Tara Schwartz was a sophomore at the University of Idaho majoring in Biology during her internship at PNNL for the summer of 2003. Now Ms. Schwartz is in the middle of perusing a degree in pharmaceuticals at Washington State University. During her appointment at PNNL she monitored particulate matter over the course of several months at a number of locations throughout the Hanford Site. The goal was to measure and evaluate any relationships found between PM2.5, PM10, and TSP. From the experience, Ms. Schwartz gained further knowledge and appreciation for environmental protection.

Brad Fritz is an engineer with degrees in physics from Eastern Oregon University and environmental engineering from Washington State University. Currently he is a research scientist at Pacific Northwest National Laboratory and specializes in atmospheric monitoring. He is involved in monitoring ambient air for regulatory compliance, conducting research studies on fundamental properties of atmospheric emissions, soil gas monitoring around contaminant plumes, and air monitoring in industrial settings.

DUST MONITORING ON THE HANFORD SITE: AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN TSP, PM-10, AND PM-2.5

Tara Schwartz, Brad G. Fitz

ABSTRACT

High levels of particulate matter (PM) are linked to some health problems and environmental issues. Air quality standards have been developed in hopes to reduce particulate matter problems. The most common fractions of particulate matter measured include $PM_{2.5}$, PM_{10}, and total suspended particles (TSP). The focus of this study was to evaluate relationships between $PM_{2.5}$, PM_{10}, and TSP concentrations specific to the Hanford Site, near Richland, Washington. Measurements of $PM_{2.5}$ and PM_{10} concentrations continued while additional measurements of TSP were made over several summer months. Four sampling locations on the Hanford Site were used to compare spatial differences in the data. Comparison of the data revealed a strong linear correlation between PM_{10} and TSP for the time period evaluated. The correlation between $PM_{2.5}$ and TSP was not as strong, and indicated that local sources rarely were above background measurements. This was supported by the correlation of ground level $PM_{2.5}$ with $PM_{2.5}$ concentrations measured on a near by mountain.

INTRODUCTION

Particulate matter (PM) is a mixture of liquid and solid material of varying size and chemical characteristics [1]. When describing particulate matter, the entire mass concentration found in the air is called total suspended particles (TSP). On a smaller scale, particles less than 10 um in aerodynamic diameter are considered coarse particles and are denoted as PM_{10}, while particles less than 2.5 um in aerodynamic diameter are denoted as $PM_{2.5}$ [2]. Such fine particles are classified as primary or secondary particles due to their size difference and chemical compositions. Primary particles are directly emitted from sources. Secondary particles form from chemical reactions in the atmosphere [3]. Both PM_{10} and $PM_{2.5}$ are generated naturally, by human activities, and formed as a result of pollutants in the atmosphere [4].

To reduce health problems associated with particulate matter, the EPA has developed air quality standards for particulate matter. Air quality standards are based upon limiting the concentration of particles small enough to penetrate beyond upper airways. The particle size greatly affects the amount and location of particles that enter the body and lungs. Coarse particles are more likely to be deposited in the bronchial region, while fine particles have a greater chance of penetrating into the periphery of the lung [1]. A number of epidemiological studies have shown that increases in particulate concentration significantly influence respiratory health. Some relations have been found that connect suspended particulate matter with lung functions, respiratory symptoms, and mortalities [2].

At the Hanford Site in Richland, Washington, environmental surveillance personnel monitor concentrations of radionuclides and chemicals in the environment. Air, surface water, sediment, soil and natural vegetation, fish, and wildlife samples are collected and analyzed regularly [5]. To monitor air concentrations of PM_{10} and $PM_{2.5}$, Tapered Element Oscillating Microbalance (TEOM) monitors are used. The main goals of these instruments are to improve the understanding of the atmospheric fate of particulate matter in the Columbia Basin and on the Hanford Site, react to Hanford Site air quality issues during and after a fire, and supply fundamental data for atmospheric science research.

There is a sufficient amount of PM_{10} and $PM_{2.5}$ data that has been collected from existing TEOM instruments on the Hanford Site, but there is a need for TSP data. During this study, the TEOM instruments continued to collect PM_{10} and $PM_{2.5}$ data, while additional air monitoring instruments were

used to collect TSP data. The data collected allows for the investigation of relationships between TSP, PM_{10}, and $PM_{2.5}$ on the Hanford Site. The data also allows for a comparison of the accuracy of three different TSP instruments to help determine the best TSP instrument for future use. The results of this study will be incorporated into the environmental surveillance program on the Hanford Site, and will further the understanding of the generation, transport, and fate of particulate matter on the Hanford Site.

