A CFD Approach for Investigating DPM Concentration over Multiple Work Cycles of an LHD in an Underground Mine

Hongbin Zhang

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Laurentian University
Université Laurentienne
BHARTI SCHOOL OF ENGINEERING
ÉCOLE DE GÉNIE

Mirarco
MINING INNOVATION

Outline

- Research Objectives
- Prior Work
- Experiment Overview
- CFD simulation of the DPM concentration distribution over three work cycles of a LHD
- Discussion

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Research objectives

- Use CFD to figure out the acceptable airflow requirement to dilute the DPM level under the regulatory limit
- Investigate the DPM concentration behaviour over multiple work-cycles of a LHD in a dead-end heading

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Prior Work

- Experiment in an underground mine in the western U.S.
- Methodology of hybrid model established
- Initial findings published in the MPES 2017 conference

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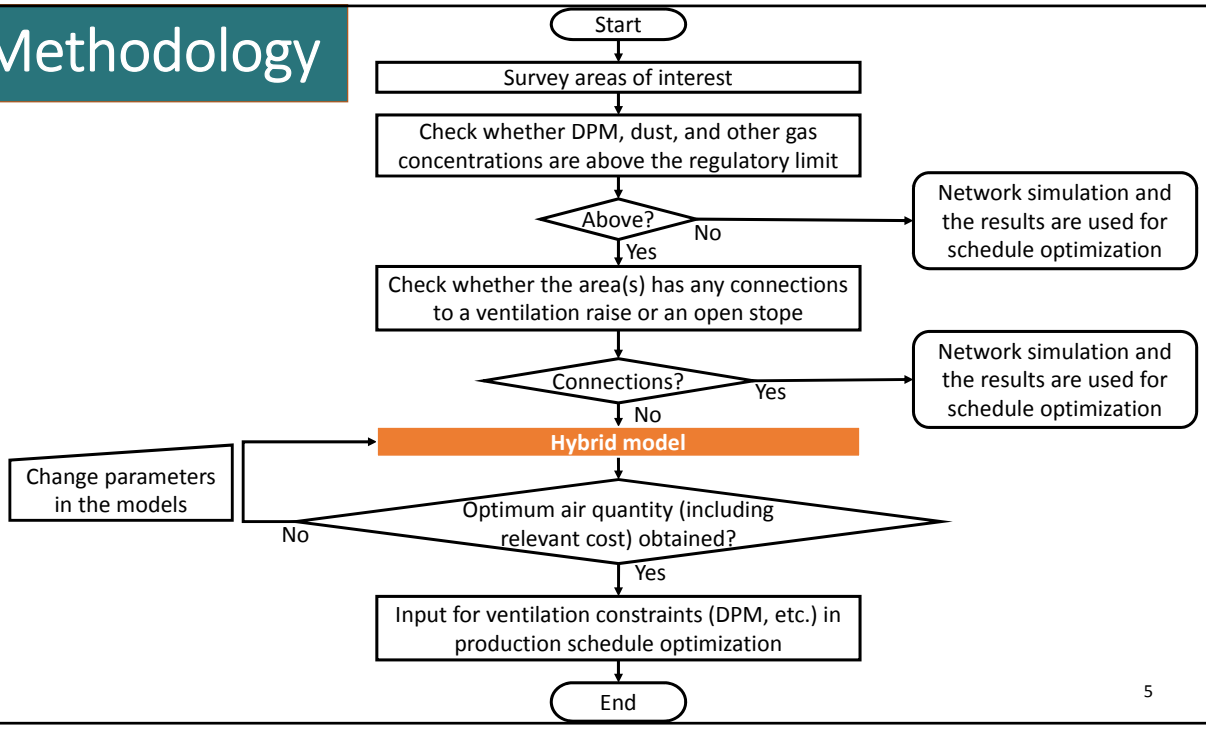
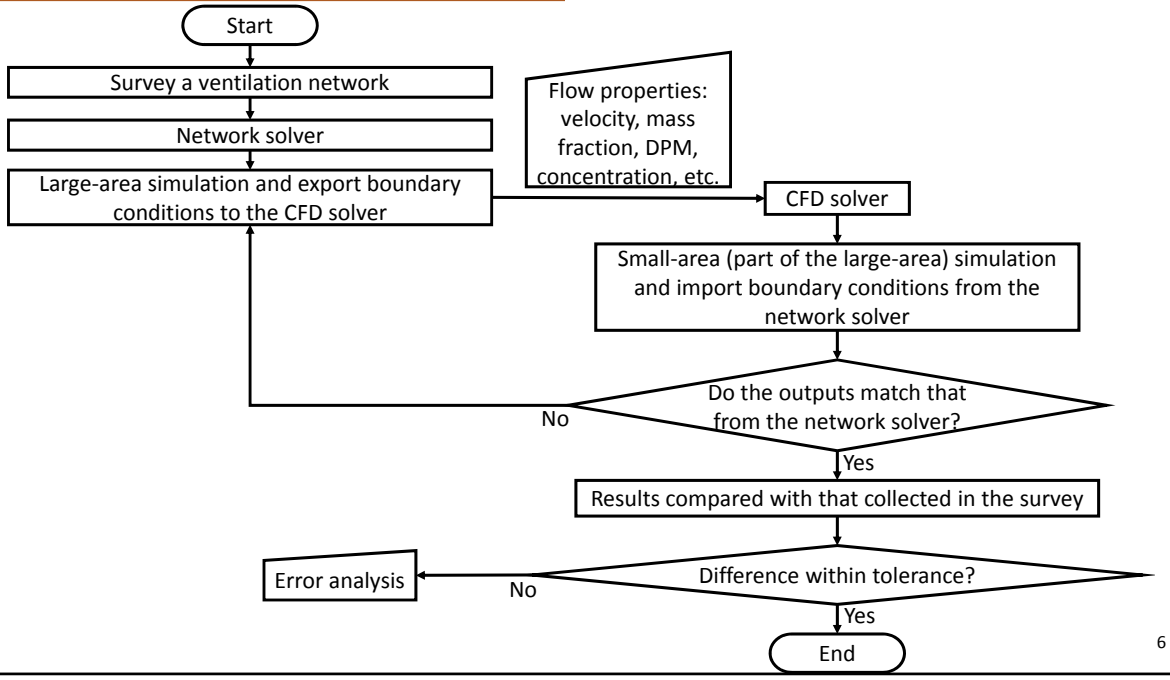
Methodology



5

Method of the Hybrid Model



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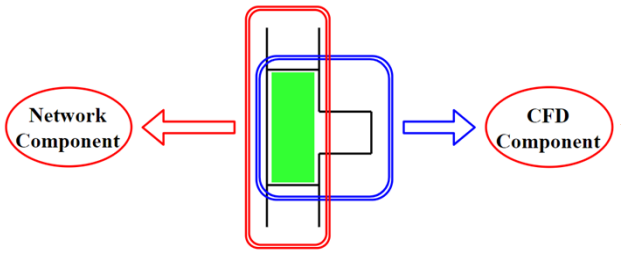
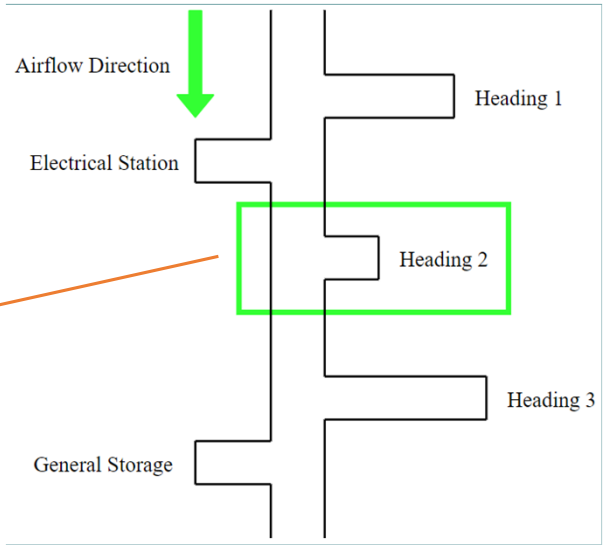
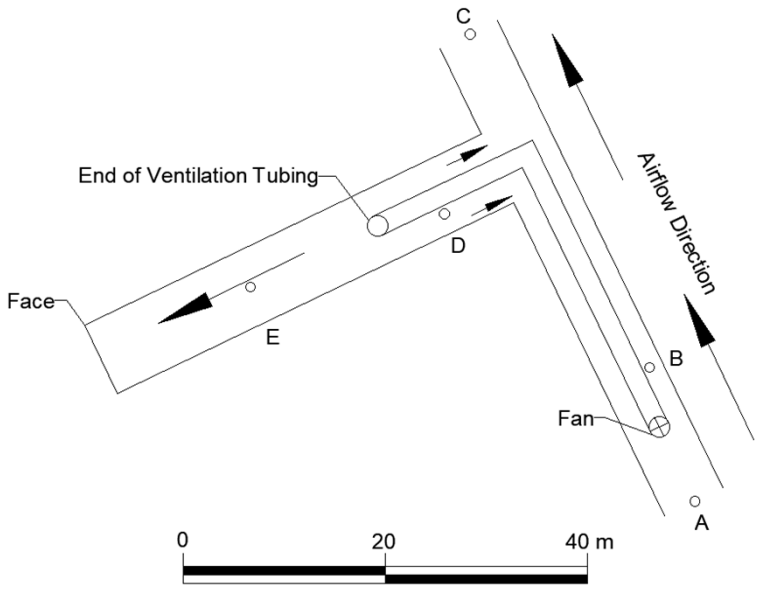
Simple network model, Simple 3D CFD model, and Hybrid CFD-network model





