APPENDIX AVAILABLE ON THE HEI WEB SITE

Research Report 178

National Particle Component Toxicity (NPACT) Initiative Report on Cardiovascular Effects

Sverre Vedal et al.

Section 1: NPACT Epidemiologic Study of Components of Fine Particulate Matter and Cardiovascular Disease in the MESA and WHI-OS Cohorts

Appendix F. Supplemental Monitoring Campaign

Note: Appendices that are available only on the Web have been assigned letter identifiers that differ from the lettering in the original Investigators' Report. HEI has not changed the content of these documents, only their identifiers.

Appendix F was originally Appendix E

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This document was reviewed by the HEI NPACT Review Panel but did not undergo the HEI scientific editing and production process.

APPENDIX E: Supplemental Monitoring Campaign

- **Sampling protocol**

- **Description and findings**

E.1 Sampling protocol

A supplemental study to this NPACT project was designed to examine the effect of differences in sampling equipment and schedule on the correlation between averages of AQS data collected on intermittent days and the integrated two-week measurements that were regularly collected under the NPACT/MESA Air field program. The purpose of the supplemental monitoring was to isolate the effect of NPACT monitors by operating them on the speciation duty cycle, and to isolate the effect of duty cycle by comparing the NPACT monitors running on the CSN duty cycle with the standard NPACT/MESA Air 50% duty cycle of 2-week duration.

For this sampling campaign, Teflon and quartz filters were deployed in $PM_{2.5}$ samplers for the regular 50% duty-cycle, two-week schedule side-by-side with Teflon and quartz filter samplers operating on a composite 1-in-3 day cycle for the same two-week intervals. The sampling schedule for the composite filters was aligned with the 1-in-3 day $PM_{2.5}$ and speciation sampling at the AQS sites—one in each of the six cities and Riverside, CA —where the samplers were collocated. Composite samples were typically collected over an integrated duration of 4 or 5 days, depending on the AQS speciation calendar and the deployment and retrieval schedule for NPACT sampling. The schedule of speciation sampling dates for the mid-January through August 2009 time frame of this study is shown in Appendix Table E.1. A schematic representation of the monitoring design is displayed in Appendix Figure E.1. The 2-week sample collected on Teflon filter media was already in place for on-going MESA Air fixed site sampling, requiring the addition of a 2-week quartz filter sample and the 1 day in 3 composite samples collected on media for quantification of mass, metals, OC and EC.

This supplemental sampling program was conducted at a total of seven sites using the collocated fixed sites listed in Table 3 in Appendix B except for S-001 Ramsey Co. Health Center and W-002 Clemons. Site LR-002 in Riverside, CA only had total PM2.5 available from AQS monitors for comparison with NPACT samplers. Samples were collected between January 14, 2009 and July 31, 2009, with additional samples collected in Chicago during August 2009.

Supplemental fixed site samples were collected using a custom valve and timer system that switched the air flow drawn by the sample pump between the sample filters on the designated sampling days and paired waste filters on the off days. The pumps operated continuously at a nominal 1.8 L/min flow rate during the two-week NPACT sampling duration but did not record the flow rate on a minute by minute basis due to a memory limitation that was exceeded during 100% duty cycle operation for two weeks. The TSI SP530 pumps did record total flow volume and total run time to allow for documentation of intended pump operation. A programmable timer in the sampling system, shown in Appendix Figure E.2, activated valves for both the Teflon and quartz filter samples and an elapsed timer tracked the total time that air was drawn through the sample filters. The speciation sample schedule (Appendix Table E.1) was followed in setting the programmable timer allowing samples to be collected on the filter media from midnight to midnight on speciation days, creating a composite sample of multiple days over the 2-week interval.

Two duplicate systems were circulated among the sites in the different MESA Air cities to provide an identical system to operate concurrently and to collect duplicate samples for comparison with the primary samples. A set of duplicate samples was collected at each site for at least three consecutive 2-week events during the supplemental study period. The duplicate samples were used to assess method precision, and in some instances were substituted for an

invalid primary sample to improve the availability of data. A duplicate sampling system was operated identically yet completely independently of the primary sampling system.

Sample results were first evaluated for quality to determine which sampling events would allow for valid comparisons within the data sets. Filter samples were considered invalid if the sampling duration was less than 3 days or more than 6 days, or did not match the AQS speciation schedule. The sample flow rate was also used to screen out invalid samples, with acceptable flow rates ranging from 1.62 L/min to 1.98 L/min. The pump-induced flow rate was measured at the sampler inlet with a rotameter at both deployment and retrieval, and then adjusted to standard conditions based on temperature and barometric pressure; the initial and final flow rates were averaged. Sampler damage in the field, or lab handling issues, could also invalidate a sample.

E.2 Description and findings

The comparisons possible with the data collected in the supplemental study and its concurrent AQS results include the following two pairings of the available data:

- two-week NPACT samples vs. 1-in-3 day NPACT samples
- 1-in-3 day NPACT samples vs. average of matching AQS 1-in-3 day data

The first compares results from sampling on specific intermittent days and an integrated average over a two-week duration with samplers operating at 50% duty cycle (5 minutes on, 5 minutes off). The second compares the sampling methods and equipment of the AQS speciation sampling system and the low-flow rate portable component sampling train employed in the NPACT field program.

The counts of deployed and valid samples and duplicates for different analysis types are summarized in Appendix Table E.2. Overall, 85 valid Teflon filters were collected in this supplemental fixed site monitoring campaign – 72 samples and 13 duplicates. This reflected

84% and 59% capture rates for the samples and duplicates, respectively. Pump failure or incorrect field scheduling leading to sample duration problems were responsible for the majority (9% Teflon, 8% quartz) of fatal filters. Unacceptably high or low flow rates accounted for an additional 6% of all Teflon filters and 3% of quartz filters being excluded from the data set.

A summary of the OC and EC results from each of the seven sites (cities) is shown in Appendix Table E.3. This compares the average results across all valid sampling events for the two different schedules of operation employed for the NPACT monitoring equipment.

The average results for the 2-week 50% duty cycle samples and the composite 1 day in 3 schedule samples both collected with NPACT equipment are shown in Appendix Table E.4 (Baltimore, Chicago, St. Paul, and Winston-Salem) and Appendix Table E.5 (Los Angeles, Riverside, and New York) for a set of 17 elements of interest. The number of paired combinations of these two sampling schedules is shown beneath the location of these results. Only those events with both 2-week and 1-in-3 samples available are used to determine the average value over the course of the study for each schedule type. These comparisons of NPACT samples that operated on different schedules are displayed for selected species in Figures 43 through 48 in Appendix L.

A comparison for total $PM_{2.5}$ of the concurrent NPACT samples operated on different duty cycles is shown in Appendix Figure E.3 which plots all supplemental study data from 2-week 50% samples vs. 1:3 composite samples employing the same type of sampling train. More paired data exist for total $PM_{2.5}$ than for individual species. The composite samples tend to be skewed more by high or low concentration days relative to the 50% duty sample that is an integrated average of all days in the same two-week interval. Still, the agreement between the schedule types is good in most locations.

Appendix Figures E.4 through E.12 illustrate the comparison of multi-day averages calculated from EPA's CSN data and the concentration from the collocated NPACT sampler operating on the one-in-three day CSN schedule over the same two week interval. Total $PM_{2.5}$ data are available from AQS sites on a frequent basis which explains the additional data points presented in Appendix Figure E.4 relative to the individual component data in subsequent figures, where only one-in-three day exact matched samples comprise the data set. AQS data for OC, EC, and metals species were available only every sixth day at the Los Angeles and Winston-Salem CSN speciation sites. Using only those 2-week events in which the NPACT composite 1:3 sampler and the AQS data match exactly, no comparison was possible for the Los Angeles and Winston-Salem sites. Only PM2.5 data from AQS are available for comparison at the Riverside monitor location where NPACT samples were collocated. For these reasons, the plots of Appendix Figures E.5 through E.12 include only four study cities.