MATERIALS AND METHODS

For this project, samples were collected at four locations on the Hanford Site (Figure 1). The 200 Area Meteorology tower was selected as one of the sample locations due to its positioning close to a high number of Hanford workers and its central location on the Hanford Site. Another location used on the Hanford Site was the 100 F Meteorology tower, on the basis of being down wind of the 200 Area Meteorology tower and providing data useful in comparing spatial variability on the Hanford Site. The other two areas involved were the Rattlesnake Mountain Peak and Rattlesnake Springs, which offered additional TEOM data to compare spatial differences in PM concentrations.

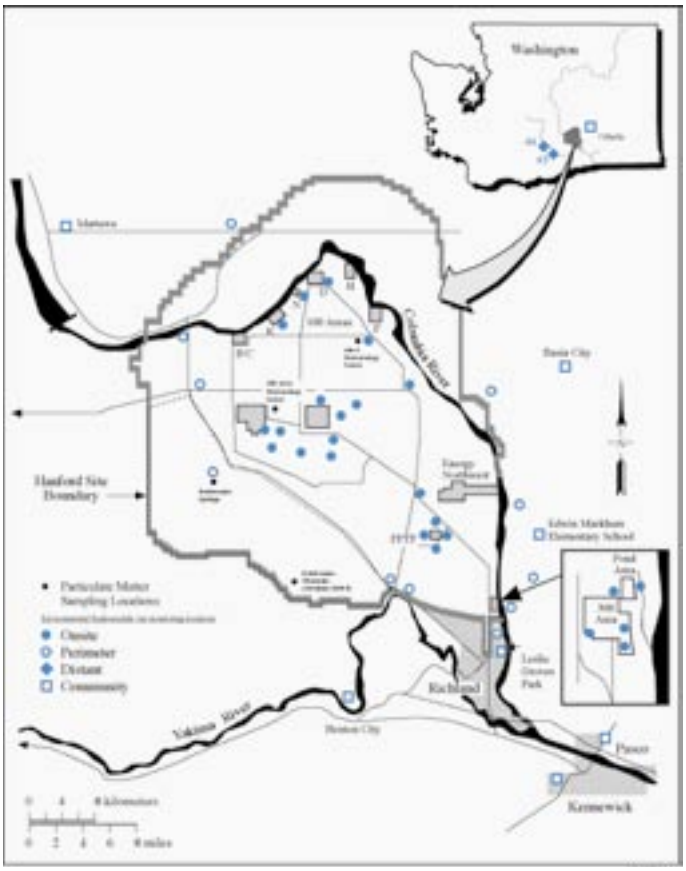

Figure 1. Map of particulate matter sample locations on and around the Hanford Site, with environmental radionuclide air monitoring locations shown for reference.

For TSP measurements, three different sampling systems with various filter sizes were utilized. One instrument was an Anderson High Volume Sampler, which used an 8 x 10 inch glass fiber filter, distributed by HI-Q Environmental Products. The sampler had a pump flow rate of 1 m^3/min and a face velocity of 18 m/min. The Anderson sampler was set up at the 200 Area Meteorology tower close to the TEOM instruments, at a sampling height of 1 meter. Another dust collection instrument based at the 200 Area Meteorology tower was a VS23-Series pump with a 2 inch diameter glass fiber filter, manufactured by I.W. Treatment Co. This sampler had a pump flow rate of .0085 m^3/min and a face velocity of 42 m/min. The VS23 pump was useful because it had the same setup as the Hanford Site environmental monitoring air sampler network (Figure 1). The last TSP instrument used in the project was a H8400 High Volume Air Sampler using a 4 inch diameter glass fiber filter from F & J Specialty Products. The sampler had a pump flow rate of 1 m^3/min and a face velocity of 120 m/min. The H8400 sampler was located at the 100 F site at a height of one meter, throughout the course of the collection period. Monitoring of all three TSP was done manually over the course of a specific time schedule and each pump had a timer to account for power outages throughout the sample collection.

