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2019 Nano diesel particulate matter (nDPM) Forum

MRIWA Project M495: A Study of Nano Diesel Particulate Matter (nDPM) Behaviour and Physico-chemical Changes in Underground Hard Rock Mines of Western Australia.

- Part B (Curtin-Led Component)

A/Prof Ben Mullins, Curtin University

DMIRS, 29 July 2019

ChemCentre EXPERT SOLUTIONS

Curtin University

Aims

- The overall aim of this component of the study was to better understand (n)DPM and related emissions and their transport in current and (future) deeper mines.

Via:

- a. Stationary Monitoring.
- b. Personal Monitoring (input to health study)
- c. Computational fluid dynamics study of nDPM transport.
- d. Deeper mine (chamber) study

Components of Study

1. In-mine study:

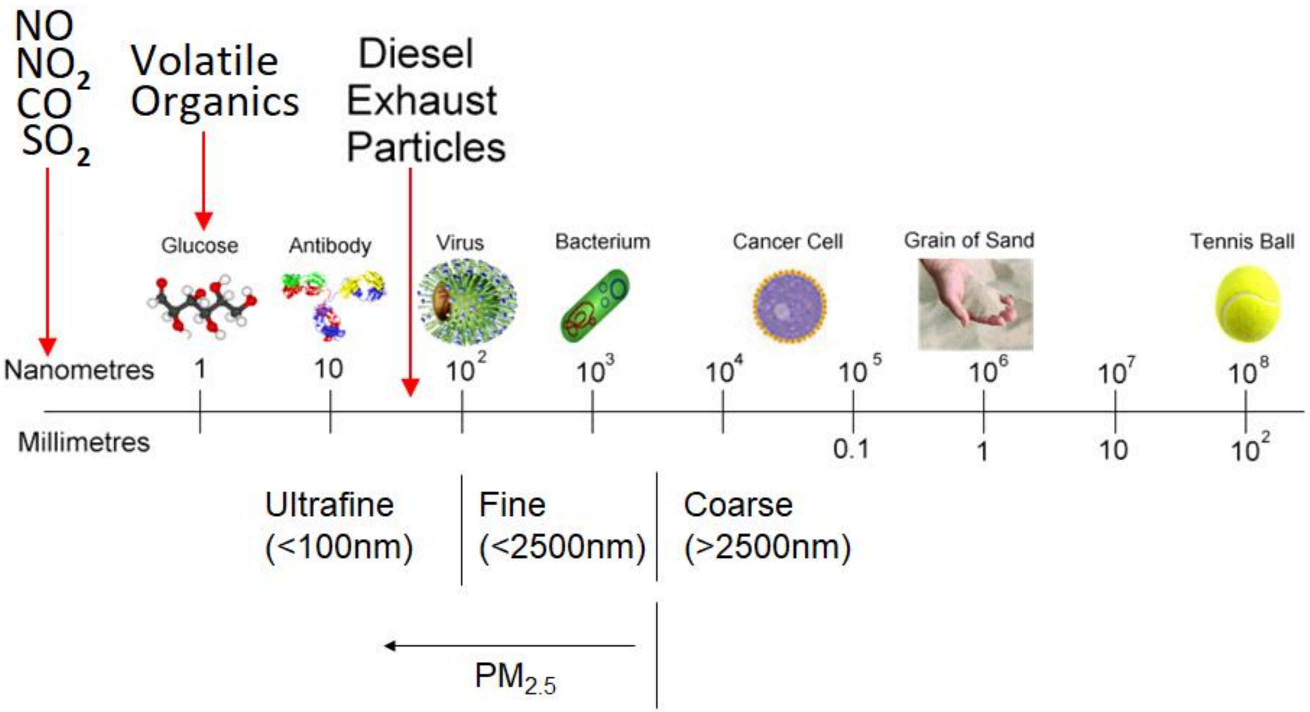
- Stationary Monitoring
- Mobile Monitoring
- Personal Monitoring

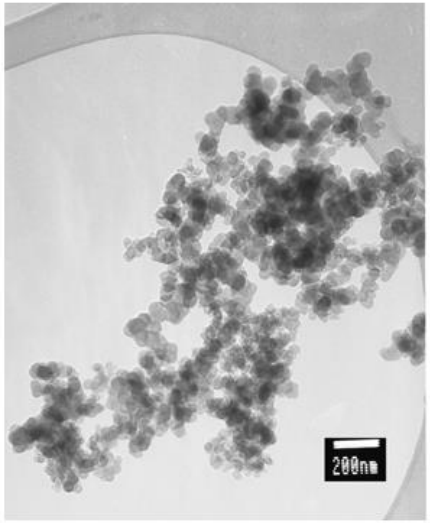
2. CFD simulation of key activities/regions in the mine.

