Coarse PM Methods Evaluation Study

Study Design and Preliminary Results

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Background

- 1997 air regulations established NAAQS for PM2.5 and PM10 as separate metrics
- U.S. courts have reviewed subsequent litigation and ruled that the PM10 metric is a "poorly matched indicator" because it includes the PM2.5 fraction
- EPA has since been considering the possibility of vacating the PM10 regulation and developing a separate standard for PMc

Study Objectives

- Evaluate the field performance of leading methods for monitoring the coarse fraction of PM10 (PMc = PM10 – PM2.5)
- Evaluate samplers which provide mass concentration measurements (based on aerodynamic diameter) and are either already commercially available or in their final stages of development
- Include both filter-based (time-integrated) and semi-continuous measurement methods

PM2.5 and PM10 FRM Samplers

Designated PM10 (WINS Removed)

Designated PM2.5 (with WINS)

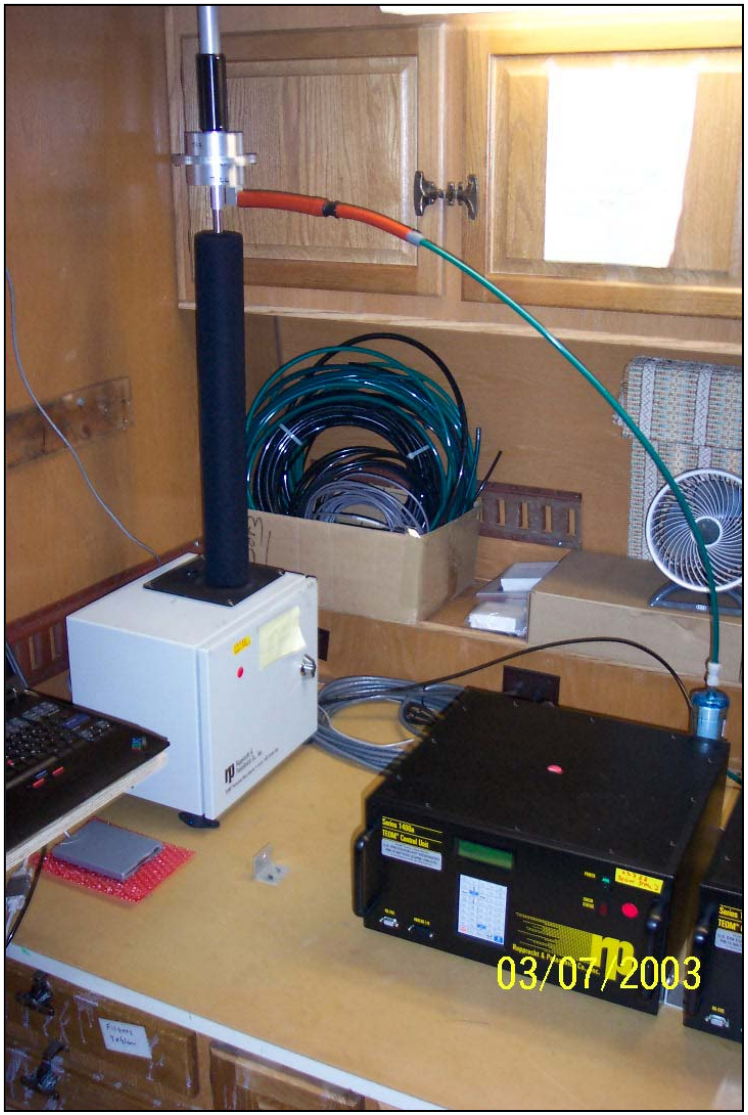
PMc = PM10 – PM2.5

- Standard low-vol PM10 inlets aspirating at 16.7 lpm (actual conditions)
- PM2.5 aerosol fractionation using aWINS equipped with DOS impaction oil
- Filters were conditioned at 22C and 35% RH, analyzed gravimetrically. Post-sampling filters archived at -30C for subsequent chemical analysis
- 3 FRM pairs from BGI, R&P, and Thermo-Andersen equipped with teflon filters (4^{th} FRM pair equipped with quartz filters)

R&P Partisol-Plus 2025 Dichot

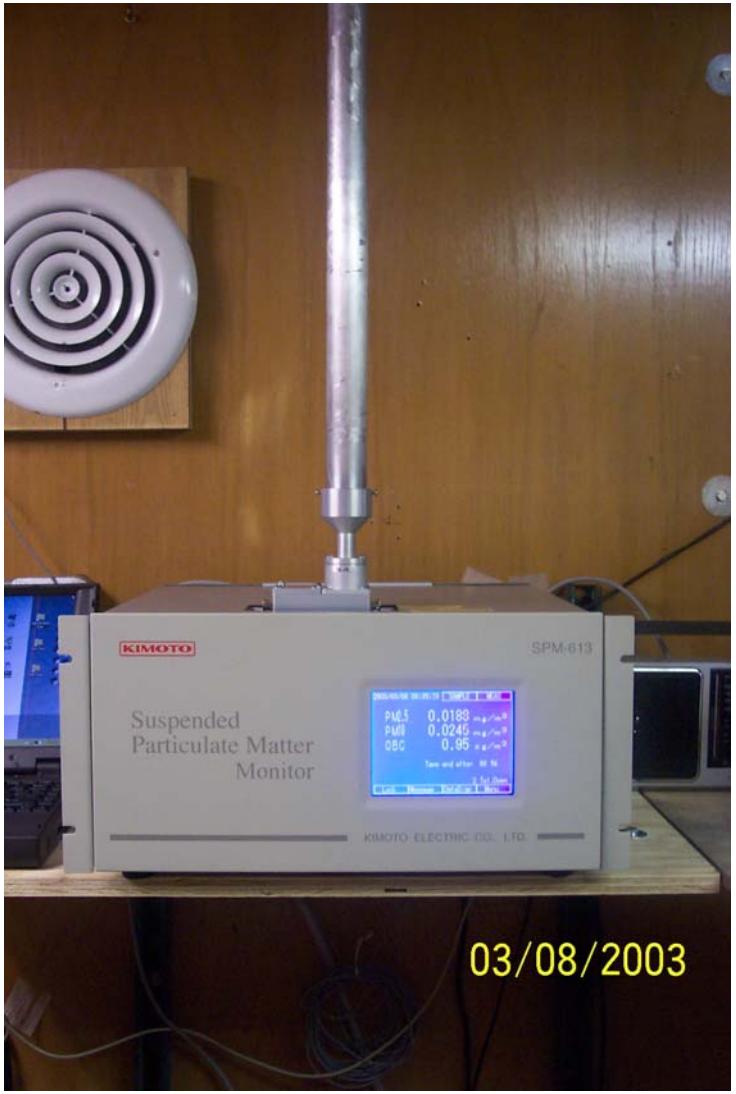
- Standard PM10 inlet aspirating at 16.7 lpm (actual)
- Aerosol fractionation by custom virtual impactor (15 lpm and 1.67 lpm)
- PM2.5 and PMc mass collected on 47 teflon filters for gravimetric analysis
- Sequential sampler with multi-day capability
- 4 units used in our study (3 teflon and 1 quartz)

R&P Coarse Particle TEOM



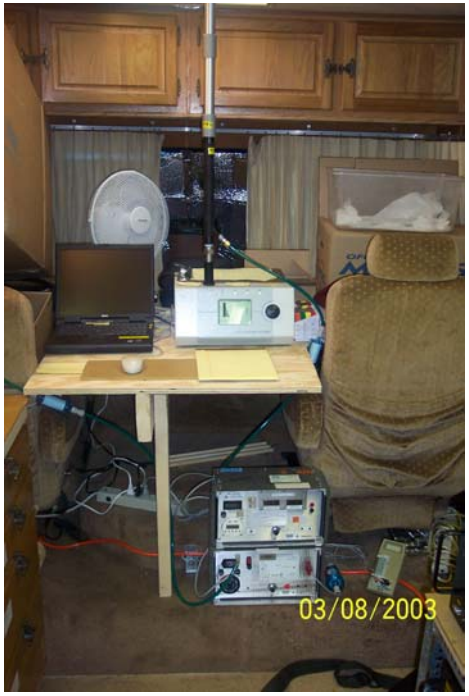
- Modified PM10 inlet aspirating at 50 lpm (actual)
- PM10 aerosol is fractionated by a custom virtual impactor (2 lpm coarse flow and 48 lpm fine flow)
- PMc fraction is heated to 50 C to remove particle bound water
- Coarse aerosol is collected and quantified by a standard TEOM sensor
- 3 units used in our study

Tisch SPM-613D Dichot Beta Gauge



- Standard PM10 inlet aspirating at 16.7 lpm (~std)
- Aerosol heated >25C
- Aerosol fractionation by custom virtual impactor
- PM2.5 and PMc mass collected on polyflon tape roll
- PM2.5 and PMc mass quantified hourly using separate beta sources and detectors
- 3 units used in our study