Appendix Table E.6 summarizes the results of the direct comparison of paired NPACT and AQS samples. The comparisons are identified graphically by city in Appendix Figures E.5 through E.12 for OC, EC, sulfur, silicon, calcium, iron, potassium, and zinc, respectively. Each co-located sample represents paired identical sampling days (4 or 5) within a given two week period (see section E.1). For each species, the selected samples summarized in Appendix Table E.6 were at levels above their respective species detection limits. For Ca, Fe, and Si, the RMSE values from the regression are slightly higher than the larger of the two reported analytical uncertainties, whereas for K, S, OC and EC these values are comparable. There is no obvious bias in the NPACT concentrations compared with the AQS values based on the fact that the regression slopes were within ± 1 standard error of unity (with that for Si only slightly outside this range). The systematically lower R^2 values for Ca (Appendix Figure E.9) and Si (Appendix

Figure E.8) might be due to actual differences in airborne concentrations between the two co-located samples, given the local gradients that are typically observed in soil components of PM.

The OC concentrations from NPACT are blank corrected whereas the AQS blanks are a small fraction of the measured value and are not blank corrected. The lower R^2 value for OC (Appendix Figure E.5) relative to EC (Appendix Figure E.6) is possibly due to the fact that the dynamic blank values of OC on the NPACT backup filter are a relatively high fraction (up to half) of the observed levels on the front filter whereas the EC NPACT dynamic blanks are a relatively low fraction (~1 percent). This additional uncertainty in the NPACT OC blank correction would add additional variability to these samples that would be reflected in a lower correlation with comparable AQS OC values. A summary of the blank corrections used for OC and EC samples is presented in Appendix Table E.7.

We evaluated the dynamic blanks in relation to the primary filter samples collected in the NPACT samplers operating on the one-in-three day CSN schedule. These paired dynamic blanks were located behind (downstream) the regular quartz filter sample within the same sample filter holder. Blank levels were compared with the corresponding sample concentrations to assess which carbon fraction results are most significant. We are interested in whether a significant association exists between sample concentration and dynamic blank concentration (i.e. was the slope significantly different from zero) and/or whether an average blank value can be ascertained independent of the upstream filter sample value. A summary of results on a fraction by fraction basis is as follows:

C fraction	blank relative to sample
Pk1	many blanks equal or greater than sample; noisy; fraction likely not usable
Pk2	moderate association; slope varies 0.2-0.6 by city

Pk3	weak to no association; use average blank except St. Paul and Baltimore
Pk4	not significant except St. Paul (slope = 0.53); use average blank
Pyrolytic	some dependence, slope varies by city; strongest association in L.A. and Chicago
EC1	weak to moderate association; slope varies from near zero up to 0.3
EC2	little association; use average blank, except possibly L.A. and N.Y.
EC3	very low sample and blank levels

The finding that dynamic blank associations with primary samples varies by carbon fraction and an average blank level (by city based on study design) may or may not represent the dynamic blank is important for the NPACT quartz filter samples collected at all fixed and home sites in 2007-2008. During this earlier period, the study sample protocol called for paired dynamic blanks to be deployed with only 20% of the field samples. In contrast, nearly all of the one-in-three day composite quartz samples run on the CSN schedule during the supplemental study included paired dynamic blanks. These results extrapolate to the spatially rich data set that has more limited dynamic blank data. The city by city results differ for total OC as shown in Appendix Table E.7, but the EC blanks were uniformly negligible, reported as zero to two significant digits.

Total carbon comparisons are shown in Appendix Figure E13. The result is that the total carbon concentrations agree fairly well. The mean total carbon concentration in this comparison data set is 2.7 $\mu g/m^3$ for the both the AQS samples and the matched NPACT samples. A linear regression model without forcing the intercept to zero shows a tendency to measure slightly less total carbon with the NPACT sampler than with the AQS sampler: $NPACT_{TC} = 0.87(\pm 0.15)* AQS_{TC} + 0.19 (\pm 0.41)$; $R^2 = 0.74$, RMSE = 0.42 $\mu g/m^3$. Data from Winston Salem and Los Angeles did not meet our exact match criterion. In Winston Salem,

there were data quality issues for our sample pumps. In Los Angeles, the AQS site ran only on a 1in 6 day schedule which provided too little mass for our sampler. Comparison of our 1 in 3 day composite sampler with the 1 in 6 day AQS site in LA gave comparable results to the other four cities for total carbon: $NPACT_{TC} = 0.87(\pm 0.17)*AQS_{TC} + 0.23 (\pm 0.59)$; $R^2 = 0.77$, RMSE = 0.45 $\mu g/m^3$.

The mean elemental carbon concentration is 1.0 $\mu g/m^3$ and 0.7 $\mu g/m^3$ for the NPACT sampler and the AQS sampler, respectively. Similar correlations are observed for elemental carbon as for total carbon, with a tendency to overestimate EC with the NPACT sampler as indicated by the mean values: $NPACT_{EC} = 1.29(\pm 0.14)*AQS_{EC} + 0.10 (\pm 0.11)$; $R^2 = 0.88$, RMSE = 0.21 $\mu g/m^3$.

The mean organic carbon concentration is 1.7 $\mu g/m^3$ and 2.0 $\mu g/m^3$ for the NPACT sampler and the AQS sampler, respectively. In contrast to the good correlation between both methods for either total carbon or elemental carbon, the correlation between the two organic carbon measurements is lower as shown by the linear regression results ($NPACT_{OC} = 0.88(\pm 0.26)*AQS_{OC} - 0.06 (\pm 0.53)$; $R^2 = 0.47$, RMSE = 0.50 $\mu g/m^3$).

In summary, a careful comparison of our NPACT carbon concentrations with time-matched AQS measurements shows that NPACT total carbon measurements are in reasonable agreement with the corresponding, time-matched AQS values. The NPACT organic carbon concentrations are slightly lower (~15% on average) and less correlated with the corresponding AQS values, and the NPACT elemental carbon concentrations are slightly higher (~30%) but reasonably well correlated with the corresponding AQS values. The consistently lower NPACT OC values would reduce the corresponding IQR values by ~15% compared with the AQS IQR

values in the subsequent health analyses and therefore raise the effect per IQR by ~15% relative to that based upon AQS data.

Appendix Table E.1 Sample Schedule Matched with EPA Chemical Speciation Network (CSN) 1:3 Speciation Monitoring.

Month	Dates of Speciation Sampling
January 2009	F16, M19, Th22, Su25, W28, Sa31
February 2009	Tu3, F6, M9, Th12, Su15, W18, Sa21, Tu24, F27
March 2009	M2, Th5, Su8, W11, Sa14, Tu17, F20, M23, Th26, Su29
April 2009	W1, Sa4, Tu7, F10, M13, Th16, Su19, W22, Sa25, T28
May 2009	F1, M4, Th7, Su10, W13, Sa16, Tu19, F22, M25, Th28, Su31
June 2009	W3, Sa6, Tu9, F12, M15, Th18, Su21, W24, Sa27, Tu30
July 2009	F3, M6, Th9, Su12, W15, Sa18, Tu21, F24, M27, Th30
August 2009	Su2, W5, Sa8, Tu11, F14, M17, Th20, Su23, W26, Sa29

Appendix Table E.2. Counts of valid filter samples from the supplemental sampling campaign according to analysis type, total of primary samples and duplicates.

