constant temperature and voltage
4 When pneumatics are conditioned with NH_3 overnight and the gases (zero air to NH_3) are manually switched at the sample inlet at the rear of the 501.
5 Applies when sampling NH_3; better results expected for NO/NOx gas measurements.

Field Quality Control Activities:

Field QA activities for the TAPI T201 consisted of routine calibrations, precision checks and zero / span checks. These activities were performed either onsite or remotely through the site's communication and data logging system.

Calibrations were performed quarterly and consisted of testing and if necessary, adjusting the zero and span values of the analyzer. Once these points were checked / adjusted, several points in between these two points were checked to determine if the instrument was linear. All points must be within 2% of a best fit straight line. During the calibration, the NO_2 converter efficiency was also determined to verify proper operation of the molybdenum converter with a maximum error of 4% of complete efficiency.

Precision checks or one point QC checks were performed approximately every two weeks and consisted of verifying a lower level concentration (closer to average ambient levels) against a generated concentration. These two values should agree within 15%, a limit that is used by EPA on similar one point QC checks on the NOx method.

Zero / Span checks were also performed approximately every two weeks. These checks verified proper measurement at both ends of the instrument's calibrated range, with the span point being approximately 90% of the range. Zero drift is limited to +/- 3ppb while the span concentration must be within +/- 10% of the reference value.

Data spreadsheets for calibrations and precision checks are available upon request. Equipment needed for these field activities include but is not limited to:

a. Dynamic Dilution calibrator with certified mass flow controllers
b. Certified EPA Protocol compressed gas cylinders of nitric oxide and ammonia (with a balance of nitrogen)
c. Zero Air Generator

PM_{10} and $PM_{2.5}$ Measurement Method - Teledyne T640X PM Mass Monitor

Theory of Operation:

The Teledyne API (TAPI) Model T640X PM Mass Monitor is a real-time, continuous particulate matter (PM) mass monitor that uses scattered light spectrometry for measurement of PM2.5, PM_{10} and PM Coarse. The T640X converts optical measurements to mass measurements with sharp accuracy by determining sampled particle size via scattered light at a single particle level according to the Lorenz-Mic theory.

The TAPI Model T640X PM Mass Monitor is officially designated as a U.S. EPA Federal Equivalent Method (FEM) for determining compliance with particulate mass concentration National Ambient Air Quality Standards (NAAQS). Designation numbers are as followed:

$PM_{2.5}$ – EQPM-0516-236
PM_{10} – EQPM-0516-239

The official list of Designated Reference and Equivalent Methods can be found here: https://www.epa.gov/sites/production/files/2019-08/documents/designated_reference_and-equivalent_methods.pdf. The T640X analyzers are operated at the Pocomoke City and Princess Anne sites.

Instrument Specifications:

Below are the TAPI T640X operational specifications:

PARAMETER	SPECIFICATION	
Measurement Principle	90° white-light scattering	
Light Source	Polychromatic LED	
Particle Size Resolution	0.18 – 20µm over 256 channels, combined to 64 channels for mass calculation	
PM Mass Resolution Measurement Range	0.1 – 10,000 $\mu g/m^3$	
Mass Measurement & Display Resolution	0.1 $\mu g/m^3$	
Precision	+/- 0.5 $\mu g/m^3$ (1-hr average)	
Lower Detectable Limit	< 0.1 $\mu g/m^3$ (1-hr average)	
Mass Concentration Accuracy T640 640X Option	 Exceeds US EPA Class III PM2.5 Exceeds US EPA US EPA PM10 FEM and Class III PM2.5 & PM10-2.5 FEM performance requirements for additive and multiplicative bias compared to FRM samplers	
Flow Rate T640 640X Option	 5.0-LPM 5.0-LPM + 11.67-LPM bypass flow	
Flow Accuracy	Within +/-1%; (Typically within +/- 0.5%)	
AC Power	Rating	Typical Power Consumption
Instrument	110-120 V, 60 Hz 3.0 A 220V-240V, 50/60 Hz 3.0 A	<120 W (at 120 VAC) <120 W (at 120 VAC)
External pump (640X Option only)	110-120 V, 60 Hz 3.0 A 220V-240V, 50/60 Hz 3.0 A	<360 W (at 120 VAC) <360 W (at 120 VAC)
Communication	1 Ethernet: 10/100Base-T (supports MODBUS and HTTP polling protocols) 2 USB device ports	
Data Storage	4 Gb memory allows for >1 year of data storage Minimum Resolution (data rate): 10 seconds, user-definable	
Dimensions ASC (heater tube) ASC w/T640 inlet ASC w/640X Option inlet Optional external shelter	H x W x D: 7" x 17" x 14" (178 x 432 x 356 mm) 43" (1092 mm) above the lid 53.5" (1359 mm) above the lid 70" (1778 mm) above the lid HxWxD: 45" x 25" x 25" (1143 x 635 x 635 mm)	
Weight	19 lbs (8.6 kg) w/ T640 ASC + inlet 27 lbs (12.2 kg); w/ 640X Option ASC + inlet 30 lbs (13.6 kg)	
Operating Conditions Operating temperature Ambient temperature Ambient Relative Humidity Sample Humidity Control	 0 - 50°C, non-condensing -40 - 60°C 0 - 100% Aerosol Sample Conditioner (ASC) 24VDC 90W (max) heater controlled to 35% RH	
Environmental Conditions	Installation Category (Over voltage Category) II Pollution Degree 2 For outdoor use only, to ≤ 5000 m altitude	
[1] As defined by the US EPA	[2] At constant temperature and pressure	