3. Simulated (deeper) Mine Experiments – ageing of diesel exhaust and secondary organic aerosol formation

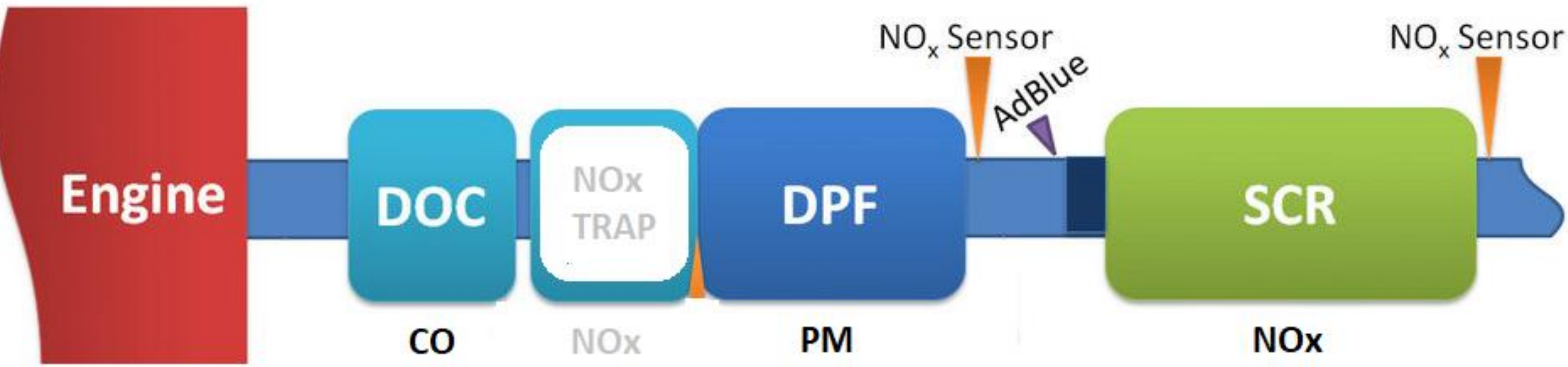
- Influence of pressure (up to ~4 km depth)
- Influence of ammonia (Ad-Blue and ANFO)

Major components of diesel exhaust





Diesel Emissions Control



Equipment

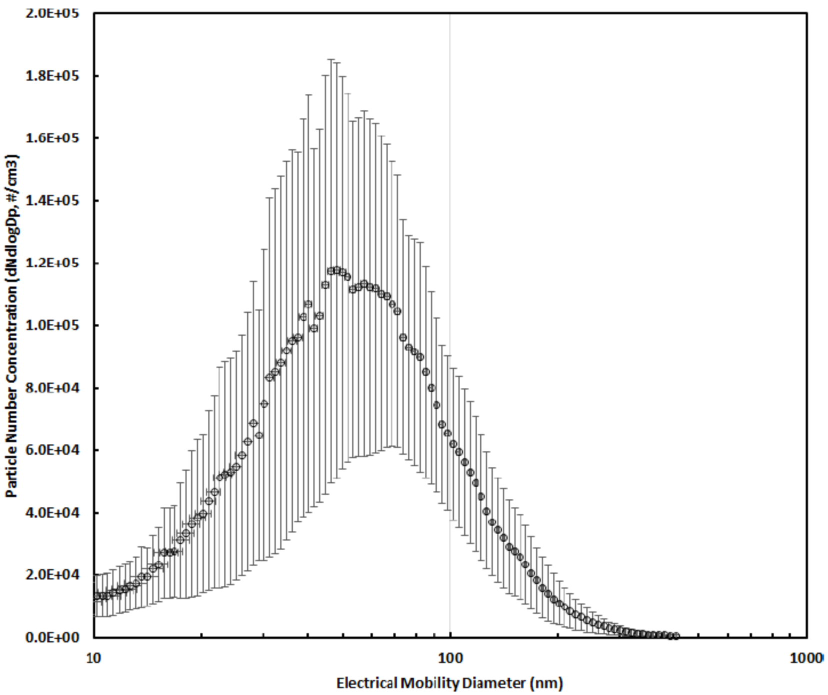
Stationary (2 setups)

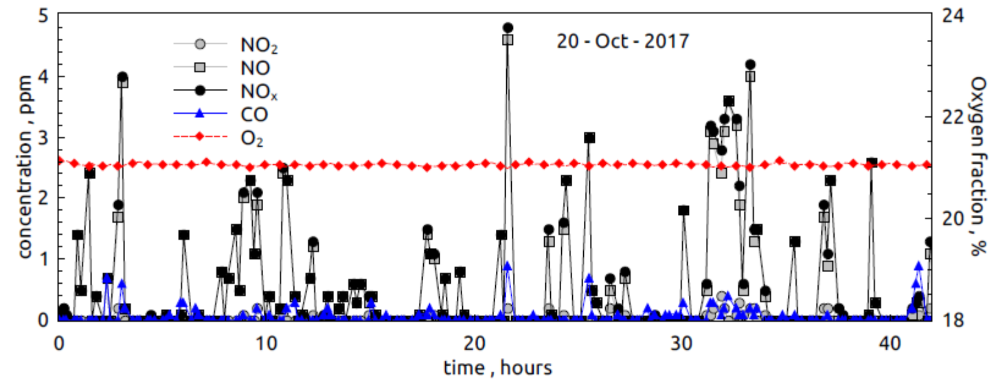
- **EC** - SKC Cyclone/Pump
- **(nano)Particle Spectrometry** – SMPS
- **Gases** – Testo 350
- **$PM_{0.1}$-PM_{32}** – PALAS Frog OPC
- **PAHs** – Tenax Tubes & SKC Pump