TSI Model 3321 Aerodynamic Particle Sizer



- Standard PM10 inlet aspirating at 16.7 lpm (actual)
- Isokinetic fraction of PM10 aerosol removed at 5 lpm and enters the APS inlet
- APS sizes individual particles aerodynamically using time of flight approach
- Single particle volume converted to mass using mean density provided by user
- Total aerosol mass is sum of individual particle mass
- APS provide only PMc; not applicable for PM2.5 or PM10
- Only sampler in study which provides detailed PM size distribution information
- 2 units used in our study

Mobile Sampling Platform (Side View)

Sampler Performance Issues

- Relative mass concentration bias (22-hr means) versus collocated FRMs. Use chemical analysis (XRF, IC, thermal optical) of archived filters to determine particle composition, which may explain observed sampler performance
- Precision (2 or 3 samplers of each type)
- Evaluation under a wide range of weather conditions and aerosol types

QA/QC Initiatives

- QAPP was reviewed and approved by EPA
- Study design and operation passed EPA's systems audit
- SOPs were reviewed by the sampler manufacturers
- Sampler manufacturers were allowed to verify the working condition of their respective samplers prior to sampling at each site
- Sampling and fractionation components cleaned prior to each study
- NIST-traceable sampler calibration equipment was used for all sampler calibrations and audits
- Three performance audits and three field blank tests were conducted at each site
- Replicate weighings were conducted at the site as well as at EPA's RTP weighing facility

Study Sites

- RTP, NC (10 days of shakedown tests, Jan. 2003)
- Gary, IN (30 days of tests under cold, snow/rain, variable PM2.5/PM10 ratios, March-April, 2003)
- Phoenix, AZ (30 days of tests under hot, dusty conditions, consistently low PM2.5/PM10 ratios, May-June, 2003)
- Riverside, CA (30 days of tests under warm conditions, higher PM2.5/PM10 ratios than Phoenix, July-August, 2003)

Gary, IN

PMc FRM MEASUREMENTS - GARY vs RTP WEIGHING
Gary, IN (March - April, 2003)

GARY WEIGHING
RTP WEIGHING

RTP/Gary = 1.00

PM2.5/PM10 Range = 0.32 to 0.83; Mean = 0.55

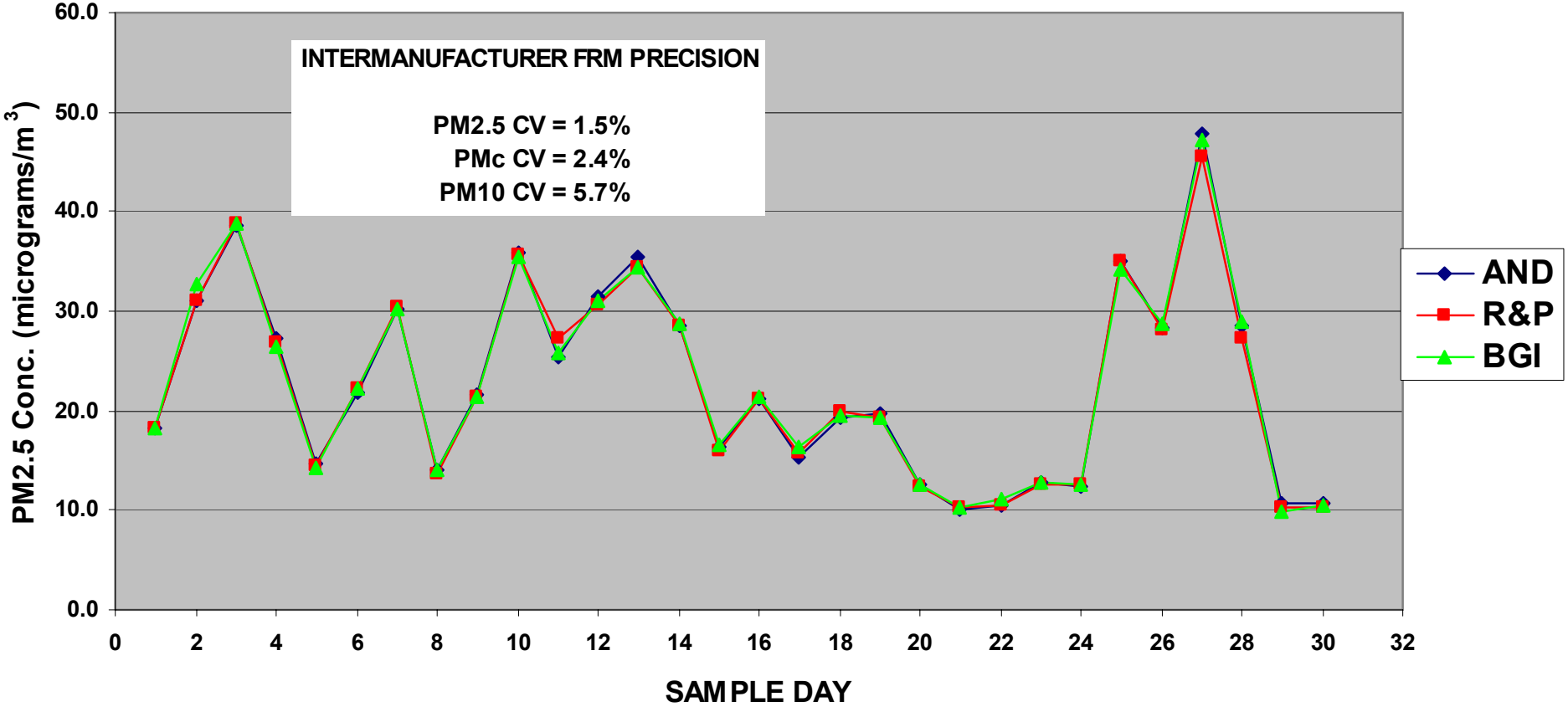
PMc Conc. (micrograms/m^3)