Study Area	PM2.5 mass from Teflon		Elemental species by XRF from Teflon		OC,EC from quartz	
	Deployed	Valid	Deployed	Valid	Deployed	Valid
Baltimore	16	15 (94%)	16	15 (94%)	16	12 (75%)
Chicago	16	15 (94%)	16	12 (75%)	18	17 (94%)
LA	15	13 (87%)	15	12 (80%)	15	14 (93%)
Riverside	14	12 (86%)	14	11 (79%)	15	13 (87%)
NYC	15	11 (73%)	15	11 (73%)	15	10 (67%)
St. Paul	17	14 (82%)	17	14 (82%)	17	14 (82%)
Winston-Salem	15	5 (33%)	15	5 (33%)	15	3 (20%)
Across all sites	108	85 (79%)	108	80 (74%)	111	83 (75%)

Appendix Table E.3. Quartz filter PM elemental and organic carbon: average concentration in supplemental monitoring from collocated fixed sites for both typical MESA Air 2-week duty cycle and composite samples operated on CSN schedule.

			OC (µg/m^3)		EC (µg/m^3)	
Region	site ID	N	2-wk cycle	CSN 1:3	2-wk cycle	CSN 1:3
Baltimore	B-3	10	3.33	3.29	1.12	0.98
Chicago	C-4	10	3.23	3.56	1.10	0.95
Los Angeles	L-1	11	3.07	3.88	1.38	1.62
LA-Riverside	LR-2	12	3.24	3.98	1.11	1.24
St. Paul	S-3	10	2.83	3.66	0.49	0.57
New York	N-1	10	3.51	3.68	1.64	1.77
Winston-Salem	W-1	6	3.19	4.26	0.71	1.06

Appendix Table E.4. Selected elemental species (arranged by atomic number) comparison ($\mu g/m^3$) of NPACT samplers between 2-week integrated and 1-in-3 day composite samples in four NPACT supplemental study locations.

N =	Baltimore 12		Chicago 7		St. Paul 11		Winston-Salem 11	
	2-wk	1 in 3	2-wk	1 in 3	2-wk	1 in 3	2-wk	1 in 3
Na	0	0	0	0	0	0	0	0
Al	0.0327	0.0358	0.0418	0.0385	0.0319	0.0336	0.0342	0.0409
Si	0.0687	0.0676	0.1057	0.0918	0.0866	0.0903	0.0702	0.0720
S	1.24	1.21	1.02	0.98	0.65	0.65	0.99	0.98
Cl	0	0	0	0	0.0066	0.0030	0	0.0006
K	0.1271	0.1142	0.1160	0.0739	0.0773	0.0729	0.0732	0.0646
Ca	0.0502	0.0487	0.0725	0.0706	0.0597	0.0670	0.0266	0.0311
V	0.0015	0.0015	0.0002	0.0004	0.0004	0.0003	0.0003	0.0001
Cr	0.0007	0.0005	0.0009	0.0007	0.0004	0.0005	0.0005	0.0011
Mn	0.0021	0.0020	0.0025	0.0021	0.0015	0.0015	0.0009	0.0012
Fe	0.0797	0.0755	0.0861	0.0826	0.0441	0.0476	0.0393	0.0439
Ni	0.0008	0.0006	0.0003	0.0003	0.0002	0.0003	0.0002	0.0001
Cu	0.0032	0.0033	0.0047	0.0033	0.0029	0.0049	0.0023	0.0010
Zn	0.0124	0.0099	0.0206	0.0168	0.0095	0.0096	0.0063	0.0058
As	0.0015	0.0014	0.0012	0.0004	0.0008	0.0010	0.0009	0.0015
Br	0.0041	0.0036	0.0032	0.0027	0.0026	0.0031	0.0031	0.0036
Ba	0.0043	0.0036	0.0115	0.0060	0.0034	0.0037	0.0037	0.0032

Appendix Table E.5. Selected elemental species (arranged by atomic number) comparison ($\mu g/m^3$) of NPACT samplers between 2-week integrated and 1-in-3 day composite samples in three NPACT supplemental study locations.

N =	Los Angeles 10		Riverside, CA 9		New York 9	
	2-wk	1 in 3	2-wk	1 in 3	2-wk	1 in 3
Na	0.2086	0.1848	0.1588	0.1457	0	0
Al	0.0367	0.0293	0.0569	0.0658	0.0336	0.0379
Si	0.1449	0.1285	0.1985	0.2375	0.0860	0.0843
S	1.18	1.26	0.99	1.06	0.98	1.03
Cl	0.0009	0.0014	0.0031	0.0033	0	0
K	0.1077	0.1131	0.1997	0.1377	0.0552	0.0555
Ca	0.0839	0.0814	0.1111	0.1278	0.0769	0.0835
V	0.0039	0.0042	0.0030	0.0030	0.0030	0.0031
Cr	0.0010	0.0009	0.0006	0.0007	0.0009	0.0009
Mn	0.0068	0.0059	0.0035	0.0039	0.0024	0.0026
Fe	0.1780	0.1669	0.1462	0.1640	0.1074	0.1075
Ni	0.0019	0.0028	0.0010	0.0011	0.0091	0.0094
Cu	0.0085	0.0086	0.0082	0.0066	0.0054	0.0070
Zn	0.0115	0.0121	0.0122	0.0144	0.0254	0.0252
As	0.0006	0.0008	0.0007	0.0007	0.0006	0.0008
Br	0.0038	0.0043	0.0052	0.0058	0.0028	0.0027
Ba	0.0128	0.0123	0.0136	0.0094	0.0064	0.0064

Appendix Table E.6. Summary of Linear Regression Comparison between matched AQS and NPACT samples both operating on a concurrent 1-day-in-3 schedule.

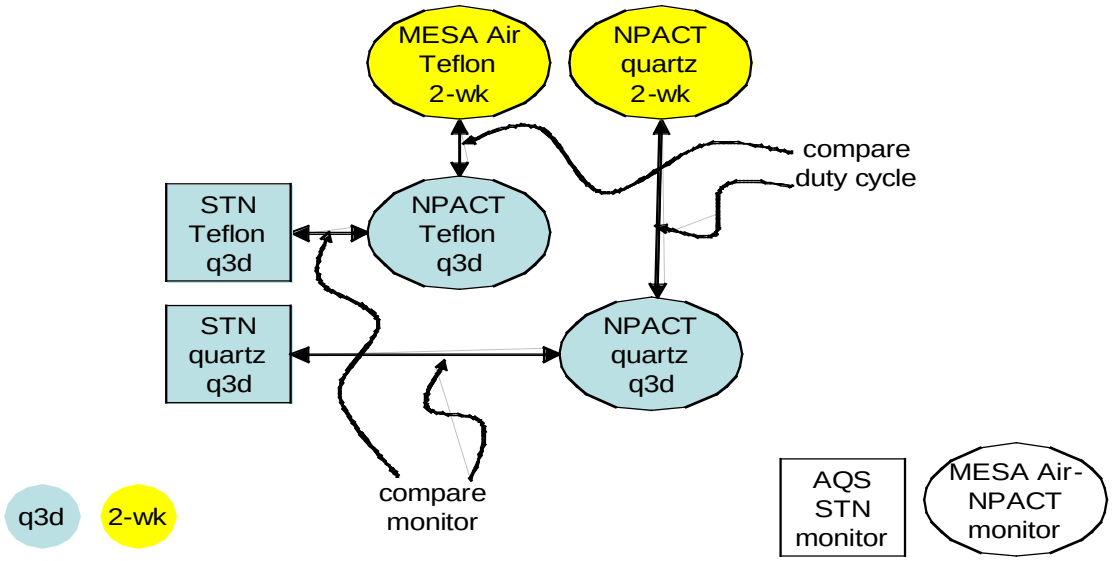
	Mean ng/m^3		Slope[b] --	Intercept[b] ng/m^3	R^2	RMSE ng/m^3	Avg. Analytical Uncertainty ng/m^3	
	AQS	NPACT					AQS	NPACT
Ca	49 (20)[a]	73 (29)	1.10 [0.20][c]	20 [11]	0.58	20	7.6	3.1
Fe	132 (32)	147 (34)	0.96 [0.10]	12 [7]	0.82	15	7.7	2.9
K	122 (56)	125 (64)	0.96 [0.08]	10 [5]	0.89	10	9.6	3.6
S	690 (280)	820 (290)	1.02 [0.07]	119 [51]	0.91	87	73	29
Si	60 (28)	85 (32)	0.77 [0.20]	39 [13]	0.45	25	12.6	3.7
Zn	14 (11)	17 (11)	0.97 [0.09]	3 [2]	0.85	4	2.7	0.8
OC	1990 (510)	1690 (660)	0.88 [0.26]	-61 [530]	0.47	495	125	465
EC	748 (430)	1014 (560)	1.13 [0.17]	165 [145]	0.78	275	63	275

