Coarse PM Methods Evaluation Study

Study Design and Preliminary Results

Thomas Ellestad, Robert Vanderpool, Paul Solomon, and Mary Harmon
USEPA/ORD/NERL

Sanjay Natarajan, Chris Noble, and Bob Murdoch
Research Triangle Institute

Vanderpool.Robert@epa.gov
919-541-7877

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 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

PM10
(WINS Removed)

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 (4th 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 size distribution information
- 2 units used in our study

Mobile Sampling Platform (Side View)

Mobile Sampling Platform (Front View)

Sampler Performance Issues

- Relative bias versus collocated FRMs
- Precision (2 or 3 samplers of each type)
- Field reliability
- 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

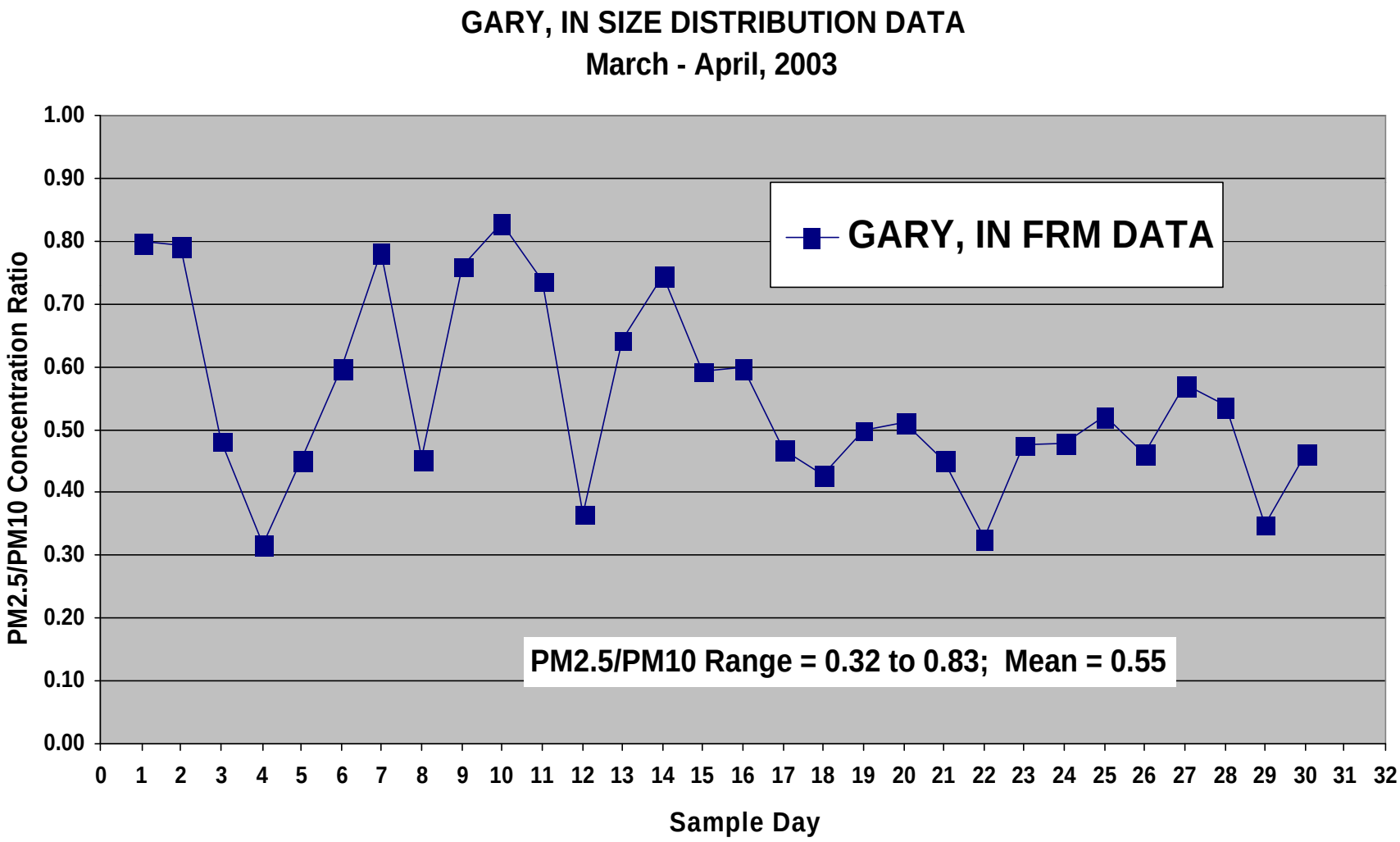
Study Details

- Using 22 hour, daily sampling periods for comparisons (11 am to 9 am local time)
- Chemical analysis (XRF, IC, thermal optical) of archived filters will provide particle composition, which may explain observed sampler performance
- Full data set from all three sites will be ready by Feb 2004. Detailed results from Gary, IN will be presented at the October AAAR meeting

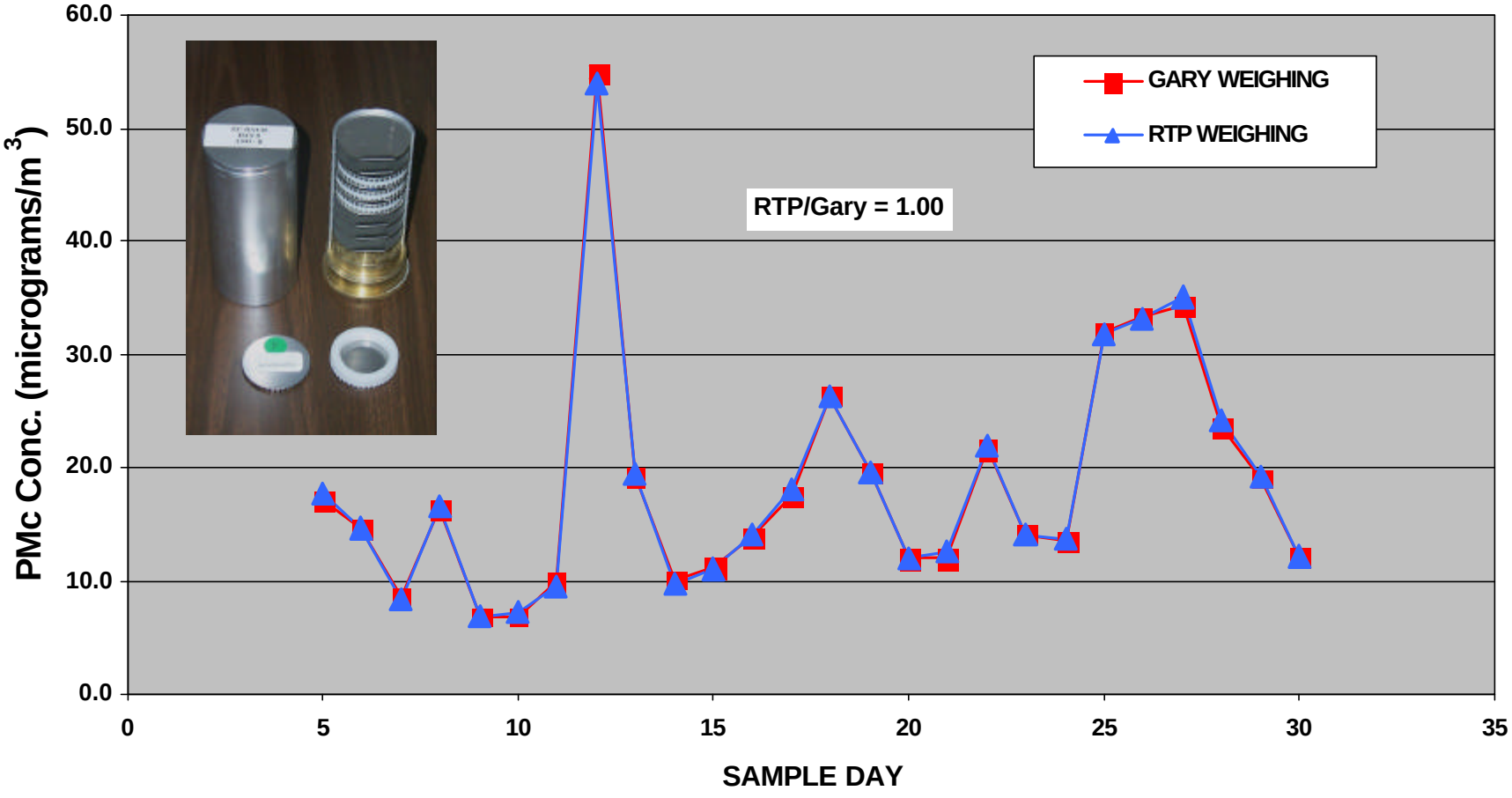
Study Sites

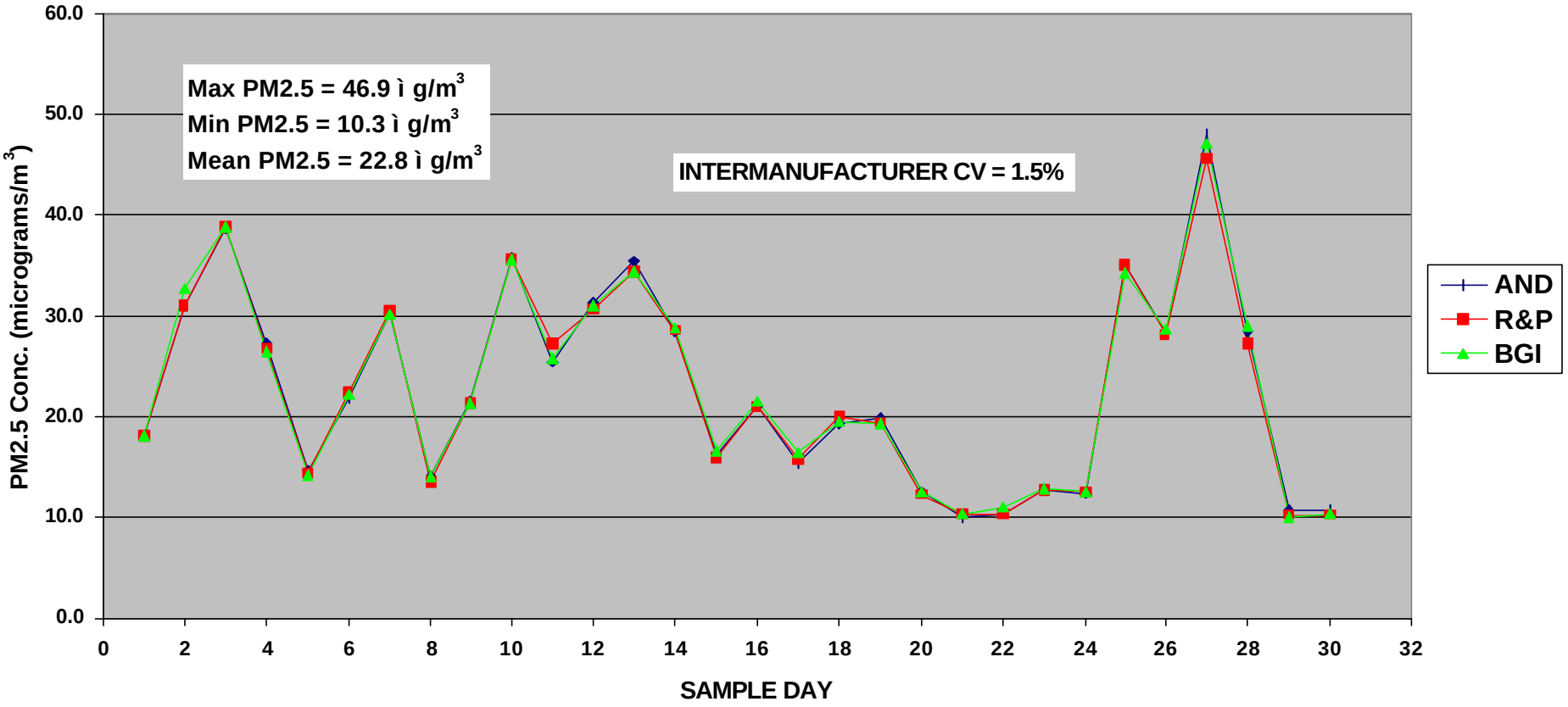
- RTP, NC (10 days of shakedown tests, Jan. 2003)
- Gary, IN (30 days of tests under cold, snow/rain, variable PM2.5/PM10 ratios, March-April, 2003)
- Phoenix, AZ (30 days of tests under hot, dusty conditions, consistently low PM2.5/PM10 ratios, May-June, 2003)
- Riverside, CA (30 days of tests under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

