Fugitive Emissions from a Dry Coal Fly Ash Storage Pile

Stephanie L. Shaw (EPRI), Stephen F. Mueller, Qi Mao, Ray Valente, and John Mallard (Tennessee Valley Authority)

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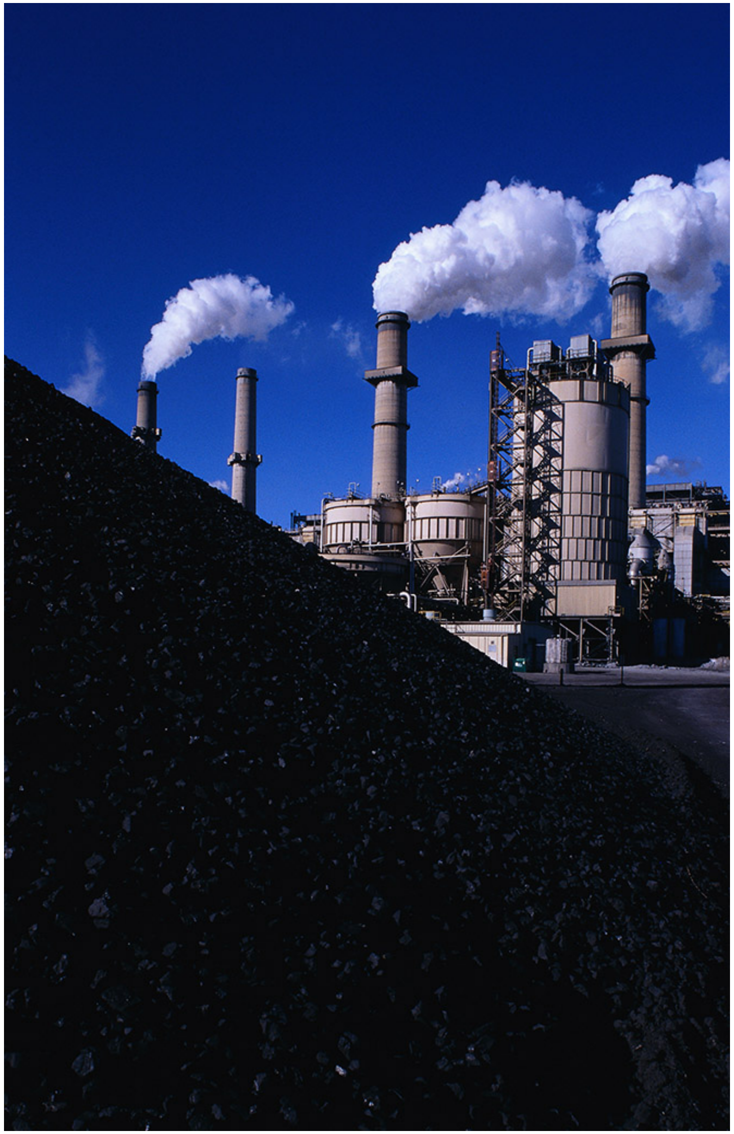
Why Are Fugitive Particulate Emissions Important?



- Upcoming coal ash storage regulation may rely on dry ash handling
- Potential impact to local communities
- EPA proposing to lower annual $PM_{2.5}$ standard to 12 µg m^{-3}.
- Detailed prevention of significant deterioration (PSD) analyses are required for a new/modified source when emissions for $PM_{2.5}$ >10 tons per year (tpy), for PM_{10} >15 tpy and for TSP >25 tpy.

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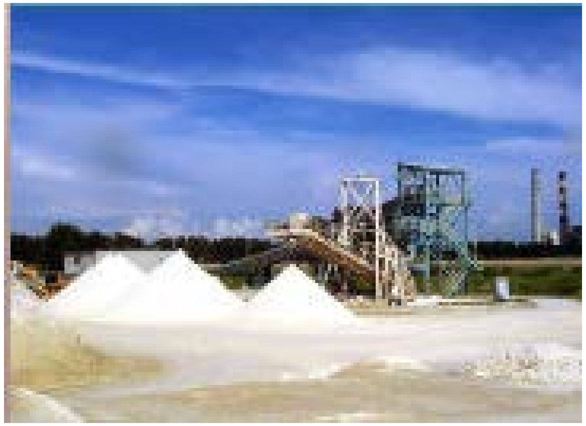
Technical Motivation to Re-evaluate Fugitive Emissions

- Inaccurate fugitive emissions can lead to ineffective emissions control

- Fugitive EFs for fly ash highly uncertain
  - Ash handling, wind erosion or pile maintenance, transfer…
  - May not account for most important materials characteristics, site-specific data, or current materials handling practices

Overall Study Plan

- Phase 1: Dry fly ash– TVA Colbert Plant (AL) 1200MW
- Phase 2: Coal dust – TVA Gallatin Plant (TN) 1000MW
- Phase 3: TBD - Limestone/gypsum? Road dust? Fly ash in Western U.S.?



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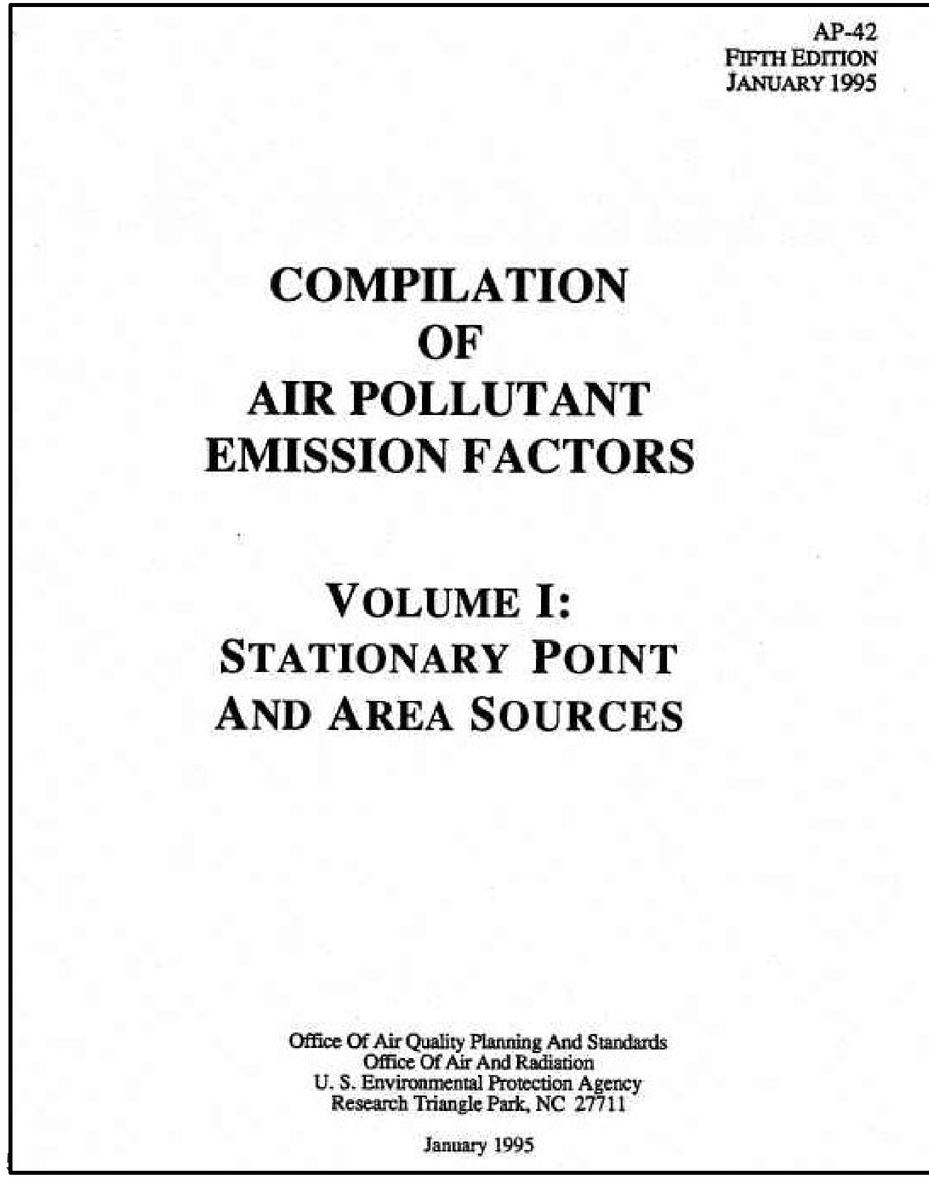
Project Goals