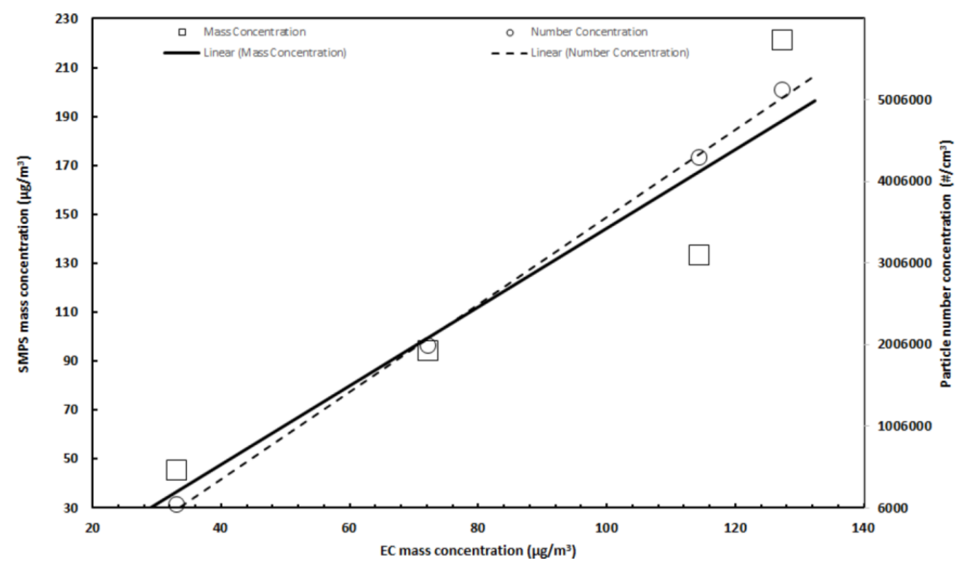
Personal Monitoring

- **EC** - SKC Cyclone/Pump
- **Particle Number/Size (& Mass)** - DiSCMini
- **NO_2, SO_x and VOCs** – Passive Samplers