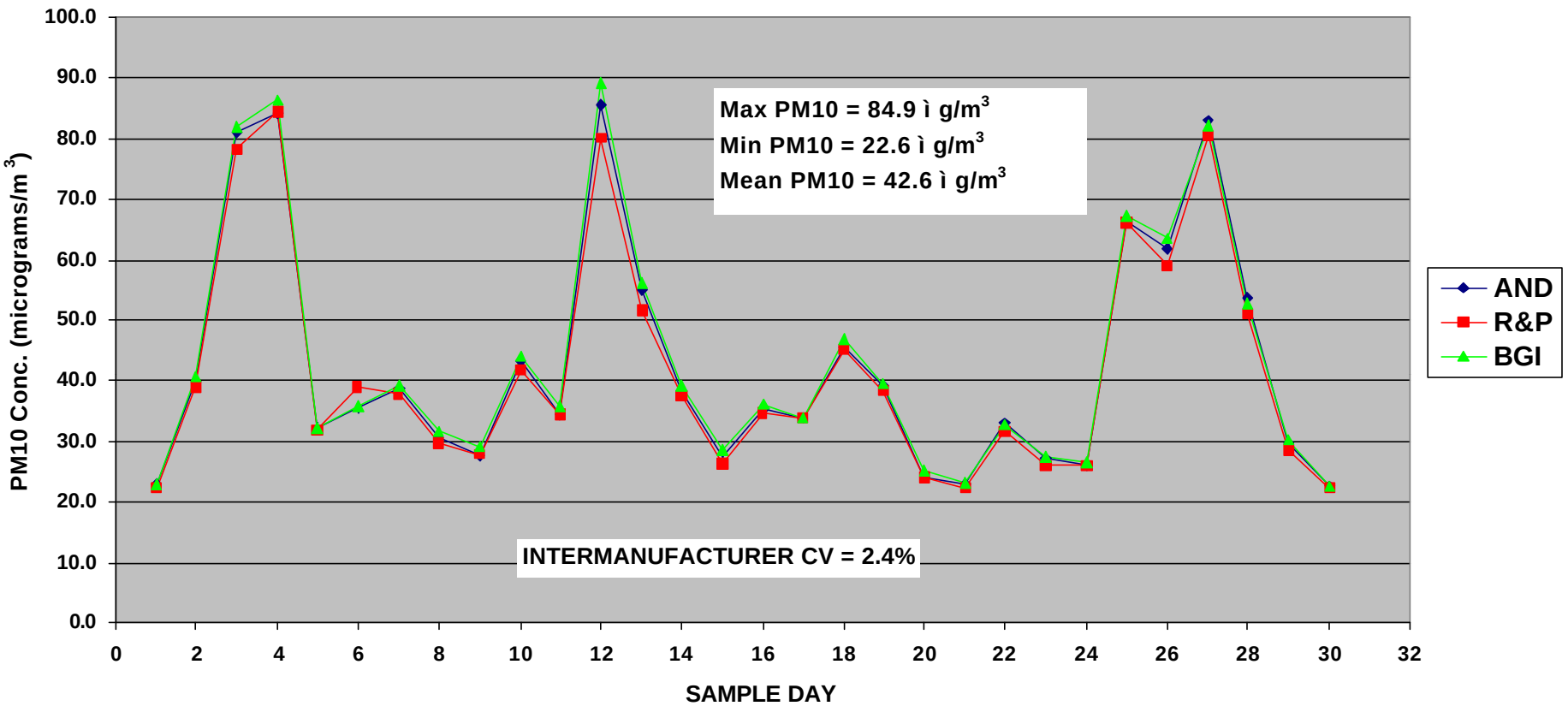
Gary, IN

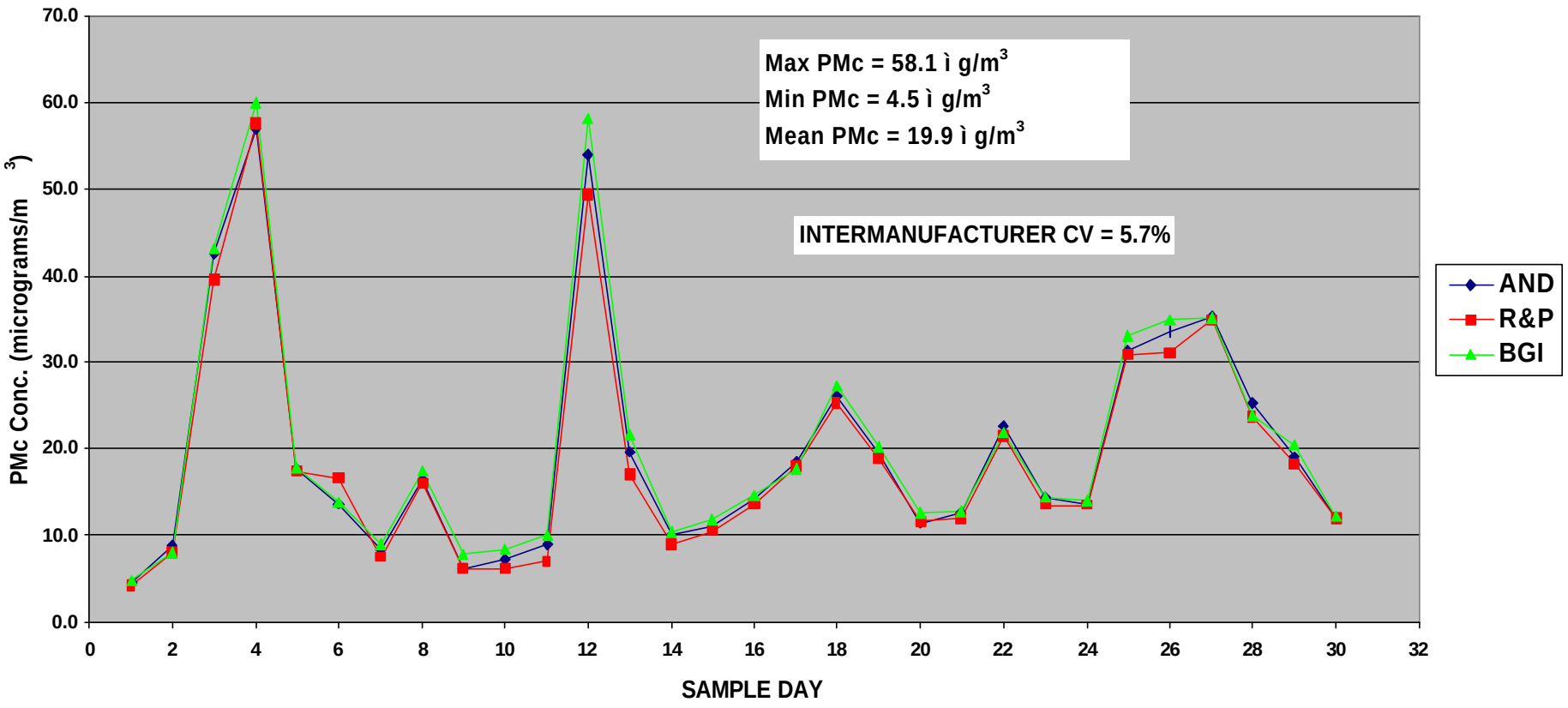

GARY, IN SIZE DISTRIBUTION DATA
March - April, 2003
GARY, IN FRM DATA
PM2.5/PM10 Range = 0.32 to 0.83; Mean = 0.55
PM2.5/PM10 Concentration Ratio
Sample Day
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