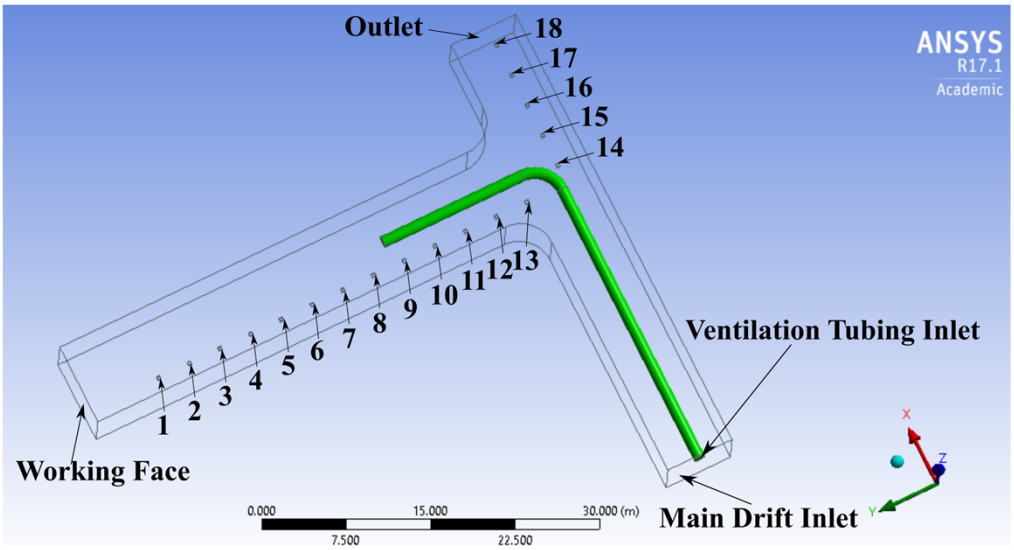
7

Plan View of the Experiment Area



8

Geometry of the Experiment Area



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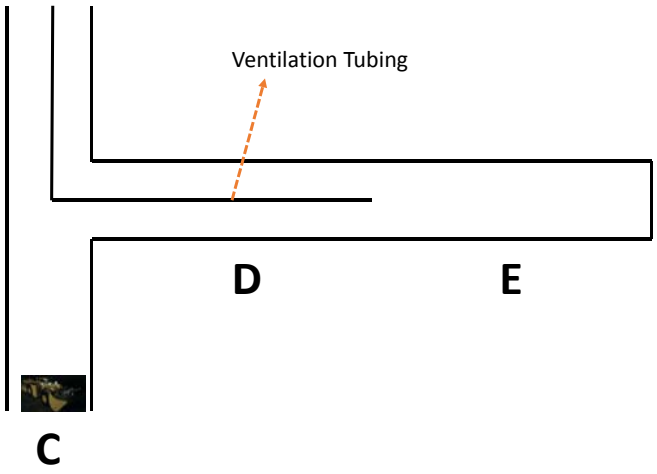
LHD Path



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DPM Simulation in Ansys Fluent

Boundary conditions:

	area (m2)	Velocity inlet (m/s)	DPM mass fraction	DPM (µg/m3)	Temperature (K)
Ventilation tubing	0.89	35.97	0	0	300
Main drift	34.08	1.61	0	0	300
LHD exhaust tailpipes (1 to 18)	0.093	profile (calculated)	profile (calculated)	profile (calculated)	594

$$DPM\ mass\ \ fraction = \frac{DPM\ concentration\ (\frac{\mu g}{m^3})}{air\ density\ (\frac{kg}{m^3})} \times \frac{kg}{10^9 \mu g}$$

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Assumptions

- In a work cycle, the DPM concentration from an LHD's tailpipe is the lowest when it is tramming into a heading with the bucket empty.
- The DPM concentration is the highest while the LHD is mucking in the heading.
- The DPM concentration is between the two concentrations mentioned above while the LHD is tramming out of the heading.
- It takes an LHD much longer to move out of a heading than to move into the heading.
- The DPM concentration levels are stable in each part of an LHD's work cycle.
- NOTE: The work to-date does not account for any effect of the LHD on the DPM concentration distribution in the heading in a work cycle of the LHD

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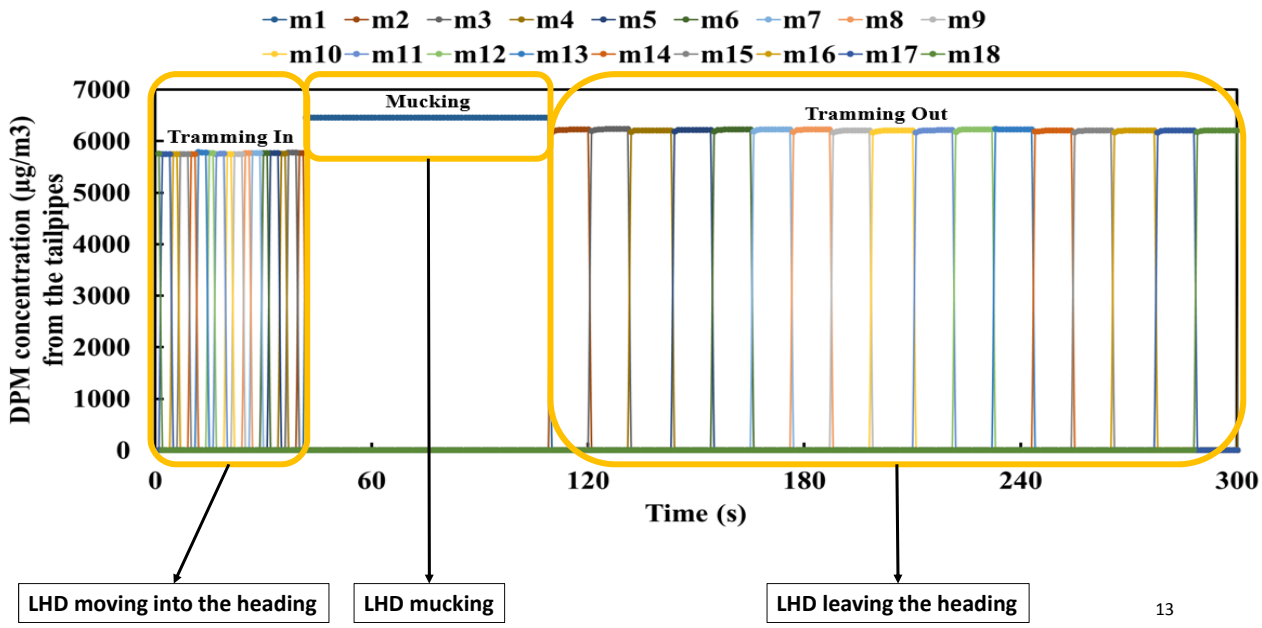
DPM Concentration Profile from the LHD Tailpipe



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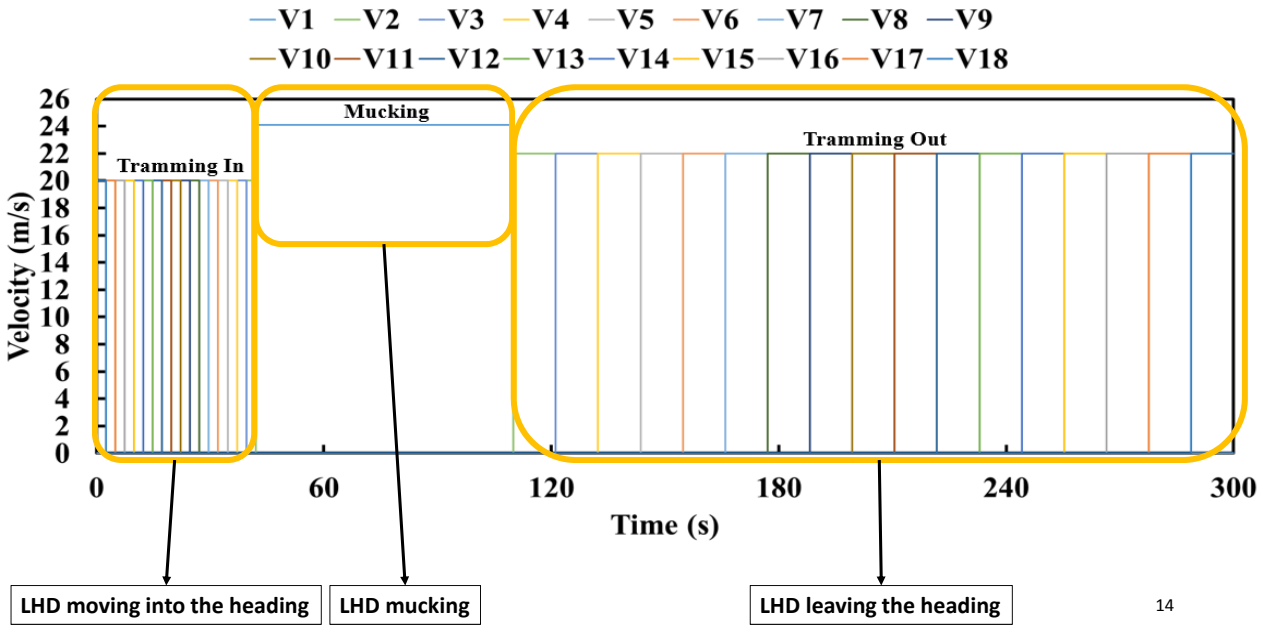
Velocity Profile from the LHD Tailpipe



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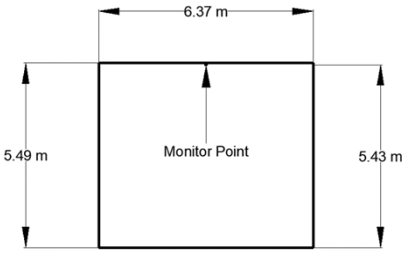
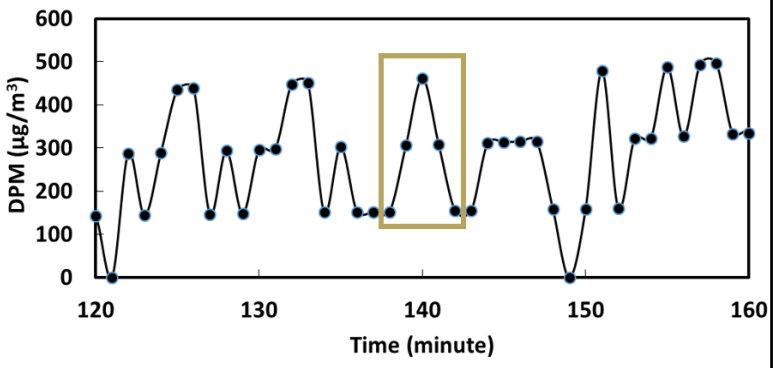
Partial DPM data collected by the Airtec DPM monitor at location D





