Nano Diesel Particulate Matter in the Underground Mine environment

A Sequal to a paper authored by

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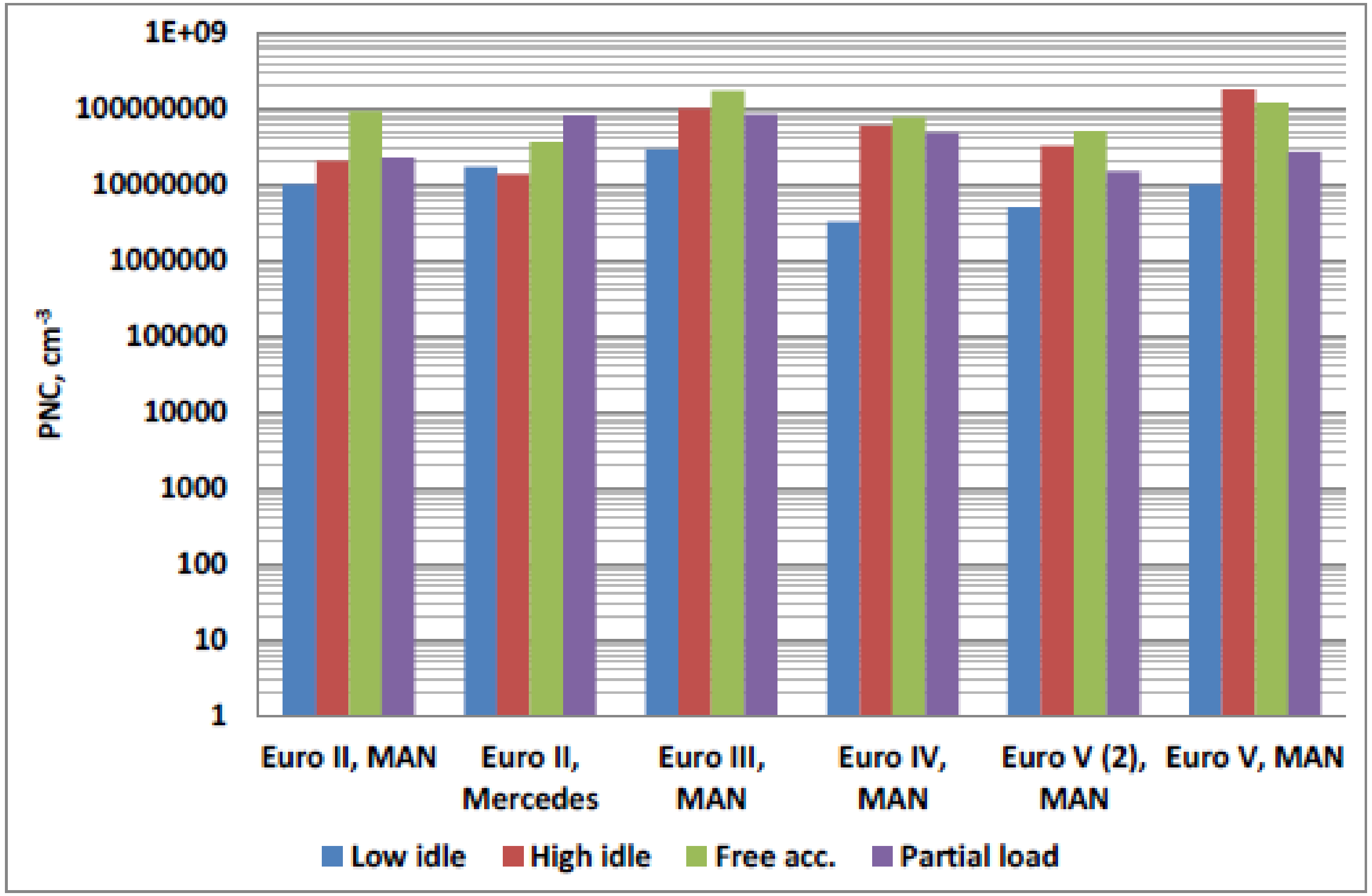
Recognition of diesel engine fumes as carcinogenic

- USA National Institute for Occupational Safety and Health (NIOSH) and the National Cancer Institute's (NCI) 20-year Diesel Exhaust in Miners Study (2012)
- International Agency for Research on Cancer (IARC) re-categorised diesel exhaust as "Carcinogenic to Humans – Group 1", (2012)

Nanoparticle number concentrations

Steady-state regimes



Complexity of the issue

- Proximity of mineworker to the source
- Level, duration and variability of exposure
- The type, condition, age, duty cycle and number of the diesel engines
- The effectiveness of a mine ventilation system in diluting the pollutants both locally and throughout the ventilation circuit
- Control measures in place, including tail-pipe after treatment devices and their effectiveness
- The temperature and humidity of the ambient air flow