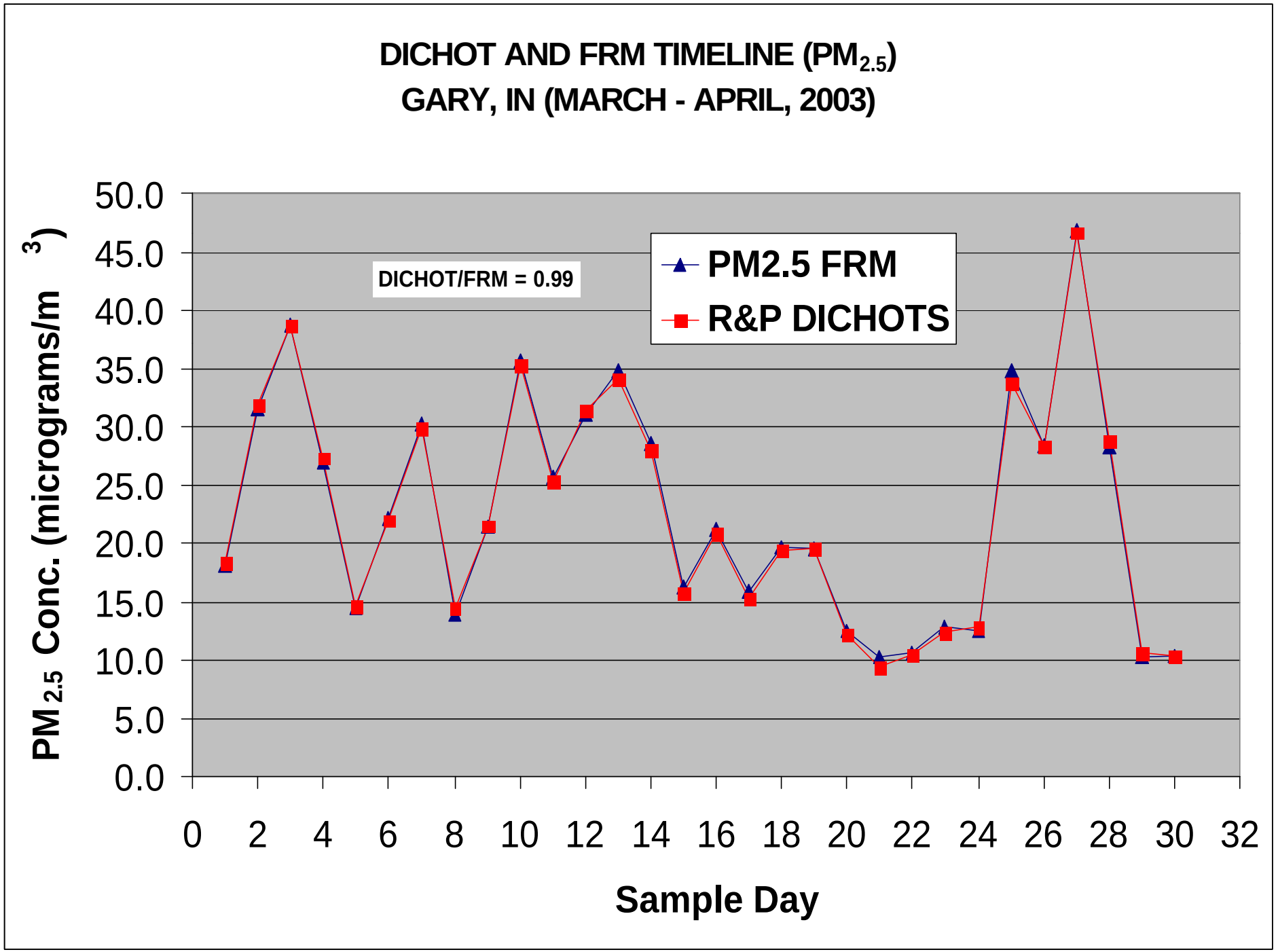
PMc FRM MEASUREMENTS - GARY vs RTP WEIGHING
Gary, IN (March - April, 2003)

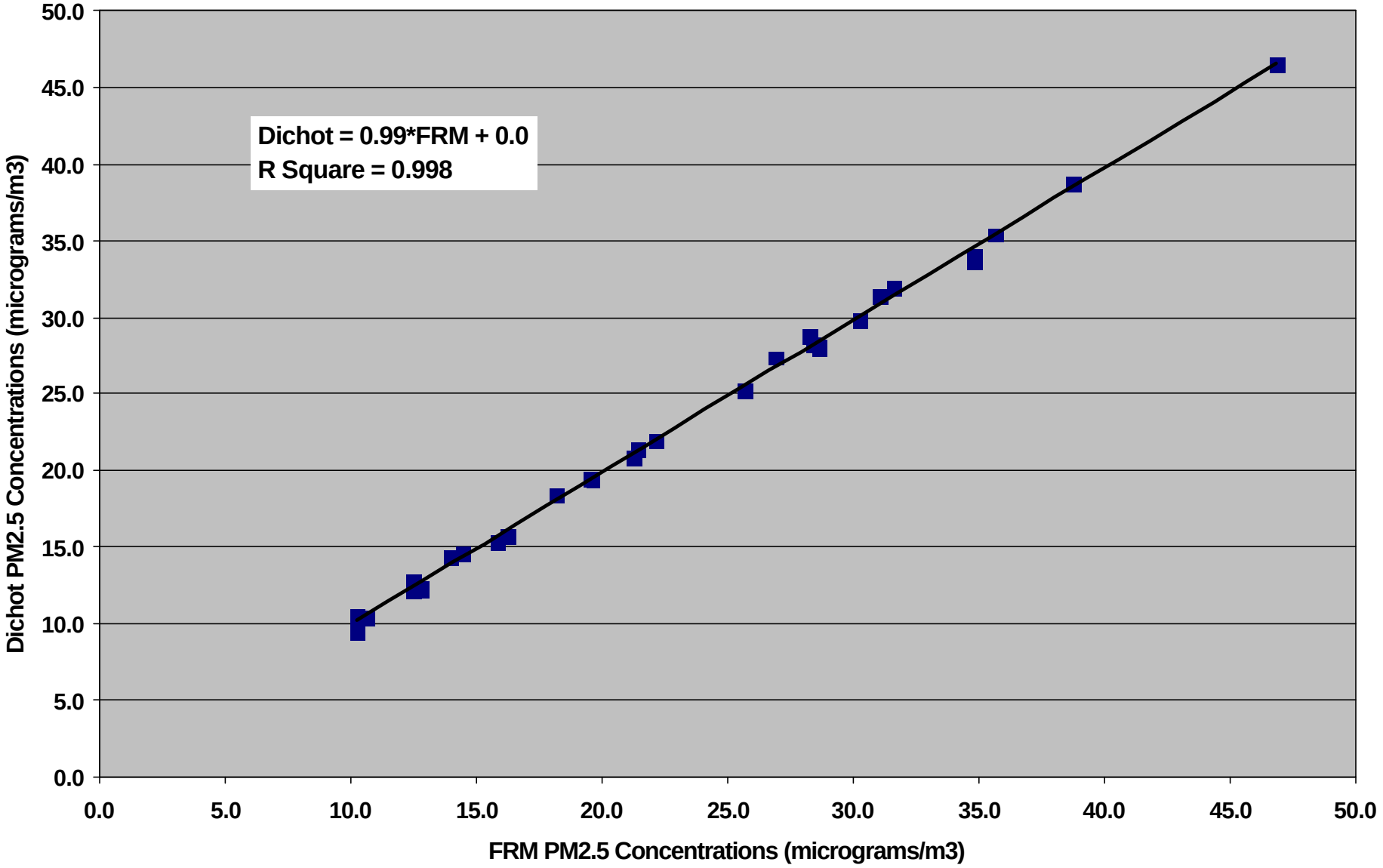



INTERMANUFACTURER PM2.5 FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)
Max PM2.5 = 46.9 ì g/m3
Min PM2.5 = 10.3 ì g/m3
Mean PM2.5 = 22.8 ì g/m3
INTERMANUFACTURER CV = 1.5%
PM2.5 Conc. (micrograms/m3)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
SAMPLE DAY
AND
R&P
BGI

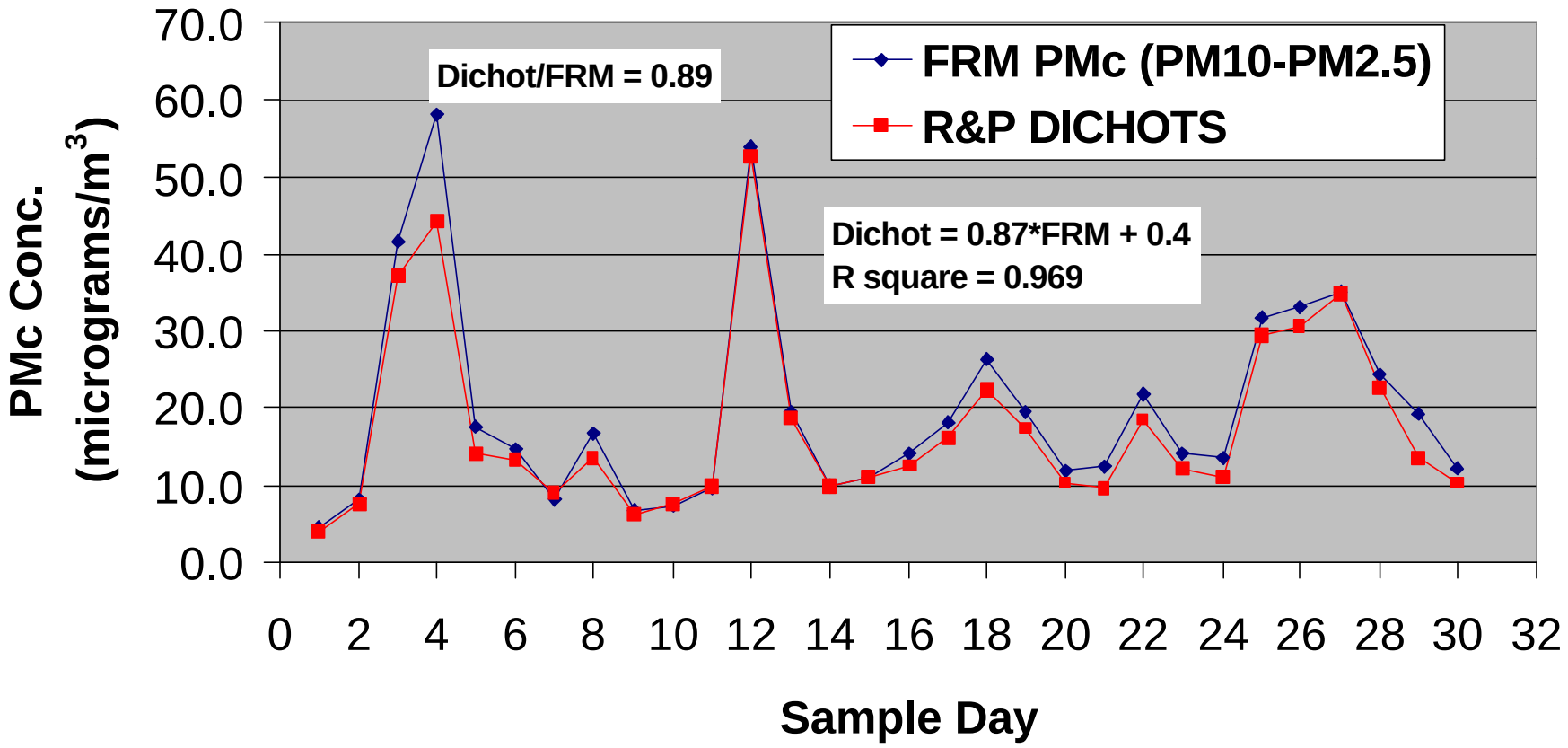

INTERMANUFACTURER PM10 FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)
Max PM10 = 84.9 ì g/m3
Min PM10 = 22.6 ì g/m3
Mean PM10 = 42.6 ì g/m3
INTERMANUFACTURER CV = 2.4%
PM10 Conc. (micrograms/m 3)
SAMPLE DAY
AND
R&P
BGI
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


INTERMANUFACTURER PMc FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)
Max PMc = 58.1 ì g/m3
Min PMc = 4.5 ì g/m3
Mean PMc = 19.9 ì g/m3
INTERMANUFACTURER CV = 5.7%
PMc Conc. (micrograms/m3)
SAMPLE DAY
AND
R&P
BGI
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