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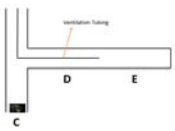
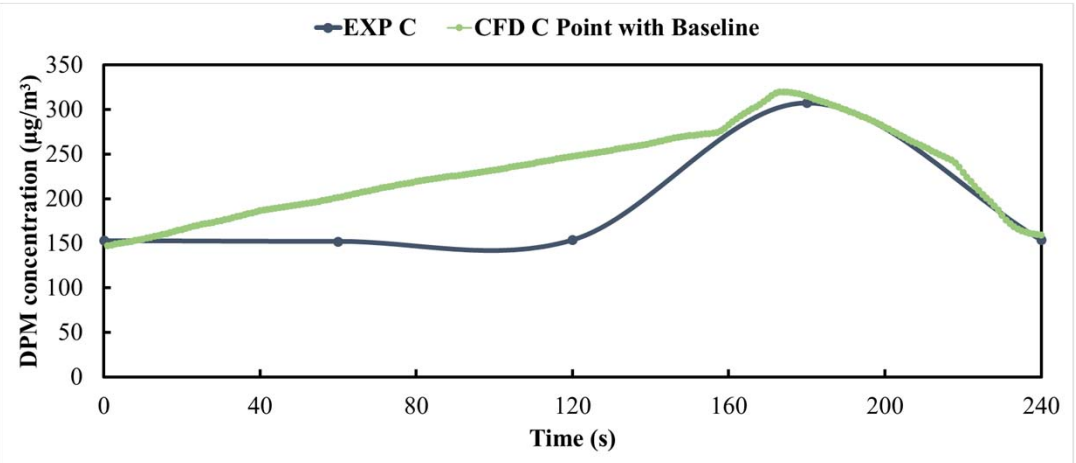
DPM Concentration Comparison at Location C in the Experiment and the CFD Model





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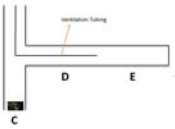
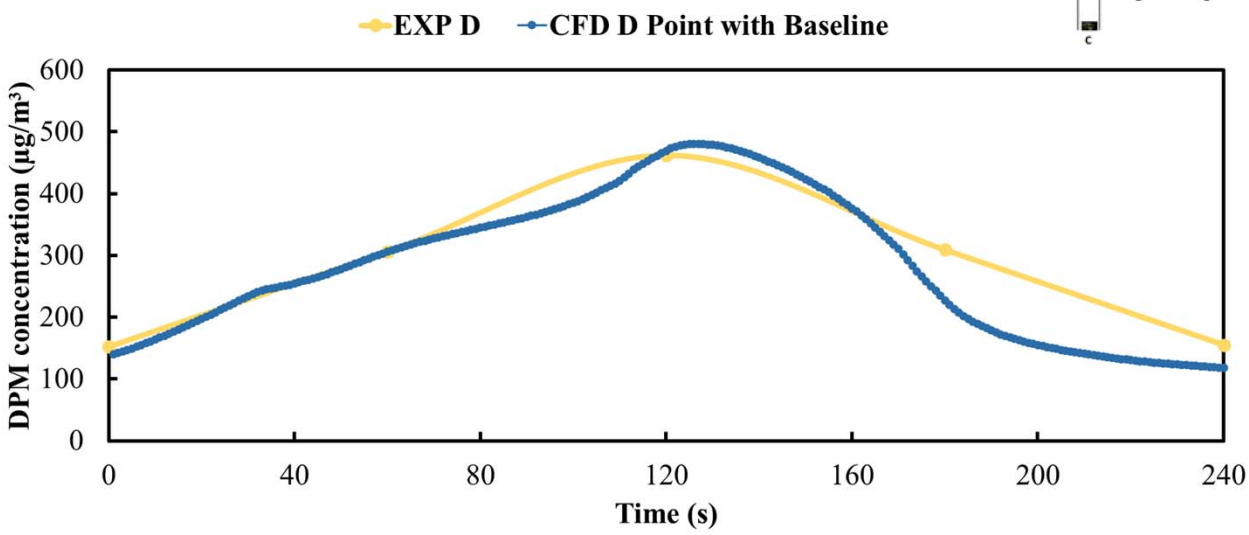
DPM Concentration Comparison at Location D in the Experiment and the CFD Model





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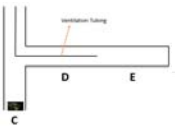
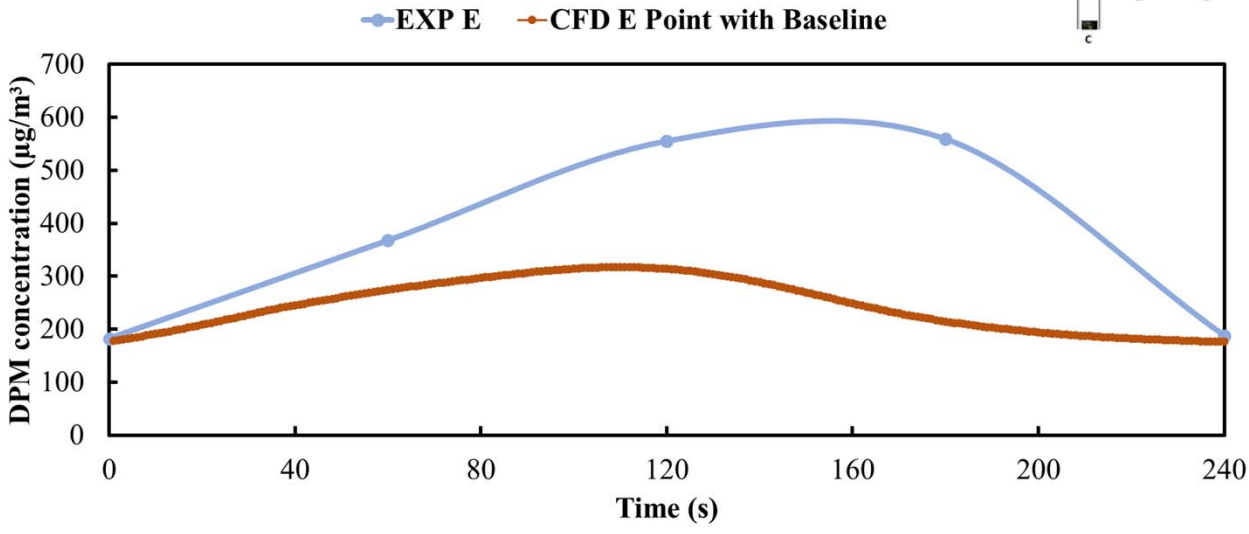
DPM Concentration Comparison at Location E in the Experiment and the CFD Model





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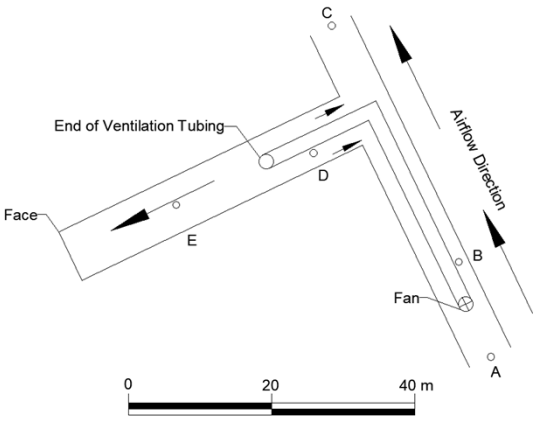
Error Analysis (CFD and Experiment)



	C	D	E
R-squared	0.67	0.94	0.50

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Main Conclusions

- The approach of using multiple tailpipes to simulate the DPM concentration generated from a work cycle of an LHD is feasible.
- The CFD model is capable of offering detailed contours of airflow and DPM concentration but it is computationally intensive
- Future work: simulate more work cycles in order to explore the DPM concentration behaviour and determine the optimum airflow quantity that keeps the DPM concentration under the regulatory limit

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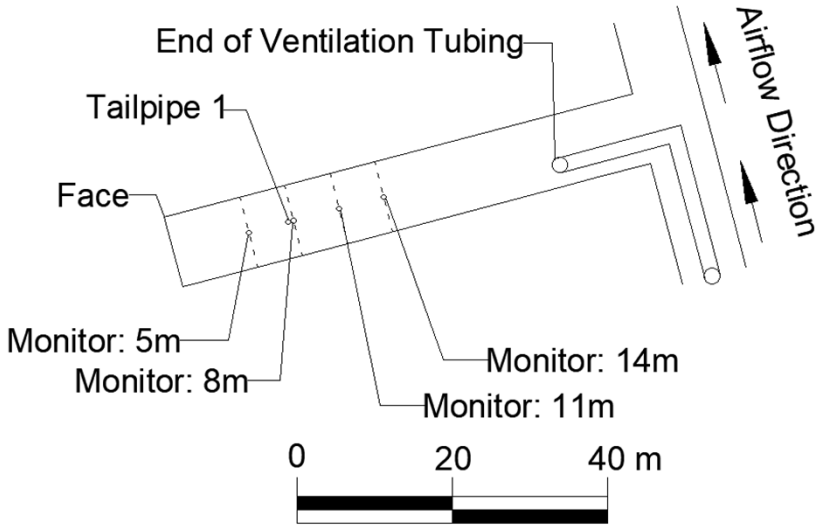
Plan View of the Experiment Area