Field Quality Control Activities:

Field QC activities on the T640X were performed at recommended periods according to the manufacturers operator's manual as well as the *Teledyne Model 640X Real-Time PM Continuous Monitor SOP* developed by EPA and Sonoma Technologies, Inc. (STI). Activities and frequency are listed below:

MAINTENANCE ACTION	FREQUENCY
Clean Inlet	Monthly, or as needed
Check/Adjust PMT with SpanDust™ (measured peak, limit value displayed on SpanDust™ bottle ± 0.5)	monthly or as needed e.g., high dust load
Check Pump Performance (Pump PWM < 80% / Valve PWM value < 85%)	monthly
Flow Rate Verification (see below)	
T640 Sample Flow: 5.0 LPM +/- 5% of standard compared to current reading on T640; (e.g., 4.75 – 5.25 lpm if T640 reads 5.00).	Monthly
T640x Total Flow: 16.67 LPM +/- 5% of standard compared to current reading on T640x. (e.g., 15.87 – 17.54 lpm if T640x reads 16.7).	Monthly
T640x Bypass Flow: 11.67 LPM +/- 5% of standard compared to reading on T640x; (e.g., 11.12 – 12.29 lpm if T640x reads 11.7).	Monthly (As needed if total or sample flow does not meet criteria. Use same tolerance as total and sample flow)
Check for leaks with "zero" filter	Monthly or as needed (Acceptance criteria is 0.0 – 0.2 μg/m^3)
Inspect and clean optical chamber and RH/T sensor.	every six months or as needed, e.g., high dust load
Change disposable Filter Unit (DFU) for 5-LPM flow and bypass flow (if installed)	Annually, or when Pump PWM Value approaches 80%.
Inspect inner and outer sample tubes	Monthly or as needed

All checks and calibrations were performed using a certified, NIST (National Institute of Science and Technology) traceable flow, temperature, and pressure standard. The standard used was an Alicat Scientific Model FP-25 Flow Calibrator (https://documents.alicat.com/manuals/Alicat_FP-25_Calibrator_Manual.pdf). Checks and calibrations were documented on separate excel spreadsheets and are available upon request.

$PM_{2.5}$ Measurement Method – Met One BAM-1020

Theory of Operation:

The Met One BAM-1020 uses beta ray attenuation to determine particulate matter concentrations (in this case PM Fine or $PM_{2.5}$) on an hourly basis. This method provides a sample determination of concentration in units of micrograms of particulate per cubic meter of air. A small C-14 (Carbon 14) element emits a constant source of high-energy electrons known as beta particulates. These beta particulates are detected and counted by a sensitive scintillation detector. An external pump pulls a measured amount of dust-laden air through a filter tape. After the filter tape is loaded with ambient dust, it is automatically placed between the source and the detector thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particle signal is used to determine the mass concentration of particulate matter in ambient air.