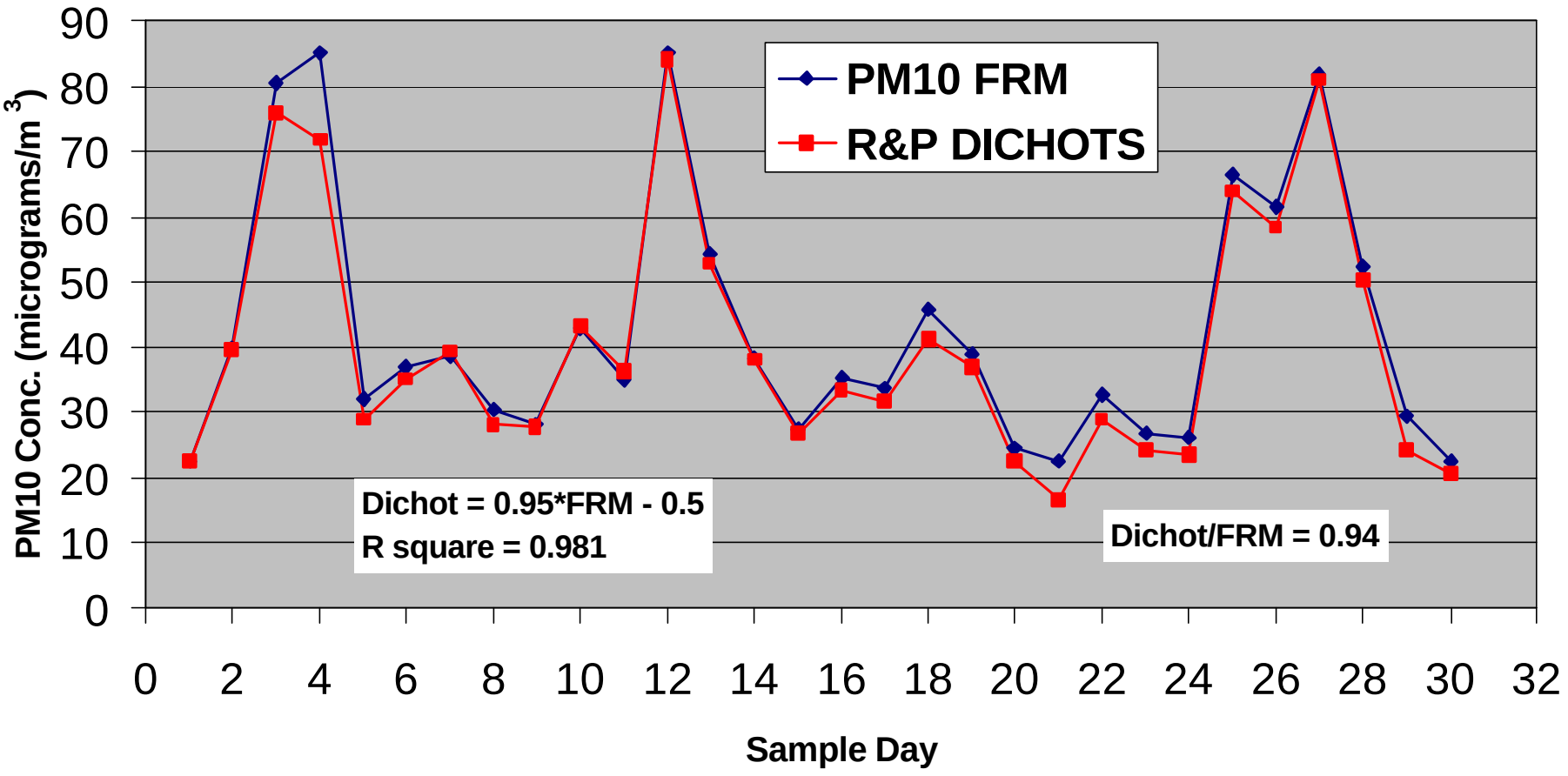

DICHOT AND FRM TIMELINE ($PM_{2.5}$)
GARY, IN (MARCH - APRIL, 2003)
DICHOT/FRM = 0.99
PM2.5 FRM
R&P DICHOTS
$PM_{2.5}$ Conc. (micrograms/m^3)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Sample Day


Dichot versus FRM PM2.5 Concentrations
Gary, IN (March - April, 2003)
Dichot = 0.99*FRM + 0.0
R Square = 0.998
Dichot PM2.5 Concentrations (micrograms/m3)
FRM PM2.5 Concentrations (micrograms/m3)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0

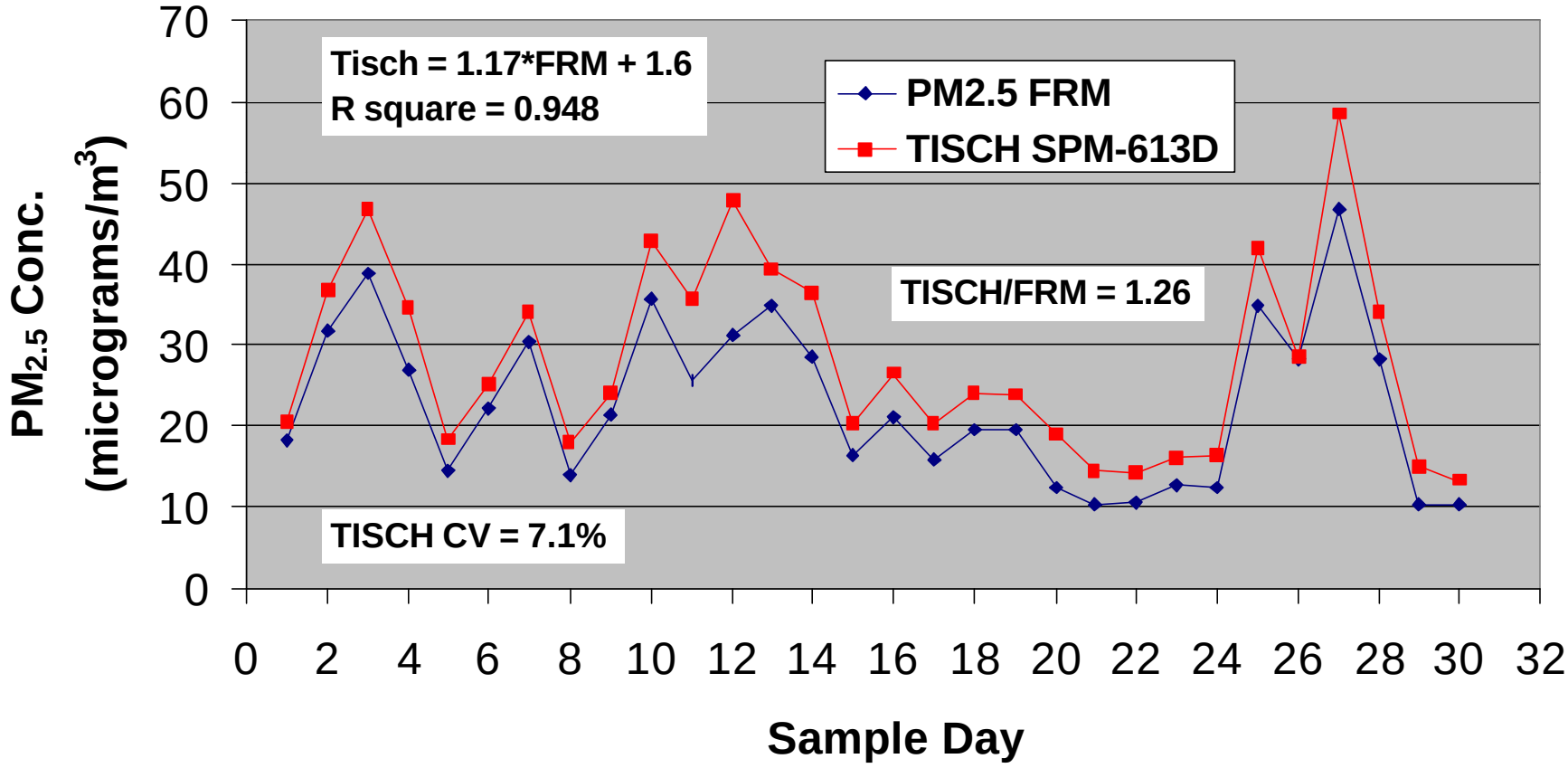
DICHOT AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)



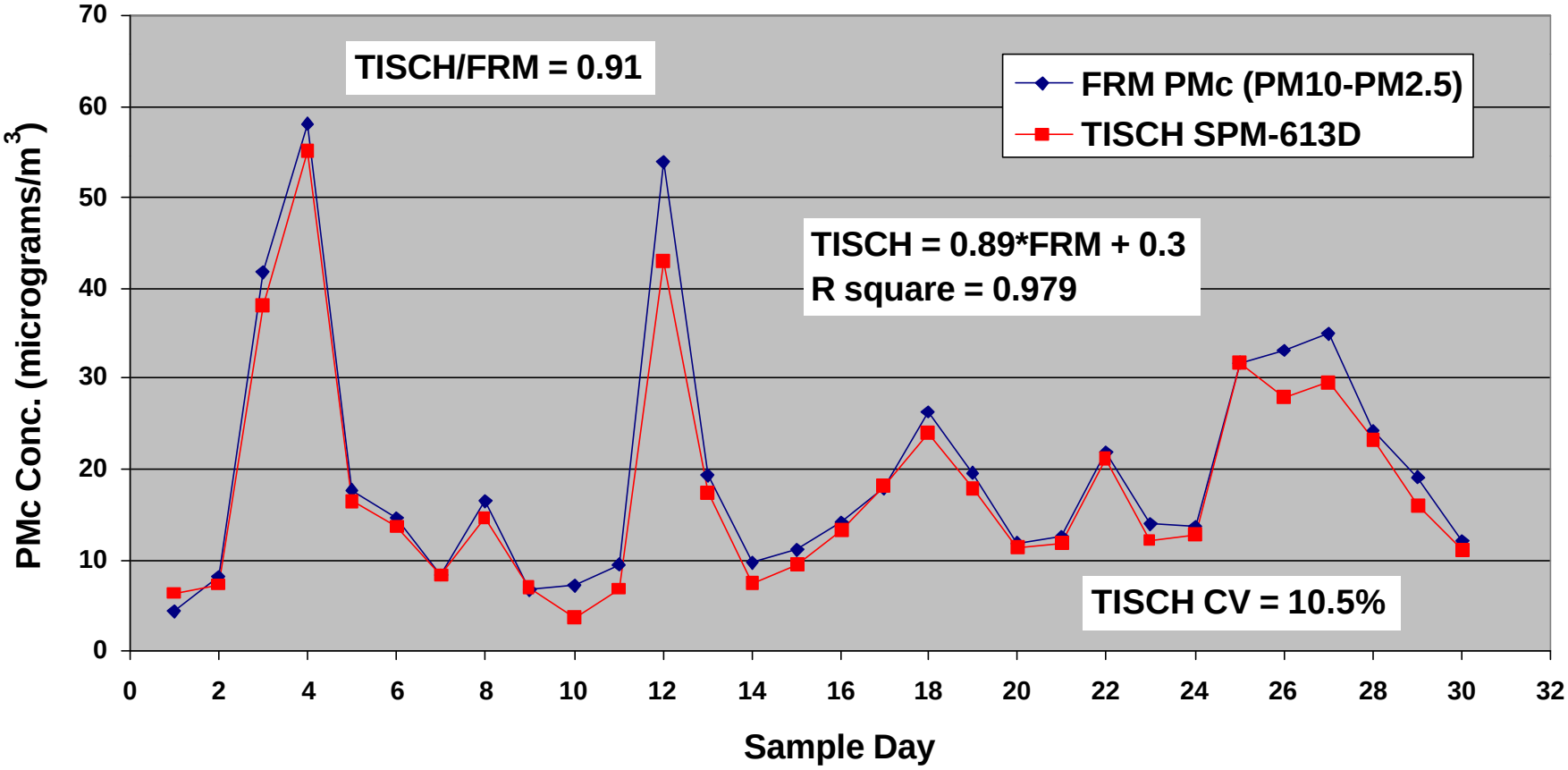
DICHOT AND FRM TIMELINE (PM10)
Gary, IN (March - April, 2003)