[a] ( ) = std. dev.
[b] NPACT = intercept + slope*AQS
[c] [ ] = std. err.

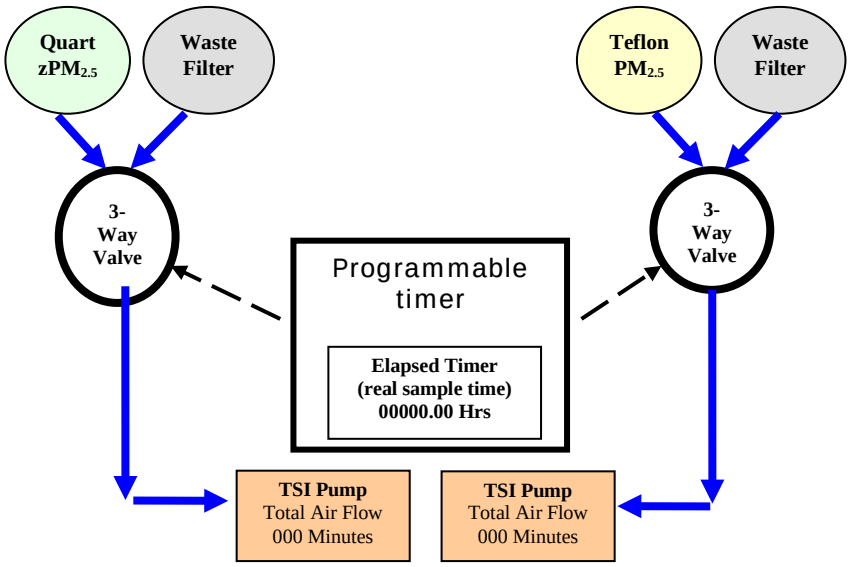
Appendix Table E.7. Dynamic Blank corrections used for NPACT composite 1-in-3 day schedule quartz filter samples. OC correction equation based on all available valid pairs of primary sample and dynamic blank regardless of availability of matched AQS data.

NPACT City	OC			EC median blank ($\mu g/m^3$)
	slope	intercept ($\mu g/m^3$)	R^2	
Baltimore	1.63 [a]		0.023	0.00
Chicago	0.489	0.34	0.494	0.00
Los Angeles	0.292	0.75	0.727	0.00
New York	0.339	0.76	0.586	0.00
St. Paul	0.501	0.16	0.774	0.00

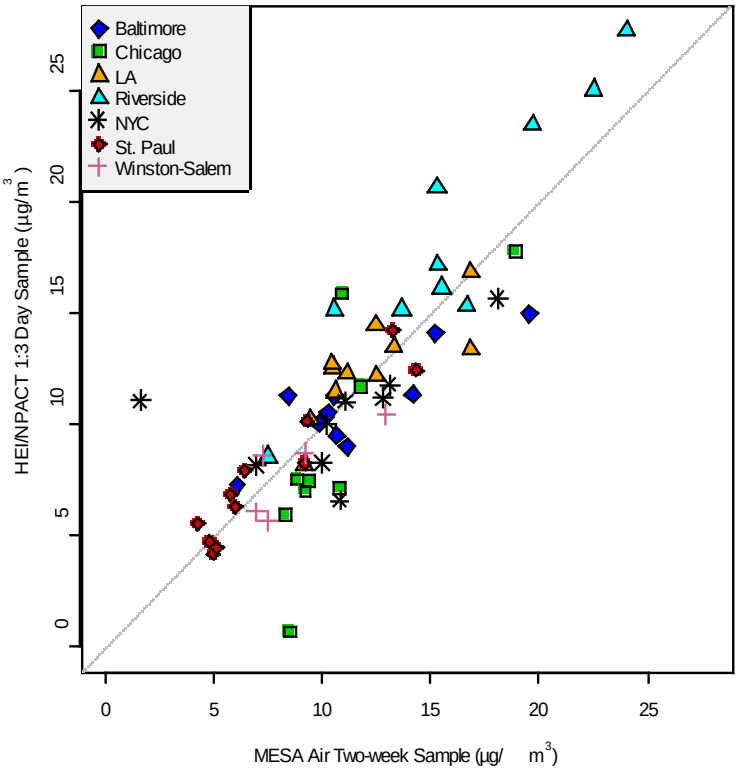
a Median blank value ($\mu g/m^3$) used for all Baltimore OC dynamic blank corrections.



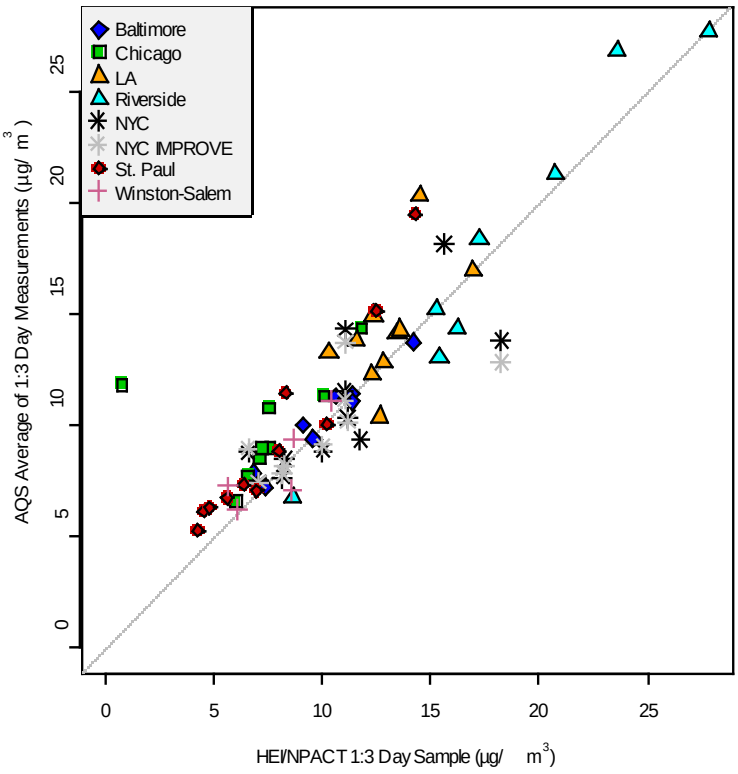
Appendix Figure E.1. NPACT supplemental monitoring design