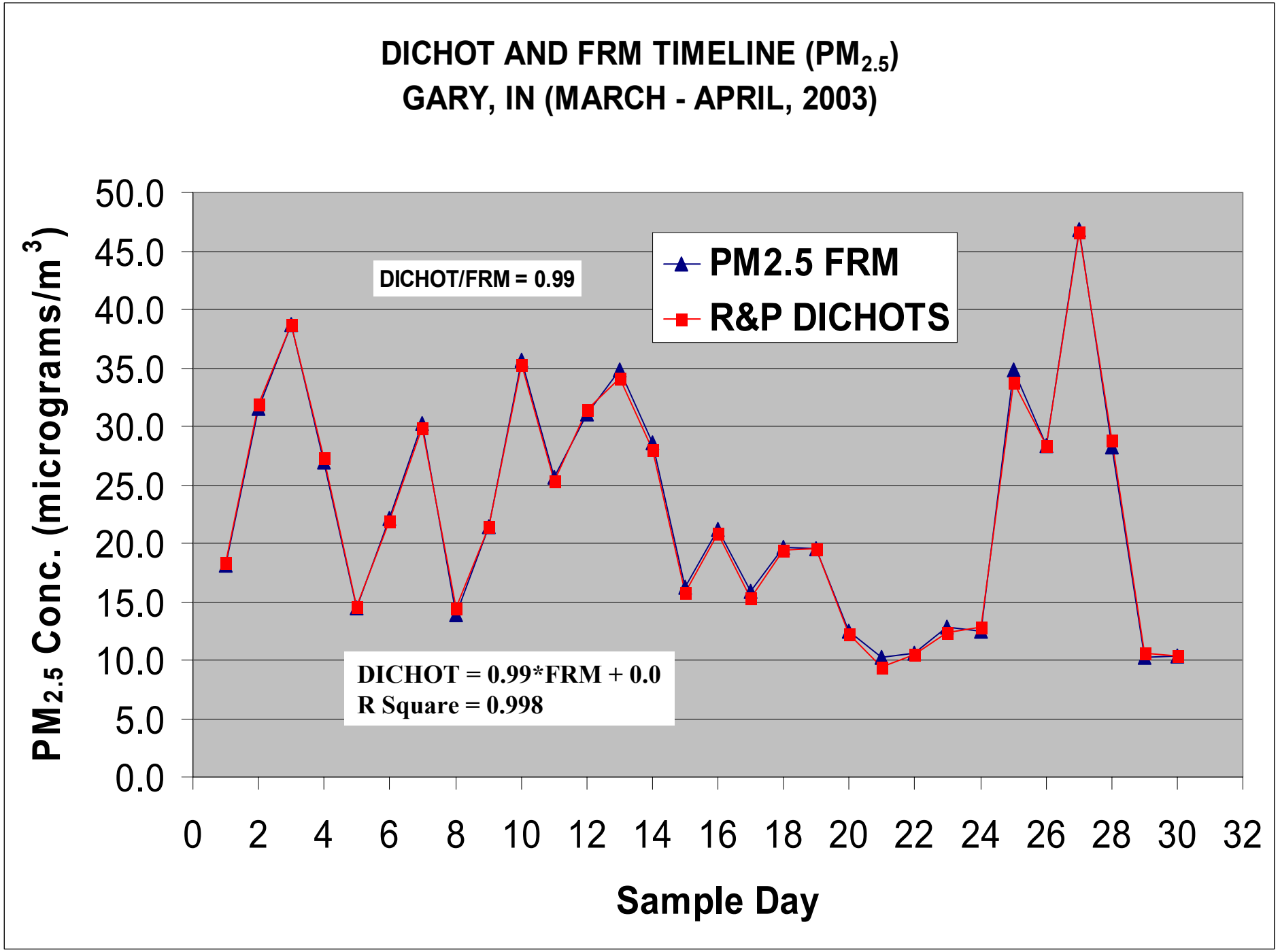
60.0
50.0
40.0
30.0
20.0
10.0
0.0

0
5
10
15
20
25
30
35

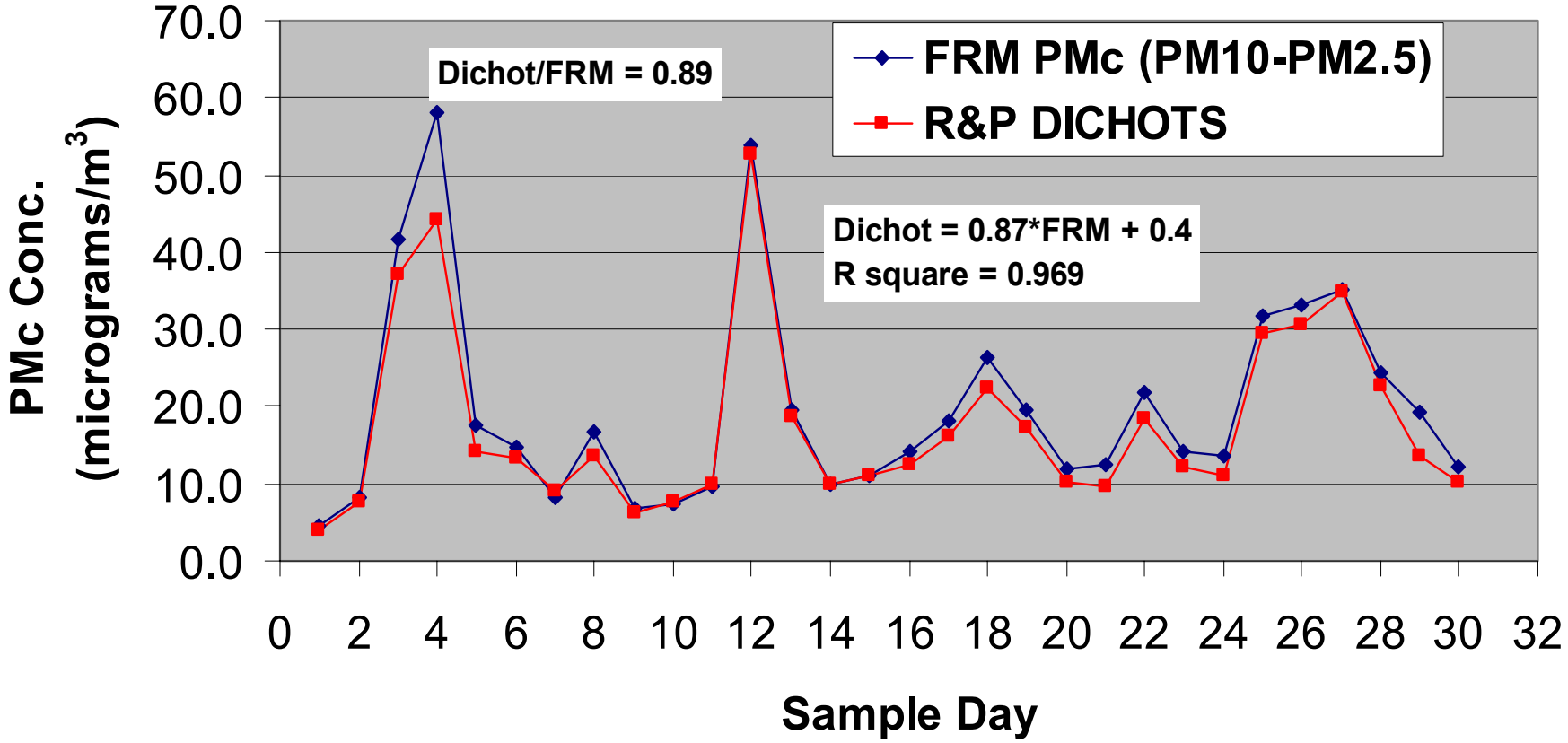
SAMPLE DAY

INTERMANUFACTURER PM2.5 FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)

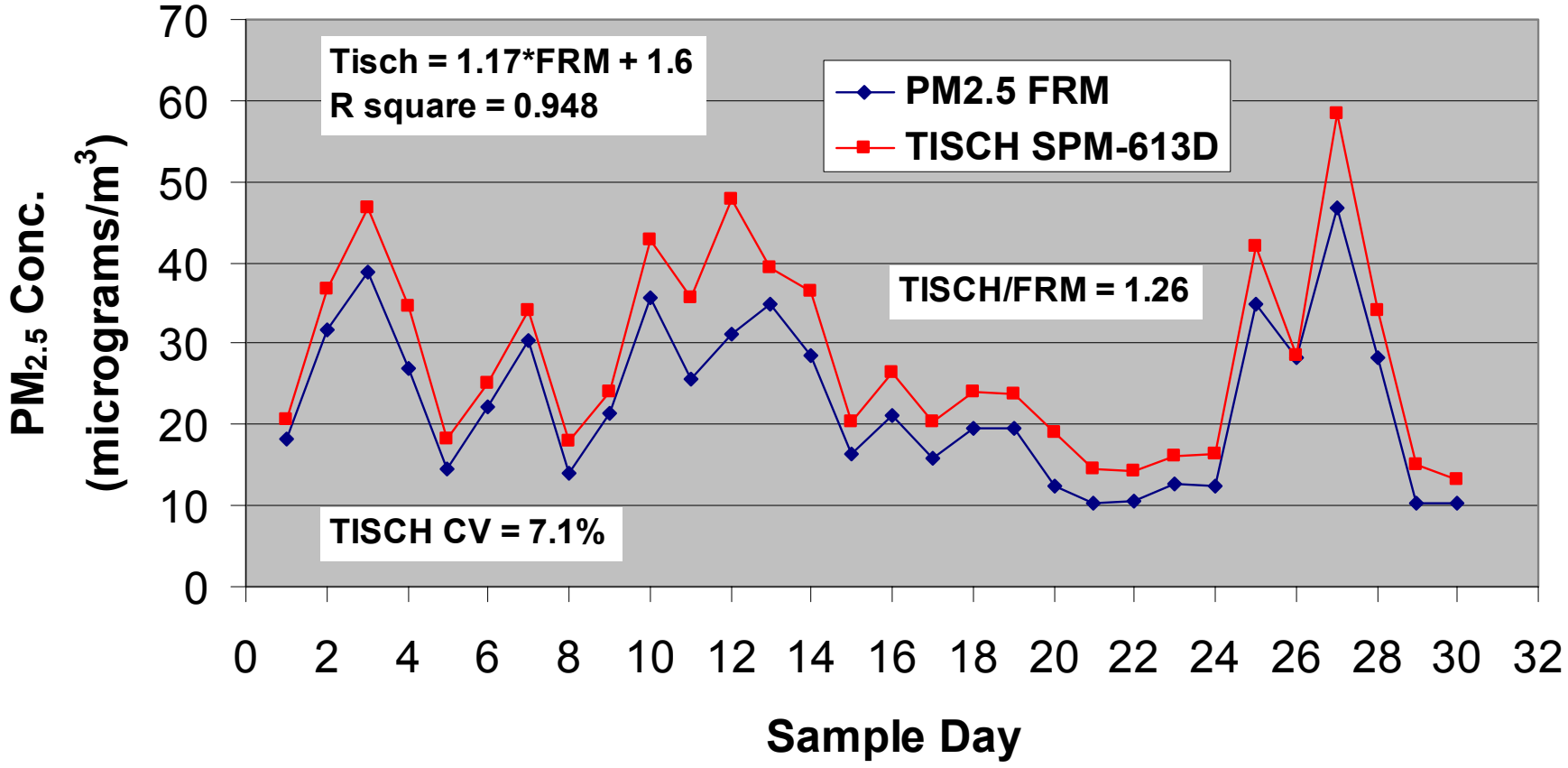



DICHOT AND FRM TIMELINE ($PM_{2.5}$)
GARY, IN (MARCH - APRIL, 2003)
$PM_{2.5}$ Conc. (micrograms/m^3)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Sample Day
PM2.5 FRM
R&P DICHOTS
DICHOT/FRM = 0.99
DICHOT = 0.99*FRM + 0.0
R Square = 0.998