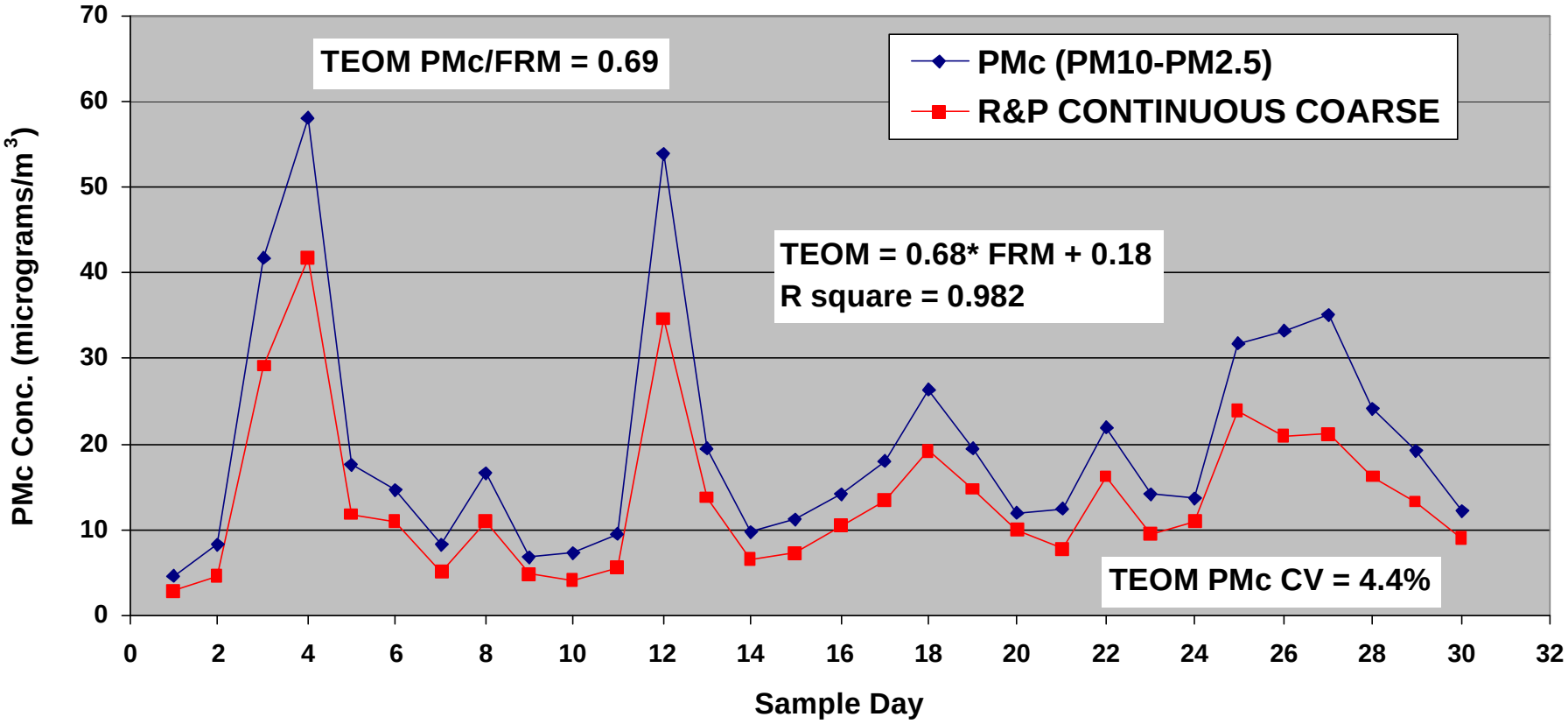
TISCH SPM-613D AND FRM TIMELINE ($PM_{2.5}$)
Gary, IN (March - April, 2003)

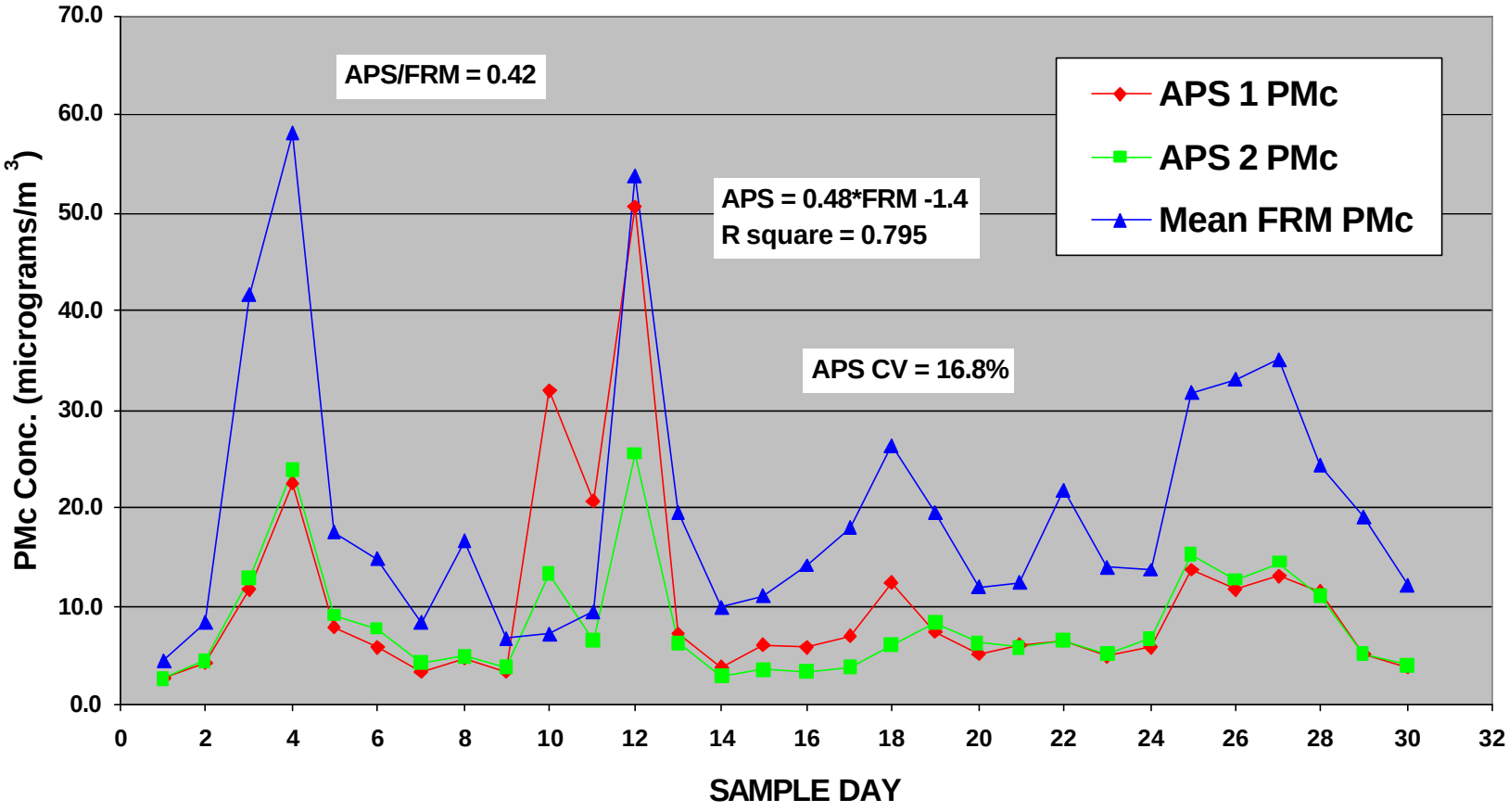


TISCH SPM-613D AND FRM TIMELINE (PM_c)
Gary, IN (March - April, 2003)



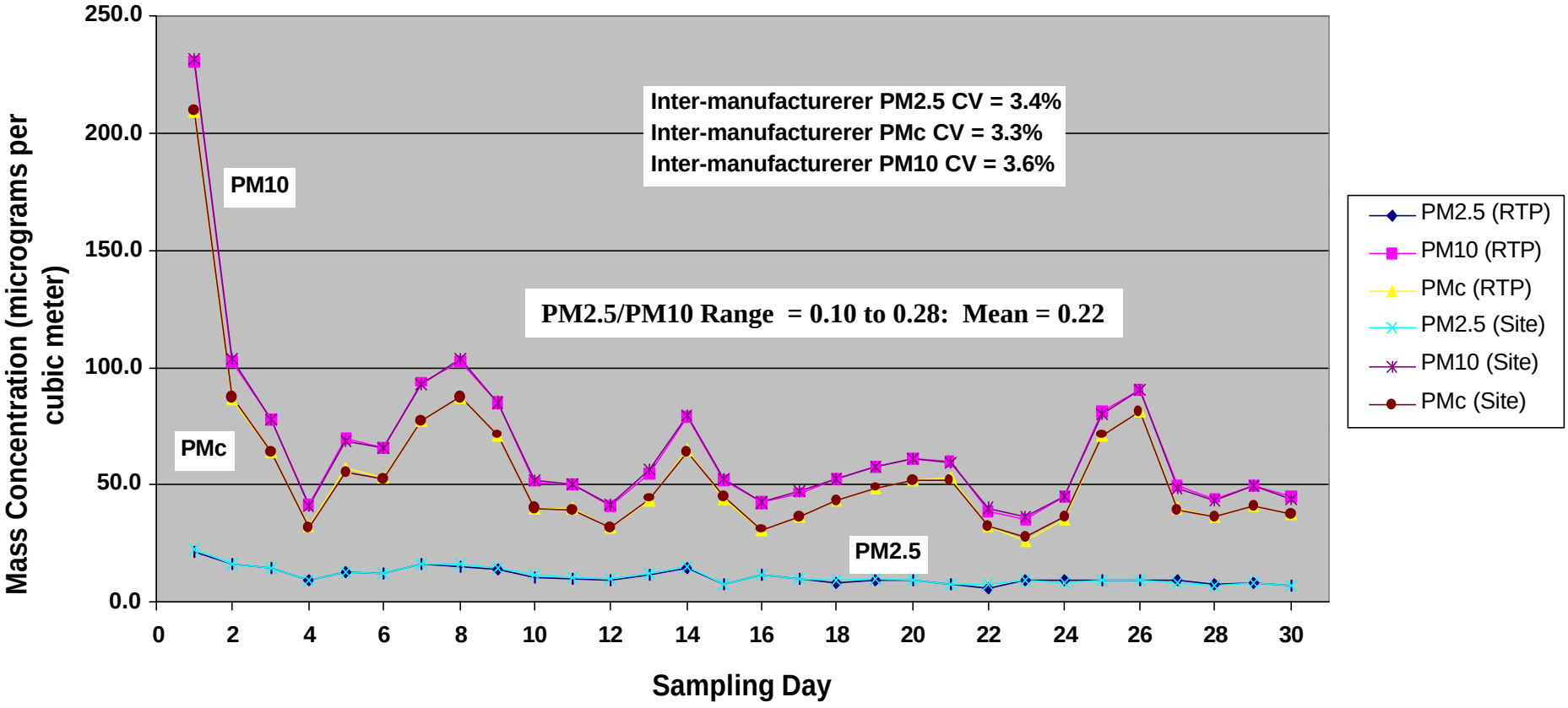
R&P COARSE TEOM AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)