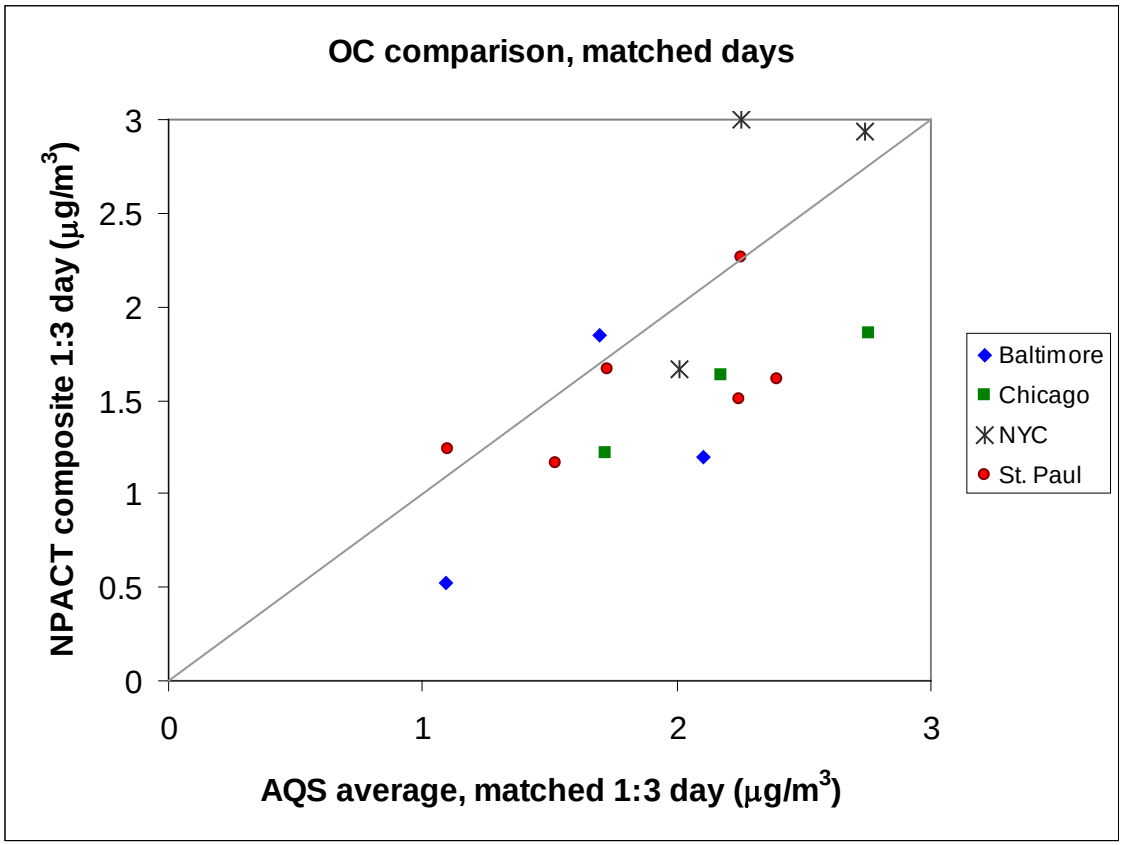
Appendix Figure E.2. NPACT supplemental monitoring timer system. A 1-in-3 day composite sample was created with the programmable timer controlling valve settings.



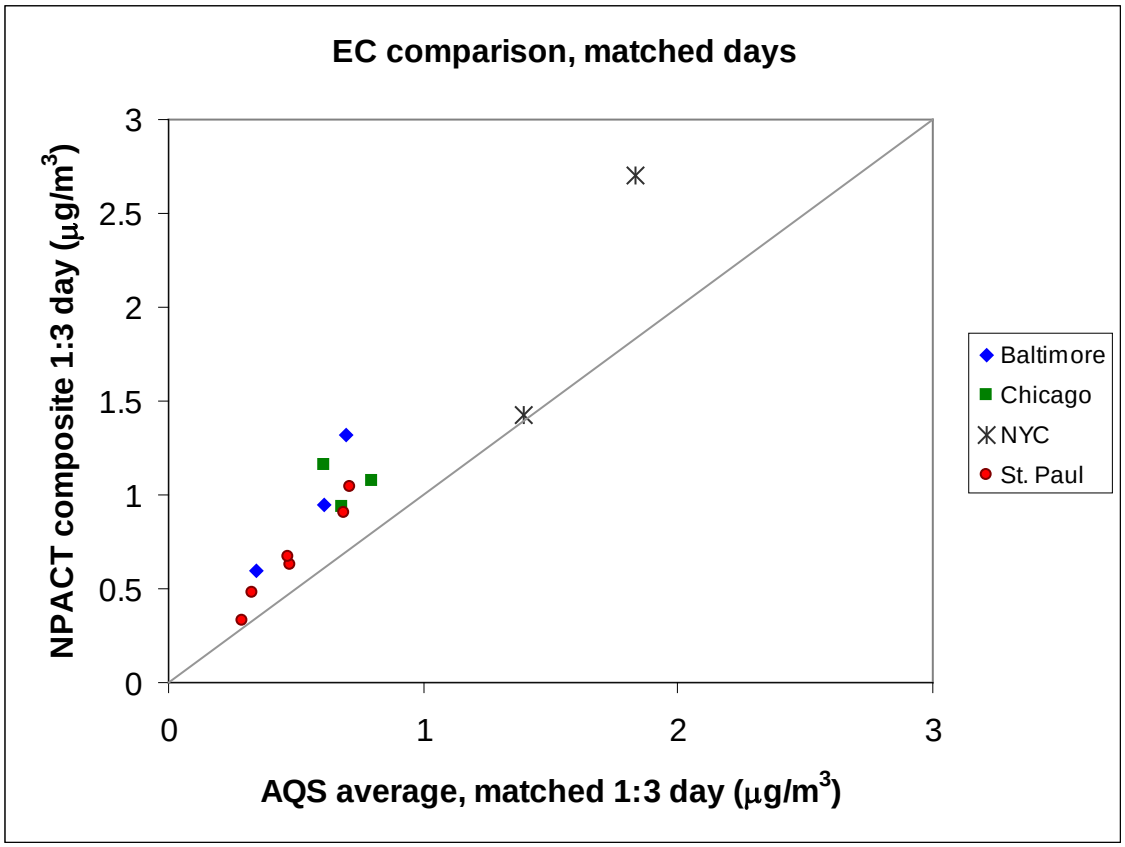
Appendix Figure E.3. Comparison of PM2.5 between NPACT/MESA Air two-week measurements and HEI/NPACT 1-in-3 day measurements for concurrent periods, by study area (overall R2 = 0.72, RMSE = 2.6 µg/m3). Standard deviations for the two-week and 1-in-3 day measurements were 4.3 µg/m3 and 4.9 µg/m3 respectively.