Composition of Diesel Engine Exhaust Fumes

Include, (this is not an exhaustive list)

- Carbon monoxide
- Oxides of nitrogen NOX
- Sulphur dioxide SOX
- Volatile organic compounds including benzene and toluene VOC
- Polycyclic aromatic hydrocarbons PAH

And last but not least

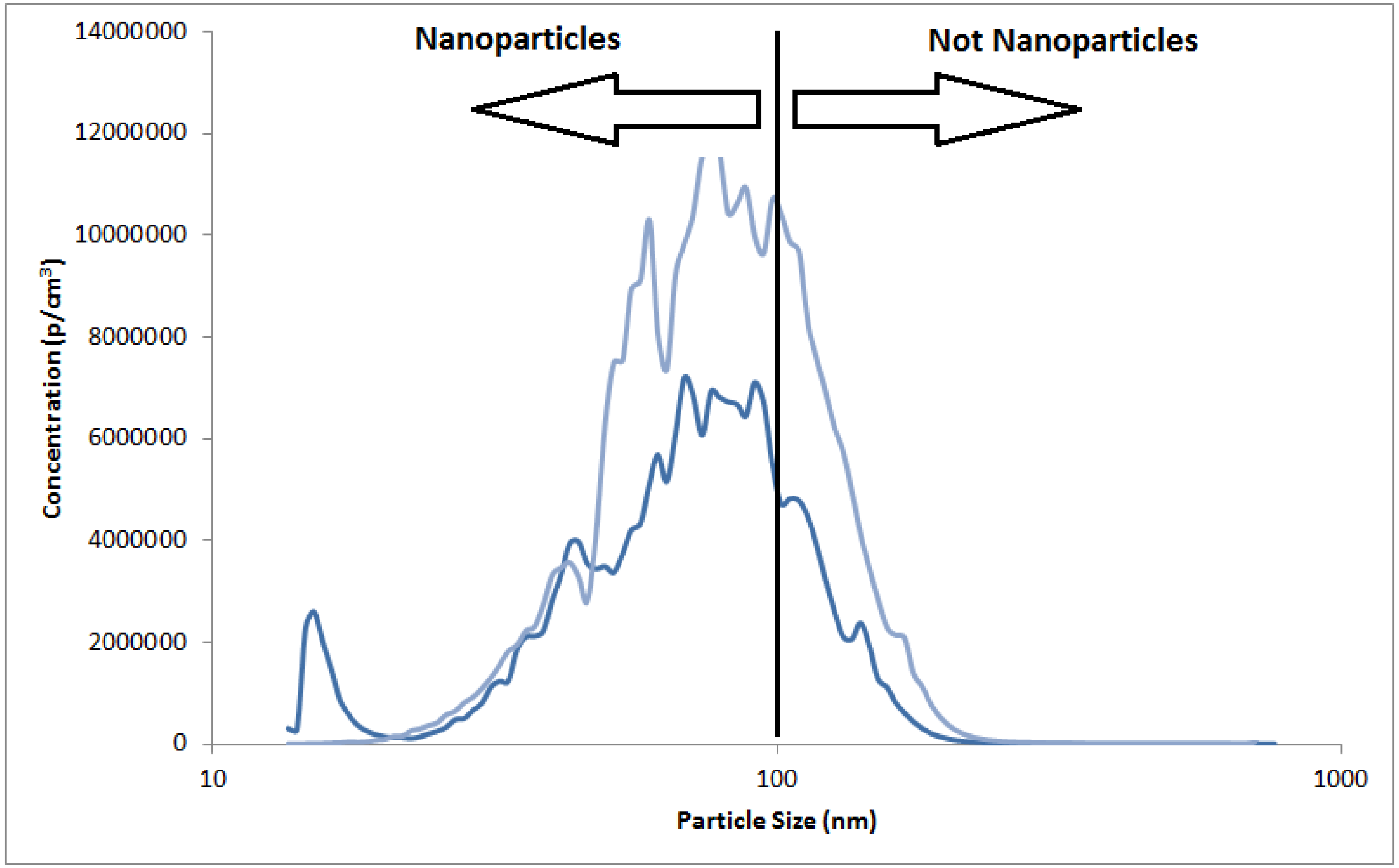
- Unburnt carbon particulates , both + micron, and
- Nano DPM

Diesel engine exhaust fumes

How do they get around?