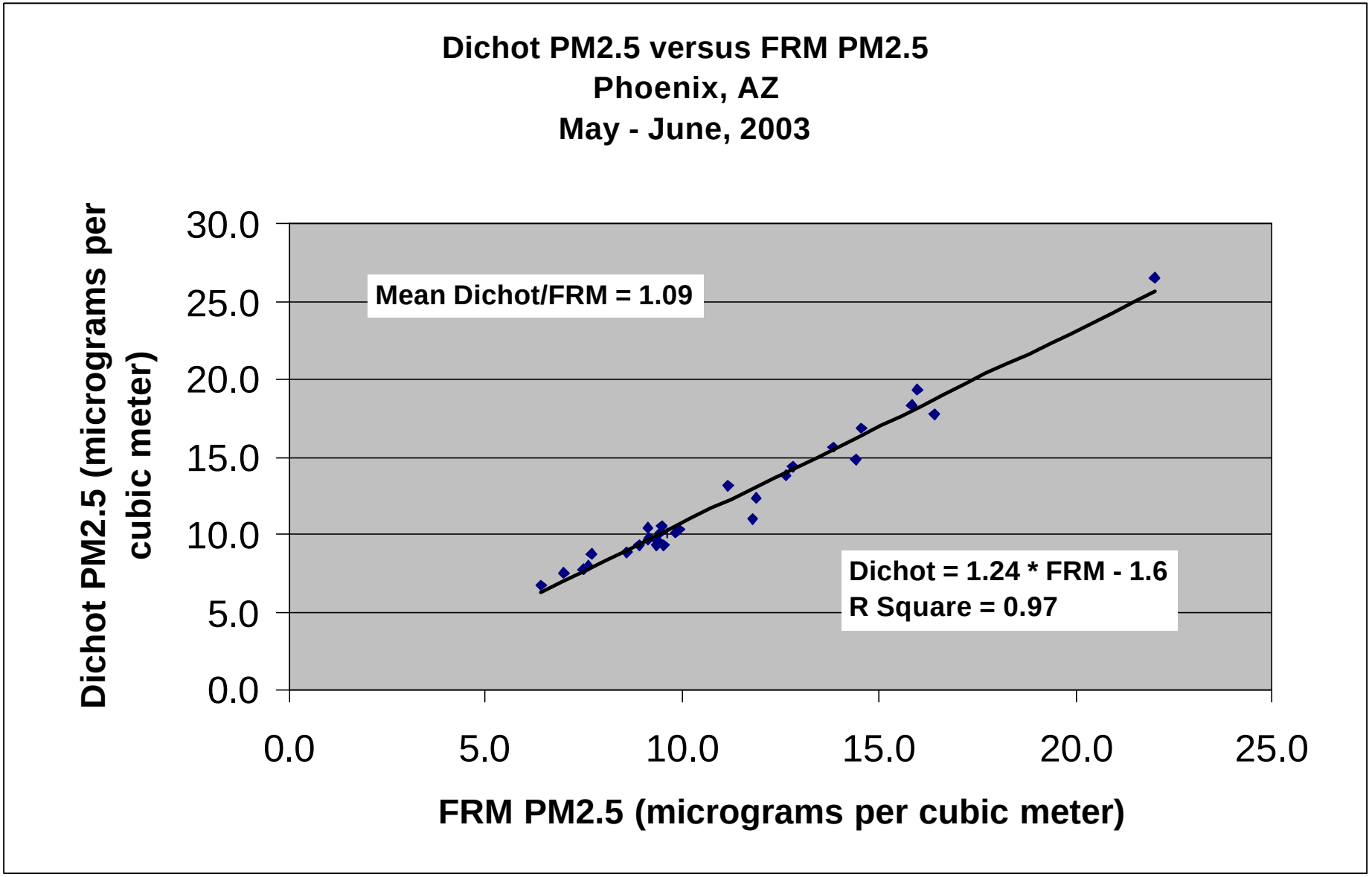



TSI APS vs FRM PMc Concentrations
Gary, IN (March - April)
APS/FRM = 0.42
APS = 0.48*FRM -1.4
R square = 0.795
APS CV = 16.8%
APS 1 PMc
APS 2 PMc
Mean FRM PMc
PMc Conc. (micrograms/m 3)
SAMPLE DAY
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32