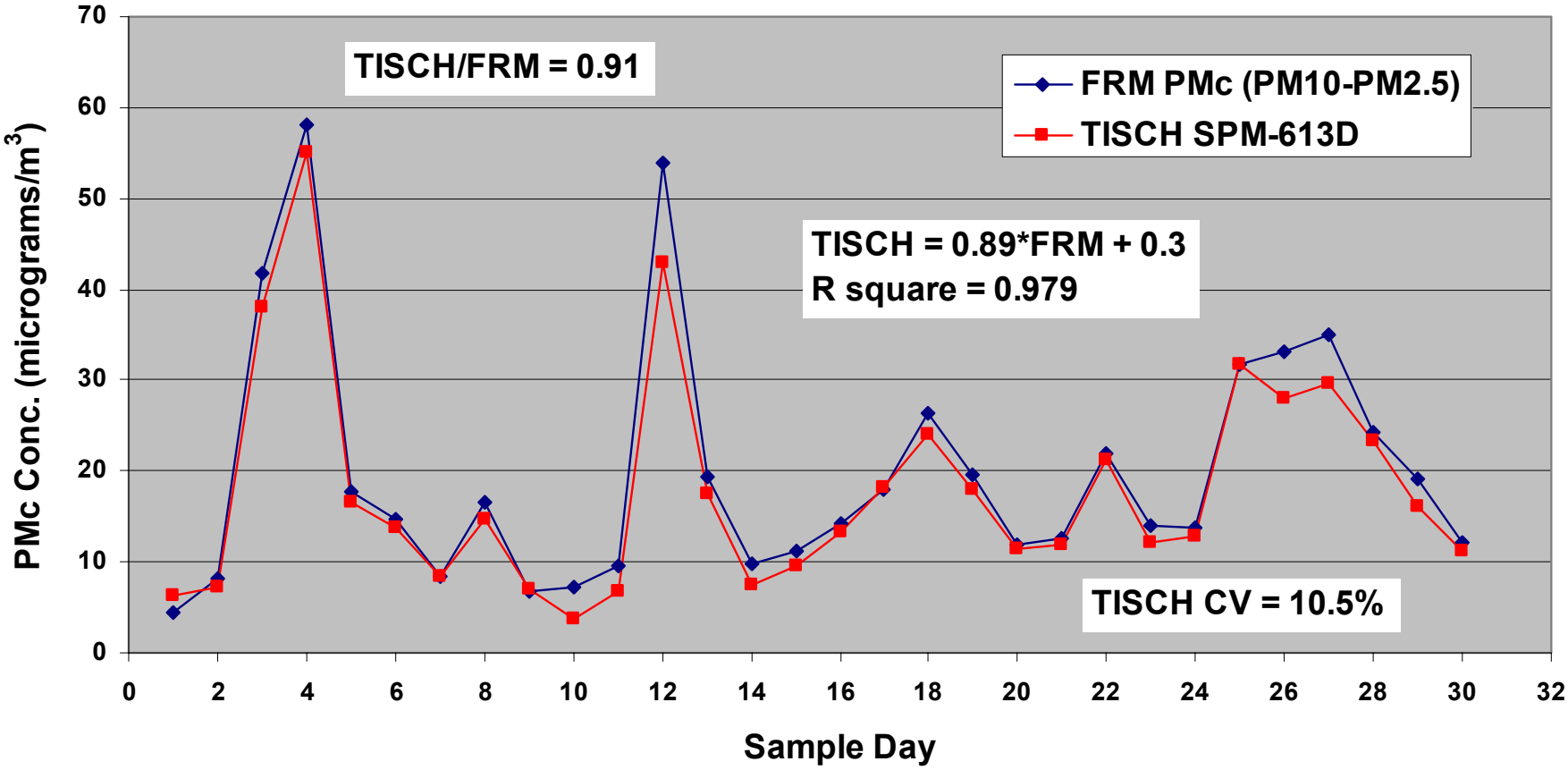
DICHOT AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)



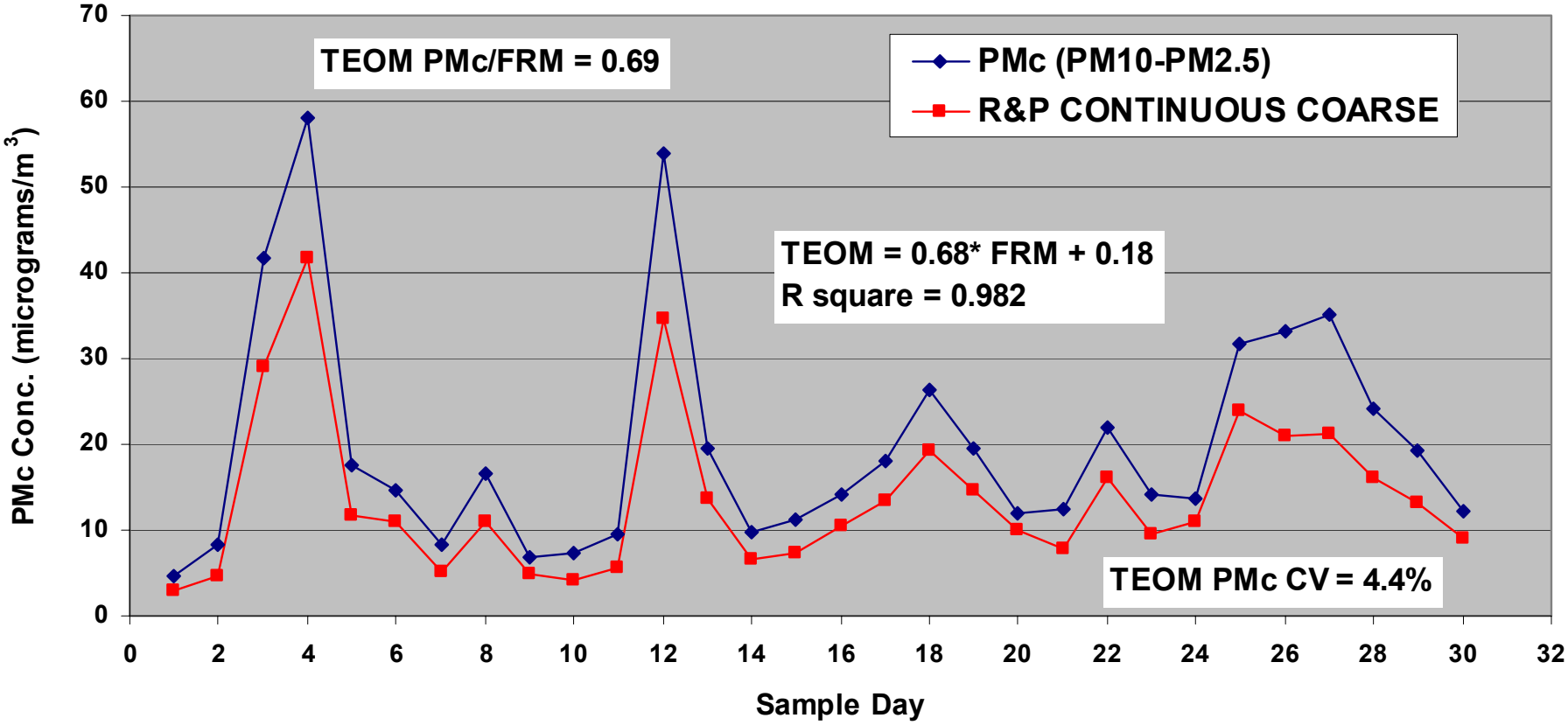
TISCH SPM-613D AND FRM TIMELINE ($PM_{2.5}$)
Gary, IN (March - April, 2003)