- Quantify fugitive particulate emissions at coal-fired power plants for different handling practices.
- Compare new emission rates with those from EPA AP-42 handbook.
- Utilities use to inform facility permitting.
- May help evaluate emission mitigation strategies


AP-42
FIFTH EDITION
JANUARY 1995

COMPILATION
OF
AIR POLLUTANT
EMISSION FACTORS

VOLUME I:
STATIONARY POINT
AND AREA SOURCES

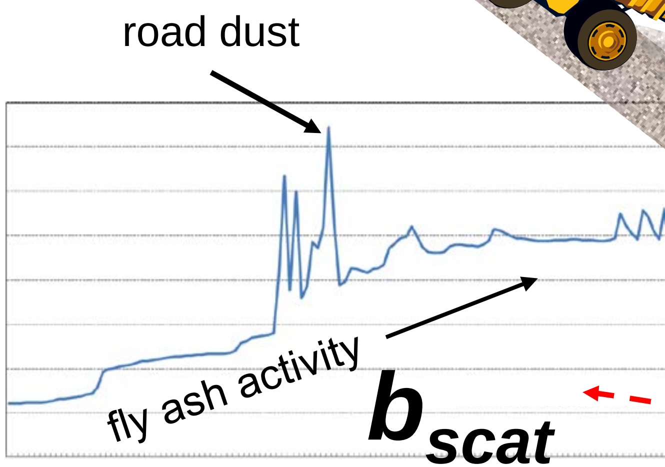
Office Of Air Quality Planning And Standards
Office Of Air And Radiation
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

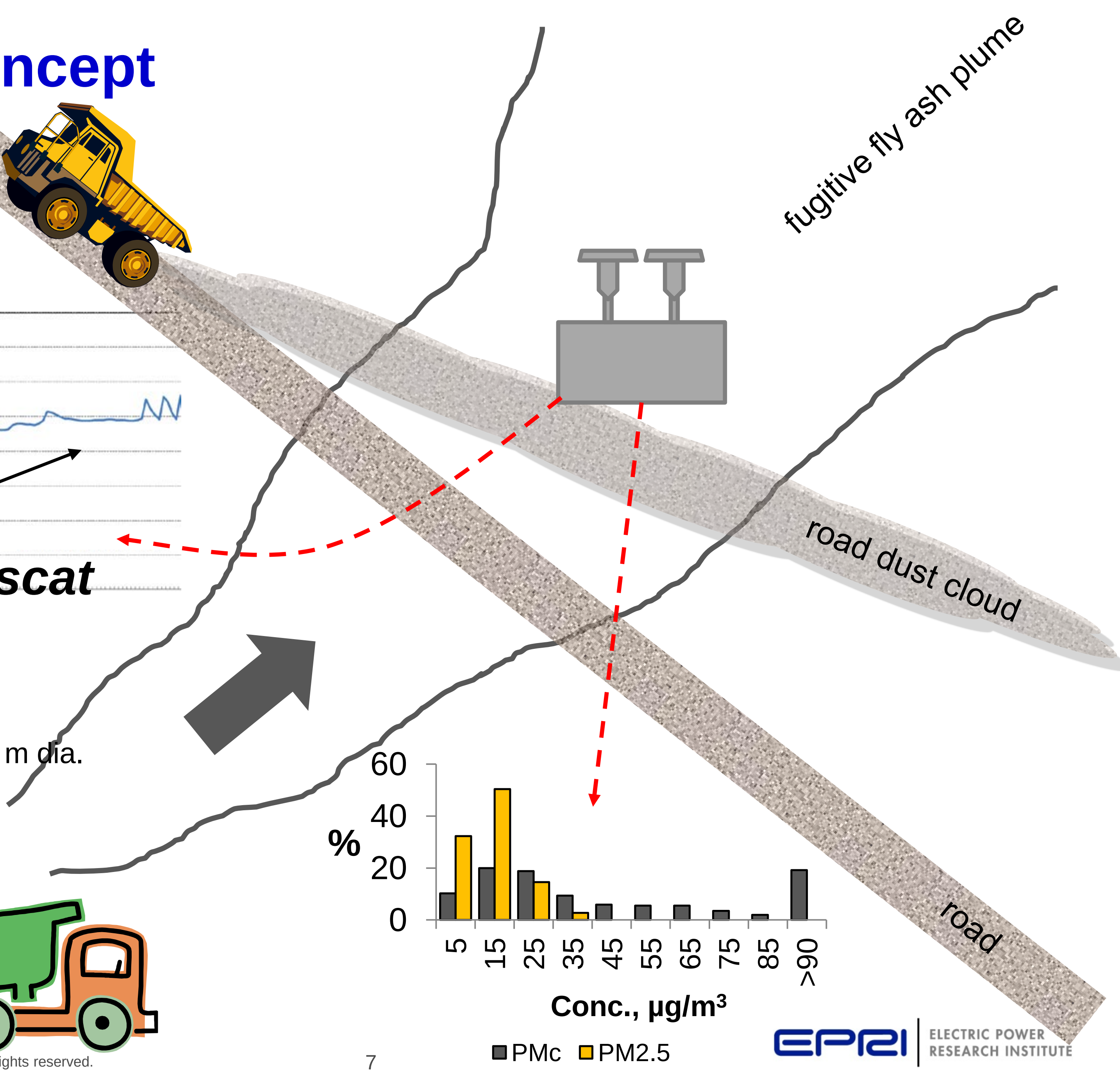
January 1995

Origins of AP-42 Fugitive Emission Factors

- Studies in 1970s measured airborne dust near unpaved roads and material handling. Multi-component statistical analyses to develop formulations. Dropping factors -1980s
- Used old measurement technologies.
- Most sources were staged & not done under actual operating conditions.
- Involved limited types of materials & limited range in conditions (vehicle speed, material moisture content, silt content).