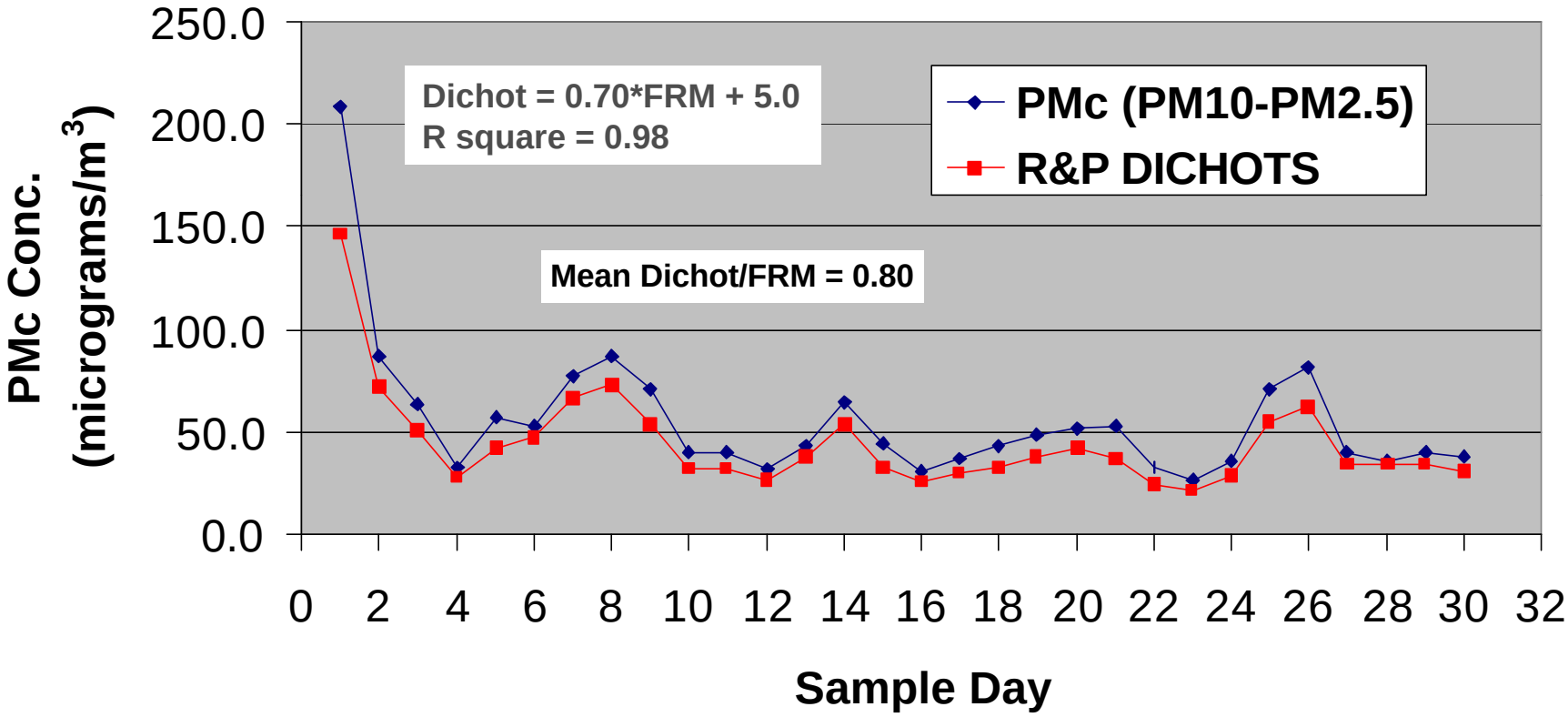

EPA704
05/10/2003

Phoenix versus RTP FRM Weighing
May - June 2003

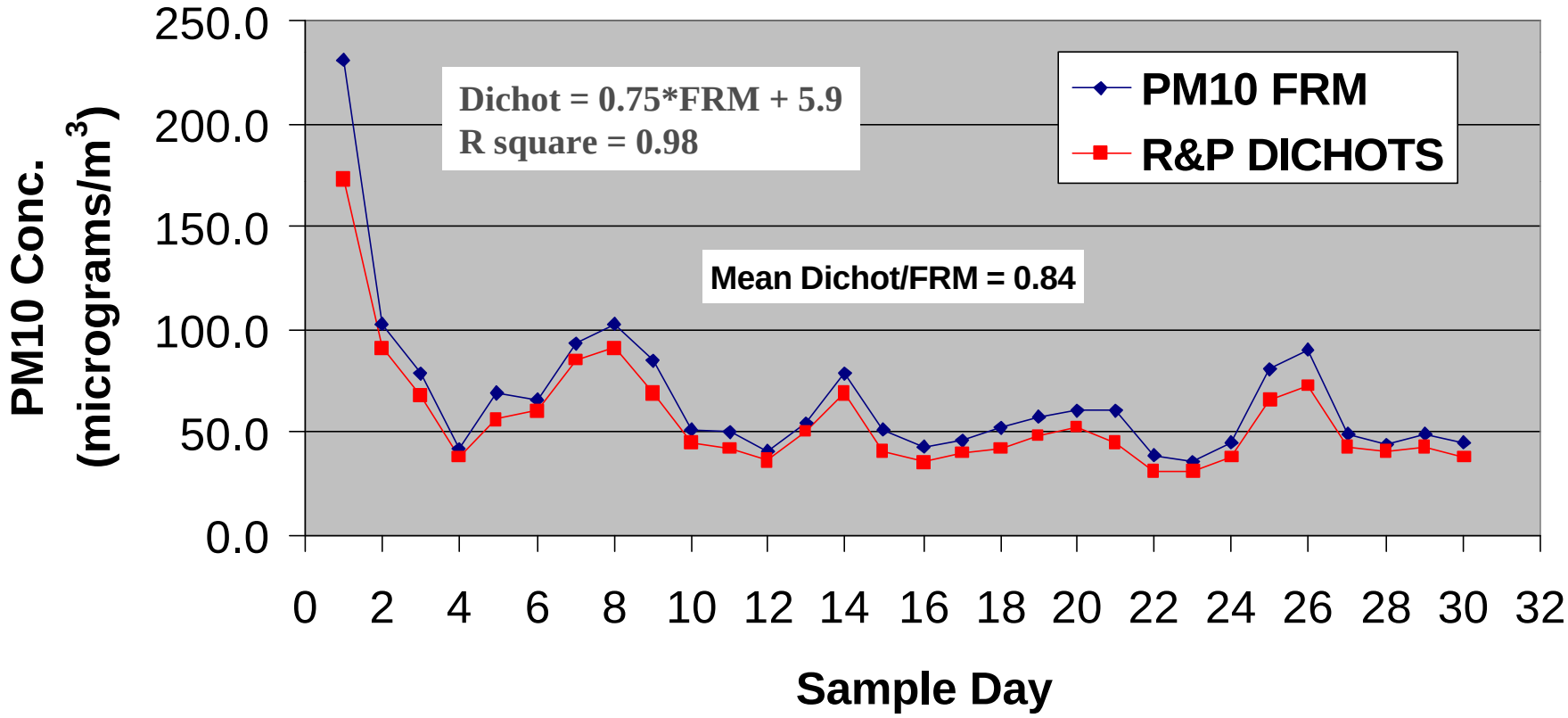


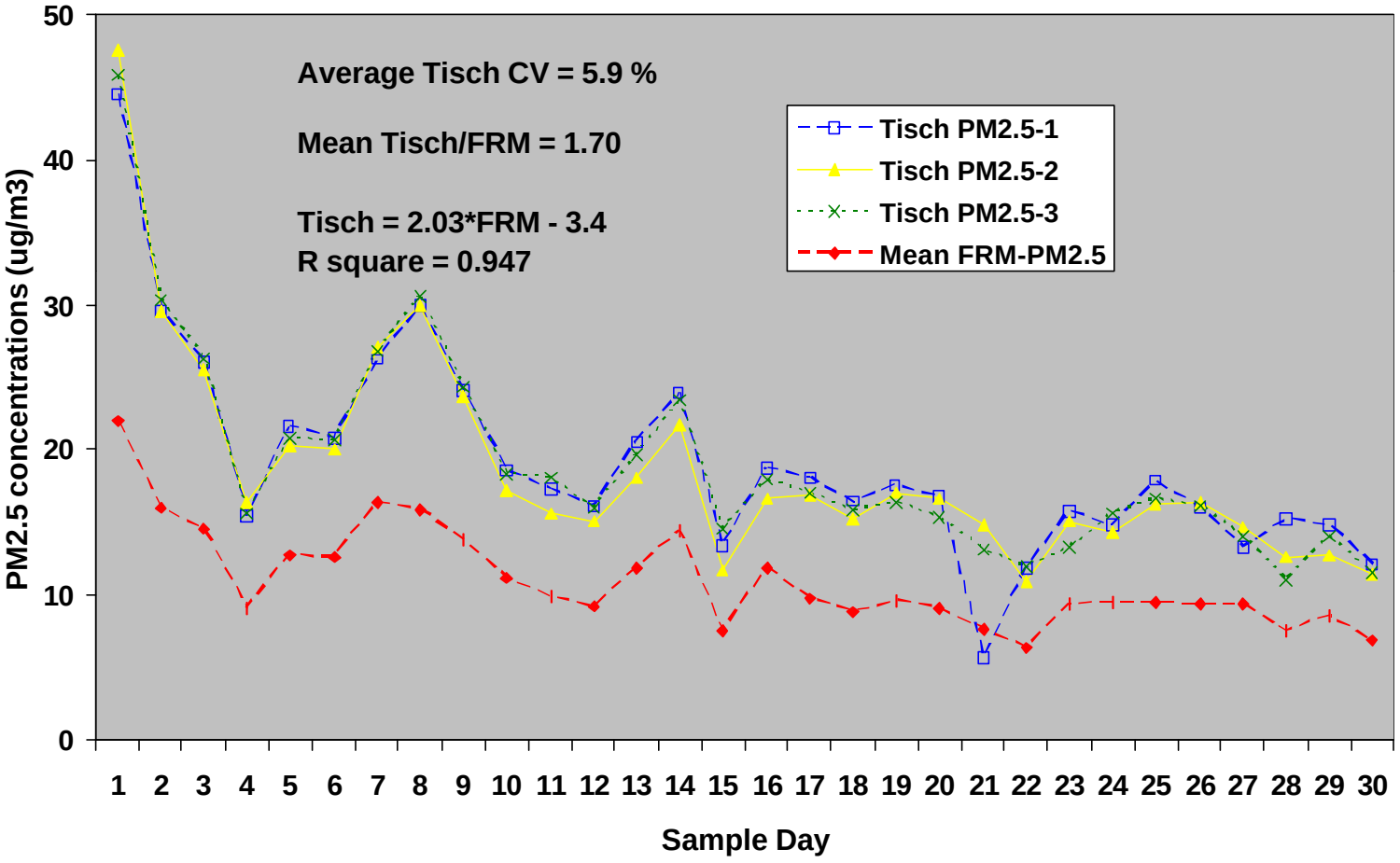

Dichot PM2.5 versus FRM PM2.5
Phoenix, AZ
May - June, 2003
Mean Dichot/FRM = 1.09
Dichot = 1.24 * FRM - 1.6
R Square = 0.97
Dichot PM2.5 (micrograms per cubic meter)
FRM PM2.5 (micrograms per cubic meter)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0

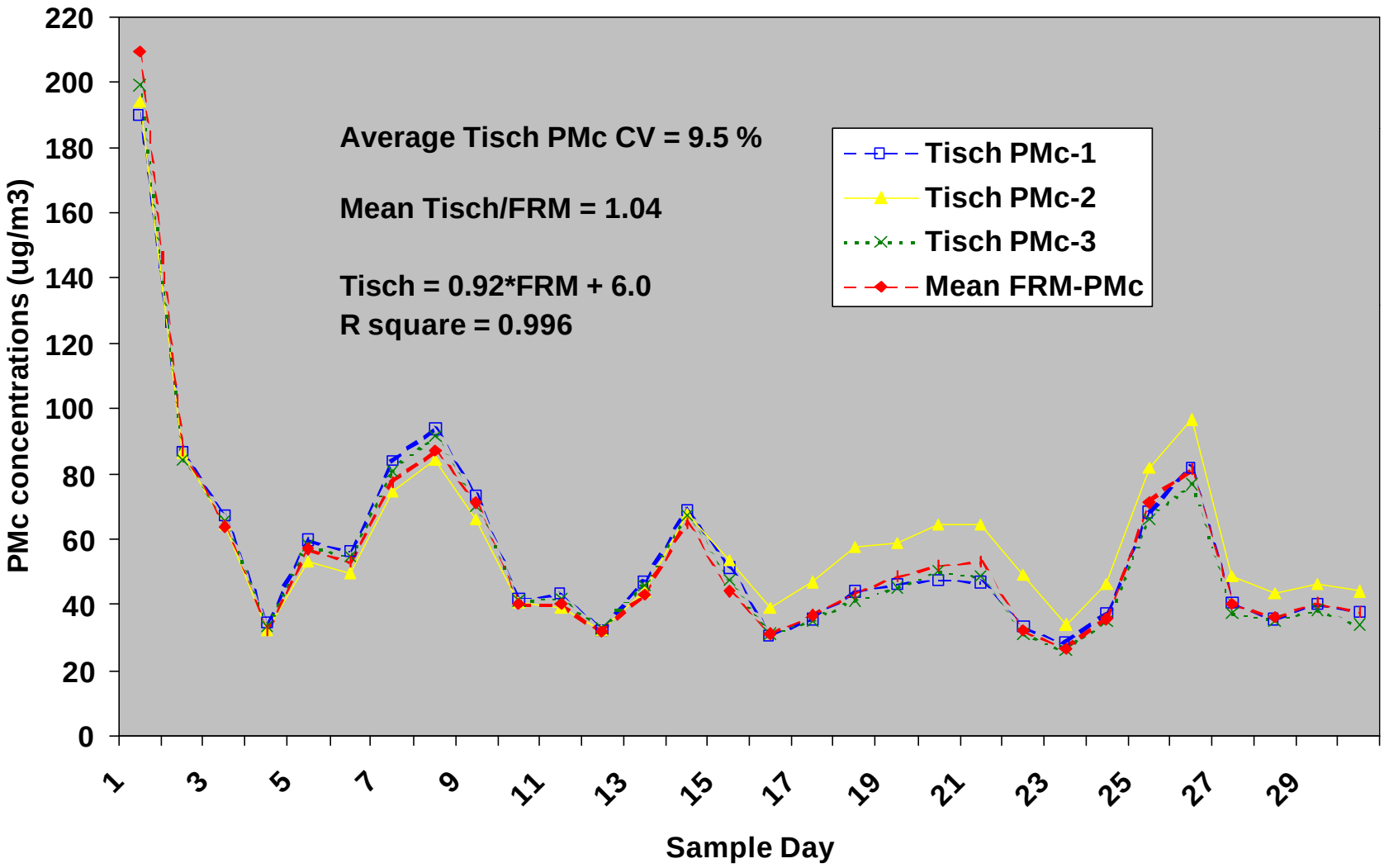
DICHOT AND FRM TIMELINE (PMc)
Phoenix, AZ (May - June, 2003)