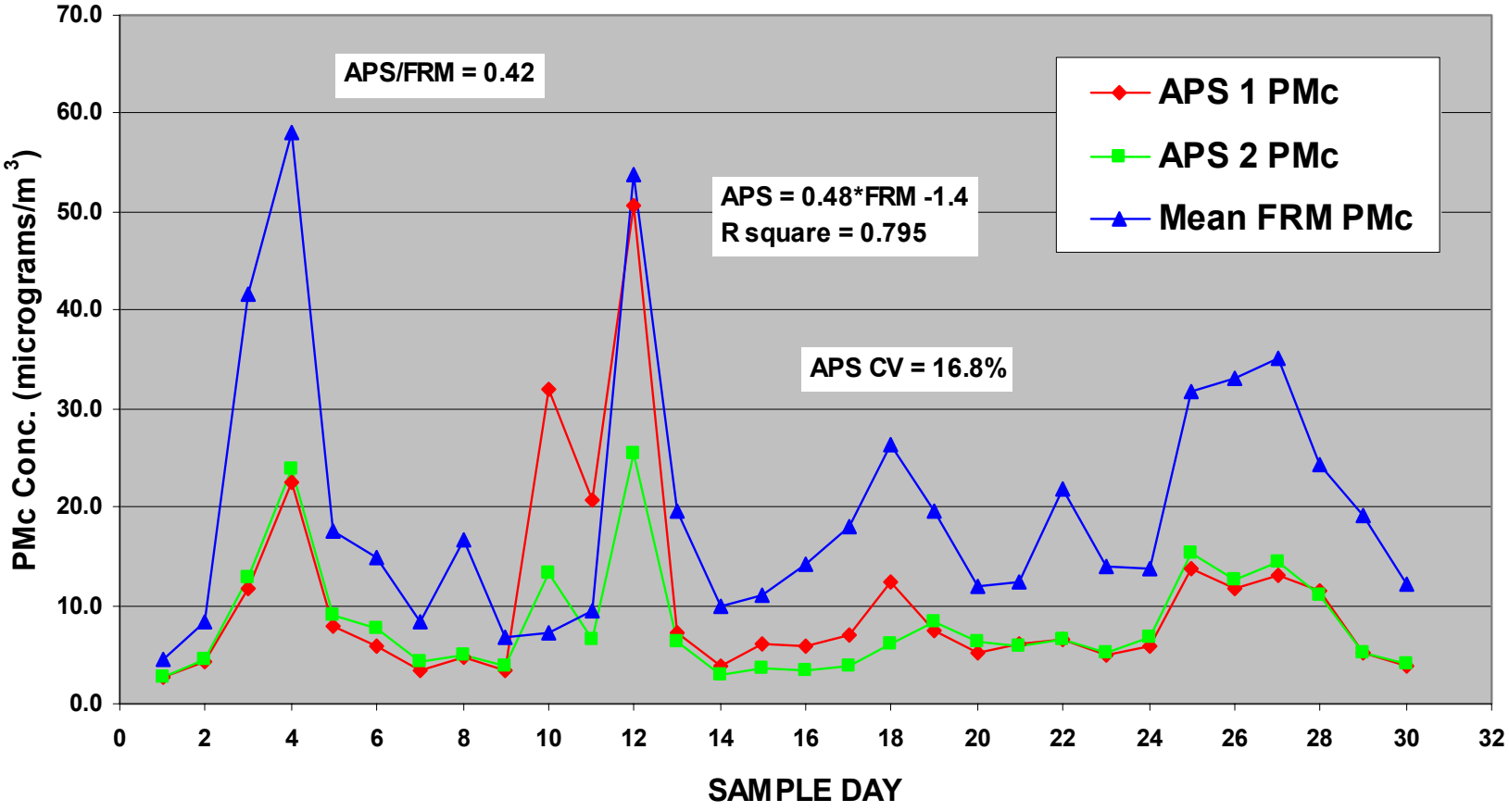


TISCH SPM-613D AND FRM TIMELINE (PM_c)
Gary, IN (March - April, 2003)

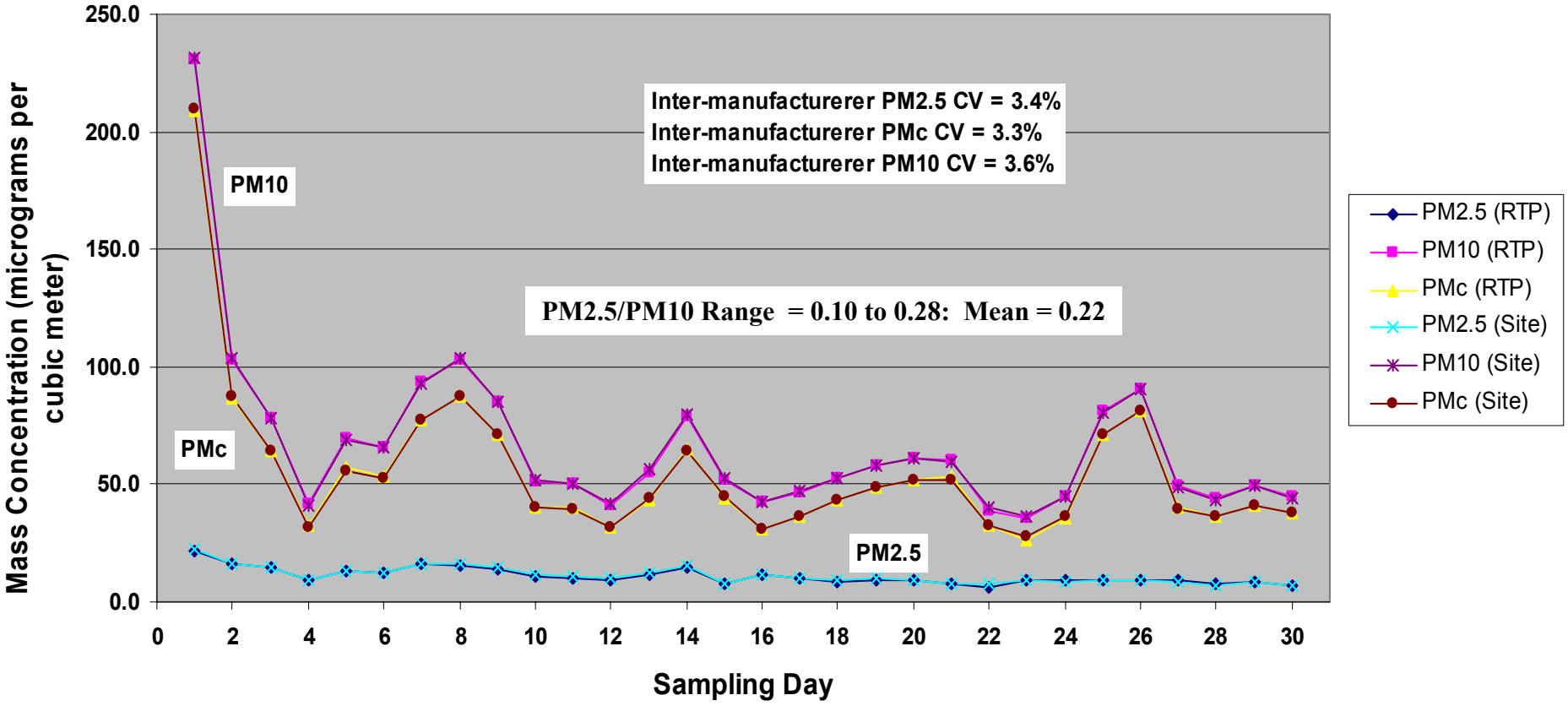


R&P COARSE TEOM AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)