The Met One BAM-1020 Beta Attenuation Mass Monitor operating with the $PM_{2.5}$ FEM Configuration is designated as an equivalent method for $PM_{2.5}$ monitoring in accordance with 40 CFR Part 53 by the U.S. EPA. The designation number is EQPM-0308-170.

Instrument Specifications:

Operational specifications for the BAM-1020 are below:

PARAMETER	SPECIFICATION
Measurement Principle:	Particulate Concentration by Beta Attenuation.
U.S. EPA Designations:	EPA Class III PM_{10} FEM: EQPM-0798-122 EPA Class III $PM_{2.5}$ FEM: EQPM-0308-170 EPA Class III $PM_{10-2.5}$ FEM: EQPM-0709-185
Standard Range:	0 - 1.000 mg/m^3 (0 - 1000 μg/m^3)
Optional Ranges:	0 - 0.100, 0.200, 0.250, 0.500, 2.000, 5.000, 10.000 mg/m^3 (special applications)
Accuracy:	Exceeds US-EPA Class III $PM_{2.5}$ FEM standards for additive and multiplicative bias.
Measurement Resolution:	0.24 μg/m^3 (1.000 mg range). 2.4 μg/m^3 (10 mg range).
Data Resolution:	1 μg/m^3 (Concentration data stored and displayed in whole micrograms).
Sensitivity Std. Deviation: (σ) (1 hour)	Less than 2.4 μg/m^3 (less than 2.0 μg/m^3 typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (1 hour)	Less than 4.8 μg/m^3 from 0.000 to 0.100 mg/m^3 (less than 4.0 μg/m^3 typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (24 hour)	Less than 1.0 μg/m^3. Auditable with zero filter test.
Measurement Cycle Time:	1 Hour
Flow Rate:	16.7 liters/minute. Adjustable 0-20 LPM range. Actual or Standard flow.
Filter Tape:	Continuous glass fiber filter, 30mm x 21m roll. > 60 days/roll.
Span Check:	Automatic 800ug (typical) span foil verified hourly. Manually auditable.
Beta Source:	C-14 (carbon-14), 60 µCi ±15 µCi (< 2.22 X 10^6 Beq), Half-Life 5730 years.
Beta Detector Type:	Photomultiplier tube with organic plastic scintillator.
Operating Temp. Range:	0° to +50°C. Shelter temperature should be stable to within ±2°C per hour.
Ambient Temp. Range:	-40° to +55°C standard. Optional -50 degree temperature sensors available.
Ambient Humidity Range:	0 to 90% RH, non-condensing.
Humidity Control:	Actively controlled inlet heater module, 10% - 99% RH setpoint (35% standard).
Approvals:	U.S. EPA, MCERTS, CE, NRC, TUV, CARB, ISO-9001.
Standard User Interface:	Menu-driven interface with 8x40 character LCD display and dynamic keypad.
Optional User Interface:	Graphic color touch screen display module, Model BX-970.
Analog Output:	Isolated 0-1 VDC output standard. 0-10V, 4-20mA, 0-16mA switch-selectable.
Serial Interface:	RS-232 2-way serial ports for PC or modem communications.
Printer Output:	Output-only serial port, data or diagnostic output to a PC or serial printer.
Telemetry Inputs:	Clock Reset (voltage or contact closure), Telemeter Fault (contact closure).
Alarm Contact Closures:	Data Error, Tape Fault, Flow Error, Power Failure, Maintenance.
Compatible Software:	Air Plus™, Comet™, MicroMet Plus®, HyperTerminal®, ProComm Plus®.
Error Reporting:	User-configurable. Available through serial port, display, and relay outputs.
Memory:	4369 records (182 days @ 1 record/hr). Extended memory Report Processor option
Power Supply:	100 - 230 VAC, 50/60 Hz. 0.4 kW, 3.4A max. Not including shelter heater or a/c.
Weight:	24.5 kg (54 lbs) without external accessories.
Unit Dimensions:	H x W x D = 31cm x 43cm x 40cm (12.25" x 17" x 16").

Specifications may be subject to change without notice.