Study Concept





<u>Ash handling</u>

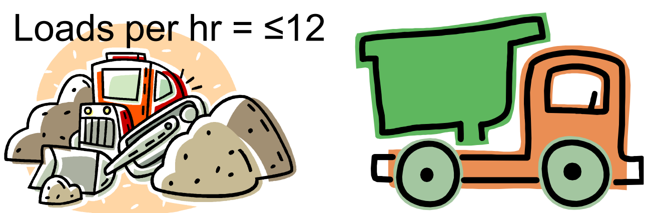
Dumping ≈25 m³ per load

Leveling to 0.5 m high x 4 m dia.

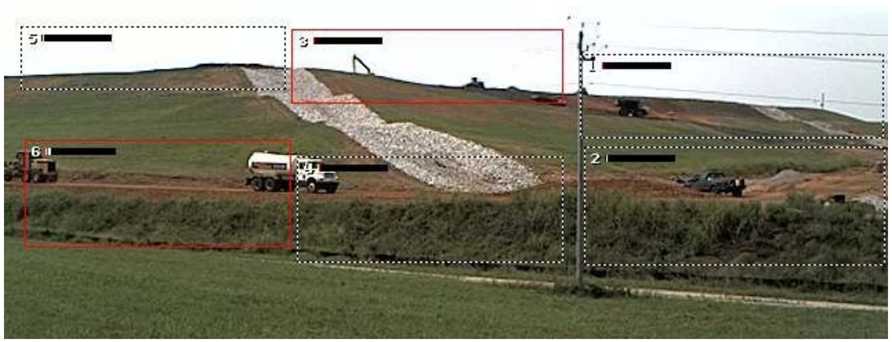
Grading time ≈8 min

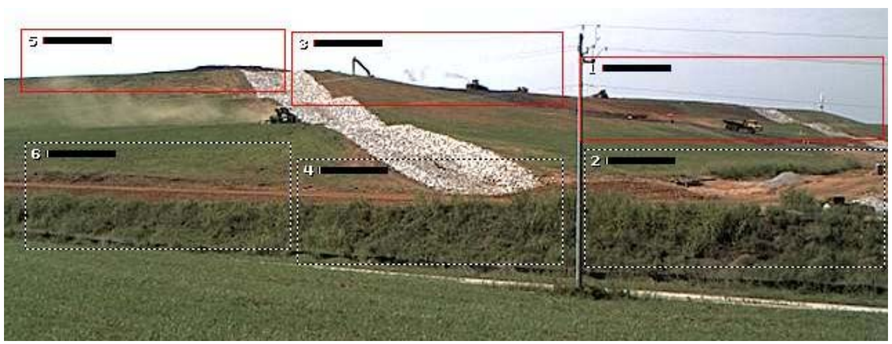
Grader speed ≈5 mph

Loads per hr = ≤12



Colbert Field Study Layout

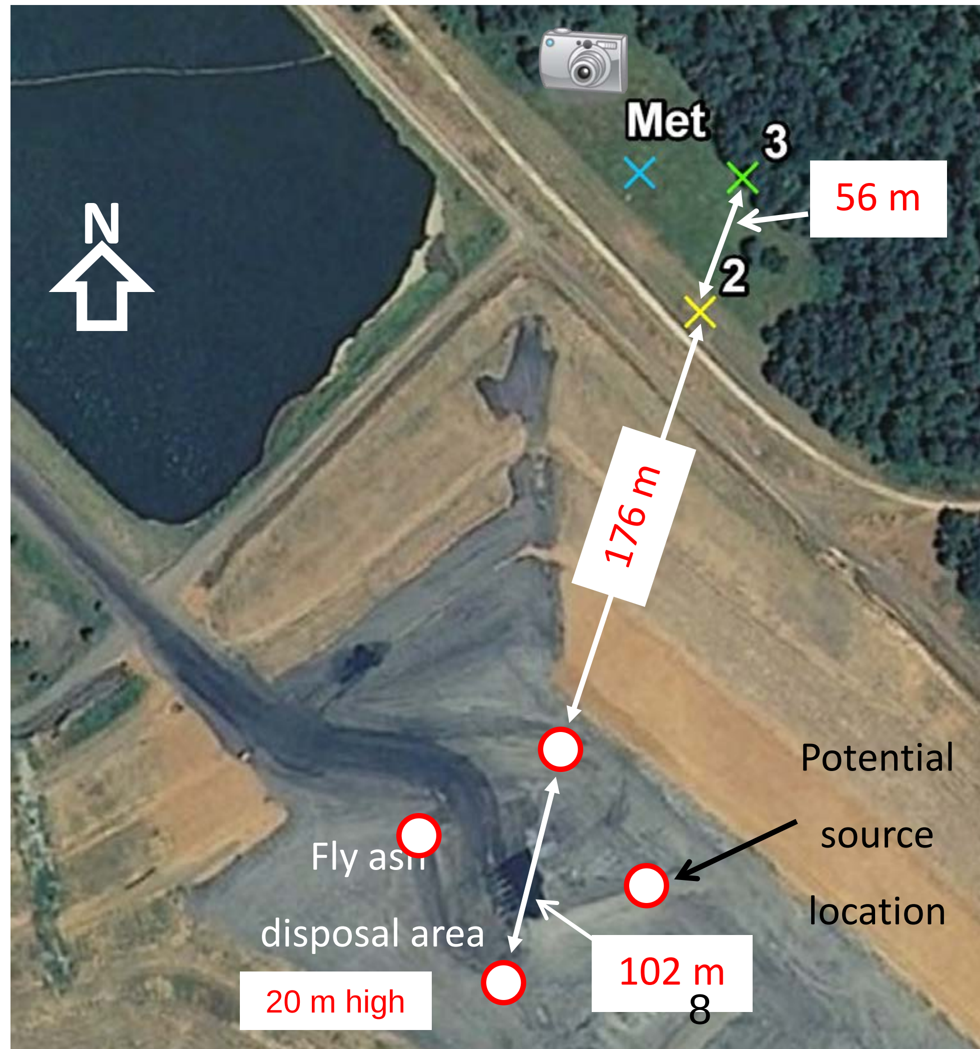




Photos:

(Top) Camera triggered by trucks moving along berm road south of air monitoring sites.

(Bottom) Camera triggered by activity on fly ash dry stack.