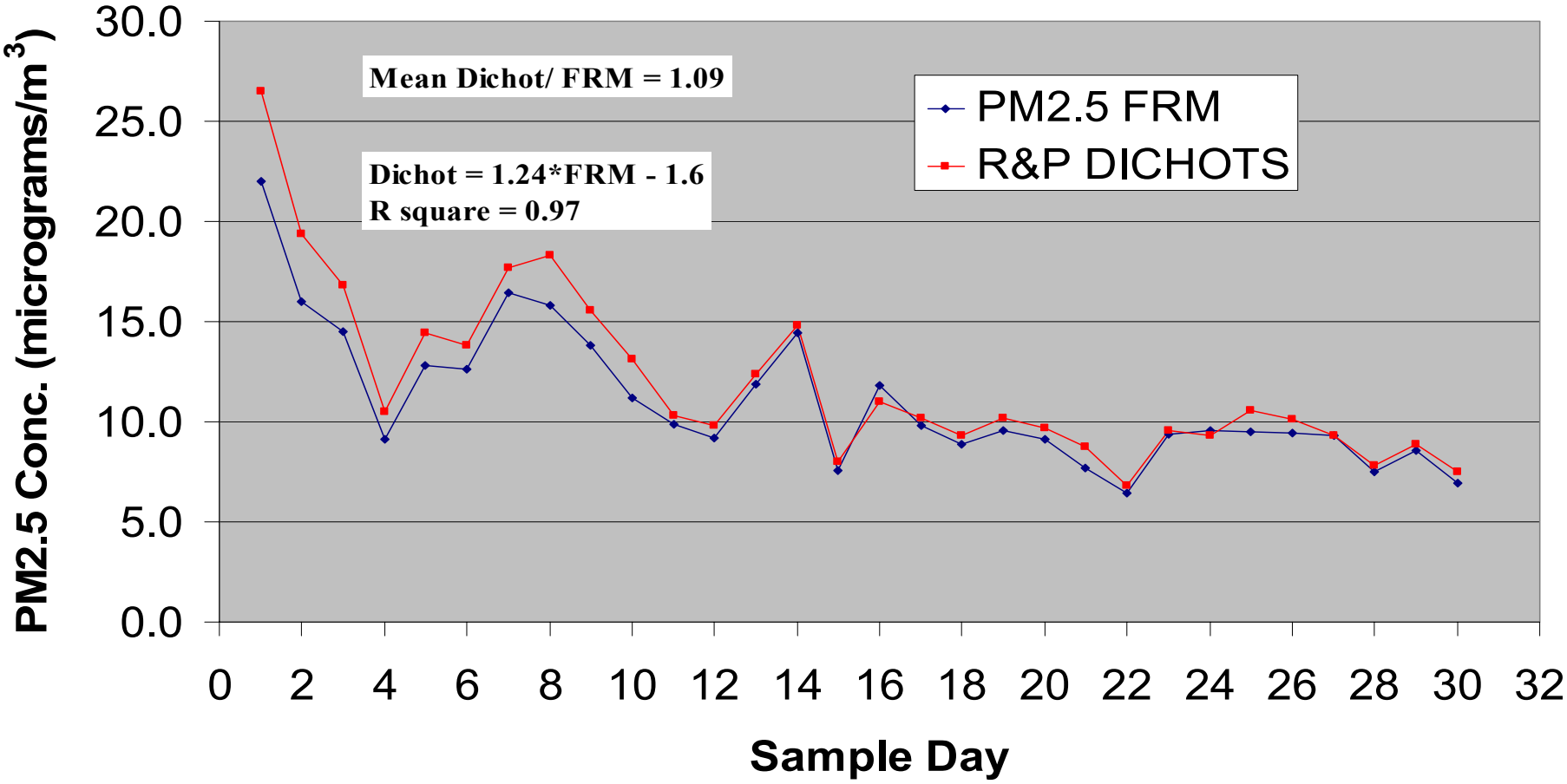


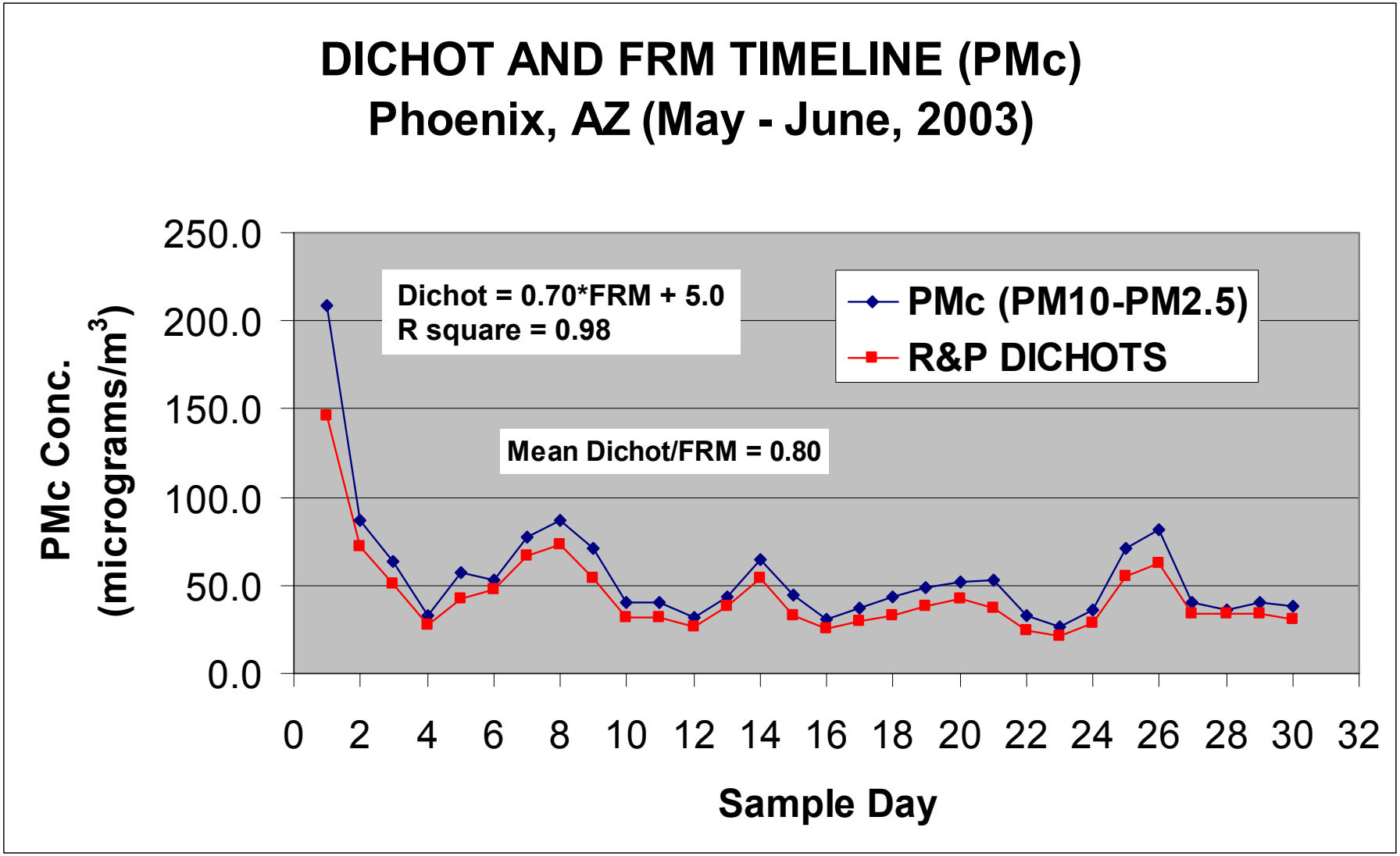

TSI APS vs FRM PMc Concentrations
Gary, IN (March - April)
APS/FRM = 0.42
APS = 0.48*FRM -1.4
R square = 0.795
APS CV = 16.8%
APS 1 PMc
APS 2 PMc
Mean FRM PMc
PMc Conc. (micrograms/m 3)
SAMPLE DAY
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