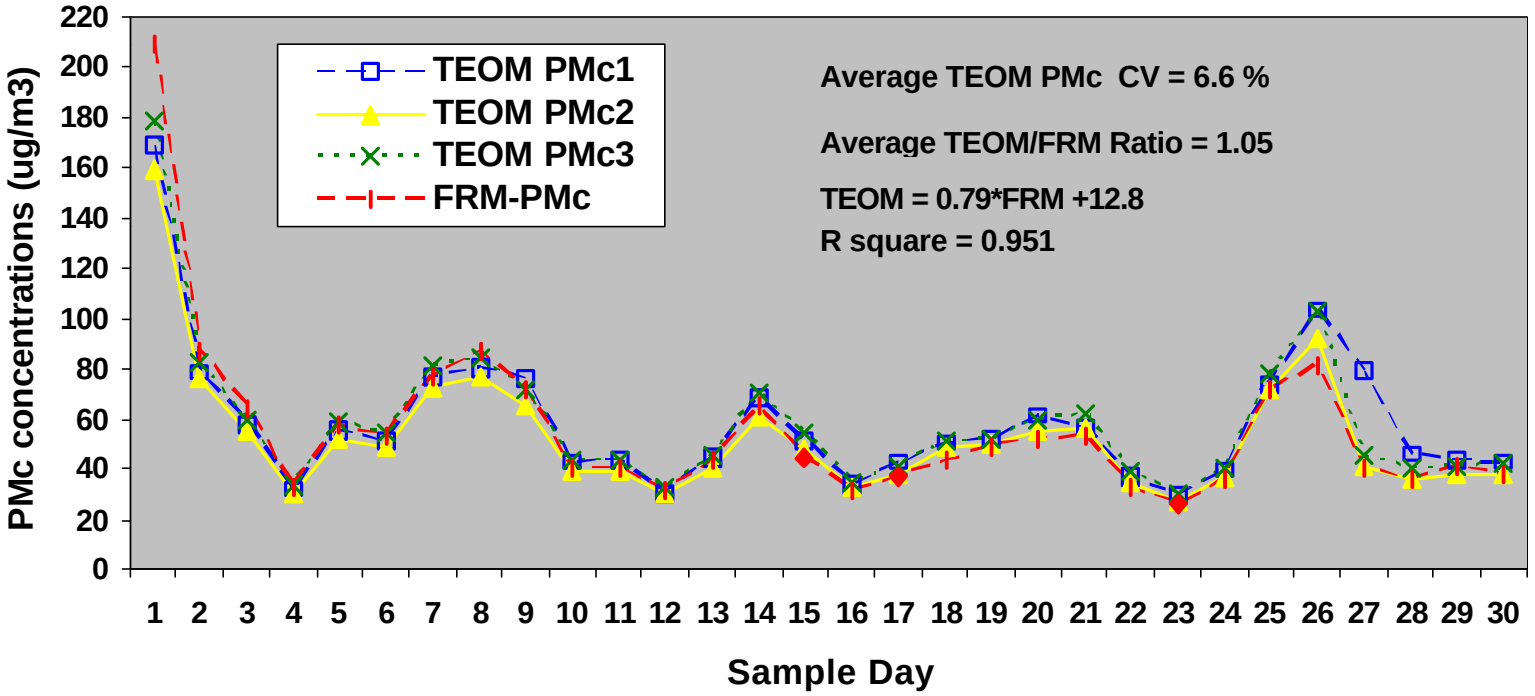
DICHOT AND FRM TIMELINE (PM10)
Phoenix, AZ (May - June, 2003)



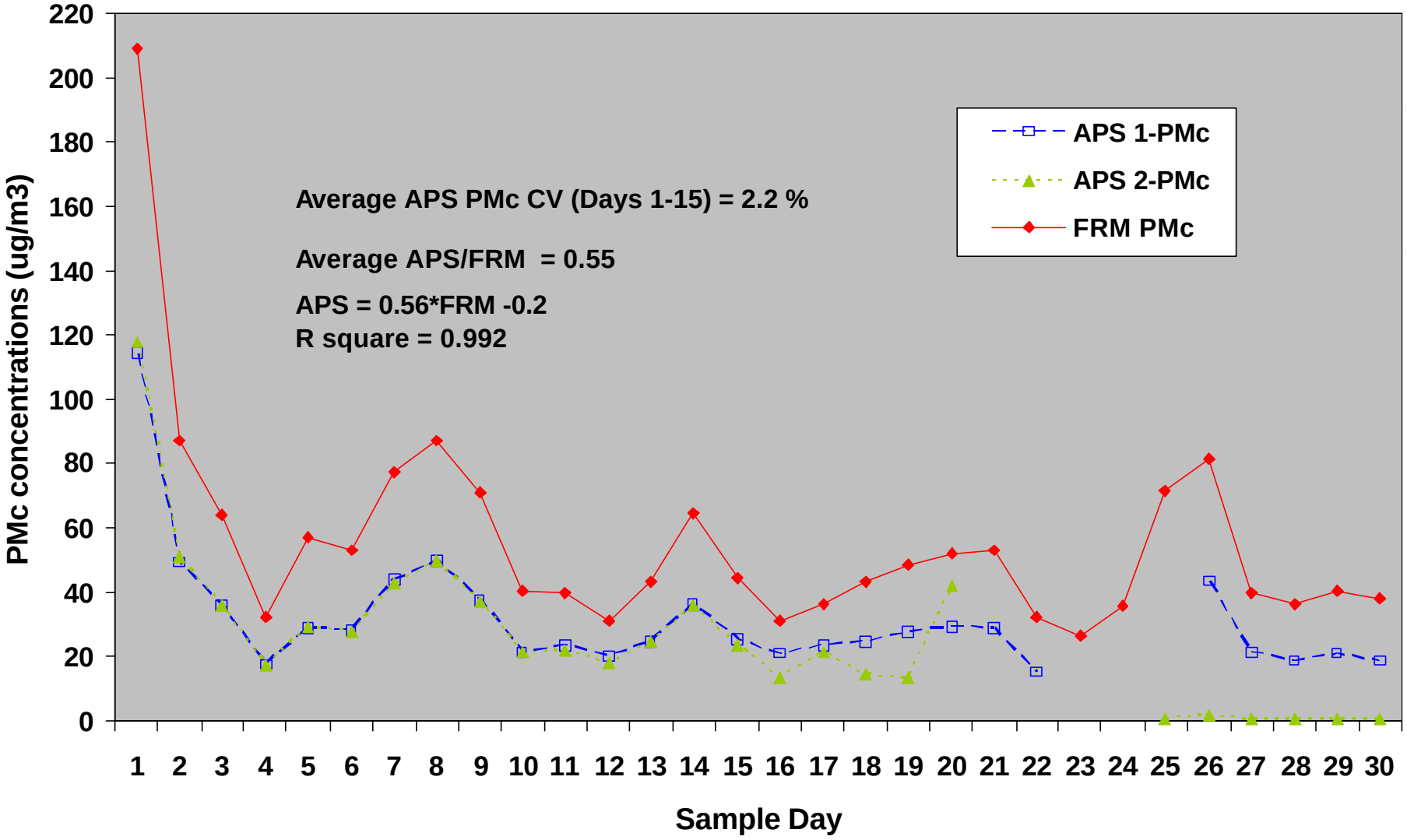

Tisch & FRM PM2.5 Concentrations
Phoenix AZ: May - Jun, 2003
Average Tisch CV = 5.9 %
Mean Tisch/FRM = 1.70
Tisch = 2.03*FRM - 3.4
R square = 0.947
Tisch PM2.5-1
Tisch PM2.5-2
Tisch PM2.5-3
Mean FRM-PM2.5
PM2.5 concentrations (ug/m3)
Sample Day
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16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

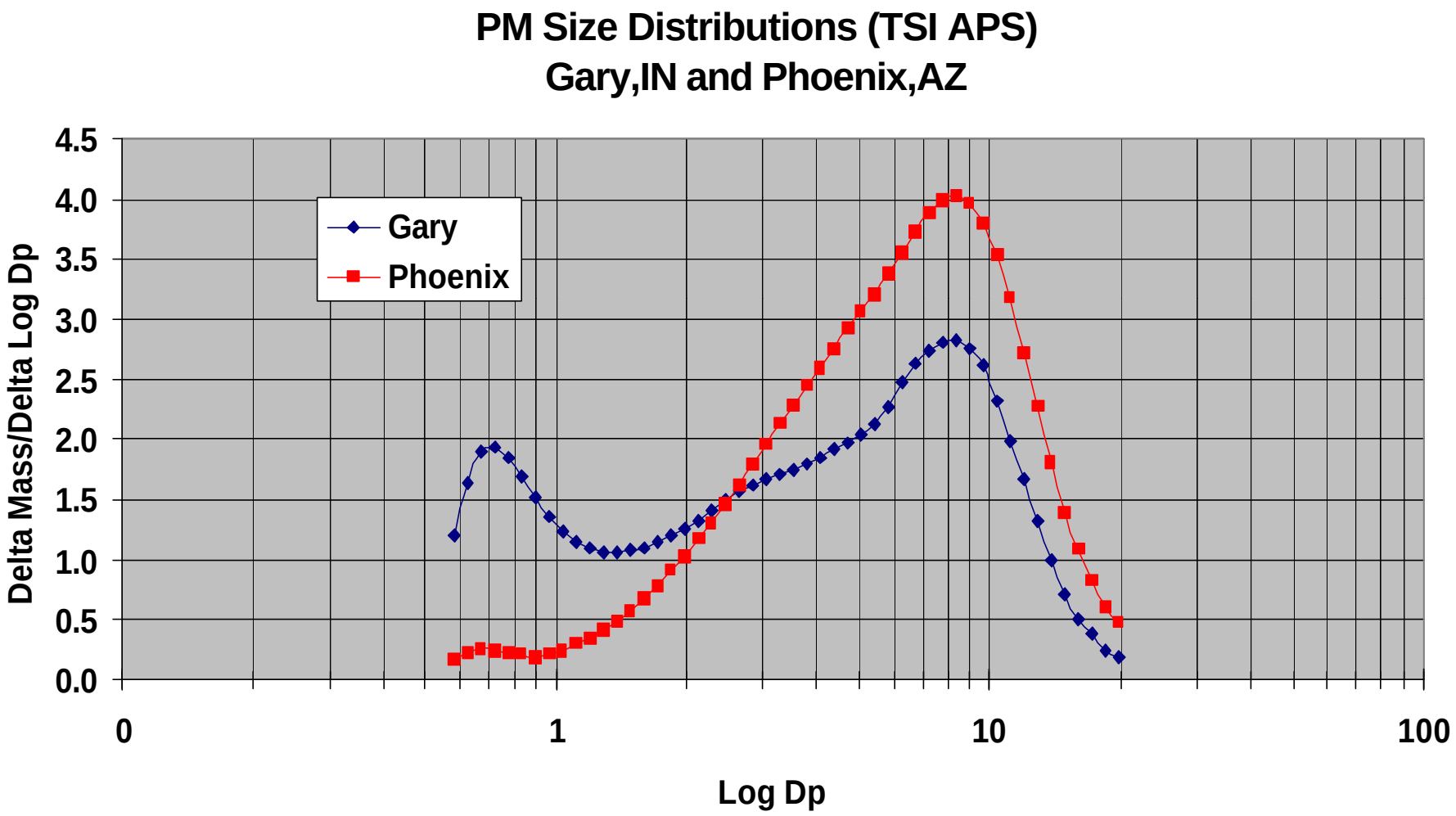

Tisch, & FRM PMc Concentrations
Phoenix AZ: May - Jun, 2003
Average Tisch PMc CV = 9.5 %
Mean Tisch/FRM = 1.04
Tisch = 0.92*FRM + 6.0
R square = 0.996
Tisch PMc-1
Tisch PMc-2
Tisch PMc-3
Mean FRM-PMc
PMc concentrations (ug/m3)
Sample Day
0
20
40
60
80
100
120
140
160
180
200
220
1
3
5
7
9
11
13
15
17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

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



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




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 (ìg/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

Acknowledgements

- Rupprecht & Patashnick, Inc.
- Tisch Environmental, Inc.
- TSI, Inc.
- Indiana Department of Environmental Management (Gary)
- Maricopa County Environmental Services Department (Phoenix)
- University of California Ag Ops (Riverside)

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.