Prior to the use of any filters, each filter had to go through a 24-hour equilibration process. This involved placing them in a sealed glove box and kept at 20°C and 40% humidity. The next step was to establish a tare weight of the filter by weighing each filter three times and averaging the results. Filters were weighed on a HR-60 analytical balance with 0.1 mg resolution. Once a tare weight was established, the filters were deployed in the field. The sample period for each filter varied from 24 hours to over a week, throughout the collection period (Table 1). After retrieving each filter from the field, the filters went through another 24-hour equilibration period. The filters were then weighed three final times and an average final weight was established. Evaluation of the precision and accuracy of the analytical method indicates that the procedure was adequate to produce results accurate to +/- 10%.

RESULTS

Table 1 provides an organized summary of the data collected. The TSP sample location, sample type, and sample period are shown. For comparison, the average PM_{10} and $PM_{2.5}$ concentrations at the 200 Area Meteorology tower, over the sampling period, are included with the TSP mass concentrations. The average TSP concentration measured over the entire study period was 31 ug/ m^3. The average PM_{10} concentration was 16.45 ug/ m^3, and the average $PM_{2.5}$ concentration was 6.76 ug/ m^3. Results of TSP measurements from the 2 inch and 4 inch instruments were similar, while the 8 x 10 inch instrument had consistently higher results. A consequence of the differences in sample height from the ground and face velocity between the three instruments could be a reason for the differences in the final results. For study period, the average concentration of TSP for the 2 inch filters was 24 ug/ m^3, the average for the

Location	Sample Type	Date On	Date Off	TSP Mass concentration	PM10 data averages	PM2.5 data averages
200 met twr	2" low vol	6/4/03 9:30	6/9/03 10:00	32	22	10
200 met twr	2" low vol	6/9/03 10:00	6/12/03 10:00	26	21	7
200 met twr	2" low vol	6/12/03 10:00	6/16/03 9:45	21	14	7
200 met twr	2" low vol	6/16/03 9:45	6/24/03 10:00	20	15	6
200 met twr	2" low vol	6/24/03 10:00	6/27/03 14:00	15	13	6
200 met twr	2" low vol	7/1/03 13:00	7/3/03 8:30	17	12	4
200 met twr	2" low vol	7/3/03 8:30	7/7/03 9:30	15	15	6
200 met twr	2" low vol	7/7/03 9:30	7/9/03 10:00	23	17	6
200 met twr	2" low vol	7/9/03 10:00	7/11/03 9:00	27	19	8
200 met twr	2" low vol	7/11/03 9:00	7/14/03 9:00	41	22	7
200 met twr	2" low vol	7/14/03 9:00	7/16/03 9:30	24	17	7
200 met twr	2" low vol	7/16/03 9:30	7/18/03 14:00	28	19	6
Average				**24**	**17**	**7**
Standard Deviation				**7.4**	**3**	**1**
100 F met twr	4"	6/24/03 9:30	6/25/03 15:00	26	13	7
100 F met twr	4"	7/8/03 9:30	7/10/03 9:00	22	14	5
100 F met twr	4"	7/10/03 9:00	7/11/03 8:30	37	21	11
100 F met twr	4"	7/14/03 9:00	7/16/03 9:00	24	17	7
Average				**27**	**16**	**7**
Standard Deviation				**6.5**	**4**	**2**
200 met twr	8x10 Hi Vol	6/12/03 10:00	6/13/03 9:30	35	15	6
200 met twr	8x10 Hi Vol	6/13/03 9:30	6/16/03 9:45	30	14	7
200 met twr	8x10 Hi Vol	6/16/03 9:45	6/24/03 10:00	44	15	6
200 met twr	8x10 Hi Vol	6/24/03 10:00	6/25/03 15:30	31	13	7
200 met twr	8x10 Hi Vol	6/25/03 15:30	6/26/03 12:00	23	13	7
200 met twr	8x10 Hi Vol	6/26/03 12:00	6/27/03 14:00	31	12	6
200 met twr	8x10 Hi Vol	6/27/03 14:00	6/30/03 10:00	43		
200 met twr	8x10 Hi Vol	6/30/03 10:00	7/1/03 9:00	22		
200 met twr	8x10 Hi Vol	7/1/03 9:00	7/3/03 8:30	27	12	4
200 met twr	8x10 Hi Vol	7/3/03 8:30	7/7/03 9:30	26	15	6
200 met twr	8x10 Hi Vol	7/7/03 9:30	7/8/03 9:30	80	21	6
200 met twr	8x10 Hi Vol	7/8/03 9:30	7/9/03 10:00	24	12	5
200 met twr	8x10 Hi Vol	7/9/03 10:00	7/10/03 9:00	33	17	6
200 met twr	8x10 Hi Vol	7/10/03 9:00	7/11/03 9:00	30	21	11
200 met twr	8x10 Hi Vol	7/11/03 9:00	7/14/03 9:00	51	22	7
200 met twr	8x10 Hi Vol	7/14/03 9:00	7/16/03 9:30	31	17	7
200 met twr	8x10 Hi Vol	7/16/03 9:30	7/17/03 9:00	44	16	5
200 met twr	8x10 Hi Vol	7/17/03 9:00	7/18/03 14:00	33	21	7
Average				**36**	**16**	**6**