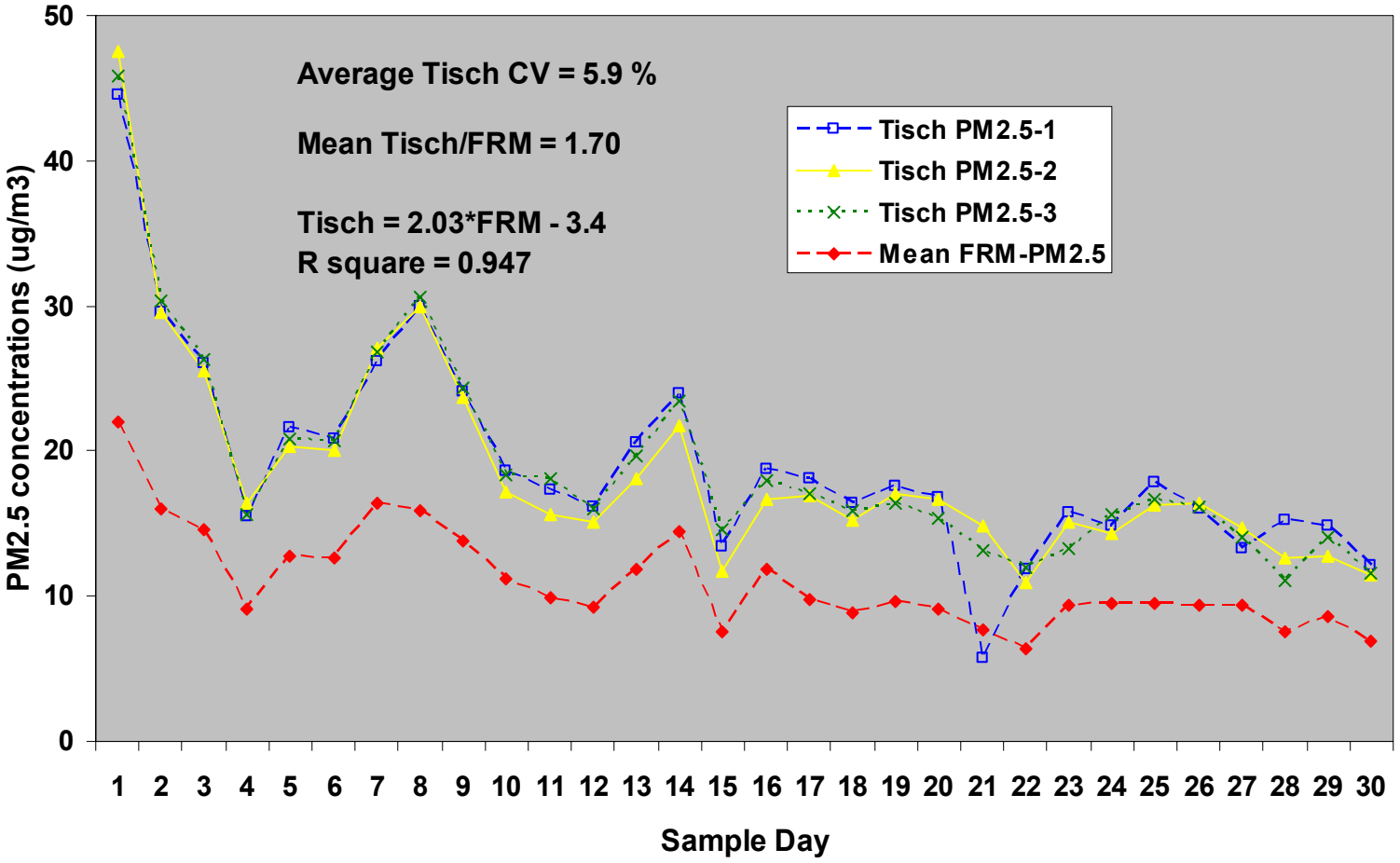

EPA704
05/10/2003

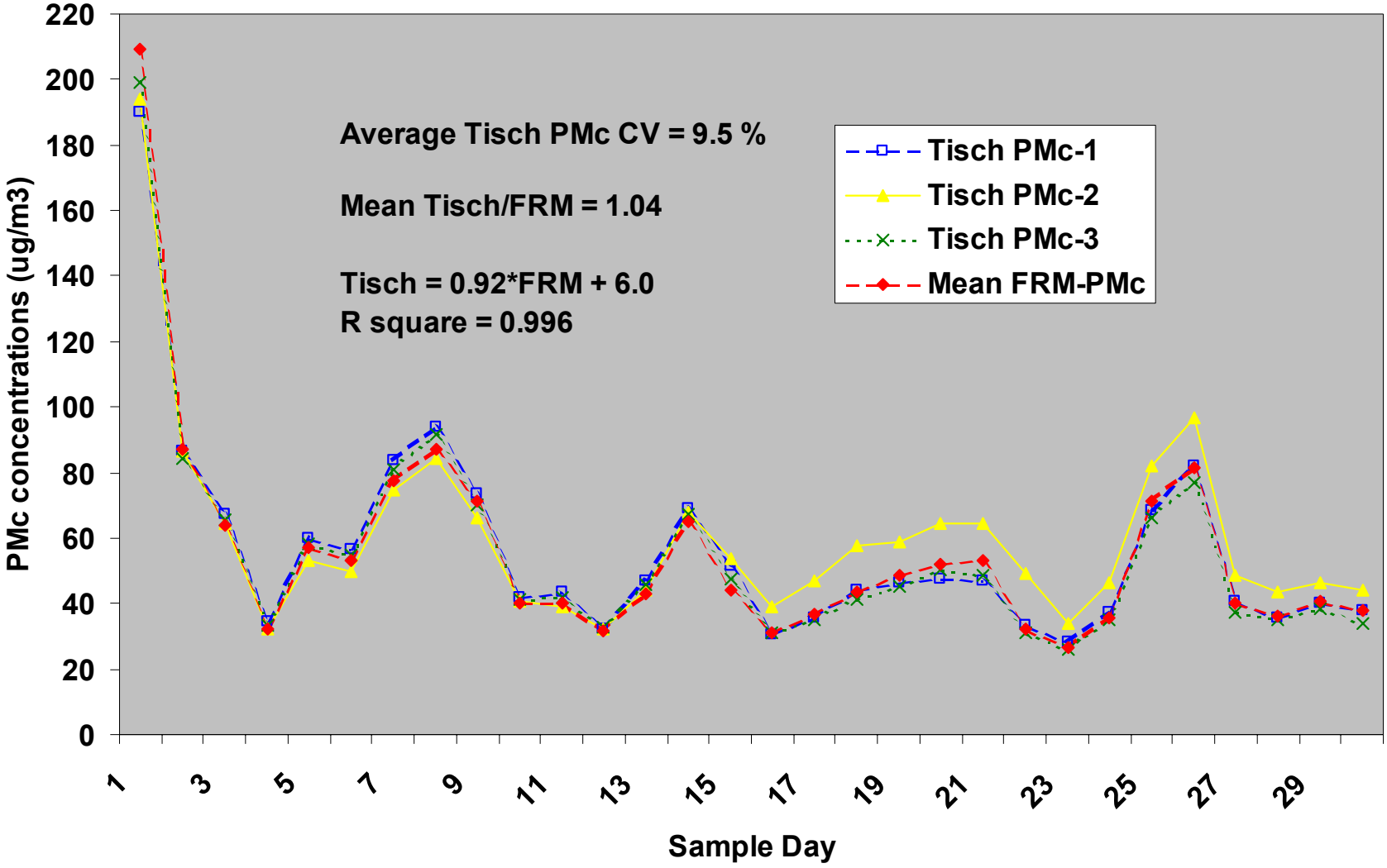

Phoenix versus RTP FRM Weighing
May - June 2003
Mass Concentration (micrograms per cubic meter)
250.0
200.0
150.0
100.0
50.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Sampling Day
Inter-manufacturerer PM2.5 CV = 3.4%
Inter-manufacturerer PMc CV = 3.3%
Inter-manufacturerer PM10 CV = 3.6%
PM2.5/PM10 Range = 0.10 to 0.28: Mean = 0.22
PM10
PMc
PM2.5
PM2.5 (RTP)
PM10 (RTP)
PMc (RTP)
PM2.5 (Site)
PM10 (Site)
PMc (Site)

DICHOT AND FRM PM2.5 TIMELINE
Phoenix, AZ (May - June, 2003)