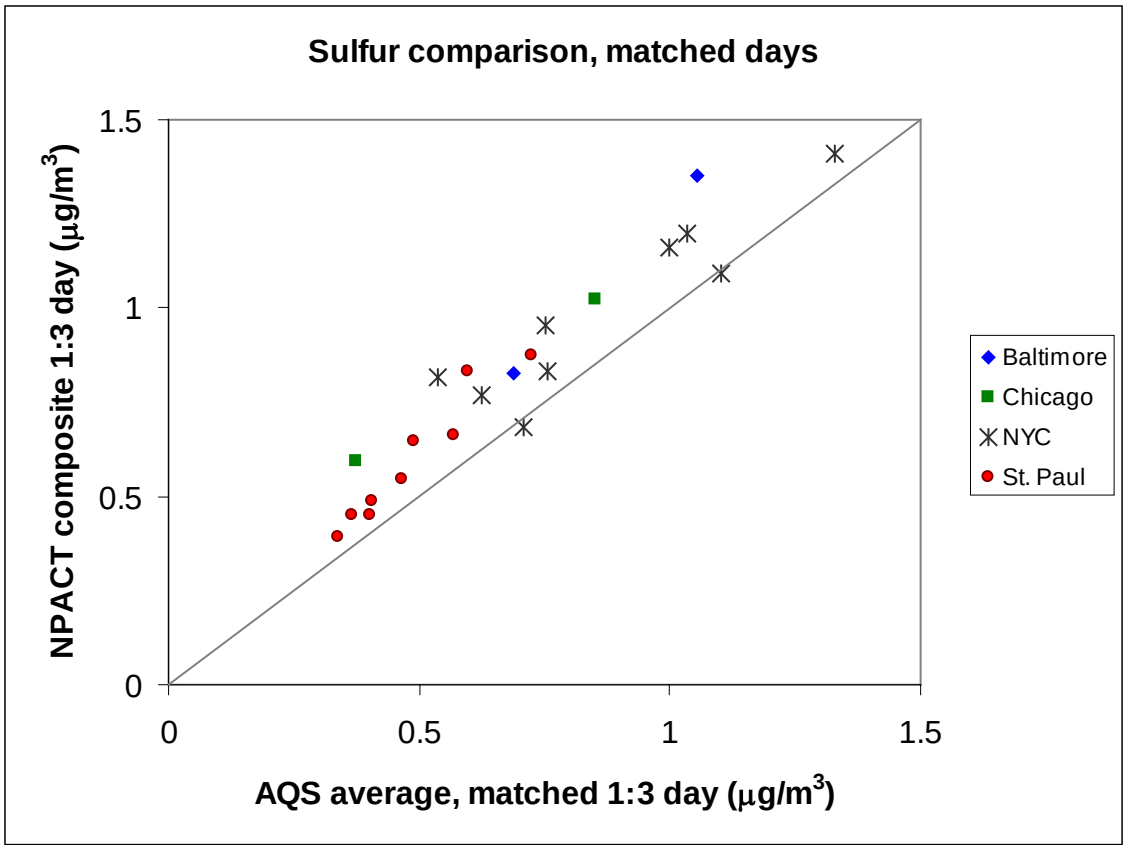
Appendix Figure E.4. Comparison of PM2.5 between HEI/NPACT 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R2 = 0.77, RMSE = 2.4 µg/m3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 4.6 µg/m3 and 4.5 µg/m3 respectively



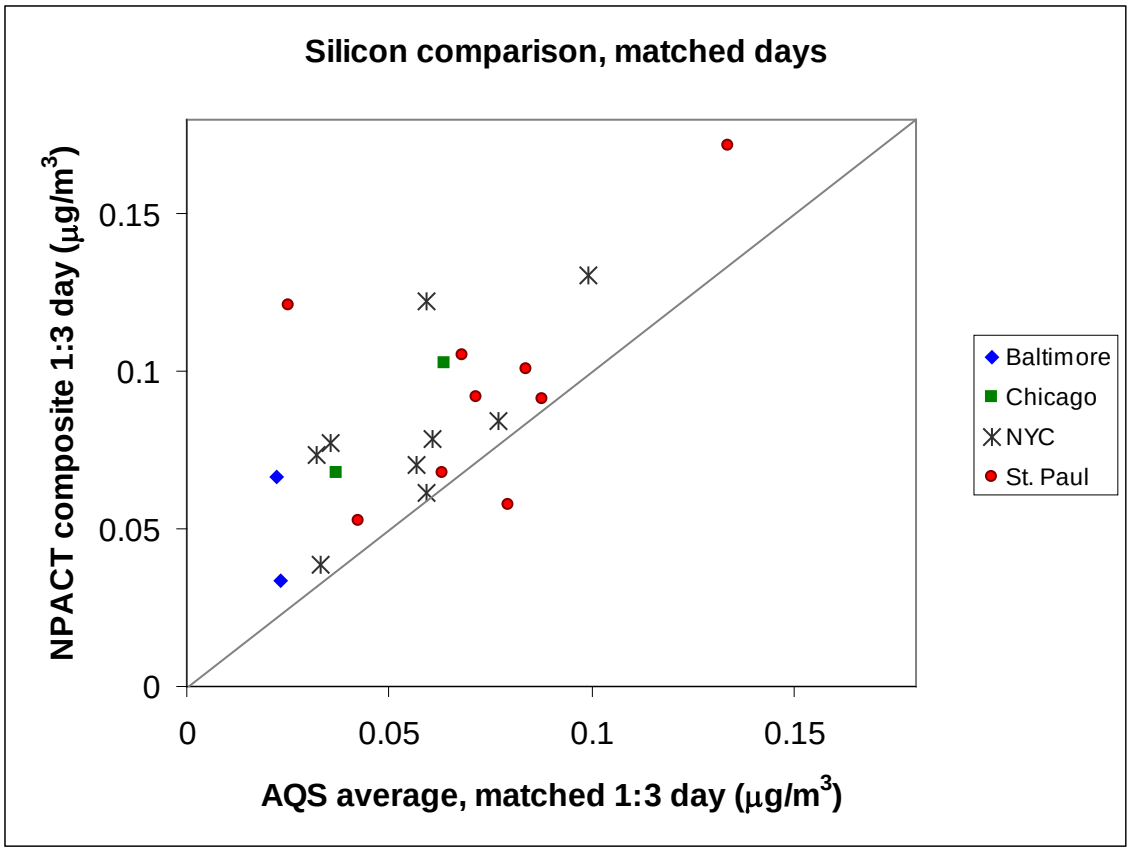
Appendix Figure E.5. Comparison for organic carbon (OC) between HEI/NPACT 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.47, RMSE = 0.50 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.65 µg/m^3 and 0.51 µg/m^3 respectively.



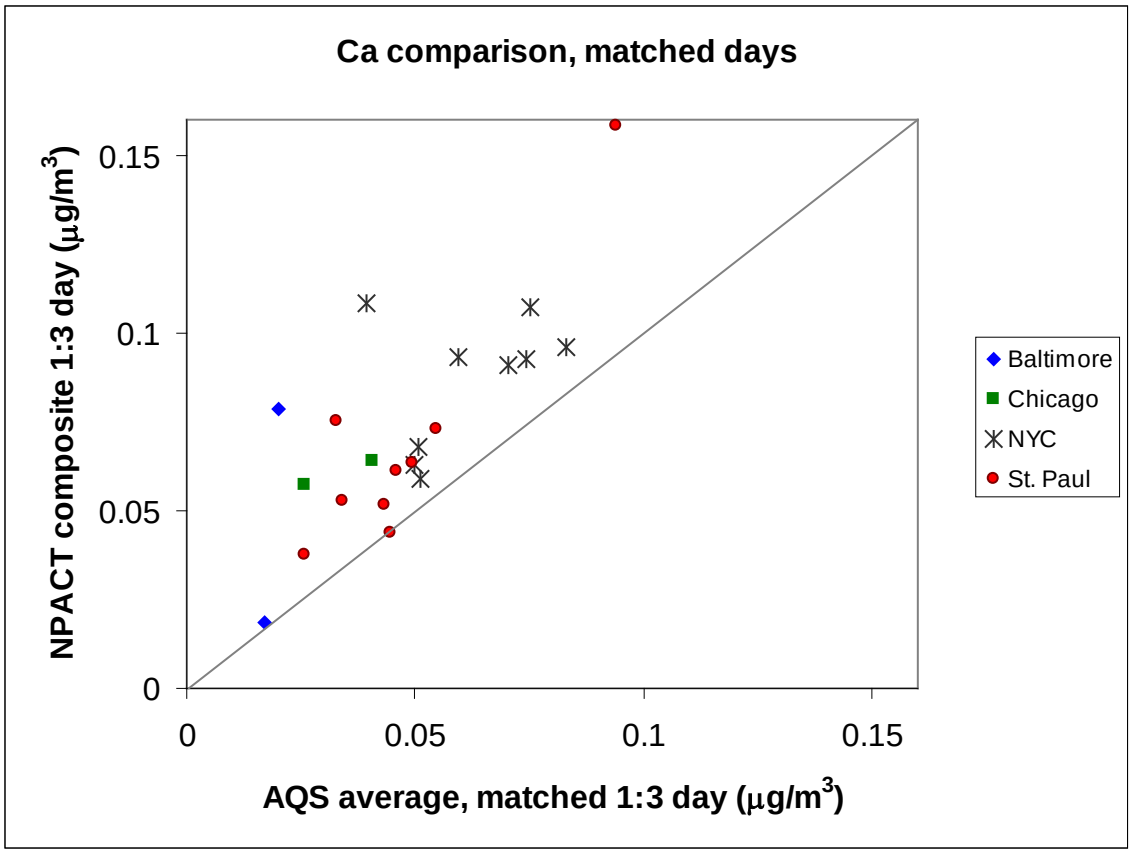
Appendix Figure E.6. Comparison for elemental carbon (EC) between HEI/NPACT PM2.5 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall $R^2 = 0.78$, RMSE = 0.28 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.58 µg/m^3 and 0.42 µg/m^3 respectively.