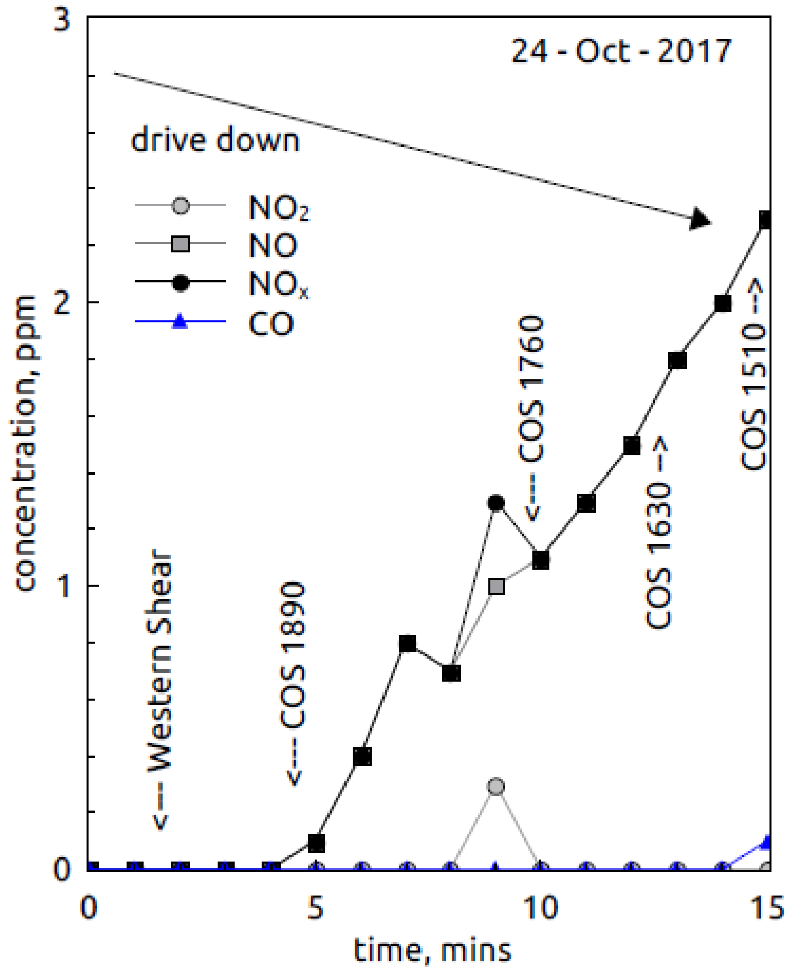
Stationary Monitoring Results



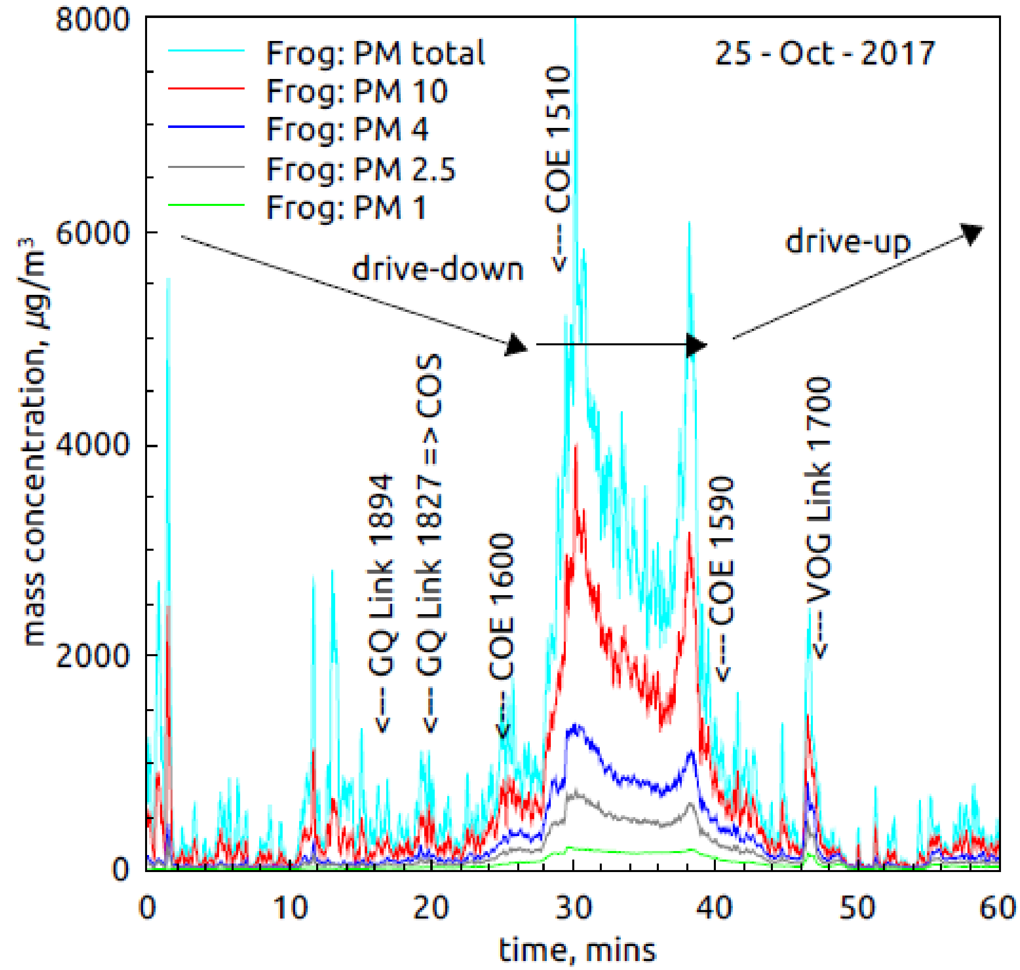




Mobile Monitoring Results

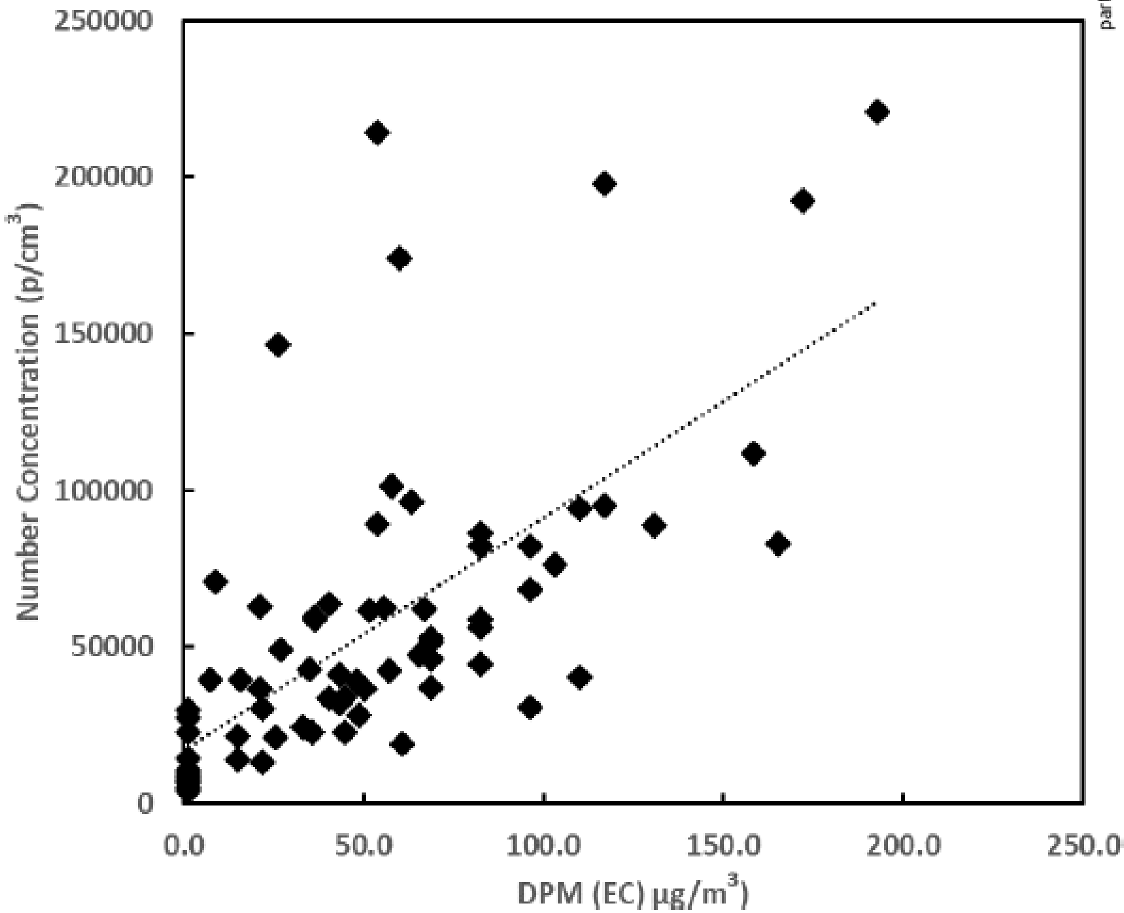


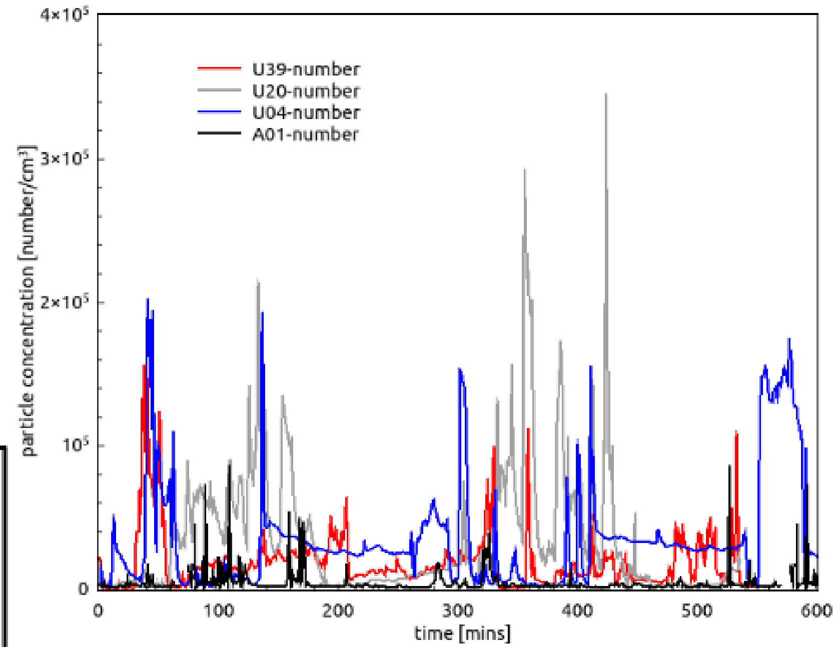
(a) gas data

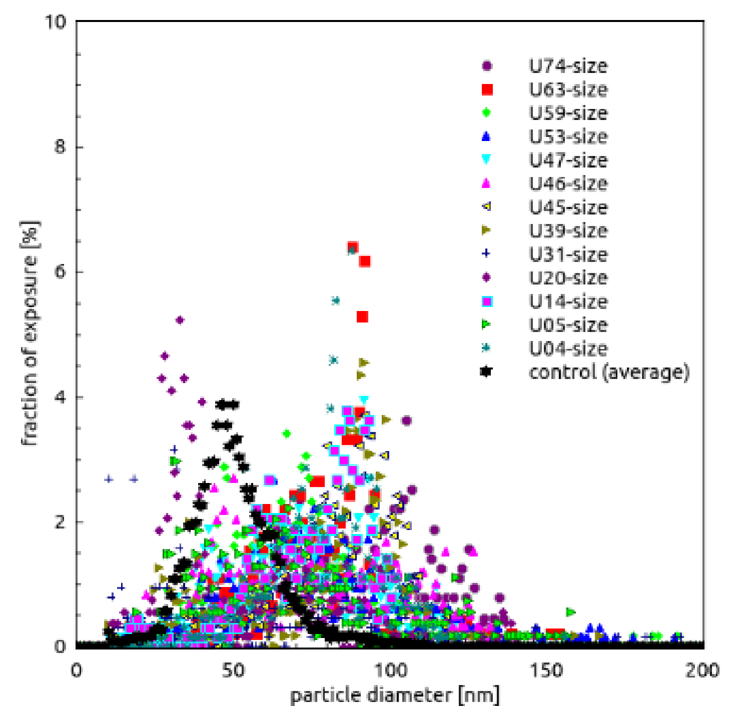