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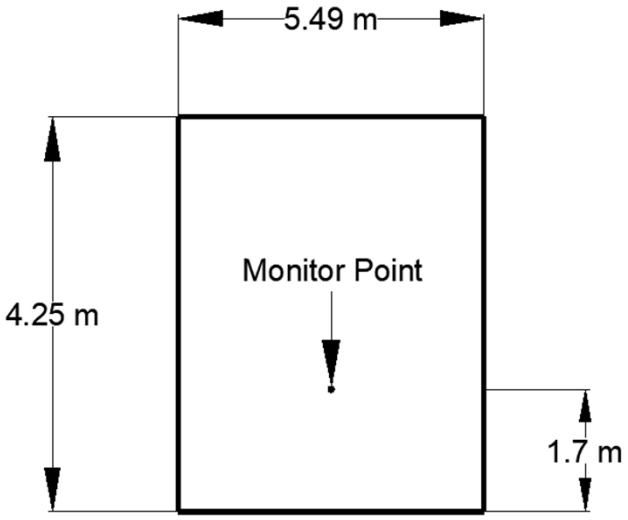
Location of a Monitor Point



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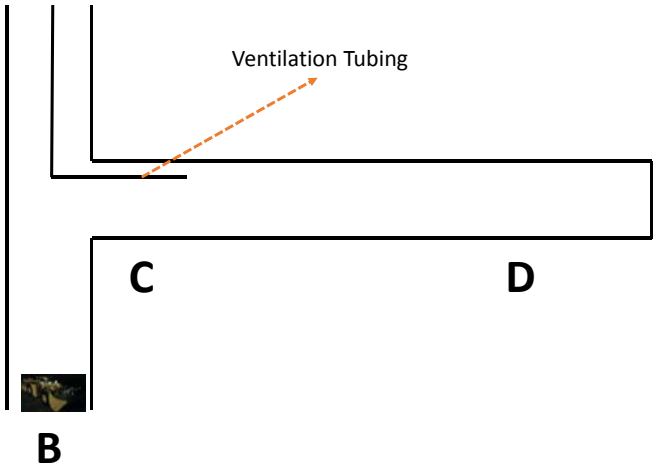
LHD Path



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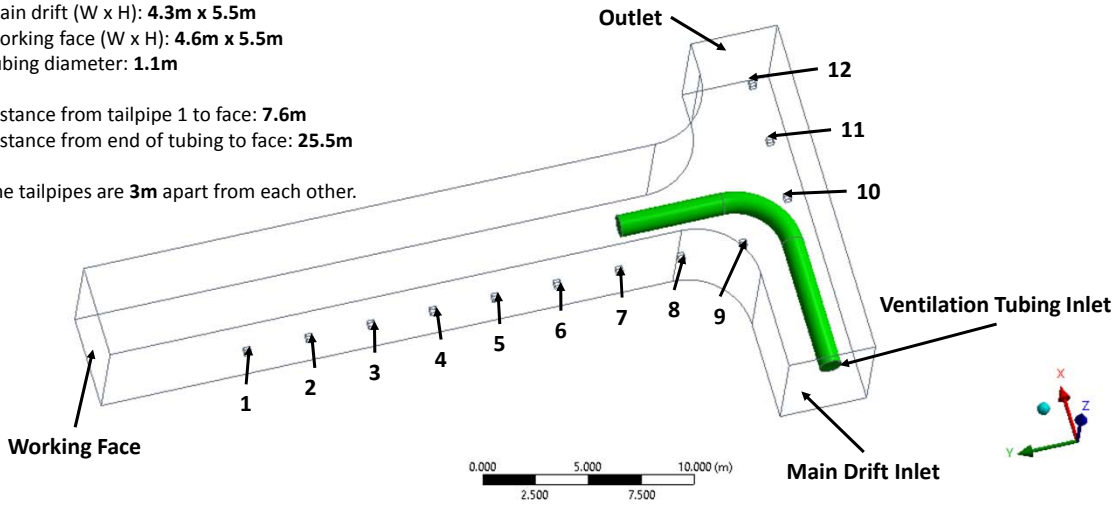
Geometry of the Experiment Area

Dimensions:
Main drift (W x H): **4.3m x 5.5m**
Working face (W x H): **4.6m x 5.5m**
Tubing diameter: **1.1m**

Distance from tailpipe 1 to face: **7.6m**
Distance from end of tubing to face: **25.5m**

The tailpipes are **3m** apart from each other.



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DPM Simulation in Ansys Fluent

Boundary conditions:

	area (m2)	Velocity inlet (m/s)	DPM mass fraction	DPM (µg/m3)	Temperature (K)
Ventilation tubing	0.89	various values	0	0	300
Main drift	22.4	0.084	0	0	300
LHD exhaust tailpipes (1 to 12)	0.093	profile (calculated)	profile (calculated)	profile (calculated)	594

$$DPM\ mass\ \ fraction = \frac{DPM\ concentration\ (\frac{\mu g}{m^3})}{air\ density\ (\frac{kg}{m^3})} \times \frac{kg}{10^9 \mu g}$$

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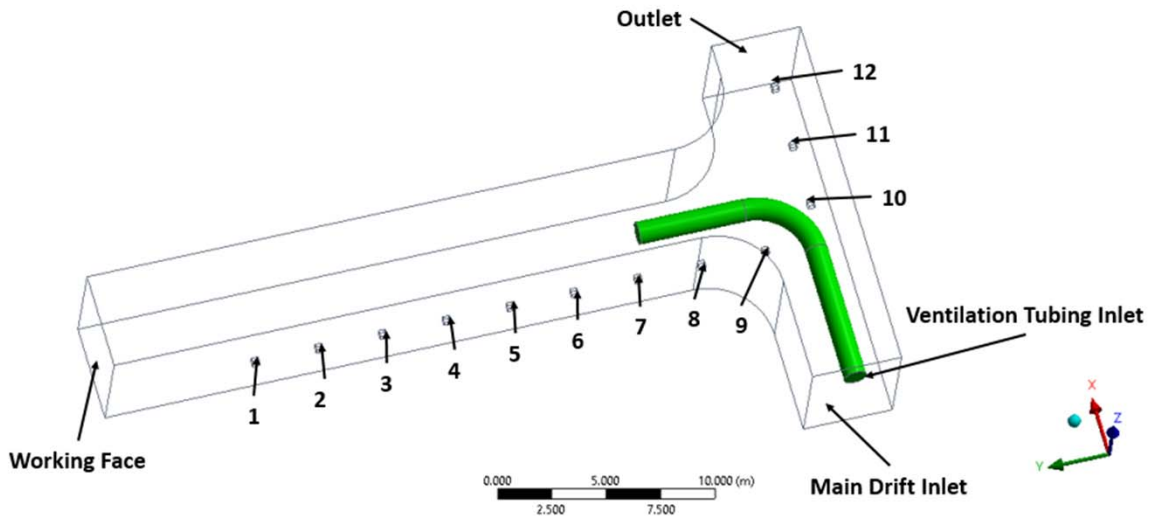
Possible DPM Profile From an LHD Tailpipe



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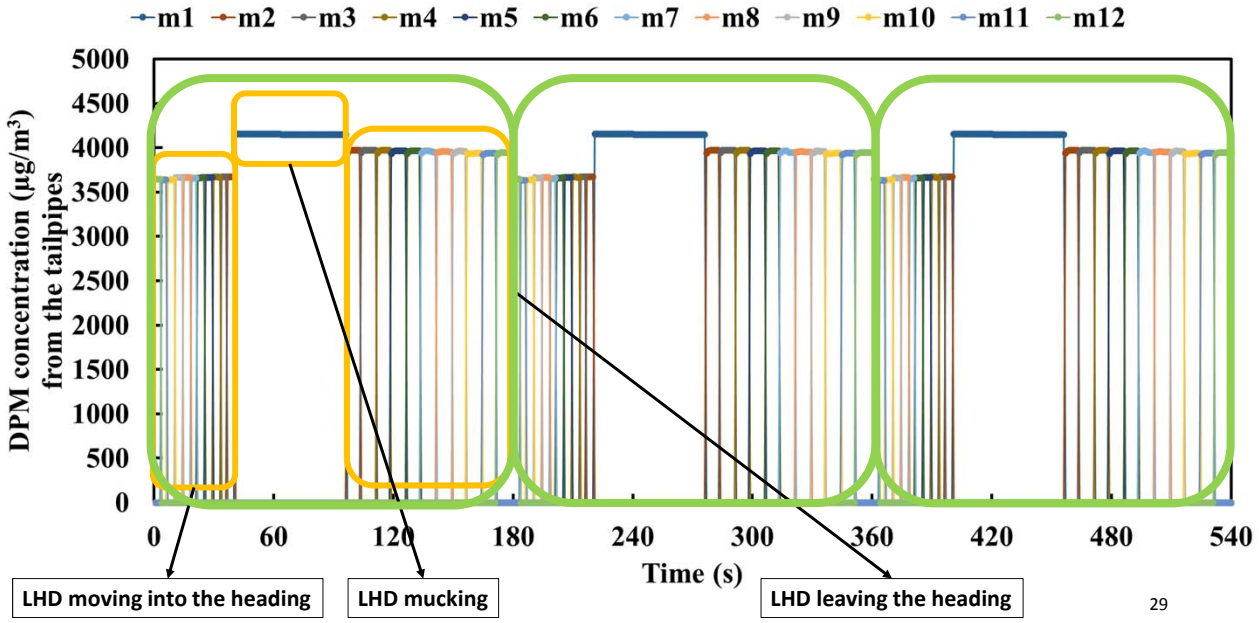
DPM Concentration Profile from the LHD Tailpipe