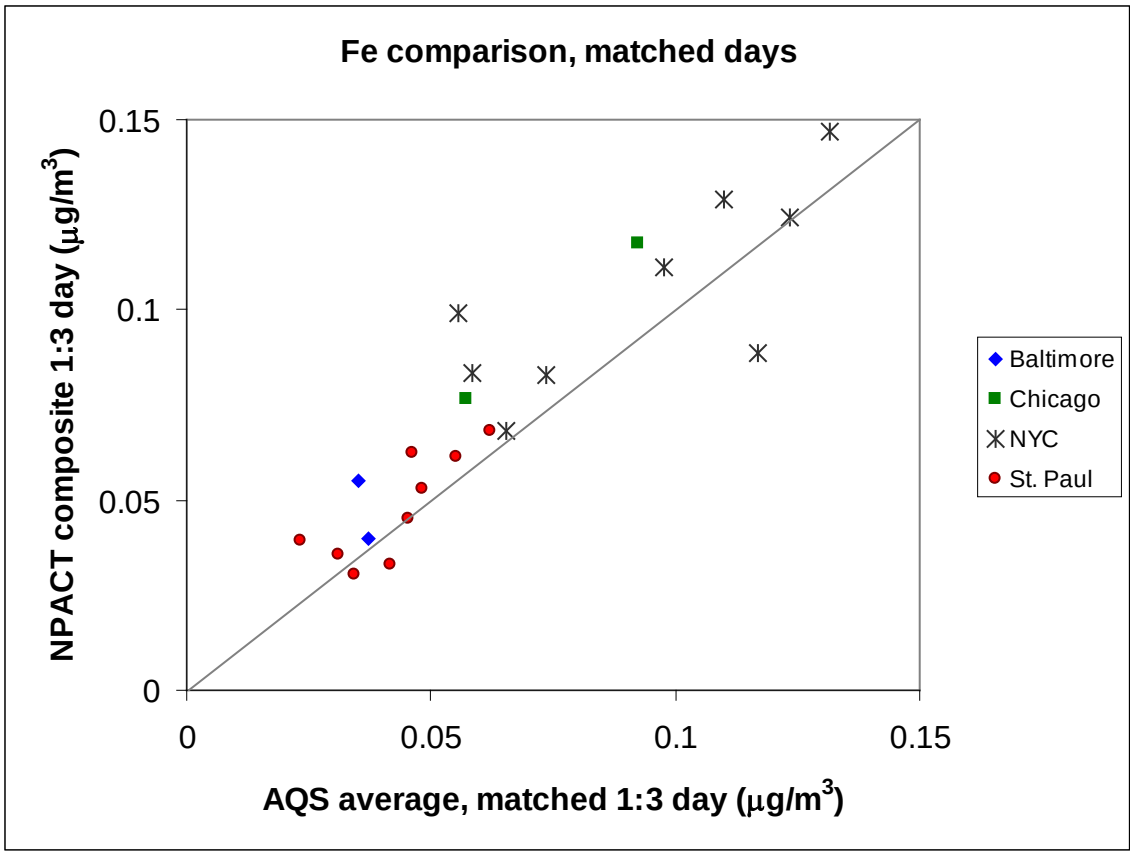
Appendix Figure E.7. Comparison for sulfur between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.91, RMSE = 0.087 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.29 µg/m^3 and 0.27 µg/m^3 respectively.



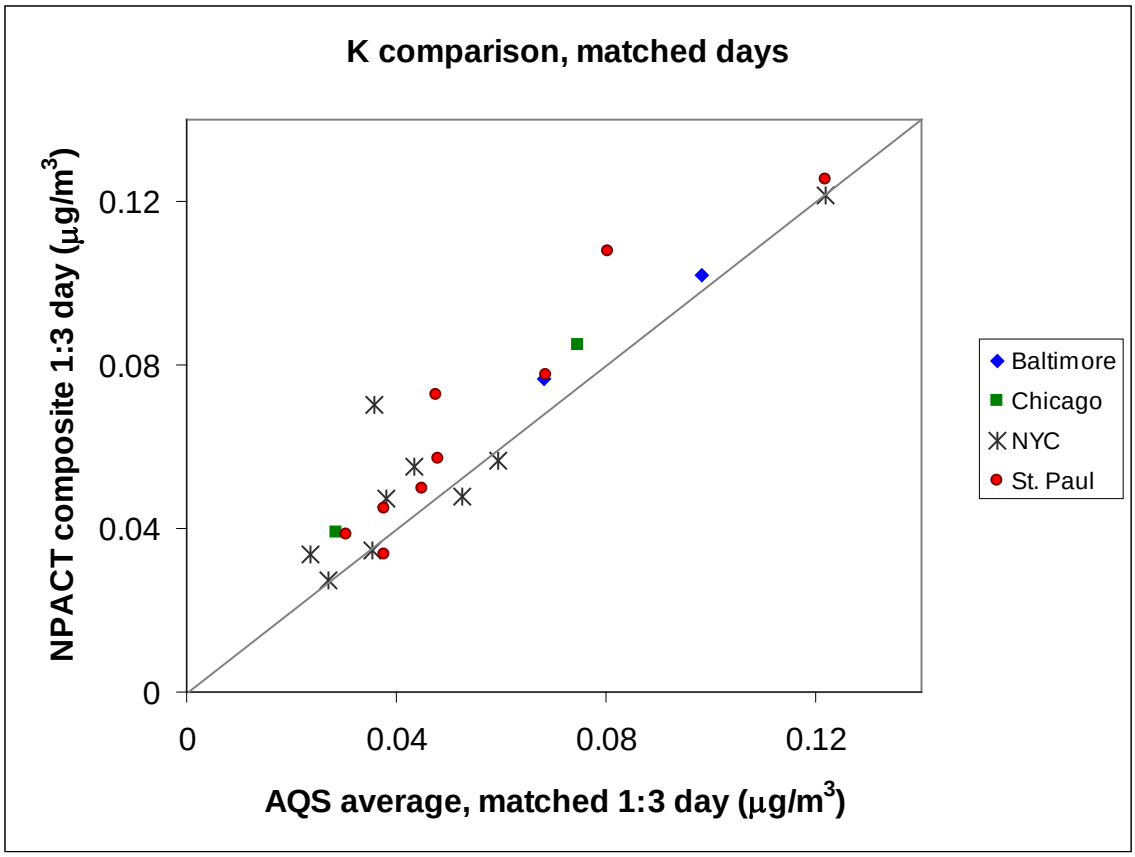
Appendix Figure E.8. Comparison for silicon between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.45, RMSE = 0.025 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.032 µg/m^3 and 0.028 µg/m^3 respectively.



