The Particulars of Particulate Matters

Presented by: Zach Faber
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How do I plan to keep you awake?
Other than bad jokes and throwing things at you…

Objective:
• Share with you real-world experience with PM emissions at nonmetallic mineral mining facilities
  • Mostly water-soluble minerals – This will be important later

Walk away with:
• Improved understanding of the types of PM and how to measure them
• New approaches to estimating realistic emissions
• Better selection of air pollution control equipment and better understanding of what emissions are achievable
• New testing strategies and understanding results
What is particulate matter?

Back to Basics

• PM is a mixture of solid particles and liquid droplets suspended in the air.
  • Dust or soil – First comes to mind
  • Organic chemicals – Oils
  • Metals
  • Acids

• Sizes we will focus on:
  • Coarse: between 2.5 µm and 10 µm
  • Fine: <2.5 µm
  • No “secondary” PM
Filterable vs. Condensable
Liquid - Solid - Gas

Filterable PM (PM-Fil): either a solid or liquid at stack conditions

Condensable PM (PM-Con): vapor or gas at stack conditions
• Condenses to a liquid or solid at atmospheric conditions
• EPA considers exhaust <85ºF filterable PM
Notes On Particle Size

PM$_{10}$ vs. PM$_{2.5}$

- PM$_{10}$ is PM diameter 10 microns and smaller
- PM$_{2.5}$ is PM diameter 2.5 microns and smaller
- This means that PM$_{2.5}$ is a subset of PM$_{10}$
- PM$_{2.5}$ should always be less than PM$_{10}$
  - Assuming uniform particle density
  - Could be equal if all of the PM$_{10}$ is 2.5 microns in diameter or smaller

What about PM-Con?

- Also, all PM-Con is assumed to be PM$_{2.5}$
  - Since PM$_{2.5}$ is a subset of PM$_{10}$, PM-Con is also PM$_{10}$
Available Test Methods
Use The Appropriate Test Method

Method 5
- Older method for PM-Fil measurement
- Still required by many rules for compliance testing
- Does not partition sizes
  - Basically collects everything

Method 201A
- Newer method for PM-Fil measurement
- Partitions the particle sizes
  - Can get measurements of PM$_{2.5}$ and PM$_{10}$
- Cannot be used if there are entrained water droplets (water-saturated exhaust)

Method 202 (Back Half)
- Measures PM-Con
- No size partitioning
- Evolved from wet impinger method to dry impinger method using N$_2$ purge
Sources of PM – Mineral Mining
Here, There, Everywhere

Point Sources
- Material handling
  - Conveyors
  - Screens
  - Crushers
  - Elevators
- Dryers
- Combustion Equipment

Fugitive Sources
- Haul roads
- Material piles (wind)
- Material moving (dozing)
- Blasting
Emission Factors
Do The Best With What You’ve Got

**EPA AP-42** (Most of these factors determined using Method 5)
- Chapter 8 – Various fertilizer prills; Sodium carbonate
- Chapter 11 – Don’t just default to 11.19.2 Crushed Stone
- Chapter 13 – 13.2 in particular for haul roads, material handling, storage piles

**Other References**
- Nevada Division of Environmental Protection Bureau of Air Pollution Control (BAPC) – Mining Industry Guidance
- Mojave Desert Air Quality Management District – Antelope Valley Air Pollution Control District – Mineral Handling EI Guidance
- Western Regional Air Partnership’s (WRAP) Fugitive Dust Handbook
- A&WMA’s Air Pollution Engineering Manual

**Size Fractions**
- AP-42 Appendix B
- Sometimes in the AP-42 section (13.2.4 particle size multipliers)
Lesson 1: Know Your Material
Inherent Control From Moisture

• Water sprays are a common dust mitigation strategy
• But what if the mineral is already wet?

• And what if it is hygroscopic?
• And what if you stockpile it and it forms a hard, crystalline crust on the surface as the water evaporates?
Lesson 1: Know Your Material

Compare
Lesson 2: Collection Efficiency

Why Is It So Dusty In Here???

Many emission estimates assume 100% capture efficiency for dust collection systems.

• This is not accurate
  • Design of “pickup” matters
  • Is the source enclosed?
  • Number of pickup points
  • Resource: Mojave Desert Air Quality Management District – Antelope Valley Air Pollution Control District

• KAR 28-19-210(f)(3)(B): Not totally enclosed, not under negative pressures? Assumed to be 50%. 
Lesson 2: Collection Efficiency

What About The Dust That Was Not Collected?

• Material handling emissions are not fugitive emissions – they are uncaptured emissions.

• Uncaptured emissions are not fugitive emissions
  • They could reasonably be directed to a control device
  • They originated from a point source

• Account for the uncaptured emissions in the PTE
  • Is there additional control afforded by a building?