Table 1. Results for Air Sampling of TSP over specific time periods with average PM10 and PM2.5 concentrations. Concentrations are in ug/m3.

4 inch filter was 27 ug/ m^3, and the average for the 8 x 10 inch filter was 36 ug/ m^3.

Evaluation of average wind speeds and peak wind speeds over the collection period for each sample revealed no correlation between dust concentrations and wind speeds. This implies that there were no significant wind blown dust events over the sampling period. This was confirmed through visual observation, and the lack of any high wind speed days. The lack of correlation of dust concentrations and wind speeds indicates that during low wind speeds, atmospheric dust on the Hanford site is not windblown dust

Figure 2 compares the amount of TSP collected by the 2 inch filters to the average PM_{10} and $PM_{2.5}$ concentrations. The data indicates a direct correlation between TSP, $PM_{10,}$ and $PM_{2.5}$ concentrations. More scatter was found in the $PM_{2.5}$ and TSP comparison (R^2= 0.25), which also had a lower increase in $PM_{2.5}$ with an increase in TSP.

In Figure 3, TSP from the 4 inch filters collected at the 100 F Meteorology tower was compared to the average PM_{10} and $PM_{2.5}$ concentrations at the 200 Area Meteorology tower. The

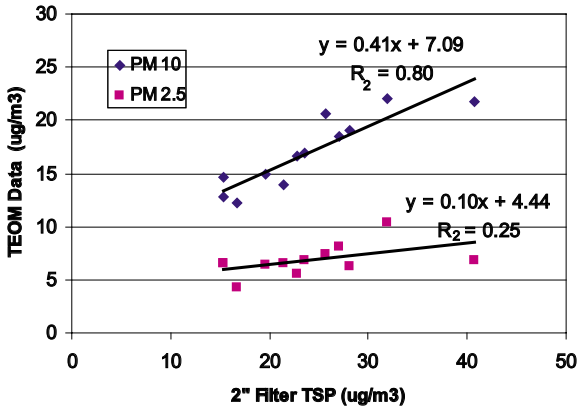

Figure 2. Results of TSP concentrations from 2 inch filters at the 200 Meteorology tower compared to TEOM PM10 and PM2.5 concentrations from the 200 Meteorology tower.

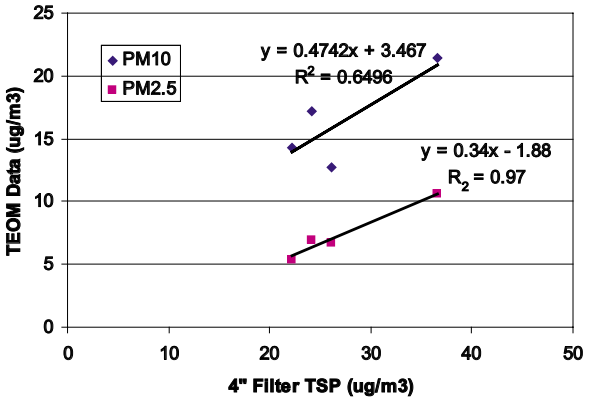

Figure 3. Results of TSP concentrations from 4 inch filters at the 100 F Meteorology tower compared to TEOM PM10 and PM2.5 concentrations from the 200 Meteorology tower.

