The Particulars of Particulate Matters

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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

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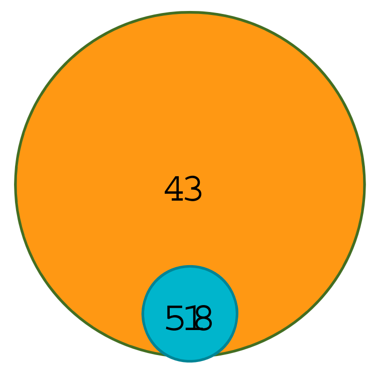
What is particulate matter?
Back to Basics

- PM is a mixture of **<u>solid</u>** particles and **<u>liquid</u>** 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



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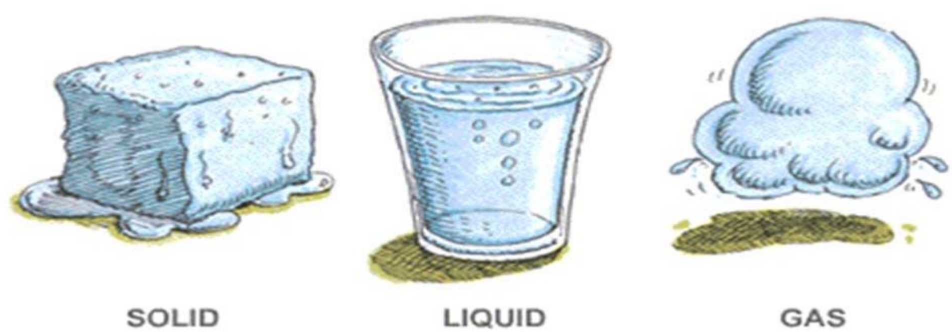
Filterable vs. Condensable

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



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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

<u>What about PM-Con?</u>

- 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}

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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

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Sources of PM – Mineral Mining

Here, There, Everywhere

<u>Point Sources</u>

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

<u>Fugitive Sources</u>

- Haul roads
- Material piles (wind)
- Material moving (dozing)
- Blasting

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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)

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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?

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Lesson 1: Know Your Material

Compare

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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%.

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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%)

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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:

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

- 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?

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Lesson 3: Go with the Flow
A Real-Life Example

<u>Design</u>

- 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

<u>Reality</u>

- Exhaust vol. rate: Around 10,000 to 15,000 **<u>dscfm</u>**
- Test PM_{10} Fil + Con: 2.60 lb/hr

$$2.60\ \frac{lb}{hr} \times \frac{7{,}000\ gr}{1\ lb} \times \frac{1\ hr}{60\ min} \times \frac{1\ min}{12{,}000\ dscf} = 0.025\ \frac{gr}{dscf}$$

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Lesson 3: Go with the Flow
What about acfm?

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

Still above the concentration limit using acfm

- Baghouse ID fan had a VFD controlled by dryer
  - Exhaust draft
  - Mineral outlet temperature

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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

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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!

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Lesson 5: Test Methods Are Not Perfect

Know Their Flaws – Another Real-Life Example

<u>Baghouse Controlling Dry Material Handling Sources</u>

- 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

<u>Test Results</u>

M201A PM_{10}-Fil	0.15 lb/hr	0.002 gr/dscf
M201A $PM_{2.5}$-Fil	0.05 lb/hr	0.001 gr/dscf
M202 PM-Con	0.50 lb/hr	0.006 gr/dscf

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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 $PM_{2.5}$-Fil + 0.50 PM-Con = 0.55 lb/hr (> $PM_{2.5}$ limit)

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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?

<u>Some theories:</u>

- 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 50º F (<85º 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

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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

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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

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THANK YOU!

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