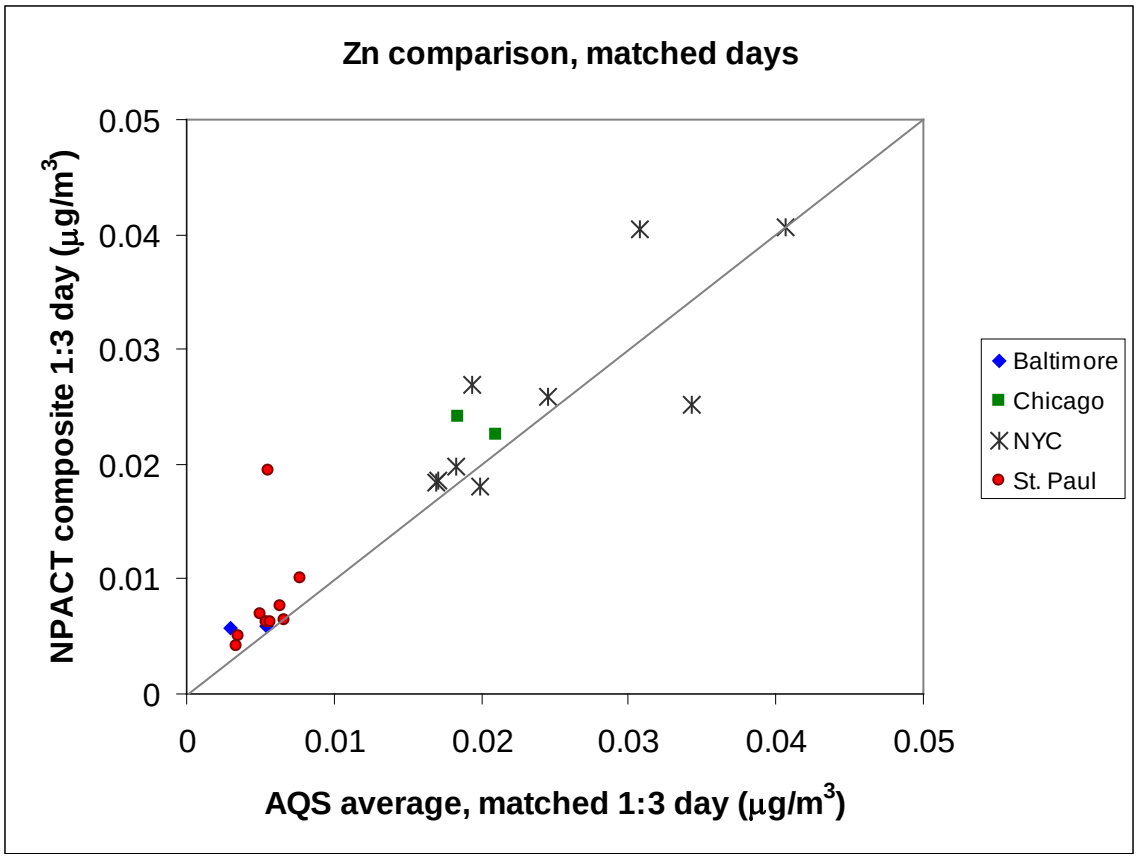
Appendix Figure E.9. Comparison for calcium between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.58, RMSE = 0.02 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.029 µg/m^3 and 0.020 µg/m^3 respectively.



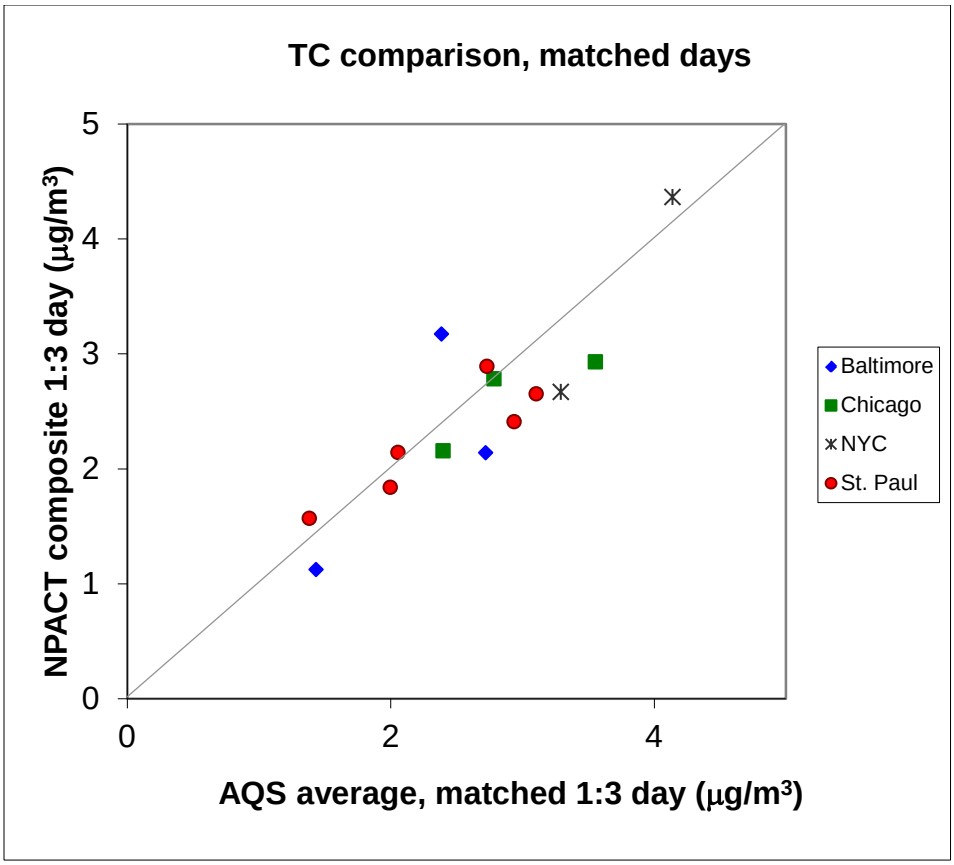
Appendix Figure E.10. Comparison for iron between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.82, RMSE = 0.015 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were 0.034 µg/m^3 and 0.032 µg/m^3 respectively.



Appendix Figure E.11. Comparison for potassium between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.89, RMSE = 0.010 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were both 0.029 µg/m^3.



Appendix Figure E.12. Comparison for zinc between HEI/NPACT $PM_{2.5}$ 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area (overall R^2 = 0.85, RMSE = 0.004 µg/m^3). Standard deviations for the HEI/NPACT composite 1-in-3 day measurements and AQS 1-in-3 day averages were both 0.011 µg/m^3.



Appendix Figure E13 Comparison for total carbon (TC) between HEI/NPACT PM2.5 1-in-3 day measurements and averages of AQS measurements for the same dates, by study area $NPACT_{TC} = 0.87(\pm 0.15)^* AQS_{TC} + 0.19 (\pm 0.41)$; $R^2 = 0.74$, RMSE = 0.42 µg/m^3