• Some sources only have covers or enclosures – No dust pickup
  • Consider the control efficiency of the enclosure
  • Resource: Mojave Desert Air Quality Management District – Antelope Valley Air Pollution Control District (½ = 50%; ¾ = 70%; Full = 85%)
Lesson 3: Go with the Flow
But make sure to use the right flow…

• Two common pieces of information from control equipment vendors:
  1) Exhaust Flow in acfm
  2) Outlet Concentration of PM in gr/dscf

• Which commonly results in this:

\[
50,000 \text{ acfm} \times 0.01 \frac{\text{gr}}{\text{dscf}} \times \frac{1 \text{ lb}}{7,000 \text{ gr}} \times \frac{60 \text{ min}}{1 \text{ hr}} = 4.29 \text{ lb/hr}
\]

• ACFM and DSCF are not the same thing when heat, moisture, and elevation are involved
  • Discuss exhaust assumptions with the design vendor
  • What will the actual exhaust flow be – VFD?
Lesson 3: Go with the Flow
A Real-Life Example

Design
• Baghouse controlling a rotary dryer
• Exhaust fan capacity: 50,000 acfm
• Vendor PM outlet concentration guarantee: 0.01 gr/dscf
• Permit Limits PM-Fil + PM-Con:
  • PM$_{10}$: 4.29 lb/hr and 0.01 gr/dscf
  • PM$_{2.5}$: 2.50 lb/hr and 0.01 gr/dscf

Reality
• Exhaust vol. rate: Around 10,000 to 15,000 dscfm
• Test PM$_{10}$ Fil + Con: 2.60 lb/hr

\[
2.60 \, \frac{lb}{hr} \times \frac{7,000 \, gr}{1 \, lb} \times \frac{1 \, hr}{60 \, min} \times \frac{1 \, min}{12,000 \, dscf} = 0.025 \, \frac{gr}{dscf}
\]
Lesson 3: Go with the Flow

What about acfm?

\[
2.60 \frac{lb}{hr} \times \frac{7,000 \text{ gr}}{1 \text{ lb}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{25,000 \text{ acf}} = 0.012 \frac{\text{gr}}{\text{dscf}}
\]

Still above the concentration limit using acfm

- Baghouse ID fan had a VFD controlled by dryer
  - Exhaust draft
  - Mineral outlet temperature
Lesson 4: Know Your PM Pollutants
Filterable, Condensable, or Both?

Same Baghouse Detailed Stack Test Results
- PM$_{2.5}$-Fil: 0.10 lb/hr
- PM$_{10}$-Fil: 0.25 lb/hr
- PM-Con: 2.35 lb/hr
  - PM-Con assumed to be PM$_{2.5}$, so it is added to both sizes

Further Research
- PM-Con was not measured for all industries
  - AP-42 Table 11.19.1-1 Footnote b: “…Condensible organic and inorganic PM emission factors are not available. Factors presented can be considered a conservative underestimate of total PM.”
  - 8.12 includes CPM to the tune of about 0.02 lb/ton
Lesson 4: Know Your PM Pollutants

What Is Your Point?

- Emission limits were determined using the previously discussed flow calculations
  - Used maximum design flow
  - Used vendor concentration guarantee

- Air pollution control equipment is a baghouse
  - Baghouses are dry control devices - Do **not** control PM-Con
  - Therefore, the vendor guarantee only applied to the PM-Fil

Emission Calculations and Limits Did Not Consider PM-Con!
Lesson 5: Test Methods Are Not Perfect
Know Their Flaws – Another Real-Life Example

Baghouse Controlling Dry Material Handling Sources

- Exhaust fan capacity: 20,000 acfm
- Vendor PM outlet concentration guarantee: 0.01 gr/dscf
- Permit Limits PM-Fil + PM-Con:
  - PM$_{10}$: 1.50 lb/hr and 0.01 gr/dscf
  - PM$_{2.5}$: 0.50 lb/hr and 0.01 gr/dscf

Test Results

<table>
<thead>
<tr>
<th></th>
<th>PM$_{10}$-Fil</th>
<th>PM$_{2.5}$-Fil</th>
<th>PM-Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>M201A</td>
<td>0.15 lb/hr</td>
<td>0.05 lb/hr</td>
<td>0.50 lb/hr</td>
</tr>
<tr>
<td></td>
<td>0.002 gr/dscf</td>
<td>0.001 gr/dscf</td>
<td>0.006 gr/dscf</td>
</tr>
</tbody>
</table>
Lesson 5: Test Methods Are Not Perfect
Condensable PM?

- Baghouse controlled equipment that processed only dried minerals
  - Belt conveyors
  - Elevators
  - Screens

- Method 202 testing was required by the permit despite the fact that gas phase PM would not be expected from such sources

\[ 0.05 \text{ PM}_{2.5} - \text{Fil} + 0.50 \text{ PM-Con} = 0.55 \text{ lb/hr} \ (> \text{ PM}_{2.5} \text{ limit}) \]
Lesson 5: Test Methods Are Not Perfect
Not Unusual

• This phenomenon occurs at multiple sites that process water-soluble nonmetallic minerals
  • Personal experience

• Common issue not specific to one source, one site, or one specific material/mineral
Lesson 5: Test Methods Are Not Perfect
Where Does The CPM Come From?

Some theories:

• An “artifact” of the test method
  • Not likely as this usually results from SO$_2$ and NH$_3$

• Dissolved minerals that precipitate in the impingers
  • Exhaust was about 50° F (<85° F, must be considered PM-Fil)

• Vacuum Filter
  • Also via mineral precipitation
  • Caused by liquid droplets pulling soluble minerals through the filter cake

• Ultra-fine particles
  • Filters can only collect mineral that is so fine – the rest passes through
  • Moisture in impingers collects and dissolves the ultra-fine material
Lesson 5: Test Methods Are Not Perfect
Solutions?

• OTM-37 has been presented by EPA to aid in reduction of artifact CPM
  • Developing method

• Ensure stack testing is done per the method

• Evaluate stack moisture conditions
  • Should the sample line and filter be heated?

This subject requires more research
Takeaways
Lessons Learned

1) Know Your Material
2) Collection Efficiency
3) Go with the Flow
4) Know Your PM Pollutants
5) Test Methods Are Not Perfect
THANK YOU!

Zach Faber
President
(316) 260-2460
zfaber@solutionsbystrata.com