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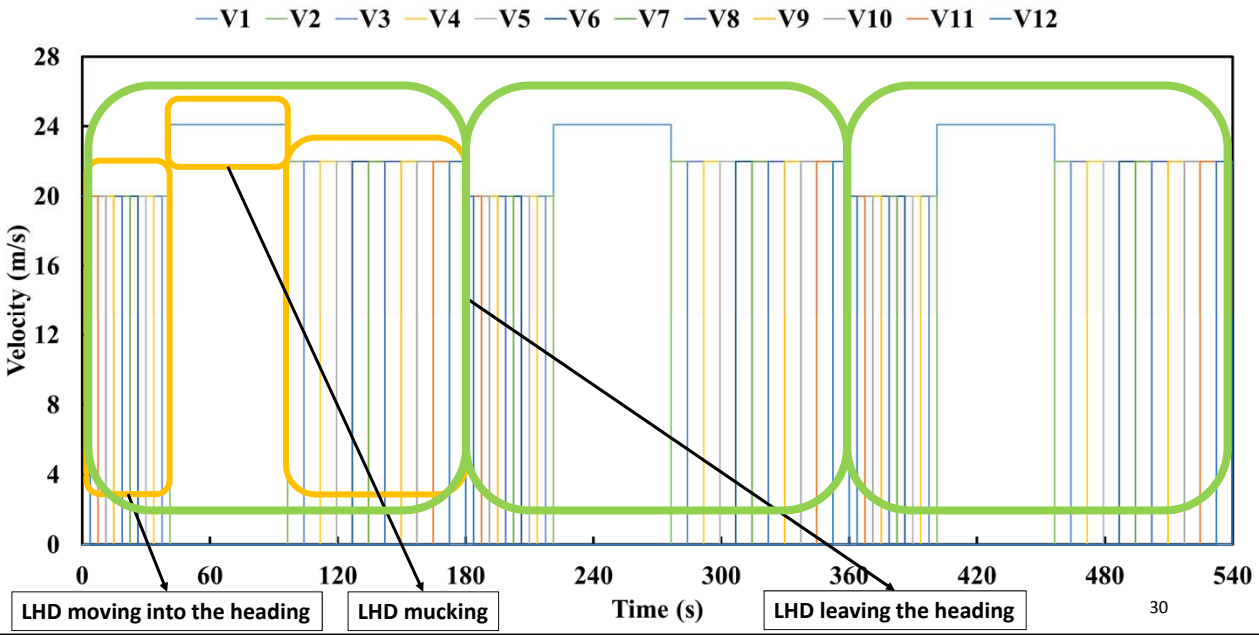
Velocity Profile from the LHD Tailpipe



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DPM Concentration Comparison at the Monitor Points

Distance from the face:

- **5 m**
- **8 m**
- **11 m**
- **14 m**

Ventilation tubing inlet velocity:

- 10.00 m/s
- 15.00 m/s
- 20.00 m/s
- 25.00 m/s
- 35.00 m/s
- 35.97 m/s

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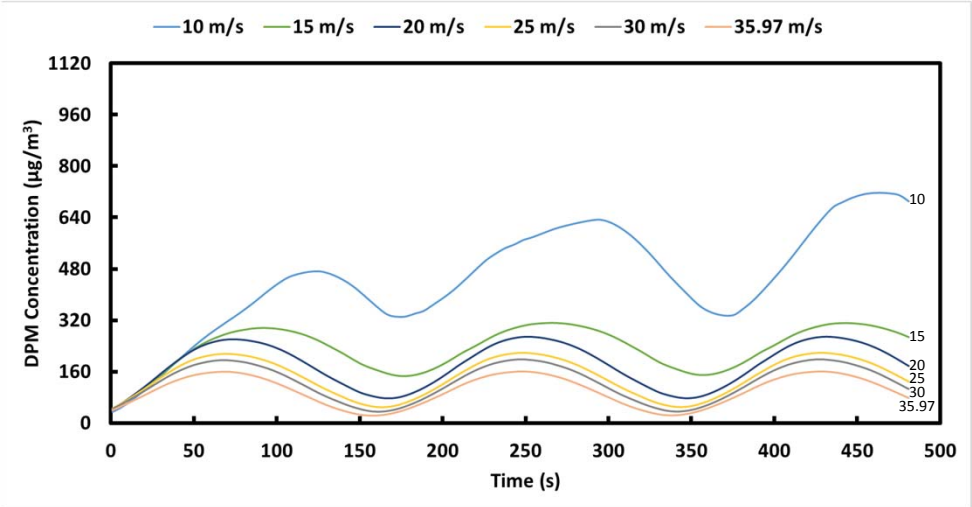
DPM Concentration Comparison at Monitor Point (5 m away from the face)



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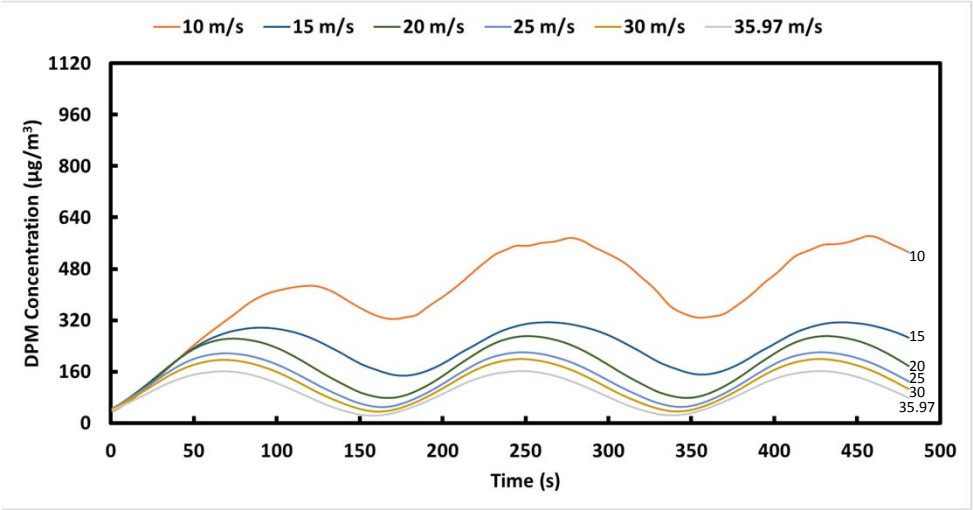
DPM Concentration Comparison at Monitor Point (8 m away from the face)



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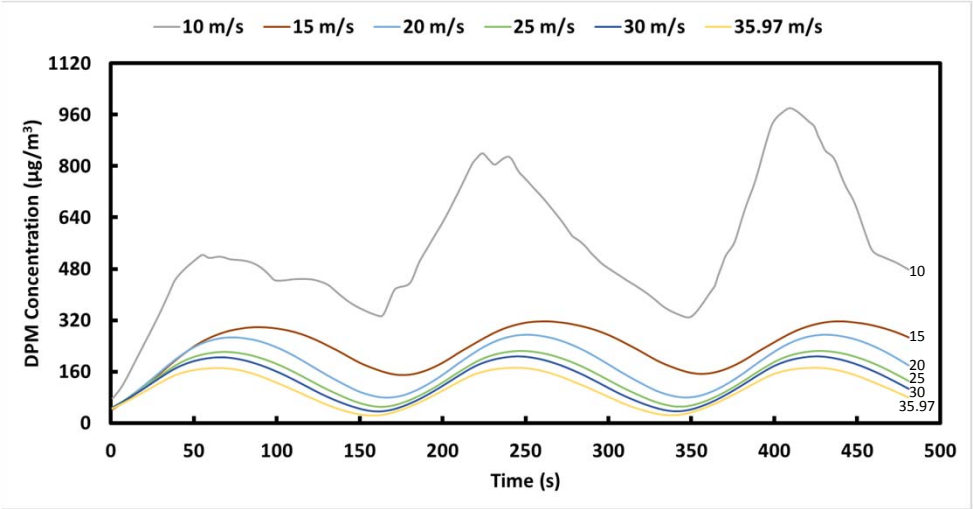
DPM Concentration Comparison at Monitor Point (11 m away from the face)



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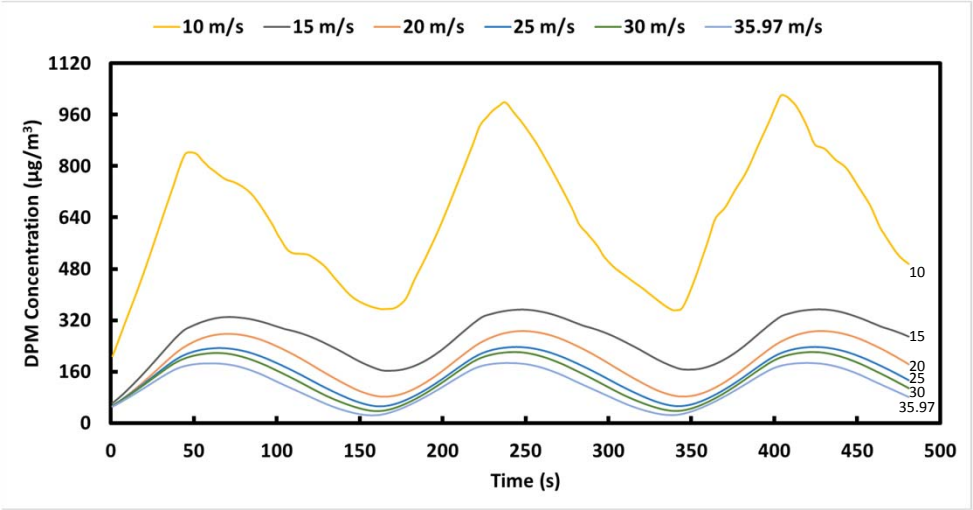
DPM Concentration Comparison at Monitor Point (14 m away from the face)



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DPM Concentration Comparison at the Monitor Planes

Distance from the face:

- **5 m**
- **8 m**
- **11 m**
- **14 m**

Ventilation tubing inlet velocity:

- 10.00 m/s
- 15.00 m/s
- 20.00 m/s
- 25.00 m/s
- 35.00 m/s
- 35.97 m/s

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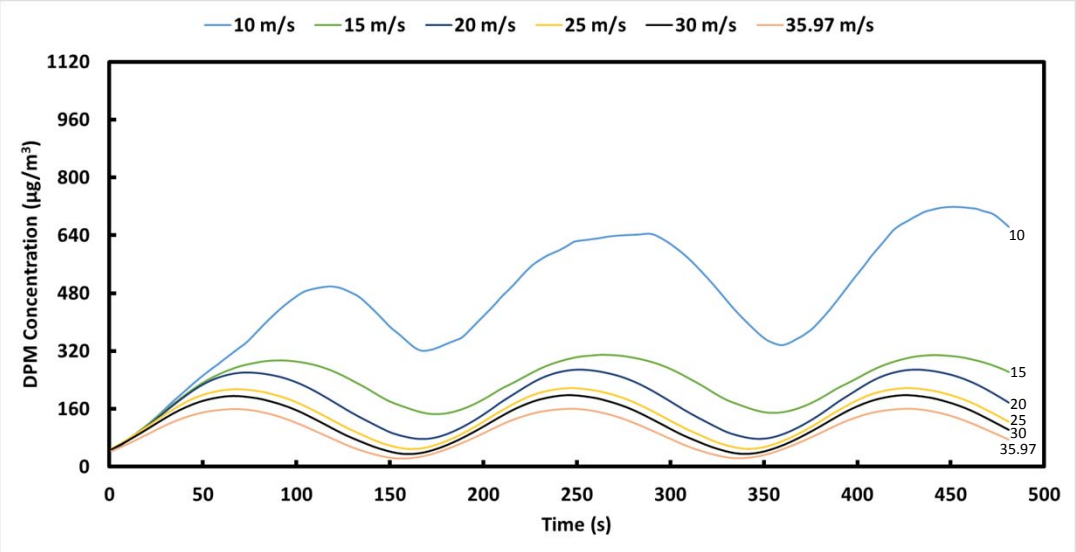
DPM Concentration Comparison at Monitor Plane (5 m away from the face)



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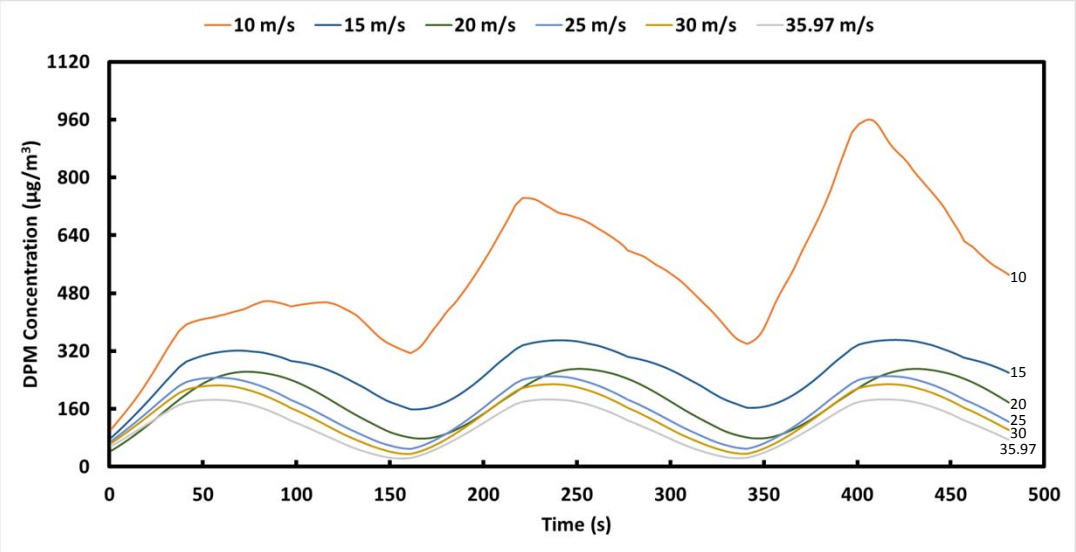
DPM Concentration Comparison at Monitor Plane (8 m away from the face)



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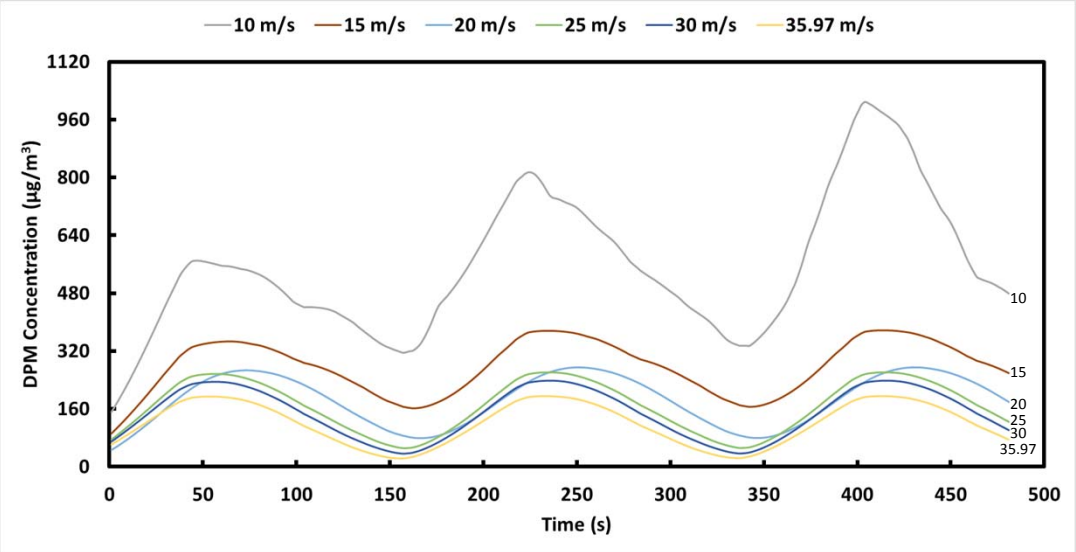
DPM Concentration Comparison at Monitor Plane (11 m away from the face)



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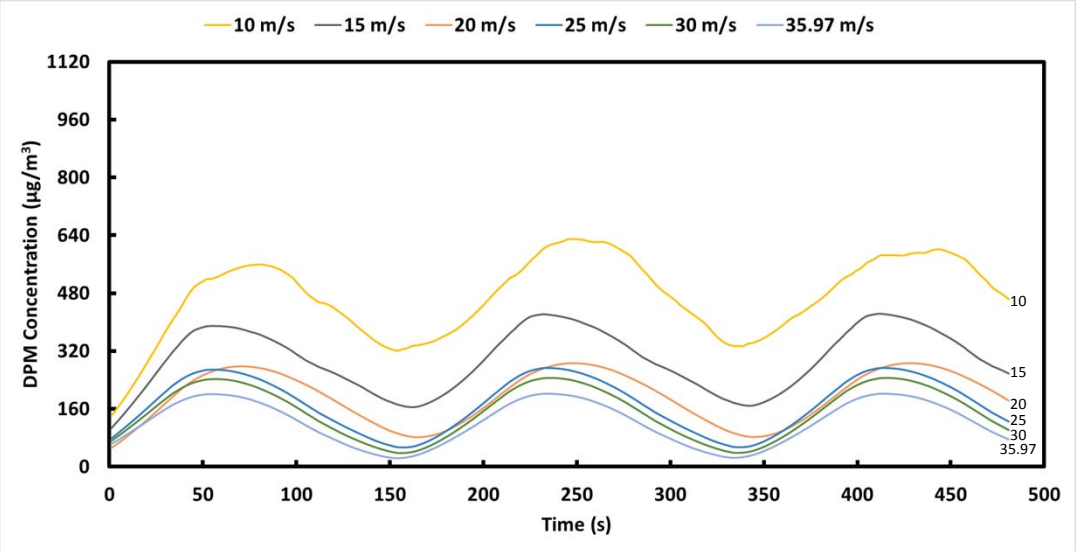
DPM Concentration Comparison at Monitor Plane (14 m away from the face)



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DPM Concentration Comparison at the Monitor Points

Ventilation tubing inlet velocity:

- **10.00 m/s**
- **15.00 m/s**
- **20.00 m/s**
- **25.00 m/s**
- **35.00 m/s**
- **35.97 m/s**

Distance from the face:

- 5 m
- 8 m
- 11 m
- 14 m

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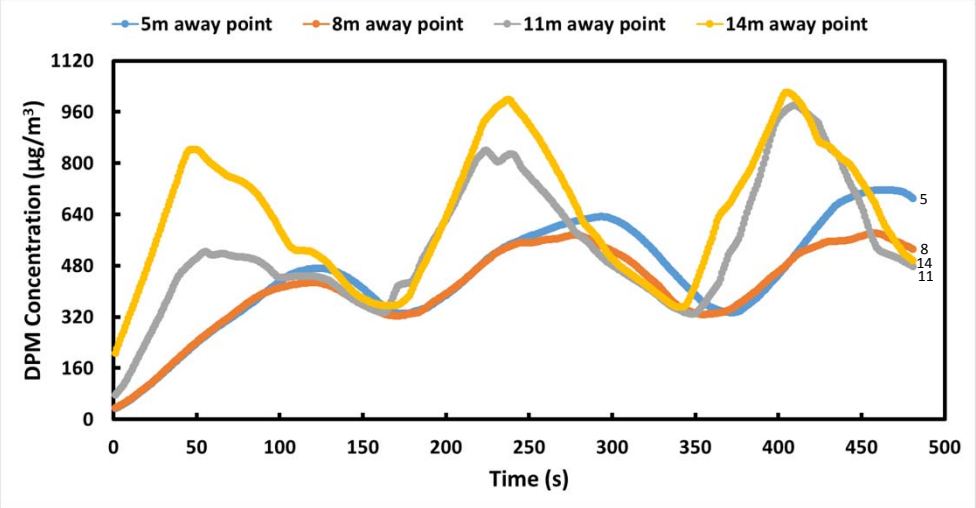
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 10 m/s)



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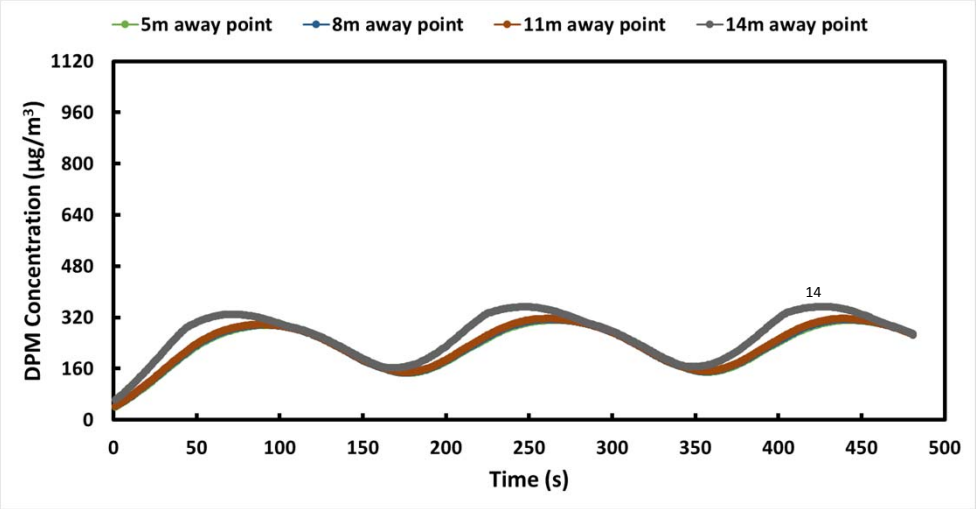
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 15 m/s)



