


DPM Monitoring & Abatement Research at Virginia Tech

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A NIOSH-funded project

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Mining Diesel Emissions Council, 22nd Annual Conference

Project Details

- Gap in development of new experts in the mining industry – especially in H&S
- Technical research needs specifically related to DPM monitoring and abatement
- Project funded by the National Institute of Occupational Safety and Health (NIOSH) to build expertise in mine occupational health
  - 5 year project (Sept 2014 – Aug 2019)
  - $1.25M
  - Expected to support a total of 8 graduate students (MS or PhD)

https://www.workplacesafetynorth.ca/news/news-post/new-and-improved-mining-health-and-safety-training

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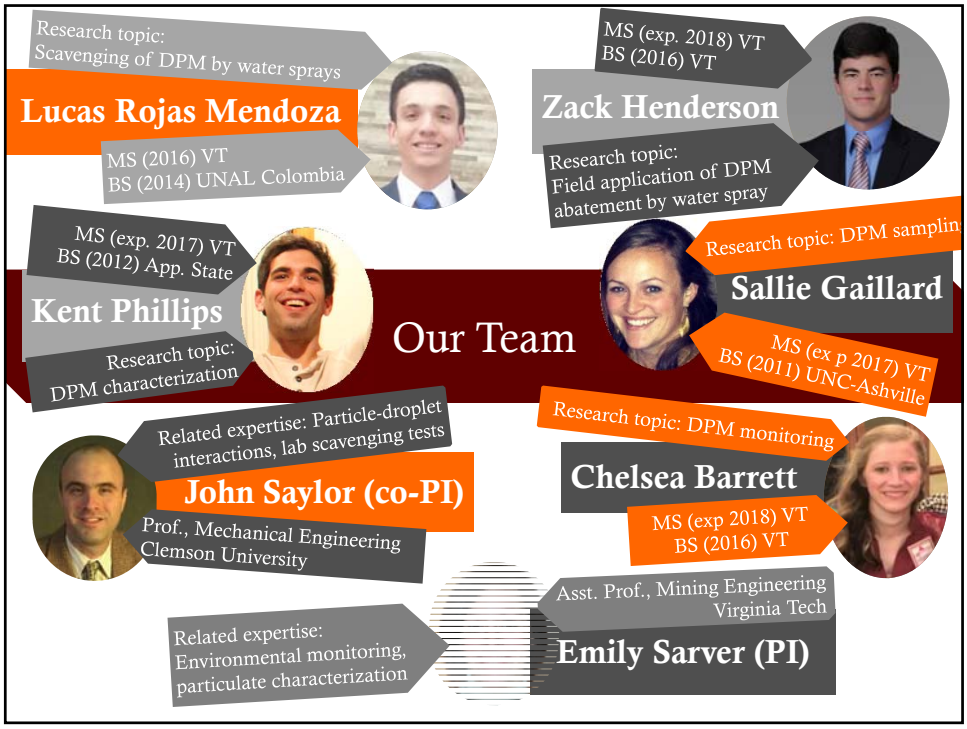

Needs in DPM Monitoring

- Many mines struggle with DPM compliance, and large opening mines are especially challenged
- In the US, compliance with DPM exposure limits requires post-shift analysis of filter samples by NIOSH 5040 method – only allows for retroactive decision making based on results
- Real-time measurement benefits
  - Proactive decision making by miners/mine operators
  - "Spot-check" surveys
- Continuous monitoring benefits
  - Better understanding of how different variables affect DPM levels
  - Know range of DPM levels that can be expected
- New monitoring methods may require new/improved sampling equipment

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Needs in DPM Abatement

- Especially where ventilation is difficult, current DPM abatement strategies (e.g., exhaust treatments) are still not enough to sufficiently curb exposures
- Water sprays are often used in mine settings to reduce airborne dust concentrations, and theory suggests that water drops may also be useful in scavenging DPM
- Our current abatement work is focused on testing the efficacy of micron-scale drops to remove DPM

http://www.e-mj.com/features/4799-ventilating-for-diesel-particulates.html#.V-v2lygrI2w

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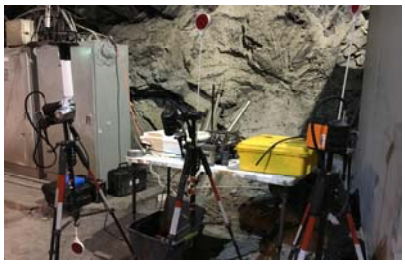
DPM Monitoring Work