Field Quality Control Activities:

Quality Control activities ranged from recommendations in the BAM-1020 Operations Manual to guidance listed in EPA's QA Handbook Vol II Appendix D. These activities included but were not limited to the following:

a. Yearly calibrations
b. Routine temperature, pressure and flow checks using certified standards for each one of these parameters
c. Periodic Background or Zero Tests
d. Periodic cleaning of the nozzle / tape interface
e. Periodic leak checks to verify ambient flow of air through the instrument
f. Constant review of digital monitor (alarm) status could point to component failure / improper operation)

PM_{10} Measurement Method – Thermo Fisher Scientific Partisol Plus Sequential Sampler

Theory of Operation:

The Thermo Fisher Scientific Partisol-Plus 2025i Sequential PM_{10} Air Sampler was used to collect PM_{10} concentrations at two of the project sites. It is a manual method that requires the installation of 47mm Teflon® filters to produce 24-hr ambient air PM_{10} concentrations. The 2025i is a federal reference method, #RFPS-1298-127. The sampler draws a particulate laden ambient air stream though a sample inlet (in this case a PM_{10} head) and then through a pre-weighed 47mm diameter Teflon® filter. A built-in pump provides the vacuum required to pull the air flow through the Teflon® filter and a mass flow controller. These pre-weighed Teflon ® filters were then post weighted to produce a PM_{10} gravimetric mass measurement. All pre and post filter weighing is performed by the Maryland Department of Health in Baltimore City.

The 2025i's sampling frequency is customizable from everyday sampling to every twelfth day sampling. In this case the 2025i sampled every sixth day, producing approximately 60 PM_{10} concentrations during the project period.

Instrument Specifications:

Below are the instrument specifications for the Thermo Fisher Scientific 2025i Sequential PM10 Sampler:

Safety/Electrical Designations	Meets the following safety and electrical designations: CE: EN550011 Group 1, Class B (Emissions); EN55082-1 (Immunity); EN611010-1 (Safety) ETL: UL- and CSA-equivalent approval IEC 60529 IPX1
Operating Temperature	-30 °C to +50 °C. Temperatures down to -40 °C require additional optional hardware.
Flow Rate	5 to 18 volumetric liters per minute
Weight	2025*i* - 101 lb (46 kg) 2025*i*-D - 115 lb (52 kg)
Power Requirements	10 Amp @ 115VAC, 50/60Hz 5 Amp @ 220-240VAC, 50/60Hz
Enclosure	15.x 25.2 x 26.3 in. (40.2 x 64.0 x 67.3cm); height is 31 in. (78.8cm) with the top cover, and 35.3 in. (89.5cm) with the inlet connector
Stand Top Section	14 x 30.8 x 27.1 in. (35.6 x 78.2 x 68.8cm)
Footprint	42.0 x 18.1 in. (107 x 46.0cm)
Internal Data Storage	Greater than 86 days of interval data (five minute logging with six data items)
Analog Outputs	6 voltage outputs; 0–100 mV, 1, 5, 10 V (user selectable), 5% of full scale over/under range (user selectable), 12 bit resolution, measurement output user selectable per channel
Digital Outputs	1 power fail relay Form C, 10 digital relays Form A, user selectable alarm output, relay logic, 100 mA @ 200 VDC
Digital Inputs	16 digital inputs, user select programmable, TTL level, pulled high
Serial Ports	1 RS-232 with two connectors, baud rate 1200–115200, data bits, parity, and stop bits, protocols: C-Link, MODBUS, and streaming data (all user selectable)
Ethernet connection	RJ45 connector for 10/100Mbs Ethernet connection, static or dynamic TCP/IP addressing
USB	USB 2.0, full speed, 12 Mbps; and low speed, 1.5 Mbps

Field Quality Control Activities:

Quality Control activities again ranged from recommendations in the Thermo 2025i Operations Manual to guidance listed in EPA's QA Handbook Vol II Appendix D. These activities included but were not limited to the following:

a. Yearly calibrations
b. Monthly temperature, pressure, and flow checks using certified standards for each one of these parameters
c. Periodic cleaning of the instrument to reduce the possibility of filter contamination
d. Monthly leak checks to verify ambient flow of air through the instrument

e. Constant review of digital monitor (alarm) status, which could point to component failure / improper operation)
f. Many lab checks / requirements associated to pre and post weighing of the filters

Meteorological Measurement Method for WS, WD, Temperature, Pressure, Relative Humidity and Rain – Vaisala WXT 536 Weather Transmitter

Theory of Operation:

The instrument used to collect meteorological measurements during the project is the Vaisala WXT 536 Weather Transmitter. It is an ultrasonic transmitter that measures the following parameters:

a. Wind Speed (WS) and Wind Direction (WD)– uses Vaisala WINSCAP technology (three equally spaced ultrasonic transducers on a horizontal plane) to determine WS and WD by measuring the time it takes the ultrasound to travel from one transducer to the other two.
b. Temperature – uses a capacitive ceramic THERMOCAP sensor
c. Pressure – uses capacitive silicon BAROCAP sensor
d. Relative Humidity – uses a capacitive thin film polymer HUMICAP180 sensor
e. Rain – uses RAINCAP Sensor 2 technology (a piezoelectric sensor mounted underneath a steel cover) to detect the impact of individual raindrops. The signal of each drop can be converted directly to accumulated rainfall. The sensor can also track current and peak intensity as well as duration of rain events.

Instrument Specifications:

Instrument specifications are unique to each parameter, and are listed below:

a. WS / WD –

Property	Description/Value
Wind speed [1]	
Observation range	0 ... 60 m/s (134 mph)
Response time	0.25 s
Available variables	Average, maximum, and minimum

Property	Description/Value
Accuracy	±3 % at 10 m/s
Output resolution	0.1 m/s (km/h, mph, knots)
Units available	m/s, km/h, mph, knots
Wind direction [1]	
Azimuth	0 ... 360°
Response time	0.25 s
Available variables	Average, maximum, and minimum
Accuracy	±3.0° at 10 m/s
Output resolution	1°
Wind measurement frame	
Averaging time	1 ... 3600 s (= 60 min), at 1 s steps, on the basis of samples taken at 4, 2, or 1 Hz rate (configurable)
Update interval	1 ... 3600 s (= 60 min), at 1 s steps

b. Temperature –

Property	Description/Value
Observation range	-52 ... +60 °C (-60 ... +140 °F)
Accuracy (for sensor element) at +20 °C (+68 °F) [1]	±0.3 °C (±0.17 °F)
Output resolution	0.1 °C (0.1 °F)
Units available	°C, °F

c. Pressure –

Property	Description/Value
Observation range	600 ... 1100 hPa
Accuracy (for sensor element)	±0.5 hPa at 0 ... +30 °C (+32 ... +86 °F)
	±1 hPa at -52 ... +60 °C (-60 ... +140 °F)
Output resolution	0.1 hPa / 10 Pa / 0.001 bar / 0.1 mmHg / 0.01 inHg
Units available	hPa, Pa, bar, mmHg, inHg

d. RH –

Property	Description/Value
Observation range	0 ... 100 %RH
Accuracy (for sensor element) [1)]	±3 %RH at 0 ... 90 %RH
	±5 %RH at 90 ... 100 %RH
Output resolution	0.1 %RH
PTU measuring interval	1 ... 3600 s (= 60 min), at 1 s steps

e. Rain –

Property [1]	Description/Value
Rainfall	Cumulative accumulation after the latest automatic or manual reset.
Collecting area	60 cm^2
Output resolution	0.01 mm (0.001 in)
Field accuracy for daily accumulation [2]	Better than 5 %, weather-dependent
Units available	mm, in
Rain	
Duration	Counting each 10-second increment whenever droplet detected
Output resolution	10 s
Intensity	Running 1-minute average in 10-second steps
Observation range	0 ... 200 mm/h (0 ... 7.87 in/h) (broader range with reduced accuracy)
Units available	mm/h, in/h
Hail	Cumulative amount of hits against collecting surface
Duration	Counting each 10-second increment whenever hailstone detected
Output resolution	0.1 hits/cm^2, (1 hits/in^2), 1 hit
Intensity	1-minute running average in 10-second steps
Units available	hits/cm^2, hits/in^2, hits
Output resolution	10 s
Observation range	0.1 hits/cm^2h (1 hits/in^2h), 1 hit/h
Units available	hits/cm^2h, hits/in^2h, hits/h

Field Quality Control Activities:

Quality Control activities are few with this type of sensor, but include:

a. Periodic cleaning of the radiation shield
b. Yearly replacement of the PTU module
c. Wind tunnel certification as needed

Appendix C –
Monitoring Site Descriptions and Maps
for the Lower Eastern Shore Air Quality Study