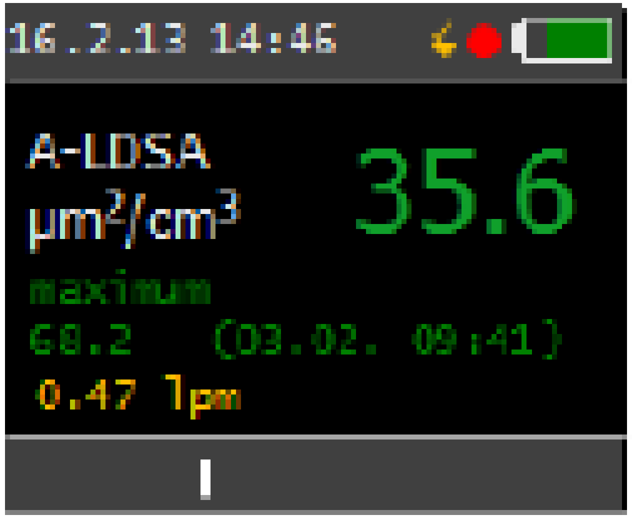
- They move with the ventilation flow
- They may condense among themselves or on the surface of large carbon particles and settle out
- Or they may hitch a ride on nDPM

There are a lot of them!



Real Current measurements

Activity	Monitor Location	Air Flow (m3/s)	Machine - Engine kW	Av number of particles per cubic centimetre	Av Diameter (nm)	Av LDSA (um2/m3	Av Mass (ug/m3)	DPF
Bogger	In Drive	14	R1700 - 242kW	109,000	74	405	342	Mammoth
Bogger	In Cabin	14	R1700 - 242kW	67,000	71	185	63	Mammoth
Bogger	In Drive	20.5	LH410 - 220kW	885,000	59	2337	589	Mammoth
Shotcrete	In Drive	28	Normet - 74.9kW	149,000	60	421	119	Mammoth
Bogger	In Cabin	13	LH621 - 345kW	50,000	50	134	30	No DPF - Tier 4i
Bogger	In Drive	13	LH621 - 345kW	170,000	61	513	172	No DPF - Tier 4i
Bogger	In Cabin	36	R2900 - 333kW	79,000	73	290	152	Cat - Original
Shotcrete	In Drive	13	Jacon Combo 6000 - 207kW + Agi Combo 6000 - 205kW	1,191,000	66	3011	1,271	Mammoth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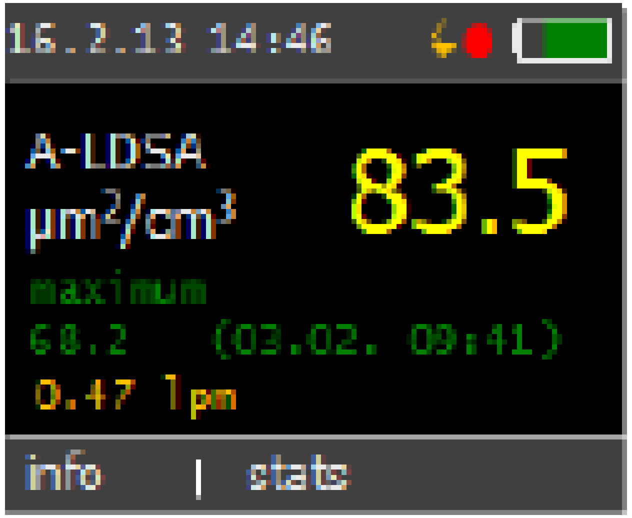
A-LDSA
$\mu m^2/cm^3$
35.6
maximum
68.2 (03.02. 09:41)
0.47 lpm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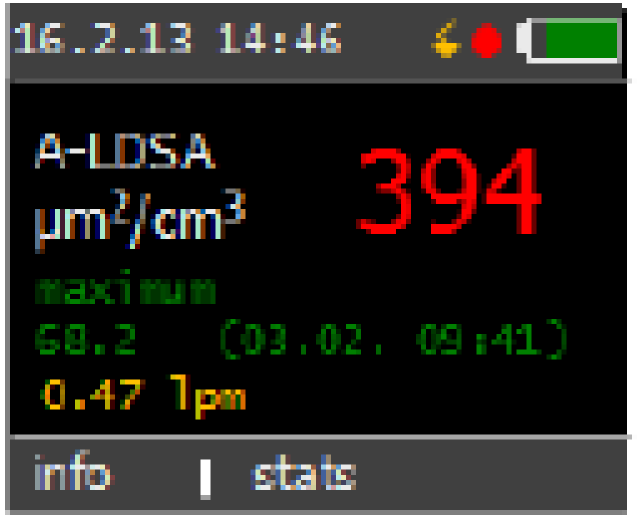
68.2 (03.02. 09:41)
0.47 lpm
info
stats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A-LDSA
$\mu m^2/cm^3$
394
maximum
68.2 (03.02. 09:41)
0.47 lpm
info
stats

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Impact on the respiratory system