Data Collection

- Data collection on this project is occurring in an underground stone mine
- We are currently using a variety of equipment (i.e., Airtecs, a prototyped Airwatch, Magee AE-33, air pumps to collect 5040 samples)
- Specific research topics include
  - Use of the Airtec unit for "spot checking"
  - Demonstration of the continuous Airwatch and AE-33 in a "high" DPM environment
  - Aging of size selectors (i.e., impactors vs. sharp-cut cyclones) generally required for DPM monitoring
  - Co-occurrence of DPM and respirable dust



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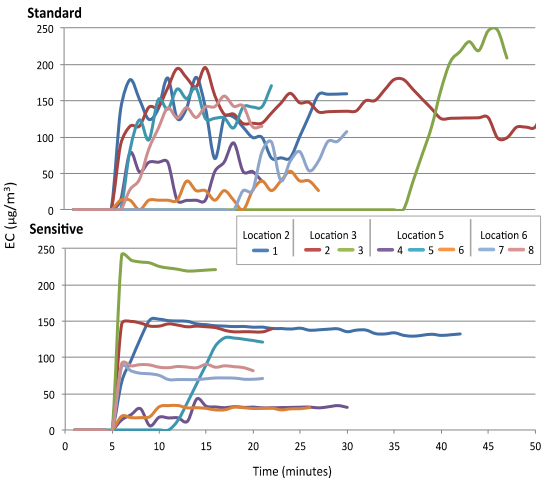
Spot-checking with the Airtec

- Airtec typically used for personal exposure monitoring over a work shift (8-10 hrs)
  - Standard 37mm diameter cassette
  - Due to limits of optical sensor, data stabilization tends to take relatively long time (i.e., enough EC must accumulate)
- To "spot-check", we tested sensitive cassettes
  - Smaller collection area results in faster data stabilization
  - Obtain reliable data in just a few minutes (~6-15 min)



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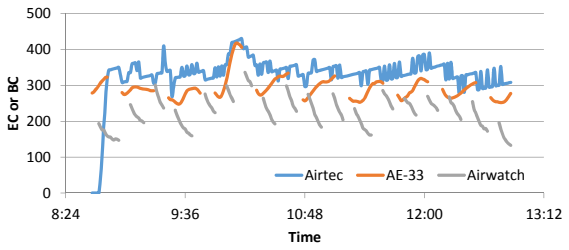
Continuous Monitoring

- Actinica Airwatch and AE-33 Aethelometer
  - Run on mine power
  - Tape advances when filter area is full
  - Length of tape is limiting factor to length of use
  - Both instruments have potential to work well; loading factor is one of several issues that still needs to be addressed in the Airwatch



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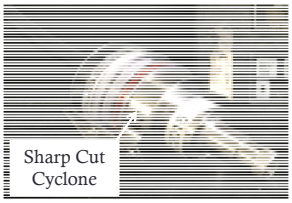
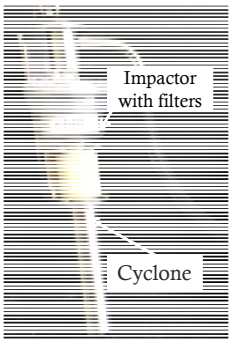
Aging of Size-selectors

- Currently, impactors are used (often in combination with Dorr-Oliver cyclones) to discard particles greater than about 1um when sampling for DPM
- Impactors are consumable, and are recommended for replacement after 8-24 hours of sampling
- Sharp-cut cyclones (SCCs) offer a non-consumable alternative, which is needed for continuous monitoring applications
- Little information available on how often SCCs need to be cleaned to maintain consistent cut point





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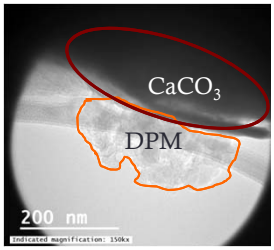
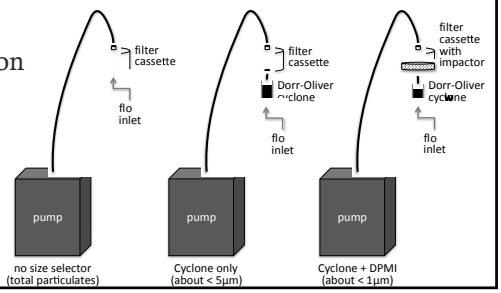
Co-occurrence of DPM and Dust