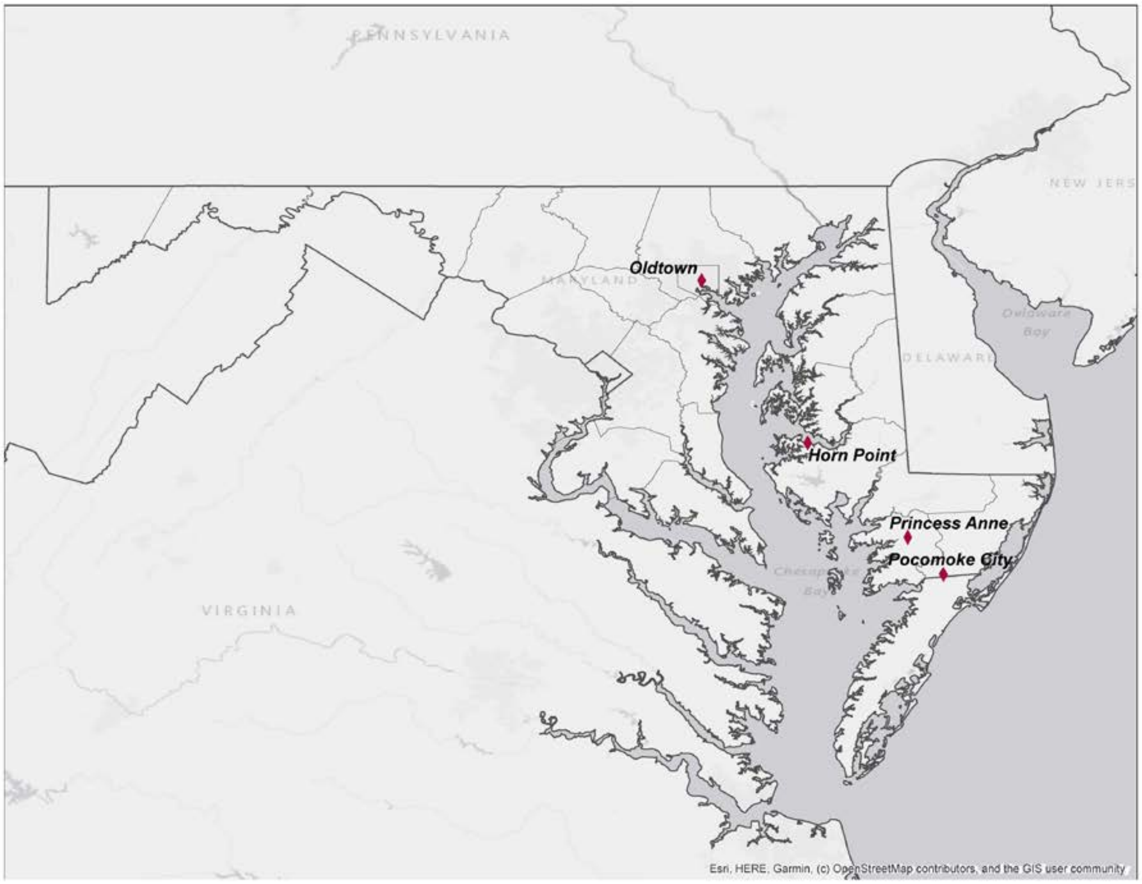


Figure 1. Map of air monitoring sites for the Lower Eastern Shore Study in Maryland.