(b) DPM data

Personal Monitoring Results



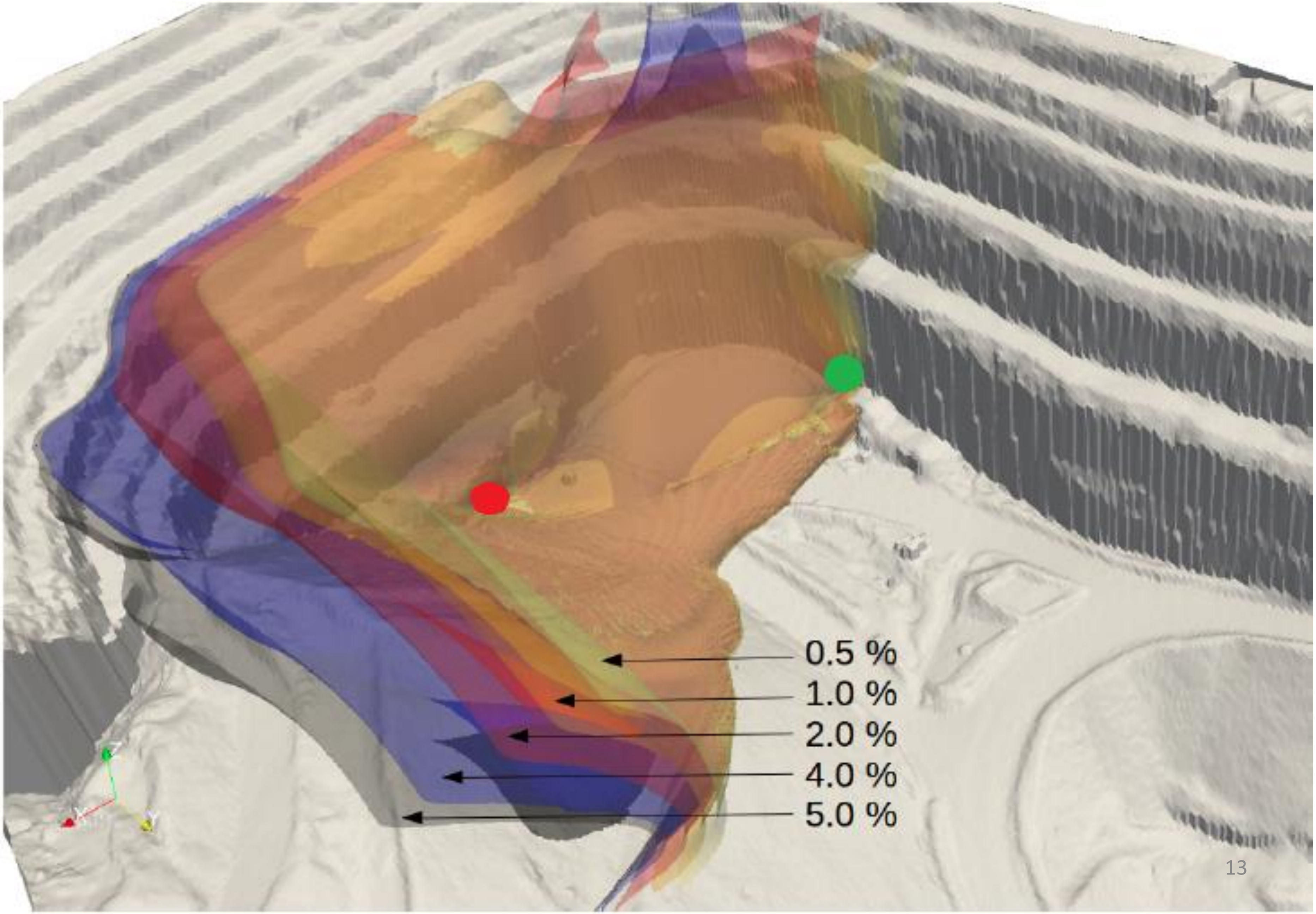




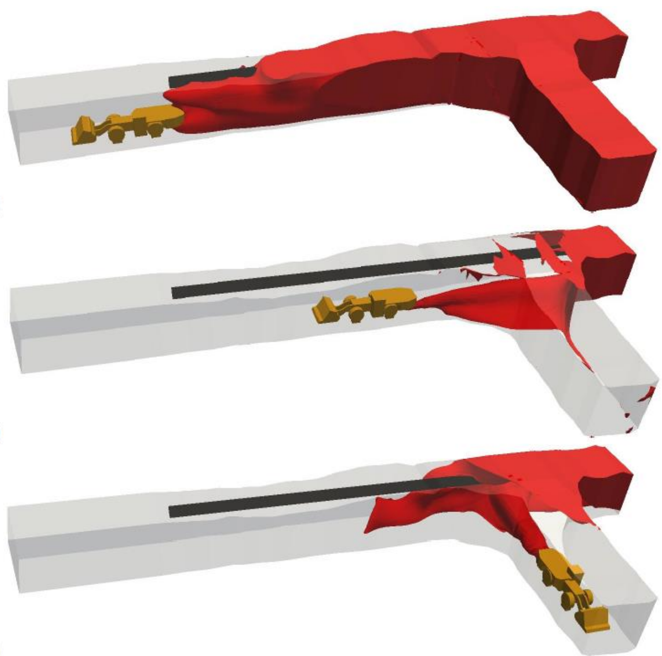
Monitoring Results

- Both stationary and personal monitoring found a significant agreement between EC and particle number concentration.
