Southeast PM$_{2.5}$ Data Analysis

Analysis of PM$_{2.5}$ FRM data and data for monitors in southeast Pennsylvania.

Monitor Information

Site Name	County	FRM Start Date	FRM Sample Frequency	Speciated Start Date	Speciated Frequency
Lancaster	Lancaster	1/1999	1/3	4/2002	1/6
Freemansburg	Northampton	1/1999	1/1	NA	NA
Bristol	**Bucks**	**2/1999**	**1/3**	**NA**	**NA**
New Garden	**Chester**	**1/2002**	**1/3**	**4/2002**	**1/6**
Chester	**Delaware**	**1/1999**	**1/3**	**4/2002**	**1/6**
Norristown	**Montgomery**	**2/1999**	**1/3**	**NA.**	**NA**
AMS Lab	**Philadelphia**	**2/1999**	**1/1**	**5/2006**	**1/6**
500 Broad St	**Philadelphia**	**2/1999**	**1/3 to 1/1**	**NA.**	**NA**

Items in BOLD are within the Philadelphia-Wilmington nonattainment area.

Data Analysis:

Design Value Contribution Analysis:

Only one monitor in southeast Pennsylvania currently exceeds the annual PM$_{2.5}$ NAAQS (15.0 µg/m^3). PM$_{2.5}$ annual design values for 2006 are listed in Table 1 for six FRM monitoring sites in southeast Pennsylvania. Design values across southeast Pennsylvania have remained relatively stable for most monitors over the last five years.

Table 1.
Annual PM$_{2.5}$ Design Values

Site	2002-04	2003-05	04-06
Lancaster	16.8	17.5	16.3
Freemansburg	14.0	14.1	13.6
Bristol	**13.9**	**13.9**	**13.2**
New Garden	**14.8**	**15.2**	**14.2**
Chester	**15.0**	**15.6**	**15.2**
Norristown	**13.2**	**12.8**	**12.2**
AMS Lab	**14.5**	**14.3**	**13.9**
500 Broad St	**15.4**	**15.0**	**15.0**

Items in BOLD are within the Philadelphia-Wilmington nonattainment area.

The nature of the annual standard makes it difficult to determine what causes a monitor to exceed the annual PM$_{2.5}$ standard. For a well-run monitor, between 365 to 1096 FRM

measurements make up its annual design value. The shear number of samples makes it very difficult to determine what days (samples) are contributing to monitor's annual design value.

A monitor's annual $PM_{2.5}$ design value is determined by first calculating its quarterly average. Quarterly averages are then averaged to calculate the monitor's average annual $PM_{2.5}$ concentration. Three consecutive years of average annual $PM_{2.5}$ concentrations are then averaged to determine a monitor's annual $PM_{2.5}$ design value. Thus any one particular sample will make only a minor contribution to a monitor's annual $PM_{2.5}$ design value.

The Pennsylvania DEP has come up with a methodology to quickly analyze a monitor's design value and determine which measurements (or types of measurements) are contributing to a site's design value. Each twenty-four hour $PM_{2.5}$ FRM measurement's contribution to the monitor's annual design value is calculated. FRM 24-hour concentrations are then grouped into different sample ranges to gauge each sample range's contribution to the monitor's annual design value. Monitors then can be compared to determine which monitor sample ranges are important.

For the purposes of this analysis, contributions are determined such that contributions from samples less than 15.0 $\mu g/m^3$ are negative and those samples that are greater than 15.0 $\mu g/m^3$ are positive. The break point of 15.0 $\mu g/m^3$ represents the break-off point for the annual $PM_{2.5}$ standard. Mathematically the contributions for each sample range can be represented by this equation:

For values less than or equal to 15.0 $\mu g/m^3$:

$$0 < x \leq 15$$

$$\sum_{x=0}^{15} \frac{x-15}{n*12}$$

For values greater 15.0 $\mu g/m^3$:

$$15 < x < \text{Max}$$

$$\sum_{15}^{\text{Max}} \frac{x-15}{n*12}$$

Contributions from several ranges of sample concentrations then can be summed to determine a monitor's annual design-value concentration. Table 2 shows the results of the design-value contribution analysis for six monitors in southeast Pennsylvania. The list includes all of the PA DEP maintained monitors in the Philadelphia-Wilmington $PM_{2.5}$ nonattainment area plus the Lancaster monitor which lies west of Philadelphia and the Freemansburg monitor which lies to the north.