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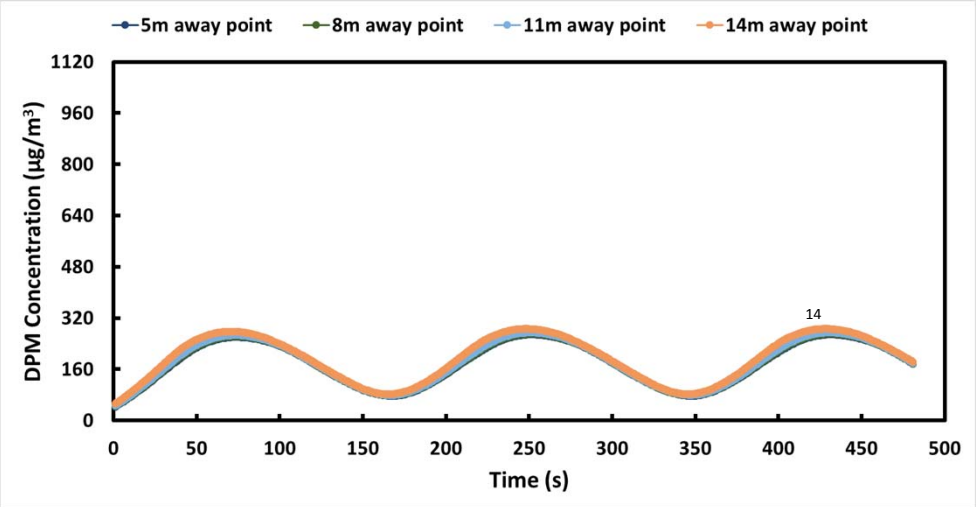
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 20 m/s)



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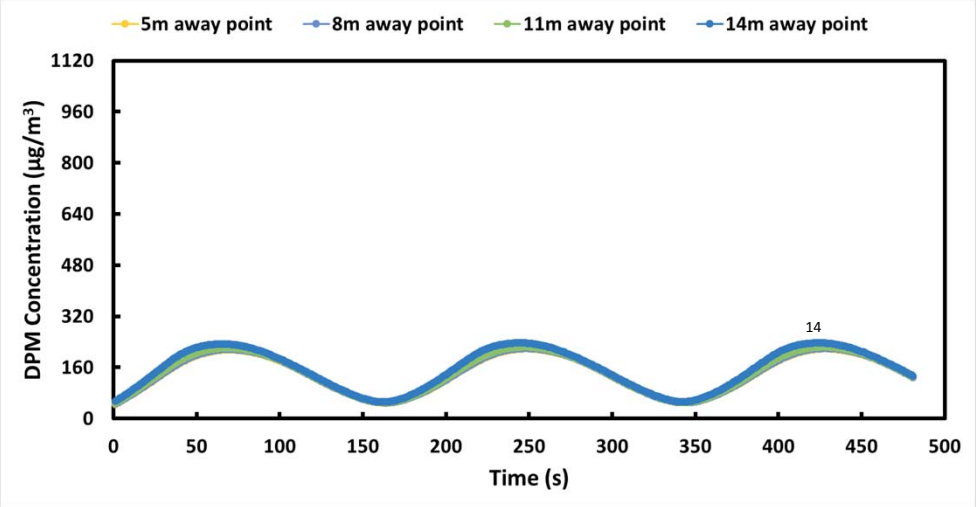
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 25 m/s)



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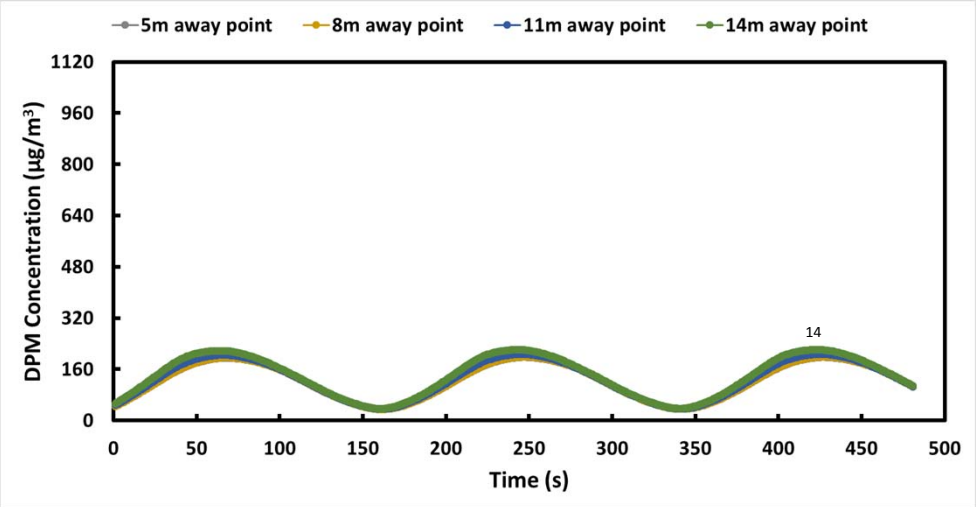
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 30 m/s)



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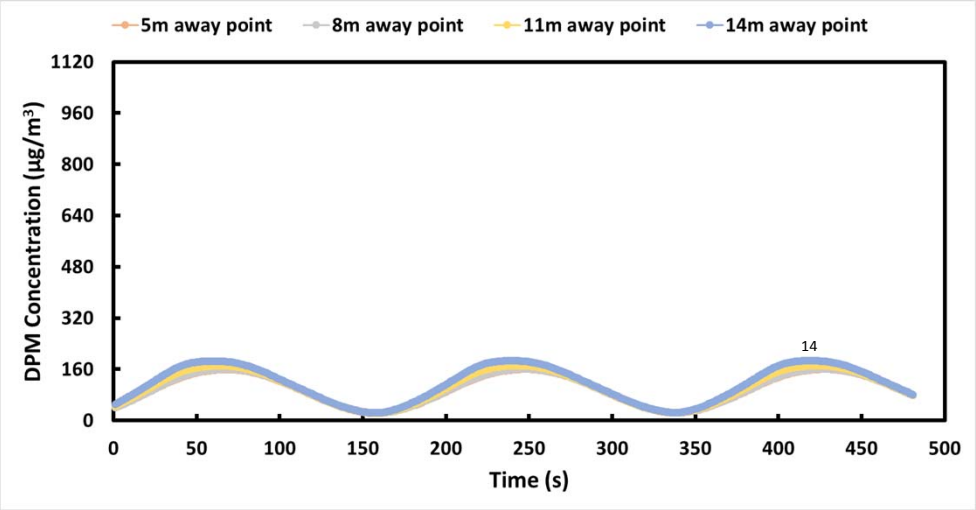
DPM Concentration Comparison at the Monitor Points (Ventilation Tubing Inlet Velocity = 35.97 m/s)



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DPM Concentration Comparison at the Monitor Planes

Ventilation tubing inlet velocity:

- **10.00 m/s**
- **15.00 m/s**
- **20.00 m/s**
- **25.00 m/s**
- **35.00 m/s**
- **35.97 m/s**

Distance from the face:

- 5 m
- 8 m
- 11 m
- 14 m

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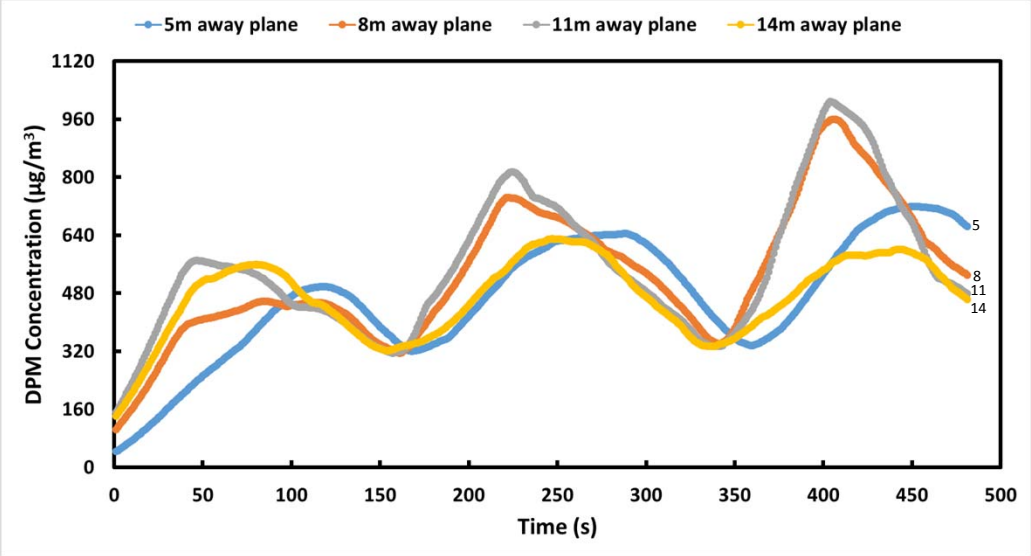
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 10 m/s)