- Difference in relationship due to resolution between DiSCMini and SMPS.
- NO_x around 10x higher than NO_2. Passive samplers can only measure NO_2.
- Mobile monitoring very useful tool for understanding ventilation performance at current levels of mine activity.

CFD Study Results



CFD Study Results



(a)

(b)

(c)

Figure 23: Regions where DPM concentrations are greater than 0.1 mg/m^3 in the mine region during bogging activity

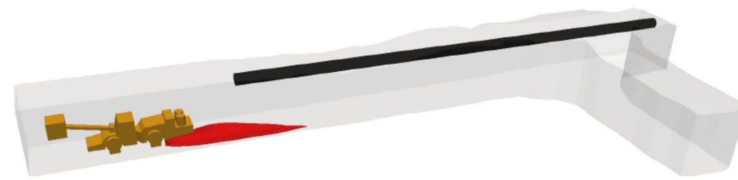
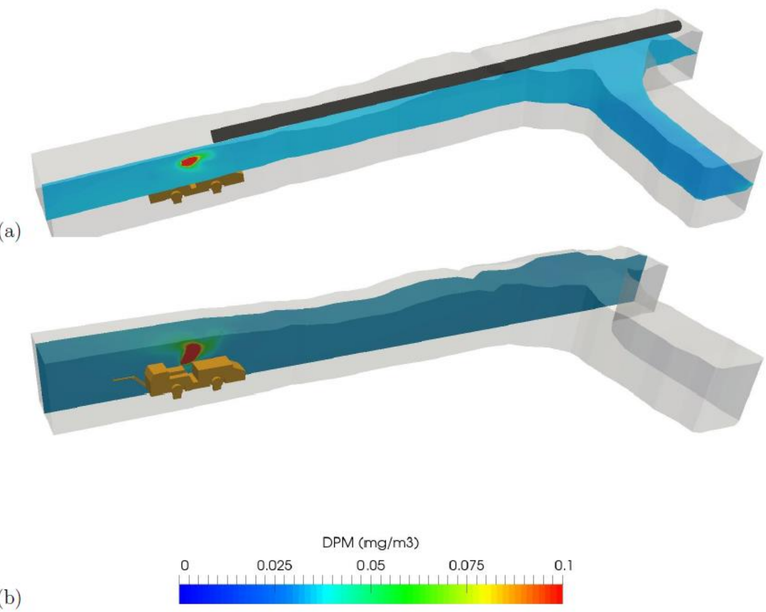