Table 2.
Design Value Contribution Analysis

Site	0-15.0	15.0-40.5	40.5-65.5	>65.5	Sum
Lancaster	-3.0663	3.7532	0.6286	0.0000	1.3155
Freemansburg	-4.2393	2.5064	0.2885	0.0000	-1.4444
Bristol	**-4.3432**	**2.5612**	**0.0000**	**0.0000**	**-1.7820**
New Garden	**-3.7375**	**2.8114**	**0.2304**	**0.0000**	**-0.6956**
Chester	**-3.2745**	**3.3408**	**0.0719**	**0.0000**	**0.1000**
Norristown	**-4.7638**	**1.9427**	**0.0000**	**0.0000**	**-2.8211**
AMS Lab	**-3.9434**	**2.6133**	**0.2299**	**0.0000**	**-1.1000**
500 Broad St	**-3.2481**	**3.0771**	**0.1973**	**0.0000**	**0.0000**

Items in BOLD are within the Philadelphia-Wilmington nonattainment area.

The break lines in Table 2 are roughly based on the twenty-four hour AQI scale for $PM_{2.5}$ with the lower scale being cut off at 15.0 μg/m³. Most of the PA DEP monitors within the Philadelphia $PM_{2.5}$ nonattainment area meet the annual standard (except Chester). Surprisingly, there appear to be fewer days with high $PM_{2.5}$ concentrations (> 40.5 μg/m³) in the Philadelphia nonattainment area than in areas to the west (Lancaster) and north (Freemansburg). The Chester and to a lesser extent the 500 Broad Street monitors also appear to have fewer days with concentrations less than 15 μg/m³ than the other four (4) Philadelphia monitors in this analysis.

Design Value Contribution Analysis Summary:

- **Only one monitor in the Philadelphia-Wilmington $PM_{2.5}$ nonattainment area exceeds the annual standard though there are data capture issues for the Philadelphia County monitors.**
- **There appear to be fewer days with high $PM_{2.5}$ concentrations (> 40.5 μg/m³) in the Philadelphia-Wilmington nonattainment area than there are in areas to the west (Lancaster) and north (Freemansburg).**
- **The Chester and 500 Broad Street monitors appear to have fewer days with $PM_{2.5}$ concentrations less than 15 μg/m³ than other monitors in the region.**

Correlation Coefficient Analysis:

Correlation coefficients are a statistical measure to determine how well two different samples track one another. There are three possibilities; the two samples react similarly, they appear to be random or they react oppositely. Daily FRM $PM_{2.5}$ measurements from six monitors in southeast Pennsylvania (2000-06) were correlated with one another to determine how well the monitors tracked each other over time. PA DEP monitors were also compared with monitors to the west and north to determine how well the Philadelphia area monitors tracked concentrations in nearby regions.

The largest distance between monitors is approximately 80 miles (between Lancaster and Bristol). The bulk of the monitors are within 30 miles of one another. There are no large terrain features in the region so airflow is generally unrestricted.

Table 3 lists the correlation coefficients for several FRM monitoring sites in southeast Pennsylvania. Coefficients range from 1.0 to –1.0. Correlation ranges and their meaning are broken down as follows:

1.0 to 0.667	Positive correlation (samples move in a similar direction)
0.667 to -0.667	Samples not well correlated (0.334 to – 0.334, random)
-0.667 to –1.0	Negative correlation (samples move in opposite direction)

Table 3.
Southeast Pennsylvania $PM_{2.5}$ Correlation Coefficients

	Lancaster	Freemansburg	Bristol	New Garden	Chester	Norristown
Lancaster		0.8528	0.8594	0.9211	0.8346	0.8639
Freemansburg	0.8528		0.8855	0.8751	0.8113	0.8838
Bristol	0.8594	0.8855		0.8915	0.8602	0.9059
New Garden	0.9211	0.8751	0.8915		0.8928	0.9030
Chester	0.8346	0.8113	0.8602	0.8928		0.8580
Norristown	0.8639	0.8838	0.9059	0.9030	0.8580	