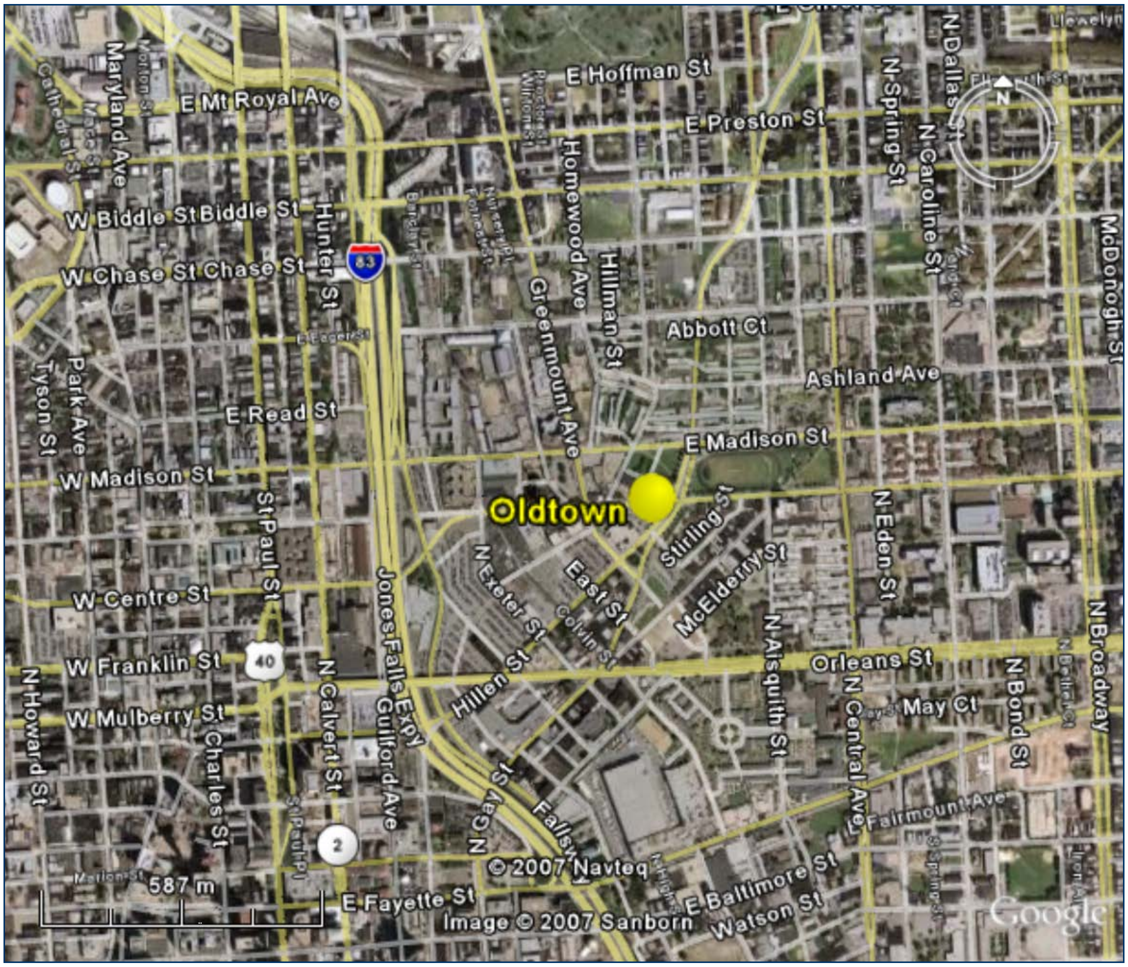


Figure 2. Map of Oldtown air monitoring site in Baltimore City, MD.

The Oldtown monitoring station is located in an urban and center city setting with NO poultry operations. The Oldtown trailer sits in a parking lot off to the side of a very busy four-way intersection right by a bus stop where buses stop often. There is also a fire station within a couple hundred feet of the trailer and nearby sidewalks by the bus stop and along the street next to the trailer.

Figure 3. Map of the Horn Point air monitoring site in Dorchester County, MD.

The Horn Point monitoring station is located in a rural setting with NO poultry operations. The site is located on the lower eastern shore and sits in an open field with pine trees in the distance surrounding the site. The University of Maryland Center for Environmental Studies is next door to the site.

Figure 4. Map of the Pocomoke City air monitoring site in Worchester County, MD.

The Pocomoke City monitoring station is located in a rural setting with a HIGH poultry operation density. Almost 900,000 chickens are within a 2-mile radius and about half that number within 1 mile. The site is impacted from multiple directions, and many more chicken houses are located outside of a 2-mile radius. Twenty nine (29) broiler houses (green stars on the map) are located within a 1-mile radius and 70 houses are within a 2-mile radius.

Figure 5. Map of the Princess Anne air monitoring site in Somerset County, MD.

The Princess Anne monitoring station is located in a rural setting with a LOW poultry operation density. This site is much less impacted by poultry operations within a 2-mile radius. The site is located approximately 14 miles to the NE of Pocomoke City site. No broiler houses are located within a 1-mile radius and 7 houses are within a 2-mile radius.