Figure 26: Regions where DPM concentrations are greater than 0.1 mg/m^3 in the mine region during charging activity

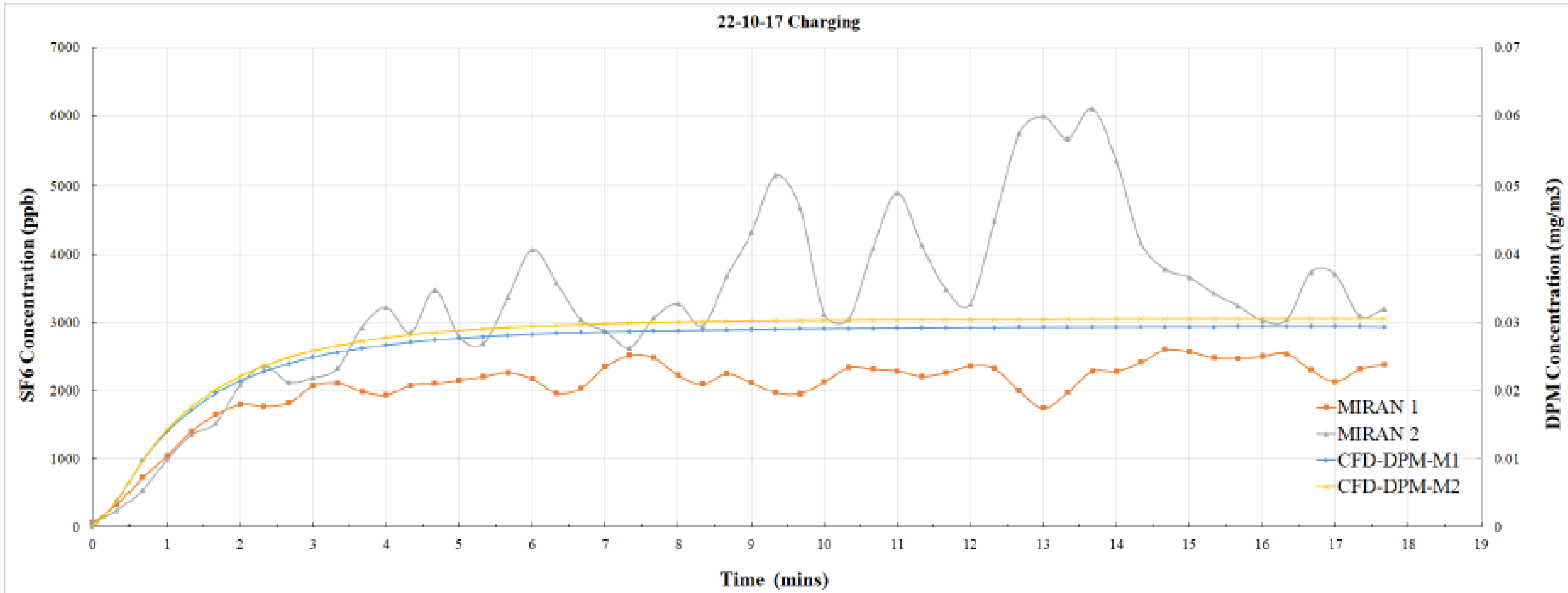


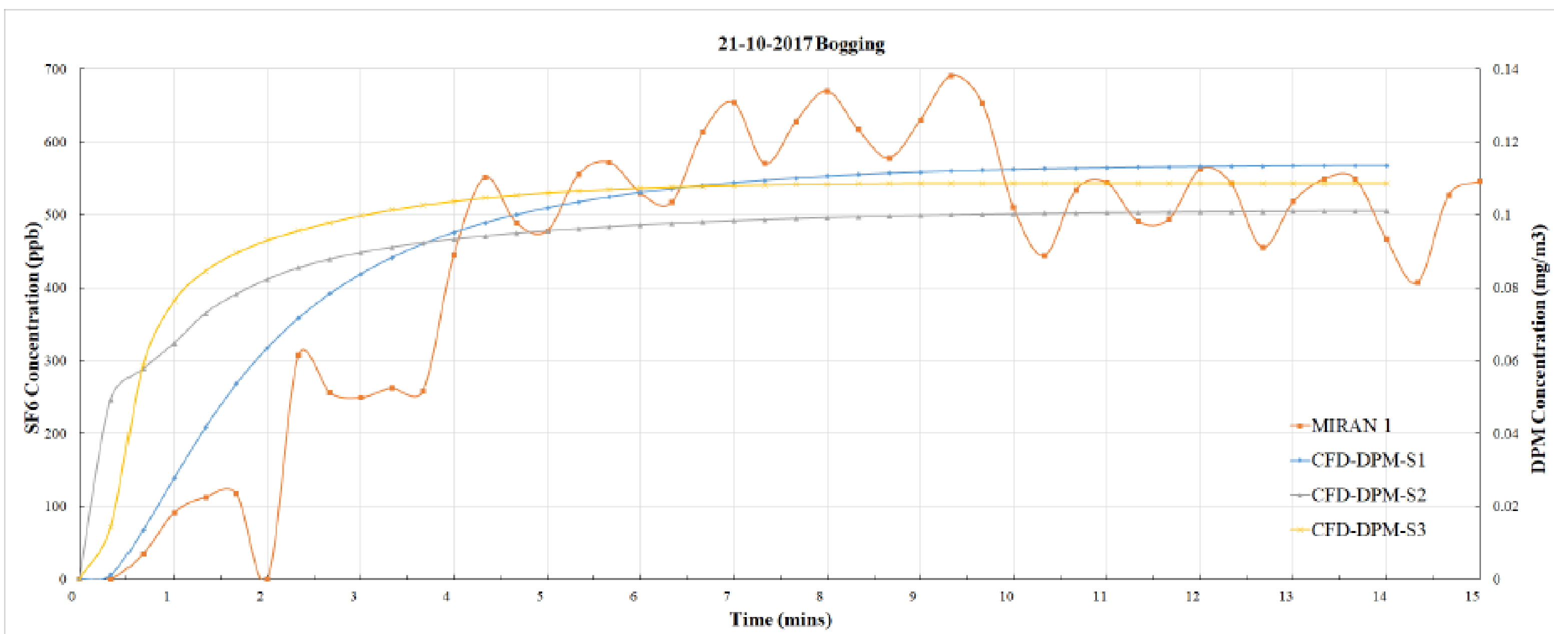
(a)

(b)

Figure 17: Contours of DPM concentration in the mine region during shotcreting activity

CFD Study Results





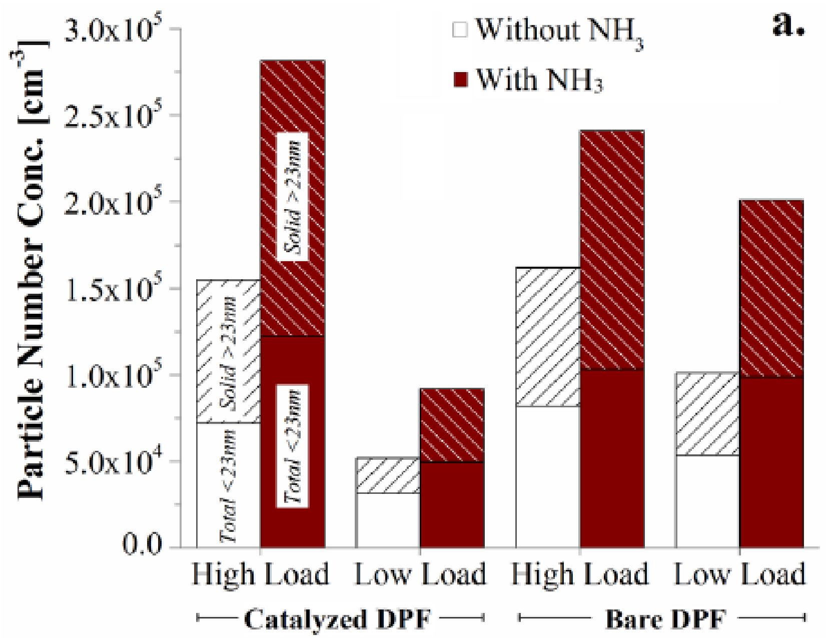
Summary – CFD Results

- CFD Appears to be a useful tool to manage DPM as it offers higher resolution than conventional 1D tools (e.g. Ventsim)
- Good agreement was found between CFD and average tracer gas measurements
- CFD also useful to design portal arrangement

Deeper Mine Study Results

Rationale:

- UV and ozone can combine with diesel emissions (above ground) to form "new" nanoparticles.
- Ammonia (from AdBlue) can also create new nanoparticles
- These "secondary organic aerosols" can be highly toxic



Amantidas et al. (2014)

Deeper Mine Study

Chamber simulating mine up to 4 km depth.

- Findings: Pressure cannot replace Ozone and UV to create new particles. No significant changes to nDPM at pressures <1.4 atm (~4 km depth). OH radicals (or NH_3) needed to create SOA.
- Need to ensure no sources of Ozone or UV in the mine (e.g. electric motors or switchgear, lights that emit in UV spectrum).
- Residual NH_3 causes SOA formation however levels insignificant in engines without DPF. Benefits of SCR likely outweigh disadvantages.

Summary / Key Findings

- Despite significant changes in diesel engine technology, there remains a good agreement between EC and particle number.

- Realtime instruments such as the DiSCMini – which “count” nanoparticles (via electrical charges), or high resolution optical particle counters, are useful tools for managing DPM in mines.

Summary / Key Findings (cont.)

- NO_x monitoring is also a very important management tool.
- CFD should be incorporated into ventilation design – at minimum when designing portal location
- It is important to ensure that all lighting and electrical equipment in use in the mine does not emit UV.

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- QUT: Reece Brown, Joel Alroe, Zoran Ristovski.