Monitoring Instrumentation

Meteorological

Instrument	Measurement/Purpose
R. M. Young 81000RE sonic anemometers (2 & 10 m)	Wind speed, direction, vertical velocity, horizontal & vertical turbulence; vertical gradient of speed, direction & turbulence
Vaisala HMI41 aspirated temperature & humidity sensors (2 & 10 m)	Air temperature & relative humidity; vertical temperature & moisture gradients
Campbell Scientific CNR2 net radiometer (~1.8 m)	Radiation flux (shortwave, longwave & net)
Novalynx Corp. 260-2501-A tipping bucket raingage	Precipitation amount
Campbell Scientific CS616 water content reflectometer (top 30 cm of soil)	Soil moisture content

Air Quality

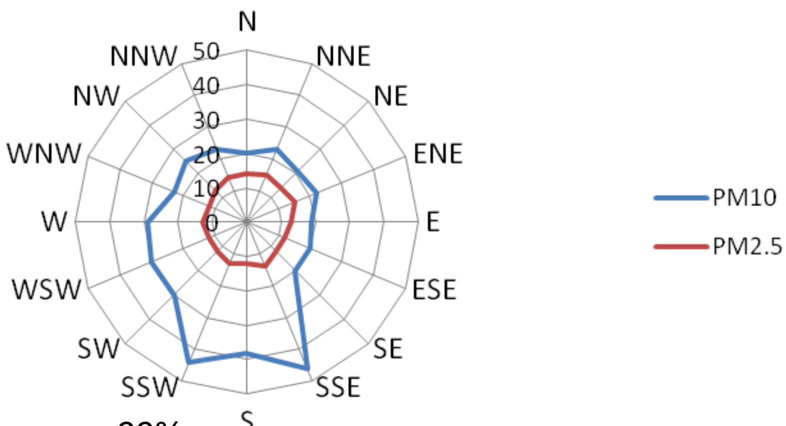
Instrument	Measurement/Purpose
Met One beta attenuation monitors (BAMs) at downwind & background sites	$PM_{2.5}$/PM_{10} concentrations (semi-continuous) @ downwind & background sites
BGI PQ-200 PM_{10} particle filter sampler	Filtered PM_{10} sample, ~12-hr samples (for chemical analysis) @ downwind & background sites
TSI 3563 3-λ nephelometer	Continuous β_{scat} @ 3 wavelengths @ downwind site
Optek nephelometer	Semi-continuous single-wavelength β_{scat} @ downwind site
Campbell Scientific video camera	Semi-continuous images of fly ash disposal site

Dry Fly Ash Handling at Colbert

- Fly ash is pneumatically conveyed to hoppers where it is conditioned with 15% moisture before transference to haul trucks.
- Each truck moves 25-28 m^3 of ash per load.
- Ash is dropped at disposal area and leveled to a depth of about half a meter (18-24 in).
- Ash grading takes about 8 min with grader moving at 2.2 $m\ s^{-1}$ (5 mph).
- Fugitive emissions are primarily due to dropping and grading operations (haul trucks moving over bottom ash road produces very little fugitive dust).

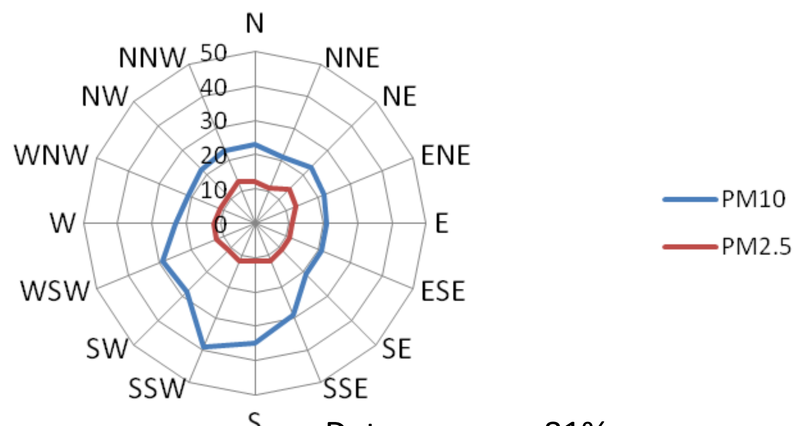
Average Particulate Concentrations by Direction
May-August 2011

Nearest Downwind Site (2)



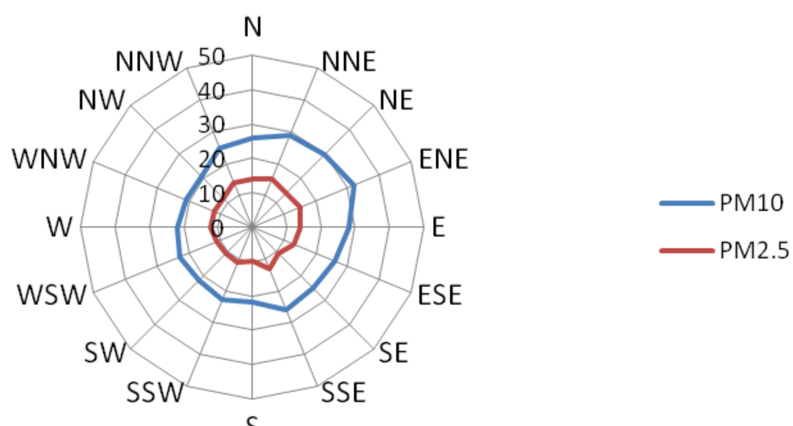
Data recovery >99%

Farthest Downwind Site (3)



Data recovery 81%

Background



Data recovery >99%

One-hr average concentrations were measured by FRM BAMs and reported here in µg m^{-3}. Wind direction was measured at a height of 10 m.