	AMS	500 Broad	Bristol	New Garden	Chester	Norristown
AMS		0.9480	0.9346	0.9346	0.9076	0.9159
500 Broad	0.9480		0.8985	0.9111	0.9024	0.8792
Bristol	0.9346	0.8985		0.8915	0.8602	0.9059
New Garden	0.9346	0.9111	0.8915		0.8928	0.9030
Chester	0.9076	0.9024	0.8602	0.8928		0.8580
Norristown	0.9159	0.8792	0.9059	0.9030	0.8580	

Correlation coefficients indicate that the six monitors within the Philadelphia-Wilmington nonattainment area respond similarly. There are greater similarities in the FRM data between monitors that are relatively close together than for monitors that are far apart. Correlations also tend to be slightly lower between monitors exceeding the annual $PM_{2.5}$ standard (Lancaster and Chester) and those that do meet the standard.

Correlation coefficients for the Chester and Broad Street monitors appear to be lower than any of the other monitors. This may indicate these monitors are behaving differently than the surrounding monitors within the nonattainment area. There also does not seem to be as much seasonal variability in correlations as was found in other areas of Pennsylvania.

Correlation Coefficient Analysis Summary:

- **Correlation coefficients constructed from 2000-06 FRM data indicate all of the monitors in the Philadelphia generally respond in a similar fashion.**
- **Correlations are better between the monitors that are close to one another.**
- **Correlations between Chester and the 500 Broad Street monitor are a bit lower than correlations between the other monitors indicating these monitors may be behaving differently than other monitors in the nonattainment area.**
- **There appears to be little change in correlations based on time of year. This is different than other areas of Pennsylvania where correlations were analyzed.**

Coefficients of Divergence Analysis:

Correlation of divergence is a statistical measure to quantify the magnitude of difference between two groups of samples. FRM samples between 2000 and 2006 were analyzed to determine the coefficients of divergence for six monitors in southeast Pennsylvania and the Lancaster and Fremansburg monitors to the west and north respectively. Table 4 summarizes the results of this analysis. In general numbers close to zero indicate small differences in daily concentrations between monitors. Numbers close to one or above indicate significant differences in the daily $PM_{2.5}$ concentrations between the two monitors.

Table 4.
Southwest Pennsylvania $PM_{2.5}$ Coefficient of Divergence

	Lancaster	Freemansburg	**Bristol**	**New Garden**	**Chester**	**Norristown**
Lancaster		0.9632	0.7667	0.2749	0.6090	0.6597
Freemansburg	0.9632		0.5653	0.5752	0.9398	0.5024
Bristol	0.7667	0.5653		0.4270	0.7206	0.3910
New Garden	0.2749	0.5752	0.4270		0.4603	0.4160
Chester	0.6090	0.9398	0.7206	0.4603		0.7349
Norristown	0.6597	0.5024	0.3910	0.4160	0.7349	

	AMS	**500 Broad**	**Bristol**	**New Garden**	**Chester**	**Norristown**
AMS		0.3274	0.2023	0.2703	0.4149	0.2343
500 Broad	0.3274		0.4952	0.3351	0.3389	0.6003
Bristol	0.2023	0.4952		0.4270	0.7206	0.3910
New Garden	0.2703	0.3351	0.4270		0.4603	0.4160
Chester	0.4149	0.3389	0.7206	0.4603		0.7349
Norristown	0.2343	0.6003	0.3910	0.4160	0.7349	

The results of this analysis indicate there are some significant differences in daily fine-particulate concentrations across southeast Pennsylvania. In particular there are significant differences in daily monitor values between the Philadelphia nonattainment area and the Lancaster and Freemansburg monitors, with the exception of the Lancaster and New Garden monitors, which surprisingly showed little difference in daily concentrations. Again there are significant differences in values between the Chester and 500 Broad Street monitors and the other monitors in the Philadelphia-Wilmington nonattainment area. This is similar to patterns observed in the correlation coefficient analysis and supports the contention that these monitors are behaving differently than other monitors in the nonattainment area. Coefficients of divergence values do not appear to vary much by time of year. This differs for from other areas of Pennsylvania that appear to show some seasonal variability

Coefficients of Divergence Analysis Summary:

- **Coefficients of Divergence constructed from 2000-06 FRM data indicate there are some significant differences in daily PM$_{2.5}$ concentrations between the Chester and 500 Broad Street and other monitors in the Philadelphia-Wilmington nonattainment area.**
- **Coefficients of Divergence do not appear to vary much by season. This differs from other areas of Pennsylvania that have been analyzed.**