- DPM is generally assumed to occur only in the sub-micron range
- In dusty environments, however, potential exists for DPM to attach to airborne dust – which may have health implications in the case of respirable particulates
- We will soon begin a series of field tests to investigate the fraction of DPM occurring in the total vs. 1-5um vs. <1um ranges





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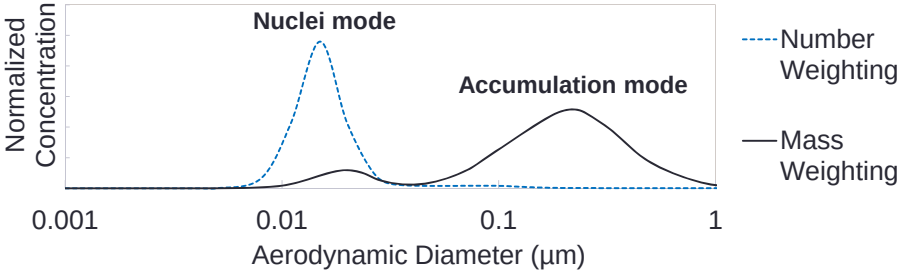
DPM abatement by micron-scale water droplets

Background

- Theory suggests DPM scavenging by micron-scale drops would likely occur by thermal coagulation (Brownian motion)
- Our objective is to test efficacy of a "fogging" treatment on DPM removal
- We are concerned with removal on both number and mass-basis



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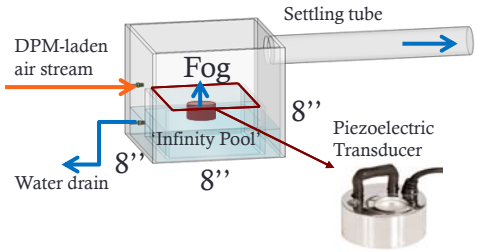
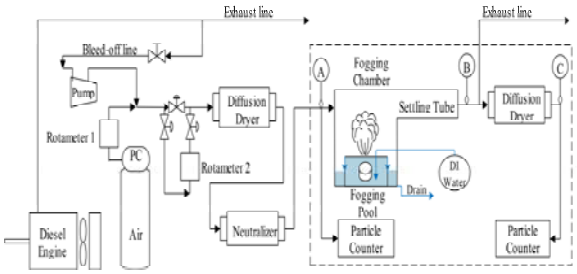
Laboratory Set-up

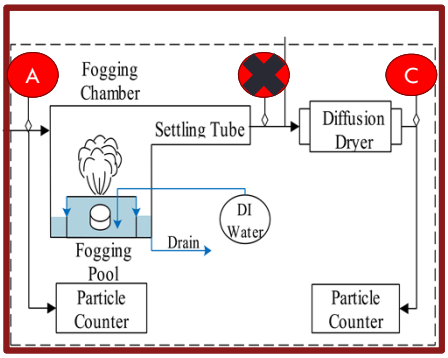
- Number and mass-based results on a diluted exhaust stream
- Mass-based results on raw exhaust stream





Number-Based Testing

- Nanoscan used to measure number concentration of DPM particles and size them into different bins
  - Neutralizer and diffusion dryers needed to properly use Nanoscan
  - Samples only taken at locations A and C
- Variables tested
  - fog ON v. fog OFF
  - long (6 ft) vs. short (2 ft) settling tube



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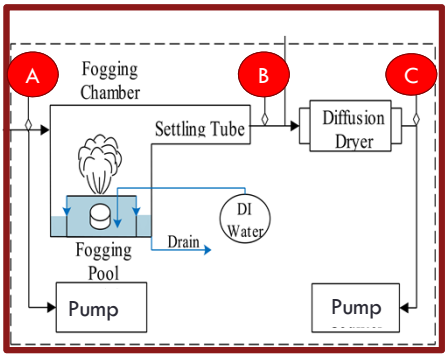
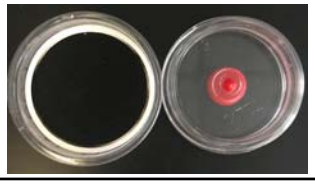
Mass-Based Testing

- Particle counters replaced with ELF pumps to sample DPM onto polycarbonate filters for gravimetric measurements
  - Sample at A,B, and C
  - Can see effect of DD
- Same variables tested
  - fog ON vs. fog OFF
  - long (6 ft) v. short (2 ft) settling tube