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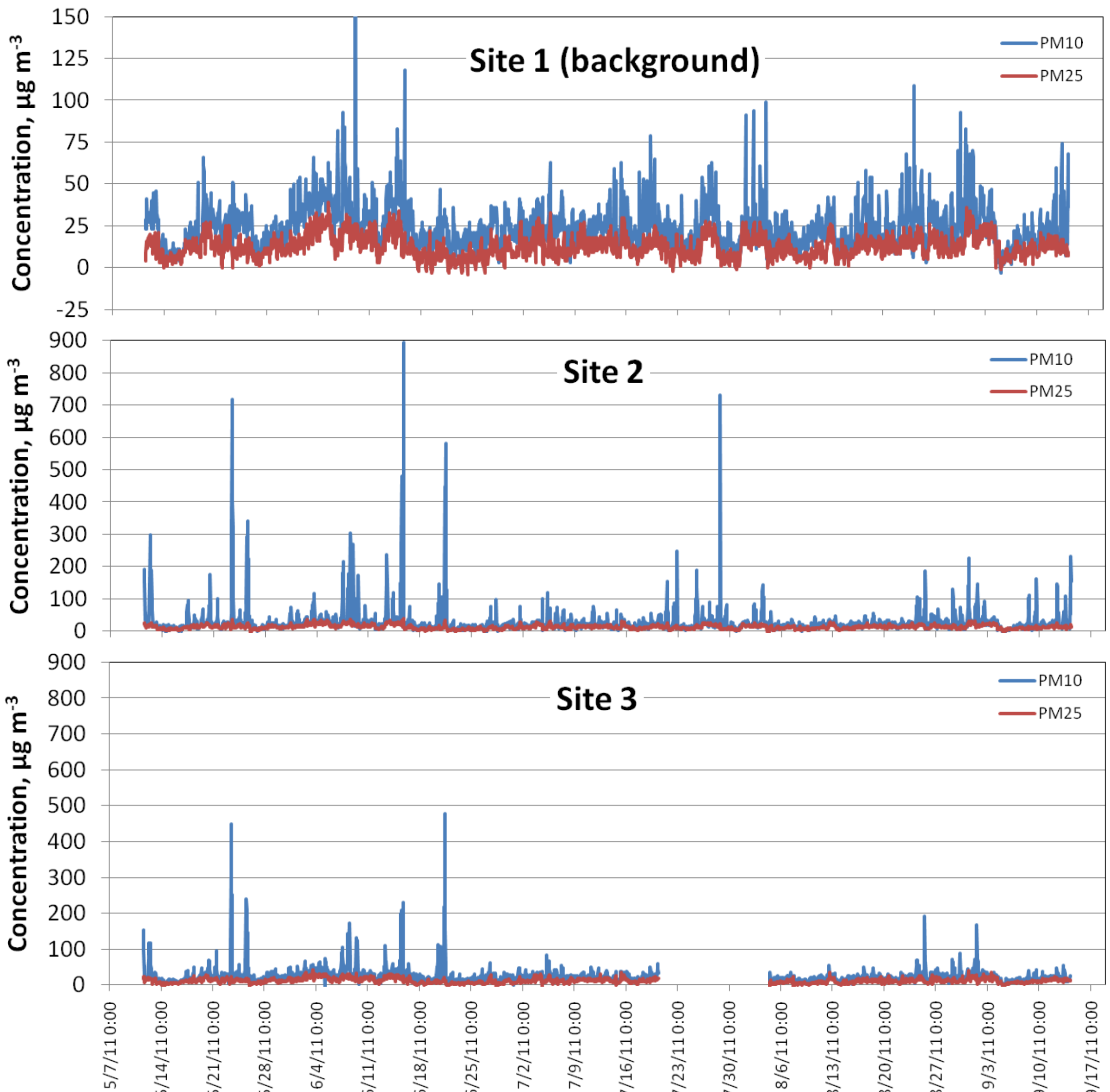
Hourly Concentrations at each Site: May-September 2011



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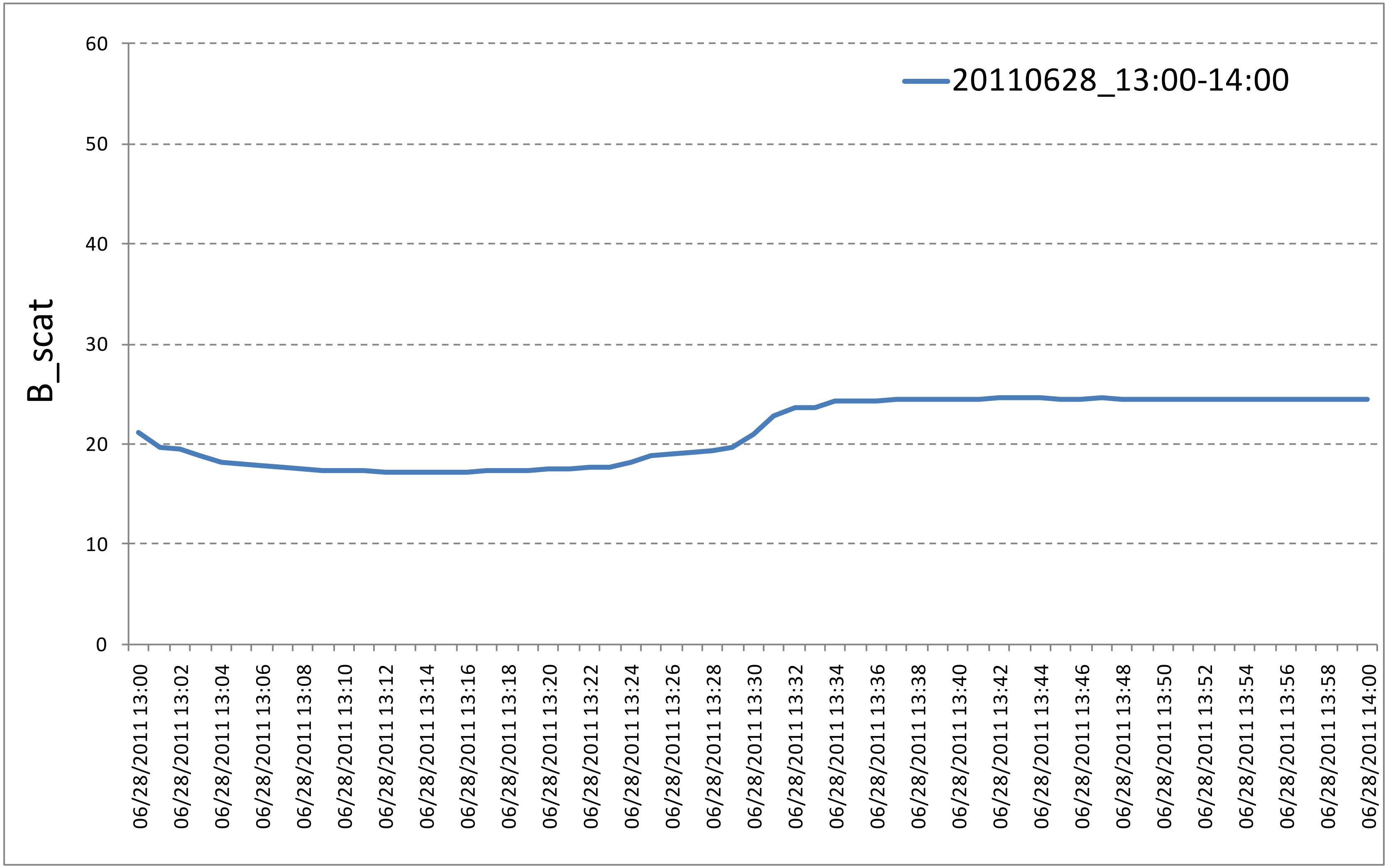
Clean Period (No Emissions)
28 June, 1300-1400 LST