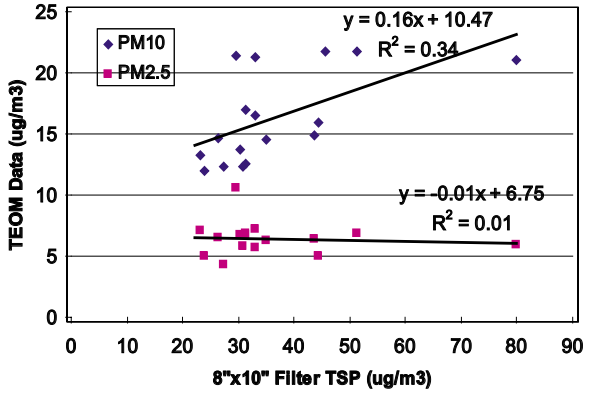

Figure 4. Results of TSP concentrations from 8 x 10 inch filters from the 200 Meteorology tower compared to TEOM PM10 and PM2.5 concentrations from the 200 Meteorology tower.

PM_{10} and $PM_{2.5}$ showed similar increases in concentration as the amount of TSP increased.

Figure 4 shows the TSP from the 8 x 10 filters verses the PM_{10} and $PM_{2.5}$ concentrations. The comparison between the $PM_{2.5}$ and TSP shows that $PM_{2.5}$ has a slope of –0.0087 and hardly changes with different TSP concentrations. From the

results there does not appear to be any correlation between the 8 x 10 inch TSP data and the PM_{10} or $PM_{2.5}$ data.

DISCUSSION AND CONCLUSION

This study will help the understanding of the relationship between TSP, PM_{10} and $PM_{2.5}$ and its effect on and around the Hanford Site. The information generated by this study will serve as a starting point for future work.

In all of the TSP concentration data, $PM_{2.5}$ showed minimal changes in concentration, while the PM_{10} concentration increased when the TSP concentrations increased. Throughout the course of the study, $PM_{2.5}$ stayed between 4 and 11 ug/m^3, PM_{10} stayed between 12 and 22 ug/ m^3, and the TSP concentrations ranged from 15 to 80 ug/ m^3. The data suggests that $PM_{2.5}$ is not produced locally, but is brought in by regional factors and is not significantly affected by increases in local TSP concentration. However, PM_{10} concentrations and TSP concentrations increased at the same times. The slopes in Figures 2, 3, and 4 have a higher increase for PM_{10} concentrations than $PM_{2.5}$ when compared to TSP concentrations. Since PM_{10} has a strong correlation with TSP concentrations, the data suggests that PM_{10} is locally produced and is of more concern to this area.

Additional data from a near by location also suggests that $PM_{2.5}$ is not a local issue, but PM_{10} is. Measurements of $PM_{2.5}$ were done on the top of Rattlesnake Mountain and were compared to the 200 Area Meteorology tower $PM_{2.5}$ data, shown in Figure 5. The unique location of Rattlesnake Mountain provides PM concentration data largely independent of local sources. $PM_{2.5}$ concentrations were similar between the two locations and help conclude that $PM_{2.5}$ is not driven by local events. Thus, $PM_{2.5}$ will not play a role in finding relationships with TSP on the Hanford Site, as $PM_{2.5}$ would likely not differ significantly across the site locations.

Measurements of PM_{10} concentrations were also done at Rattlesnake Springs and compared with the 200 Area Meteorology tower PM_{10} data, shown in Figure 6. The PM_{10} concentrations show a lot of scatter, which imply that PM_{10} concentrations are not consistent and change from each area.

The Anderson High Volume Sampler, with an 8 x 10 inch filter, did not perform consistently. Results from the 8x10 inch filter showed mass concentrations between 22 and 80 ug/ m^3 and a standard deviation of 13.6, which was approximately twice as much as the 2 and 4 inch filter's standard deviation. Handling, weighing, and calculation errors may have factored for some of the inconsistency, but the amount of scatter in the data between PM_{10} and TSP concentrations suggest that the filtering system was defective, or inappropriate for this type of testing. The Anderson High Volume Sampler gives little help to finding a correlation between TSP, PM_{10}, and $PM_{2.5}$ and is inadequate for future TSP concentrations measurements without modification.