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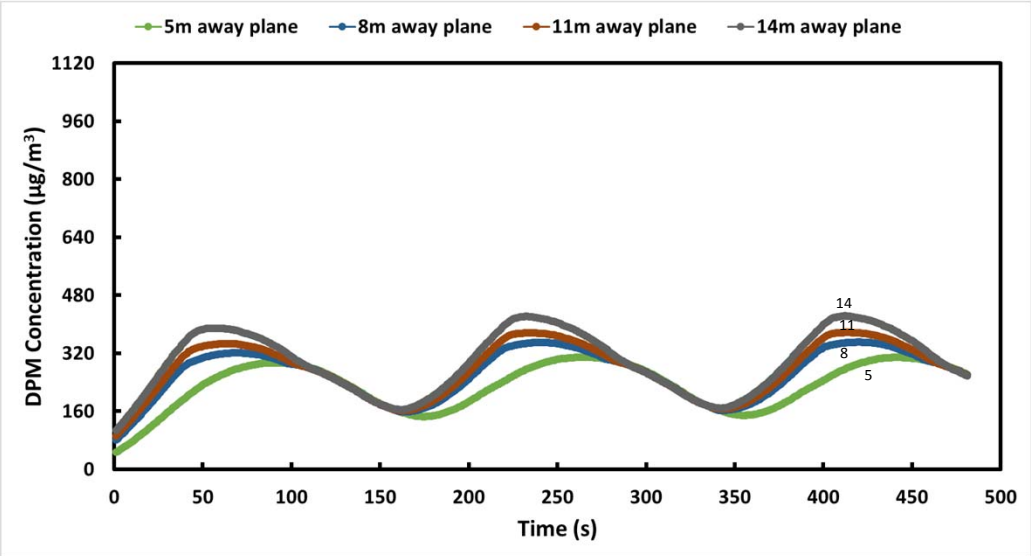
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 15 m/s)



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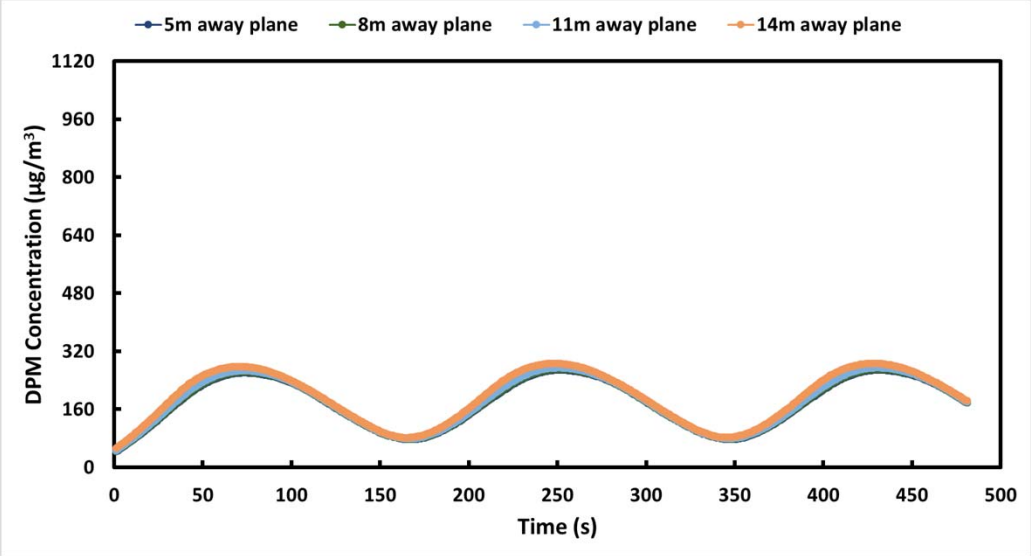
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 20 m/s)



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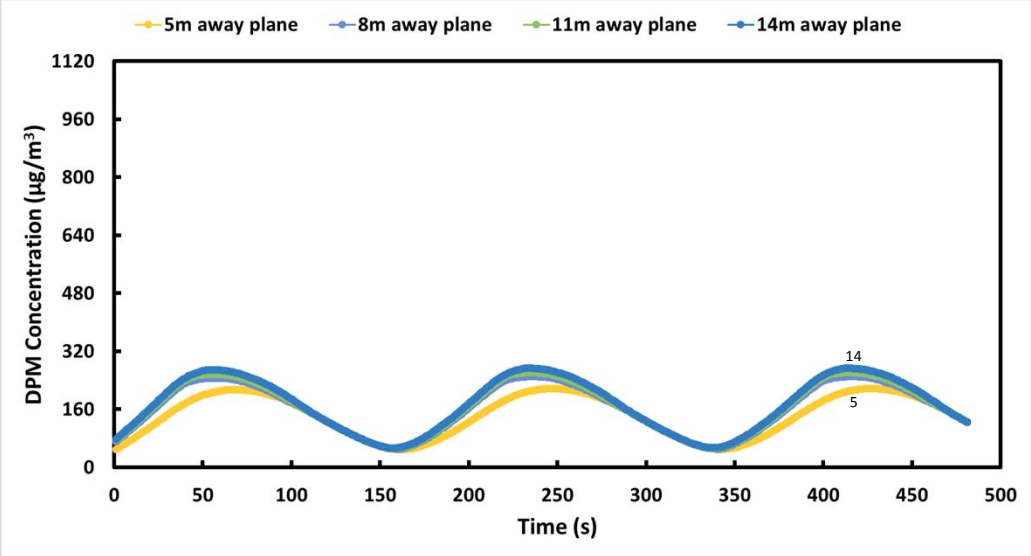
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 25 m/s)



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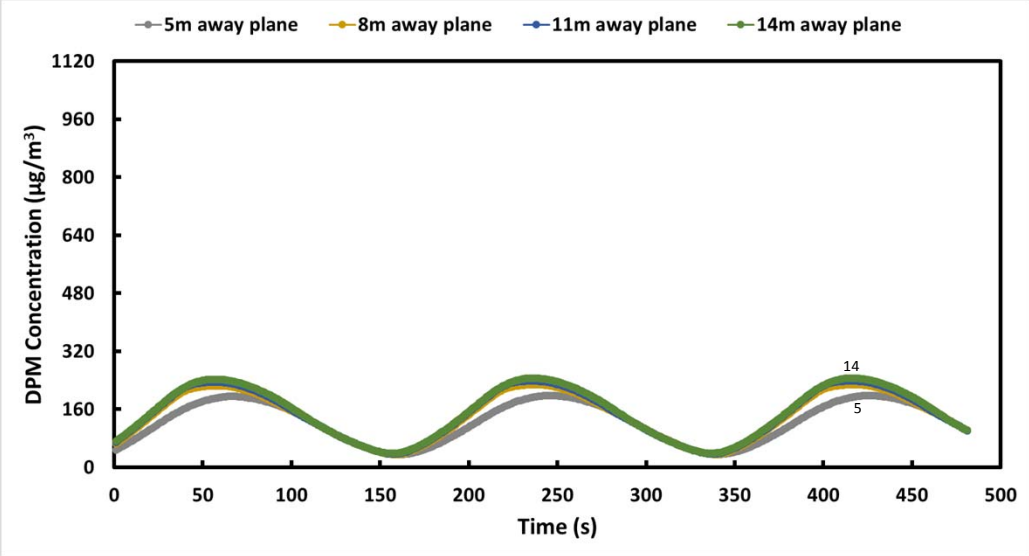
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 30 m/s)



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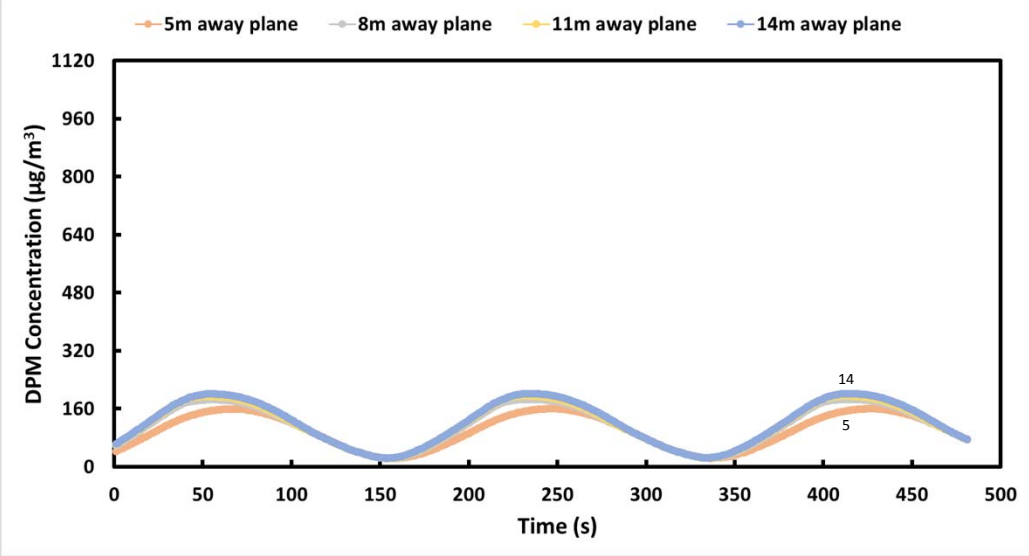
DPM Concentration Comparison at the Monitor Planes (Ventilation Tubing Inlet Velocity = 35.97 m/s)



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Conclusions and Future Work

- The lower the ventilation tubing inlet velocity, the higher the DPM concentration will get.
- When the ventilation tubing velocity is greater than 10 m/s, the highest DPM concentration does not increase significantly after the second work cycle of the LHD.
- The DPM concentration does not accumulate after each work cycle of the LHD; specifically, the lowest DPM concentration near the face does not increase.
- When the ventilation tubing inlet velocity is 10 m/s, the further the monitor is from the face (within 14 m), the higher the DPM concentration will be.
- When the ventilation tubing inlet velocity greater than 15 m/s, the DPM concentration profile along the heading does not vary over the work cycles of the LHD.

Future work:

- Results will be compared with experimental data
- Mesh independence study
- Sensitivity study on the spacing between the tailpipes
- Test the effects from different locations of the ventilation tubing in the heading
- Apply the findings to the Schedule Optimization Tool (SOT)

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Thank you

Prof. Ming Cai

Prof. Felipe Calizaya

Dr. Lorrie Fava

Dr. Jozef Stachulak

Prof. Nick Vayenas

CANMET

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