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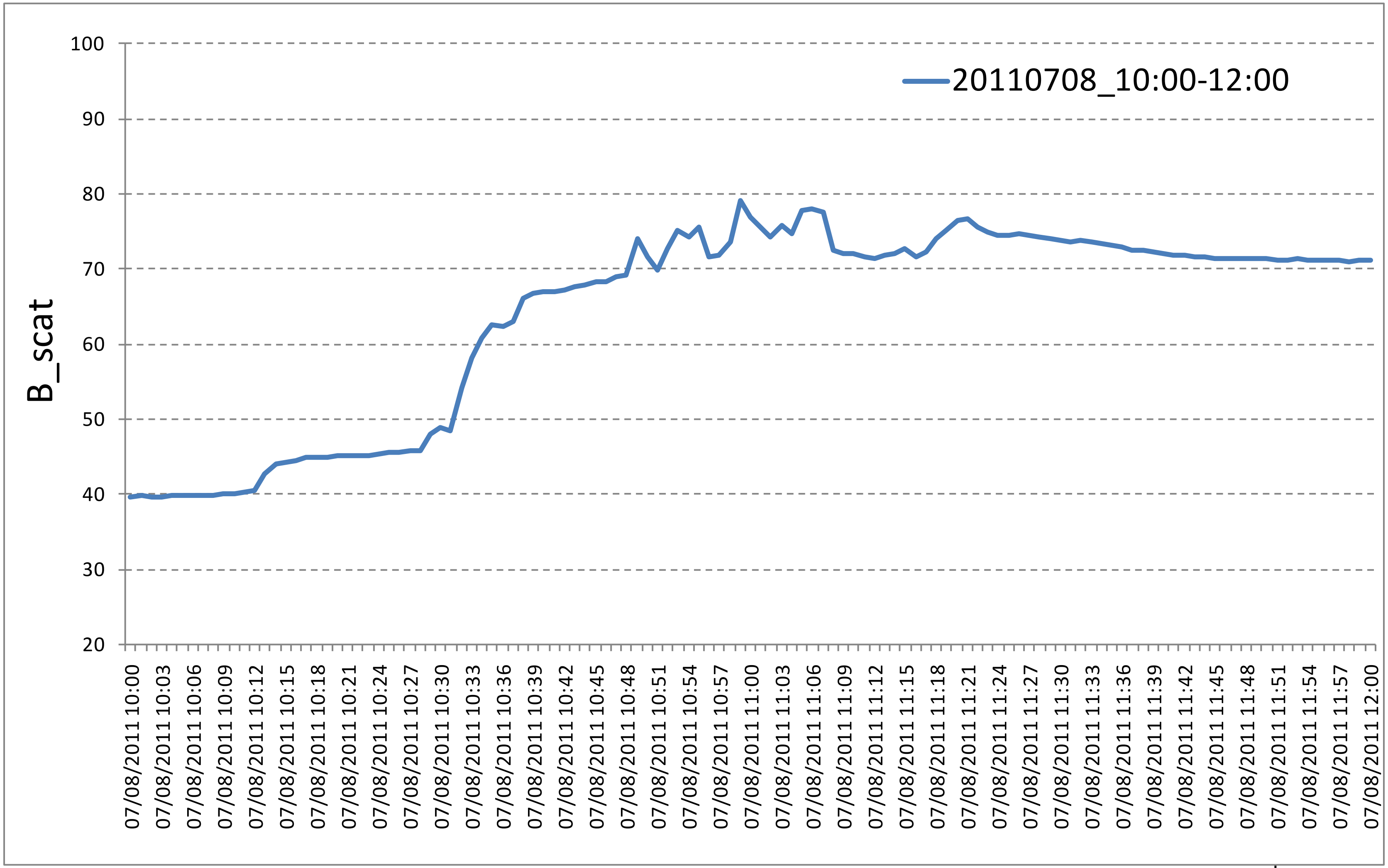
No-Vehicle Period (Fly Ash Activity only)
8 July, 1000-1200 LST



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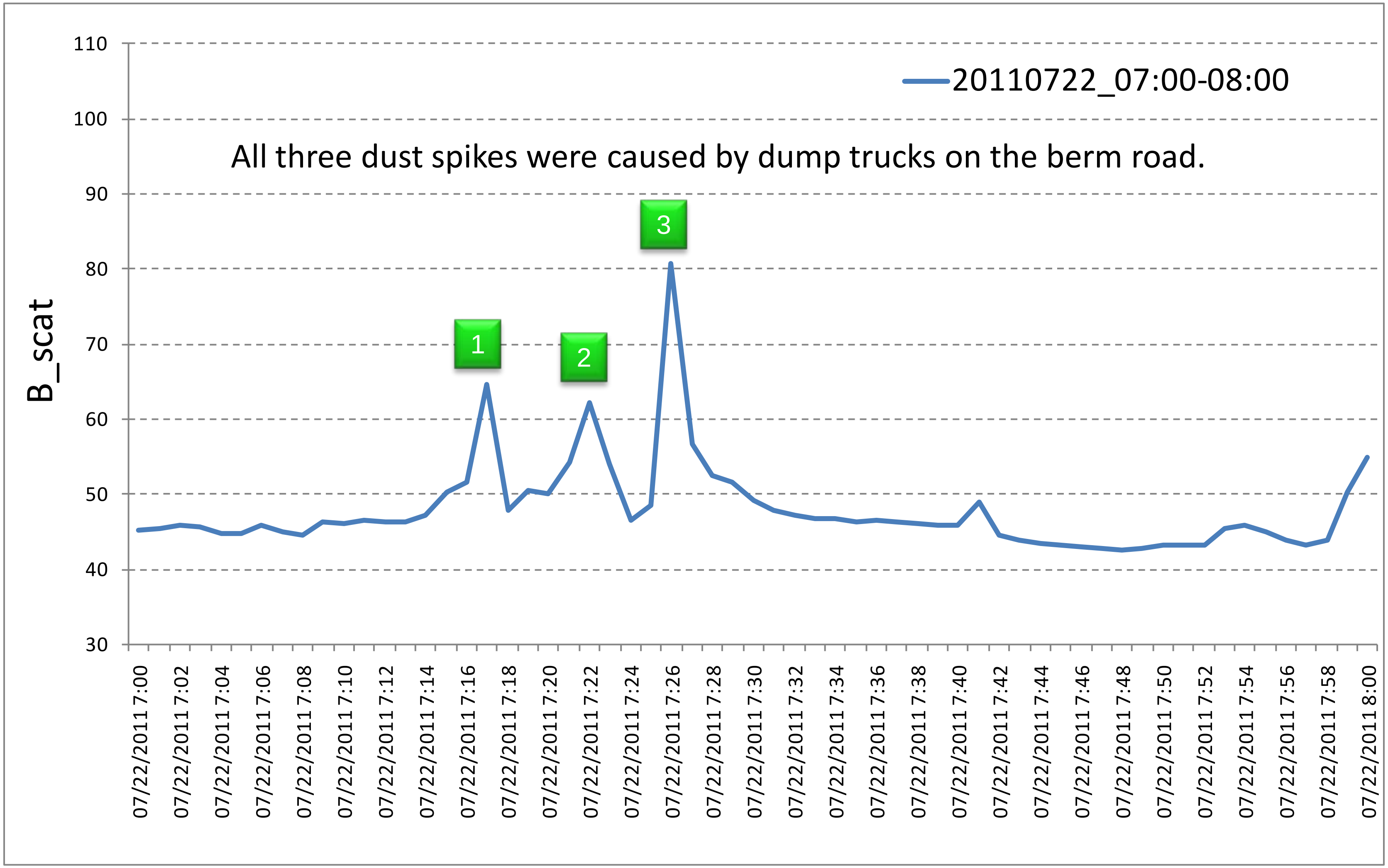
3-Vehicle Event
22 July, 0700-0800 LST