When comparing the data collected from the 2 inch filters to the 4 inch filters, similar ratios of TSP to PM_{10} concentrations were found. The slope of the 4 inch TSP concentrations was 0.47 and the slope of the 2 inch TSP concentrations was 0.41, which suggests a specific correlation between PM_{10} concentrations and TSP concentrations. With a correlation coefficient of 0.80, the TSP concentrations from the 2 inch filters have a number of data points that give a direct relationship to PM_{10} concentrations. However, the 4 inch TSP concentrations had few data points to compare, bringing into question the validity of any relationships. The correlation of the TSP con-

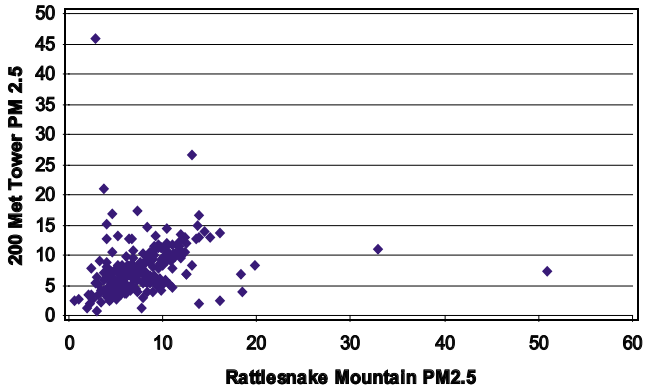

Figure 5. Comparison of PM2.5 concentrations from the 200 Meteorology tower to PM2.5 concentrations at Rattlesnake Mountain.

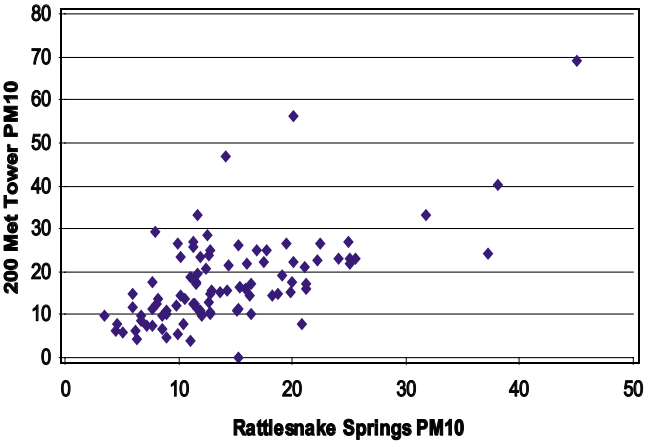

Figure 6. Comparison of PM10 concentrations from the 200 Meteorology tower to PM10 concentrations at Rattlesnake Springs.

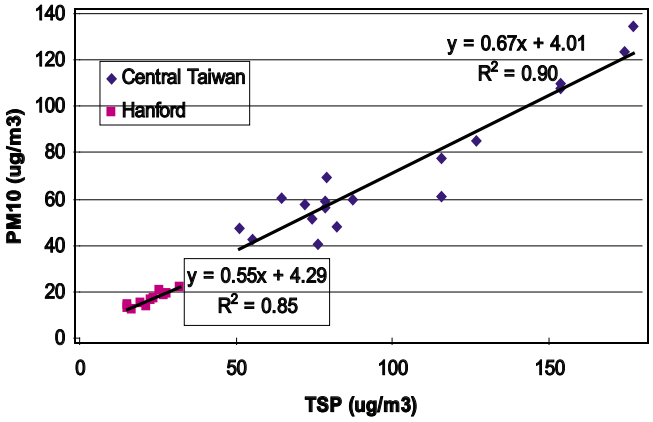

Figure 7. Comparison of PM10 concentrations in Central Taiwan and the Hanford Site to TSP concentrations in Central Taiwan and the Hanford Site.

centrations from the 2 inch filters to PM_{10} concentrations shows that the PM_{10} to TSP concentration ratio is about 0.70. From this relationship, an approximation can be made about the mass concentration of TSP concentrations on the Hanford Site based on measured PM_{10} concentrations. This will allow Hanford Site environmental monitoring personnel to estimate particulate loading on environmental air sample filters.

Other research has shown a similar relationship between TSP and PM_{10} [2]. Figure 7 shows data of TSP concentrations and PM_{10} concentrations from Central Taiwan and the Hanford Site. The Hanford Site and Central Taiwan share similar soil characteristics and should have a similar ratio of TSP concentrations to PM_{10} concentrations. One Hanford Site data point was removed from the data shown in Figure 7 because of heightened human activity near the sampling site over that sampling period. After comparing the two locations, similar slopes were noticed with the Hanford Site having a slope of 0.55 and Central Taiwan with a slope of 0.67. Additional calculations show that Central Taiwan has an average PM_{10} to TSP concentration ratio of about 0.70. Thus, the relationship between TSP concentrations and PM_{10} concentrations from the Hanford Site study can be extrapolated over a broader range of concentrations than was measured in this study.

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