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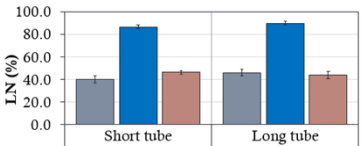
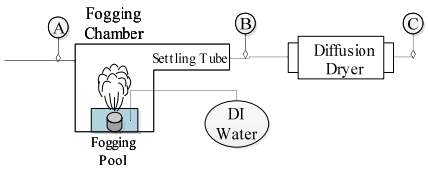
Results on Diluted Exhaust

Number-based

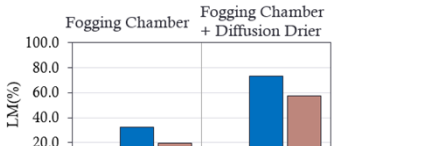


	Short tube	Long tube
Fog-off	40.2	46.2
Fog-on	86.6	89.9
Improvement	46.4	43.8

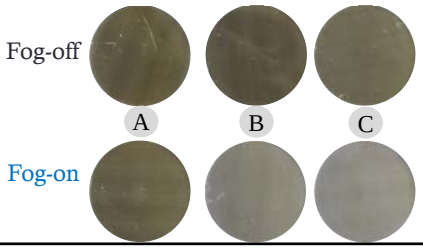
Average improvement (A-C) in DPM removal was ~45%



Mass-based



	Removal A-B	Removal A-C	Removal B-C
Fog-off	12.6	16.0	3.4%
Fog-on	32.3	73.3	41.0%
Improvement	19.7	57.3	37.6%



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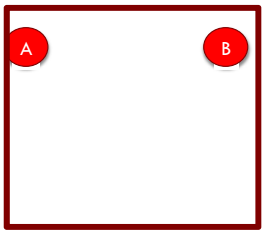
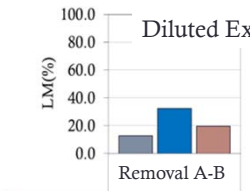
Results on Raw Exhaust

- Same setup, except no neutralizer and no diffusion dryers
  - Only mass-based results
  - Samples taken at A and B
- Results indicated that significantly more DPM mass was removed than in the case of diluted exhaust
  - increased water drop size?
  - ambient charge on DPM?





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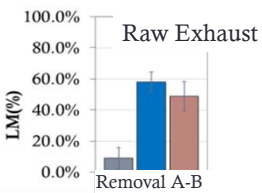

	Removal A-B
Fog-off	9.1%
Fog-on	57.9%
Improvement	48.9%

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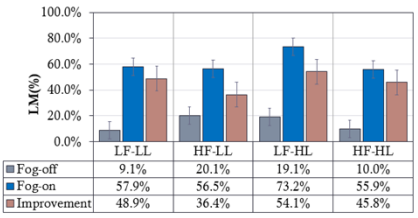
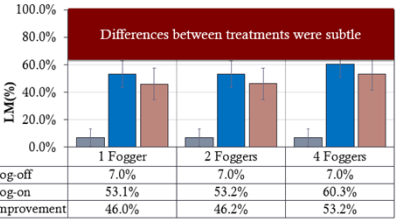
Results on Raw Exhaust

Varying load and flow



	LF-LL	HF-LL	LF-HL	HF-HL
Fog-off	9.1%	20.1%	19.1%	10.0%
Fog-on	57.9%	56.5%	73.2%	55.9%
Improvement	48.9%	36.4%	54.1%	45.8%

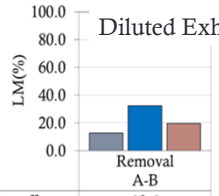
Varying number of foggers



	1 Fogger	2 Foggers	4 Foggers
Fog-off	7.0%	7.0%	7.0%
Fog-on	53.1%	53.2%	60.3%
Improvement	46.0%	46.2%	53.2%

- Not much difference observed between tested variables… but
- Significant difference between results with diluted vs. raw exhaust

Diluted Exhaust



	Removal A-B
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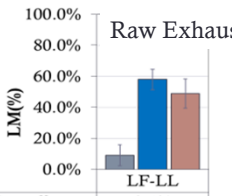
Raw Exhaust



	LF-LL
Fog-off	9.1%
Fog-on	57.9%
Improvement	48.9%

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Conclusions and Future Work

- For the conditions studied, the fog treatment resulted in significant improvement in DPM removal
- DPM-water droplet attachment, followed by droplet removal, provides a possible explanation for the observations
- The next step is to scale-up this technology for field application
  - Several alternatives are being considered
  - Currently evaluating critical variables, constraints and opportunities for integration into currently available technologies

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Thank you for your attention