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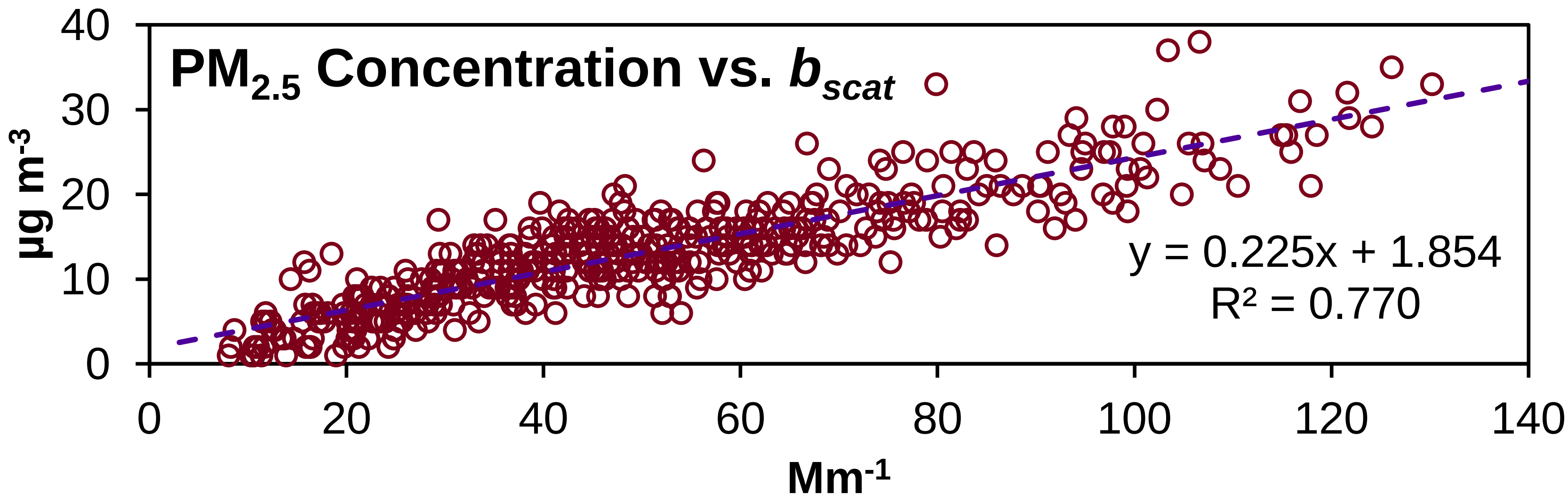
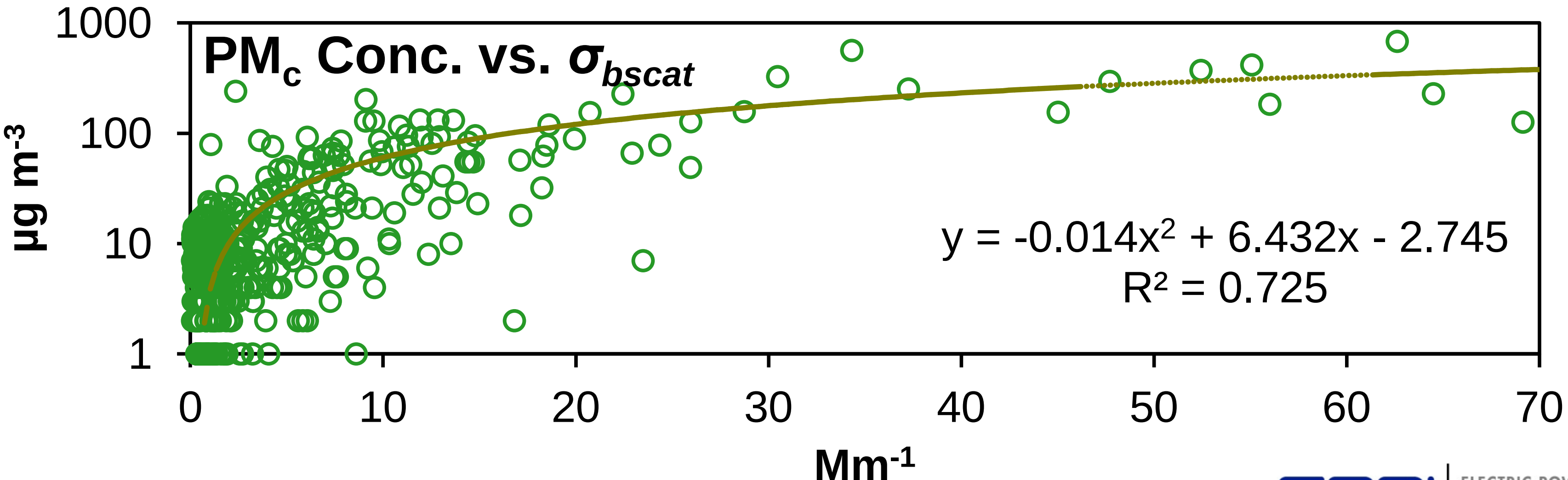
Particle Concentrations (SSE-SSW)





Models of Hourly PM_c & $PM_{2.5}$

Multivariate linear regression yields

$$C_{fine}=f_{bscat}b_{scat} + f_{U2}U_2 + C_{int} \qquad r^2=0.89$$

$$C_{coarse}=f_{\sigma}\sigma_{bscat} + f_{U2}U_2 + f_{fine}C_{fine} + C_{int} \qquad r^2=0.77$$

f :	regression slope constants
b_{scat} :	light scattering coefficient (Mm^{-1})
σ_{scat} :	standard deviation of b_{scat} (Mm^{-1})
U_2 :	wind speed at level 2 ($m\ s^{-1}$ @10 m)
C_{int} :	intercept constants ($\mu g\ m^{-3}$)
C_{fine} :	concentration of $PM_{2.5}$ mass ($\mu g\ m^{-3}$)
C_{coarse} :	concentration of PM_c mass ($\mu g\ m^{-3}$)

Steps in Estimating Fly Ash Emission Rates

For each particle size:

1. Select hours meeting minimum data requirements
2. Calculate “adjusted” concentrations at sites 2 & 3 to remove effects of nearby emissions
3. Calculate “excess” concentrations (i.e., values above background), C^{xs}
4. Compute normalized concentrations (C/Q)
5. Compute $Q_i = C^{xs}_i/(C/Q)$

