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 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

- 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 22°C and 35% RH, analyzed gravimetrically. Post-sampling filters archived at -30°C 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)

PMc = PM10 – PM2.5
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 SIZE DISTRIBUTION DATA
March - April, 2003

PM2.5/PM10 Concentration Ratio

PM2.5/PM10 Range = 0.32 to 0.83;  Mean = 0.55
PMc FRM MEASUREMENTS - GARY vs RTP WEIGHING
Gary, IN (March - April, 2003)

RTP/Gary = 1.00
INTERMANUFACTURER PM2.5 FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)

Max PM2.5 = 46.9 \mu g/m^3
Min PM2.5 = 10.3 \mu g/m^3
Mean PM2.5 = 22.8 \mu g/m^3

INTERMANUFACTURER CV = 1.5%
INTERMANUFACTURER PM10 FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)

Max PM10 = 84.9 ìg/m³
Min PM10 = 22.6 ìg/m³
Mean PM10 = 42.6 ìg/m³

INTERMANUFACTURER CV = 2.4%
INTERMANUFACTURER PMc FRM MEASUREMENTS
(RTP WEIGHING)
Gary, IN (March - April, 2003)

Max PMc = 58.1 \mu g/m^3
Min PMc = 4.5 \mu g/m^3
Mean PMc = 19.9 \mu g/m^3

INTERMANUFACTURER CV = 5.7%
DICHOT AND FRM TIMELINE (PM$_{2.5}$)
GARY, IN (MARCH - APRIL, 2003)

PM$_{2.5}$ Conc. (micrograms/m$^3$)

Sample Day

DICHOT/FRM = 0.99

PM$_{2.5}$ FRM
R&P DICHOTS
Dichot versus FRM PM2.5 Concentrations
Gary, IN (March - April, 2003)

Dichot = 0.99*FRM + 0.0
R Square = 0.998
DICHOT AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)

FRM PMc (PM10-PM2.5)
R&P DICHOTS

Dichot/FRM = 0.89

Dichot = 0.87*FRM + 0.4
R square = 0.969
DICHOT AND FRM TIMELINE (PM10)
Gary, IN (March - April, 2003)

PM10 Conc. (micrograms/m³)

Sample Day

Dichot = 0.95*FRM - 0.5
R square = 0.981
Dichot/FRM = 0.94

PM10 FRM
R&P DICHOTS
TISCH SPM-613D AND FRM TIMELINE (PM$_{2.5}$)
Gary, IN (March - April, 2003)

Tisch $= 1.17 \times $FRM $+ 1.6$
R square $= 0.948$

TISCH/FRM $= 1.26$

TISCH CV $= 7.1\%$

PM$_{2.5}$ Conc. (micrograms/m$^3$)

Sample Day
TISCH SPM-613D AND FRM TIMELINE (PM$_{c}$)
Gary, IN (March - April, 2003)

TISCH/FRM = 0.91

TISCH = 0.89*FRM + 0.3
R square = 0.979

TISCH CV = 10.5%
R&P COARSE TEOM AND FRM TIMELINE (PMc)
Gary, IN (March - April, 2003)

TEOM PMc/FRM = 0.69

TEOM = 0.68* FRM + 0.18
R square = 0.982

TEOM PMc CV = 4.4%
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%
Phoenix versus RTP FRM Weighing
May - June 2003

Inter-manufacturer PM2.5 CV = 3.4%
Inter-manufacturer PMc CV = 3.3%
Inter-manufacturer PM10 CV = 3.6%

PM2.5/PM10 Range = 0.10 to 0.28: Mean = 0.22

PM2.5 (RTP) - Blue
PM10 (RTP) - Magenta
PMc (RTP) - Yellow
PM2.5 (Site) - Light Blue
PM10 (Site) - Purple
PMc (Site) - Pink

Sampling Day
Mass Concentration (micrograms per cubic meter)
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 AND FRM TIMELINE (PMc)**
Phoenix, AZ (May - June, 2003)

- **Sample Day**
- **PMc Conc. (micrograms/m$^3$)**
- **PMc (PM10-PM2.5)**
- **R&P DICHOTS**

\[
\text{Dichot} = 0.70 \times \text{FRM} + 5.0
\]

**R square = 0.98**

**Mean Dichot/FRM = 0.80**
DICHOT AND FRM TIMELINE (PM10)
Phoenix, AZ (May - June, 2003)

Dichot = 0.75*FRM + 5.9
R square = 0.98

Mean Dichot/FRM = 0.84
Tisch & FRM PM2.5 Concentrations
Phoenix AZ: May - Jun, 2003

PM2.5 concentrations (ug/m^3)

Average Tisch CV = 5.9 %
Mean Tisch/FRM = 1.70
Tisch = 2.03*FRM - 3.4
R square = 0.947
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
TEOM, & FRM PMc Concentrations
Phoenix AZ: May - Jun, 2003

Average TEOM PMc CV = 6.6 %
Average TEOM/FRM Ratio = 1.05
TEOM = 0.79*FRM +12.8
R square = 0.951
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

Delta Mass/Delta Log Dp

Log Dp

Gary
Phoenix
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 (R²) of all continuous samplers is typically strong versus the collocated FRMs
## SUMMARY OF SITE RESULTS

<table>
<thead>
<tr>
<th>SITE AEROSOL</th>
<th>PMc Mean (µg/m³)</th>
<th>GARY, IN</th>
<th>PHOENIX, AZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5/PM10 Range</td>
<td>0.32 - 0.83</td>
<td>0.10 - 0.28</td>
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<tr>
<td>PM2.5/PM10 Ratio</td>
<td>0.55</td>
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<tr>
<td>Dichot/FRM PM2.5</td>
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<tr>
<td>Dichot/FRM PM10</td>
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<td>APS/FRM PMc</td>
<td>0.42</td>
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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)
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.