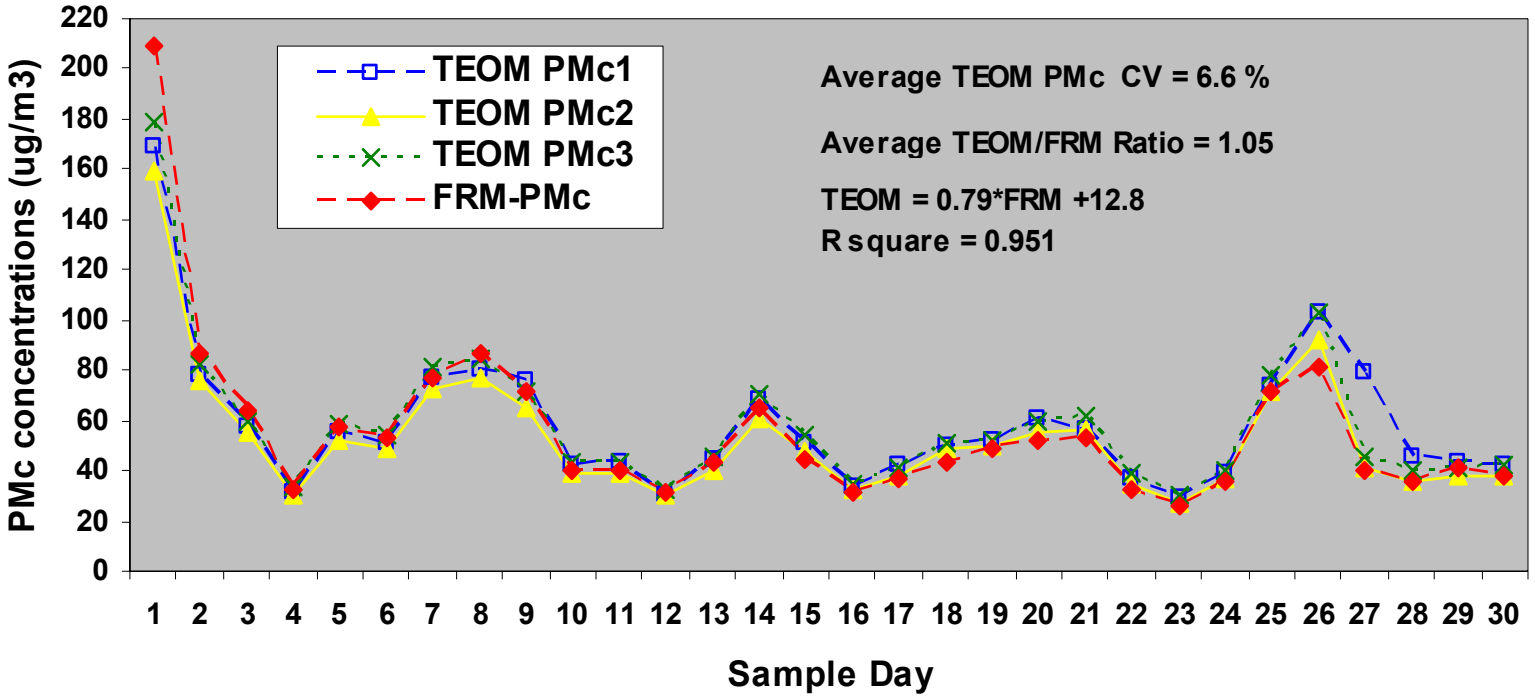


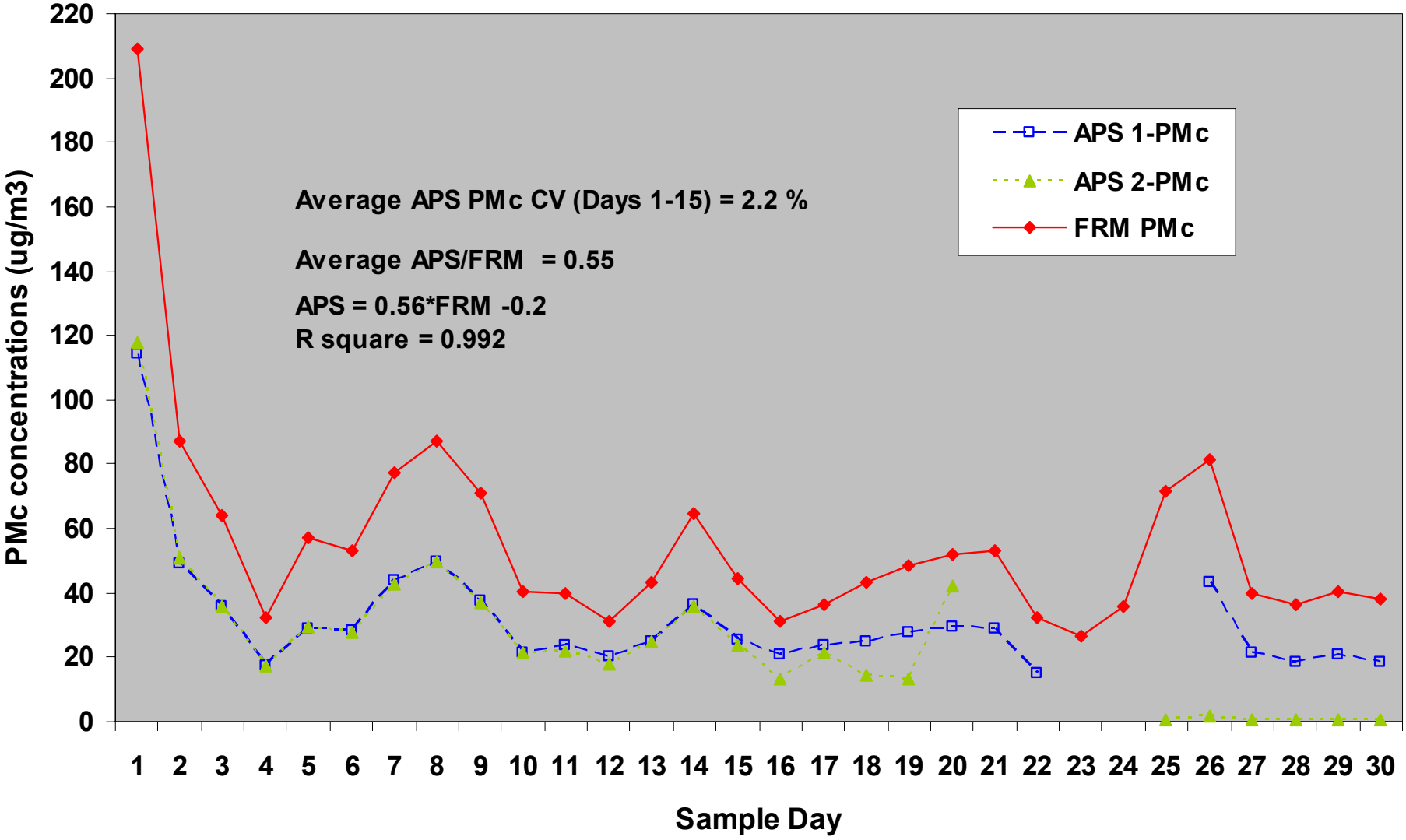

DICHOT AND FRM TIMELINE (PMc)
Phoenix, AZ (May - June, 2003)
PMc Conc. (micrograms/m3)
250.0
200.0
150.0
100.0
50.0
0.0
Dichot = 0.70*FRM + 5.0
R square = 0.98
Mean Dichot/FRM = 0.80
PMc (PM10-PM2.5)
R&P DICHOTS
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Sample Day

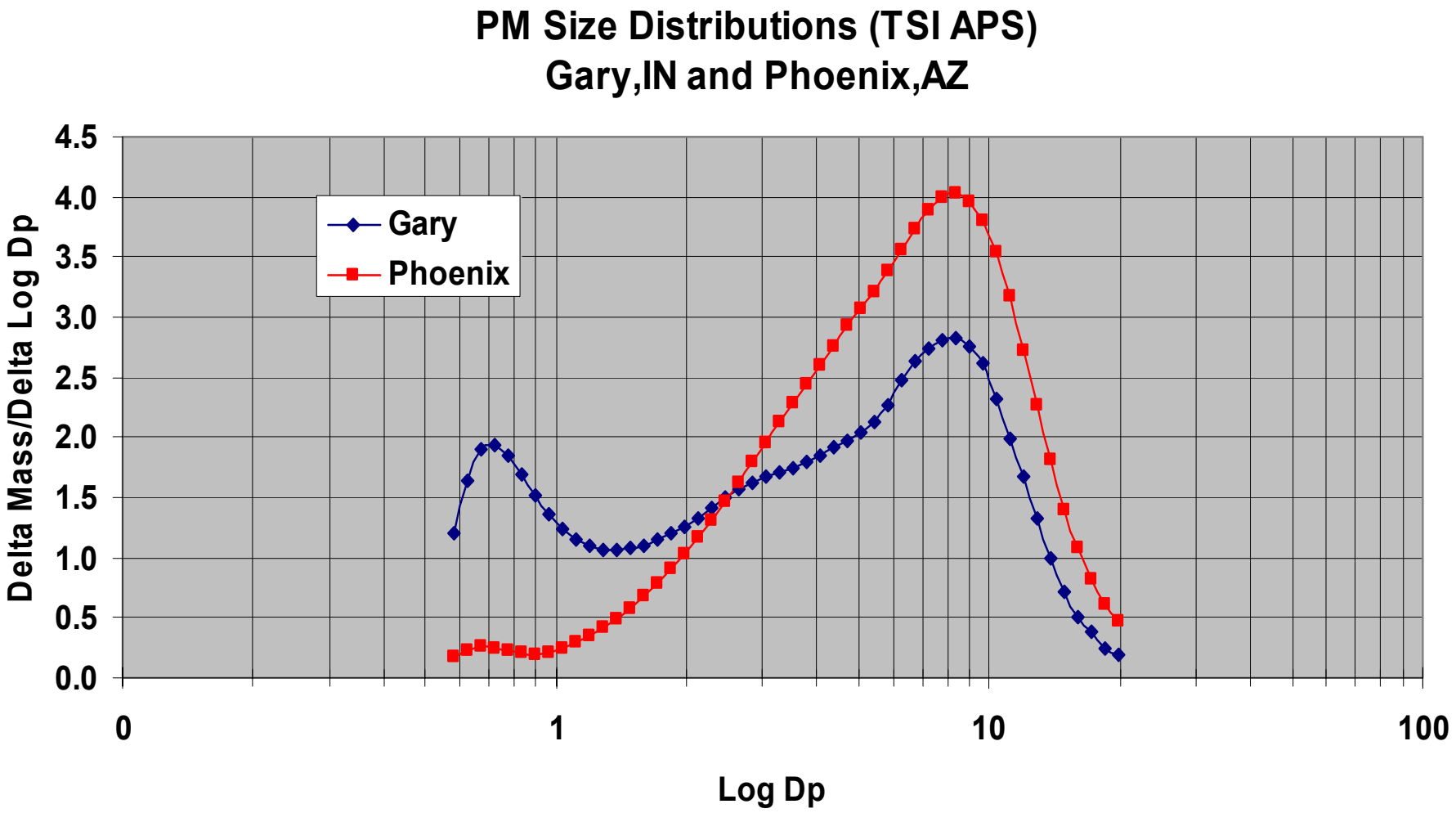

Tisch & FRM PM2.5 Concentrations
Phoenix AZ: May - Jun, 2003
Average Tisch CV = 5.9 %
Mean Tisch/FRM = 1.70
Tisch = 2.03*FRM - 3.4
R square = 0.947
Tisch PM2.5-1
Tisch PM2.5-2
Tisch PM2.5-3
Mean FRM-PM2.5
PM2.5 concentrations (ug/m3)
Sample Day
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Tisch, & FRM PMc Concentrations
Phoenix AZ: May - Jun, 2003
Average Tisch PMc CV = 9.5 %
Mean Tisch/FRM = 1.04
Tisch = 0.92*FRM + 6.0
R square = 0.996
Tisch PMc-1
Tisch PMc-2
Tisch PMc-3
Mean FRM-PMc
PMc concentrations (ug/m3)
Sample Day
0
20
40
60
80
100
120
140
160
180
200
220
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29

TEOM & FRM PMc Concentrations
Phoenix AZ: May - Jun, 2003




APS, & FRM PMc Concentrations
Phoenix AZ: May - Jun, 2003
PMc concentrations (ug/m3)
220
200
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Sample Day
APS 1-PMc
APS 2-PMc
FRM PMc
Average APS PMc CV (Days 1-15) = 2.2 %
Average APS/FRM = 0.55
APS = 0.56*FRM -0.2
R square = 0.992


PM Size Distributions (TSI APS)
Gary,IN and Phoenix,AZ
Gary
Phoenix
Delta Mass/Delta Log Dp
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
10
100
Log Dp

Summary of Results (independent of site)

- FRMs show strong inter-manufacturer precision (CV<4% for all three metrics) with no tendency for producing negative PMc values
- Filter-based dichots show strong precision (CV<4% for all metrics)
- Site weighing results agree closely with RTP results
- Precision of the semi-continuous samplers is considered to be acceptable
- Correlation (R^2) of all continuous samplers is typically strong versus the collocated FRMs

SUMMARY OF SITE RESULTS

		GARY, IN	PHOENIX, AZ
SITE AEROSOL	PMc Mean (µg/m^3)	19.9	55.6
	PM2.5/PM10 Range	0.32 - 0.83	0.10 - 0.28
	PM2.5/PM10 Ratio	0.55	0.18
DICHOTS	Dichot/FRM PM2.5	1.00	1.09
	Dichot/FRM PM10	0.94	0.84
	Dichot/FRM PMc	0.90	0.79
TEOM PMc	TEOM PMc/FRM	0.69	1.05
TISCH	Tisch/FRM PM2.5	1.26	1.70
	Tisch/FRM PM10	1.09	1.16
	Tisch/FRM PMc	0.91	1.04
TSI APS	APS/FRM PMc	0.42	0.55

Future Work

- Complete RTP gravimetric analysis of Riverside, CA filters (>1500 filter weighings per site)
- Conduct chemical analysis of archived site filters; potentially use results as "explainers" of sampler performance
- Possibly conduct comprehensive field tests at an additional field site
- Possibly perform laboratory tests with samplers to better understand aerosol fractionation and/or particle loss issues

Disclaimer

- The United States Environmental Protection Agency through its Office of Research and Development funded and managed the research described here under Contract 68-D-00-206. It has been subjected to Agency review and approved for publication.