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Fly Ash Emission Equations

Based on AP-42:

$$E_{ash} = \mathbf{N_{loads}} (E_{drop} + \mathbf{D}E_{grad} / \mathbf{m})$$

N_{loads} = ash loads per unit time
D = grader distance traveled per load processed
m = ash mass per load

$$E_{drop} = C_{drop} \frac{(U/_{2.2})^{1.3}}{(M/_{2})^{1.4}}$$

$$E_{ir} = C_{ir} \left(\frac{S}{12}\right)^{a} \left(\frac{W}{3}\right)^{0.45}$$ *grading*

Based on field data & modeling:

$$C_{xsobs} = C_{obs} - C_{local} - C_{bck}$$

$$Q_{ash} = C_{xsobs} /(C/Q)_{model}$$

$$E_{ash} = Q_{ash} /\mathbf{M_{ash}}$$

M_{ash} = ash mass deposited per area per time

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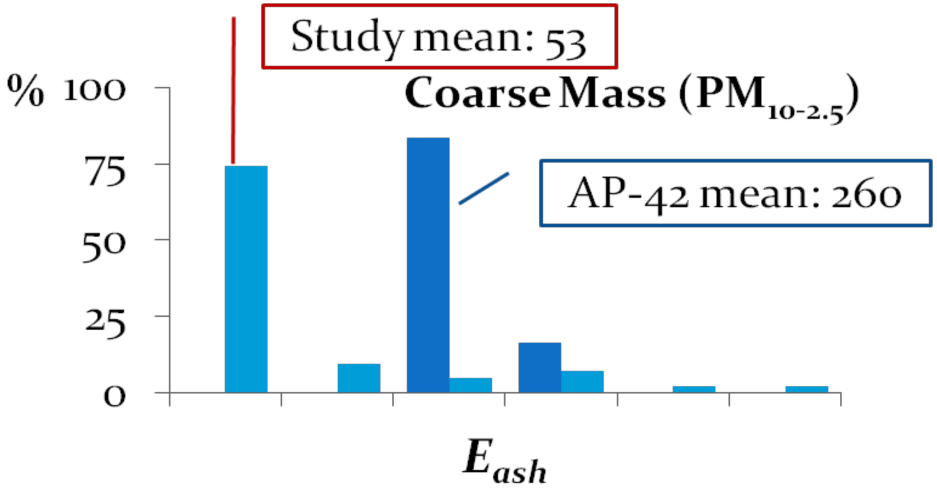
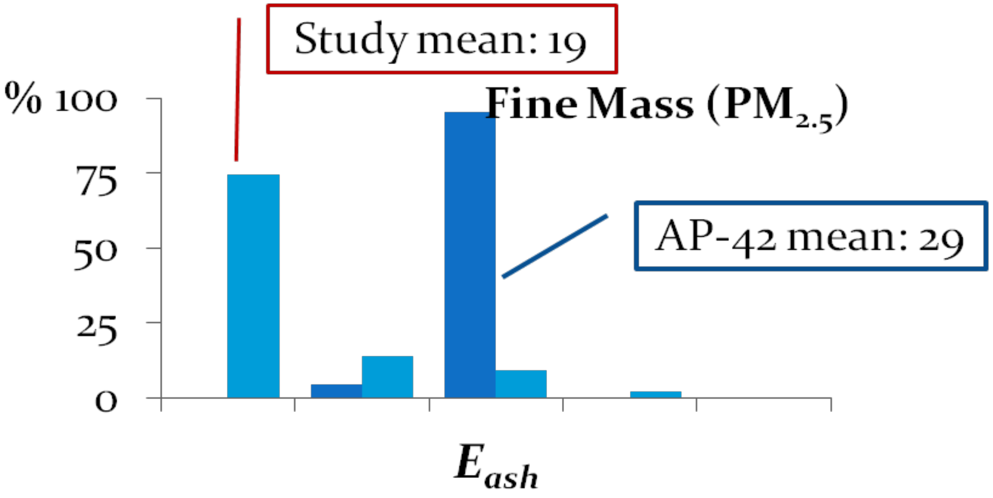
Overall Emission Factors





g particles/ metric ton of processed ash

Estimating Vehicle Dust Emissions

Assuming an infinite line source and a Gaussian plume mass profile, calculate an emission rate of mass per unit length of road per unit time as (following Hanna et al., 1982)

$$Q_i = 2.46 C_i (Kux)^{½} \exp[uz^2/(4Kz)]$$

where C_i is observed concentration of mass component i, u is wind speed, x is downwind distance, K is eddy diffusivity, and z is the vertical height displacement from the plume centerline (z=0 for a ground level source). Near the ground under steady-state conditions, K can be determined using the relation

$$u_*^2 = K(\mathrm{d}u/\mathrm{d}z)$$

with both u_* and du/dz known from measurements at the nearby meteorological tower.

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Emission Factor Summaries

Emission Factor	Coarse Mass, PM_c Mean	Coarse Mass, PM_c Median	Fine Mass, $PM_{2.5}$ Mean	Fine Mass, $PM_{2.5}$ Median
Fly Ash, **AP-42** (g PM per Mg ash)	250	232	45	41
Fly Ash, this study (g PM per Mg ash)	63	12	14-18	5-7
Road dust, **AP-42** - industrial sfc. (g PM per km traveled)	193	200	34	36
Road dust, **AP-42** - public roads (g PM per km traveled)	32	26	5.7	4.6
Road dust, this study (g PM per km traveled)	68[e]	38[e]	3.3	1.4

What controls total ash disposal EFs?

- Grading activity accounts for >95 percent of total computed fugitive fly ash emissions.
- AP-42 grading EF formulation is for vehicles on *industrial roads* but was developed from surfaces relatively low (<25%) in silt content, no moisture, higher speeds.
- Tested both AP-42 unpaved road dust formulations at Colbert on 2 roads/42 events.
- Results*: *Industrial* AP-42 EF **10x** observed for PM_c
  Industrial AP-42 EF **23x** observed for $PM_{2.5}$
  Public road AP-42 EF **2x** observed for PM_c
  Public road AP-42 EF **4x** observed for $PM_{2.5}$

*Differences between AP-42 and field results are even larger when vehicle wake effects are considered.

Conclusions

- Despite conservative assumptions, AP-42 derived fly ash handling EFs are higher than EFs derived by field measurements for both PM_c and $PM_{2.5}$
- Disparity is likely due to high bias in industrial unpaved road dust formulation (grading).

- EFs from field measurements have higher tail than AP-42 EFs. May be due to higher variability in atmospheric or ash handling conditions in real operations.

- Use of more realistic EFs can lower fugitive dust emission estimates for fly ash handling by 33% ($PM_{2.5}$) to 80% (PM_{10}). *Can benefits be expanded to TSP?*

- Observed EFs for vehicles on unpaved roads also differ from AP-42 EFs.

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