- + micron sizes deposit in the trachea-bronchial tract and are cleared within minutes / hours / days of inhalation by coughing, sneezing, swallowing and/or spitting
- But the – 500 nm particles can take weeks or months to clear
- This long retention allows
  - interactions with the alveolar cellular lining, which is not evolved for this exposure
  - transport across the pleural membrane into the blood stream and onward

Outcomes

There have been a host of recent papers on the consequences of long term exposure to diesel exhaust fumes. A sample of these are

• Peters et al (2016)	Lung cancer
• Latifofic et al (2015)	Bladder cancer
• Duan et al (2016)	DNA damage

Ultrafine particle dangers
(University of Edinburgh)

- More health effects coming to light:
- AIR QUALITY AND HEALTH WORKSHOP: Fate and transport of ultrafine particles
  - Dr Nicholas Mills, University of Edinburgh

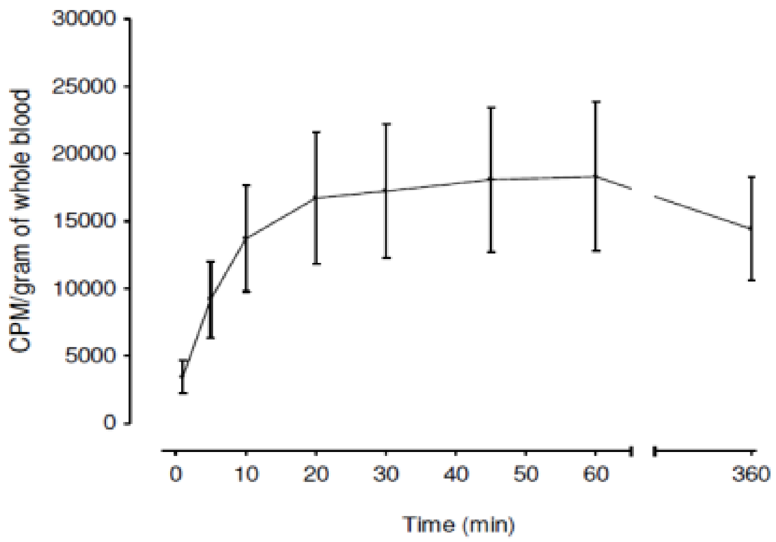
Human exposure studies to understand the effect of air pollution on the heart and blood vessels

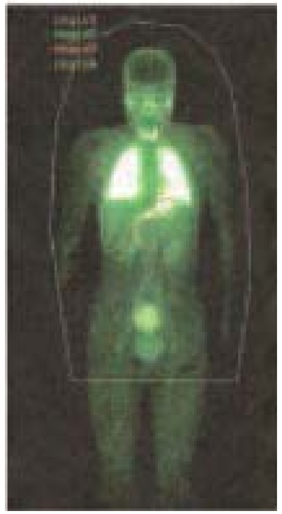
PM concentration 300μg/m^3 (median diameter 54nm; range 20-120); particle number = $1.26 \pm 0.01 \times 10^6$ particles/cm^3; NO_x = 4.45 ± 0.02ppm; NO_2 =1.01 ± 0.01ppm; NO = 3.45 ± 0.03ppm; CO = 2.9 ± 0.1ppm; total hydrocarbon 2.8 ± 0.1ppm

Ultrafine particle dangers

2. Can ultrafine particles translocate into the circulation?

^{99m}Technecium-labelled carbon nanoparticulate (5-20nm) - Technegas





Radioactivity detected rapidly in the bloodstream

Exposure metrics

- Many jurisdictions rely on one metric, elemental carbon (EC)

  The EC metric is obsolete and should not be used

- It has become clear than, because the complexity of the UG atmosphere, something else is needed
- Just measuring the number and size distribution of nDPM cannot be considered an effective metric as it has no regard to the gases adhering to the particles
- A way forward may be the review of biomarkers

Extracts from the current WA Guideline Management of diesel emissions in Western Australian mining operations

- "Safety over the past few years indicate that it is reasonably practicable for underground mines to achieve compliance with the AIOH recommendation of 0.1 mg/m3 for DPM. However, some sites have not effectively controlled emissions to maintain employee DPM exposure levels below 0.1 mg/m3"
- "The Department of Mines and Petroleum is aware that technological advances, particularly in regard to monitoring nanoparticles in diesel emissions, and emerging epidemiological studies may lead to calls for an exposure standard, and mining operators should consider this when developing their long-term management strategies."
- Read section 3 of the guidelines. It's all there

A mine wide study

A study was done underway at an UG mine in Western Australia in 4/4 2017. It was a first for Australia and maybe the world in its scope and size, including examining

- Exhaust gases and their behavior through the ventilation system
- Blood and urine samples from up to 100 workers pre and post shift

This study may progress the development of biomarkers to better measure and assess exposure to diesel exhaust

Conclusion

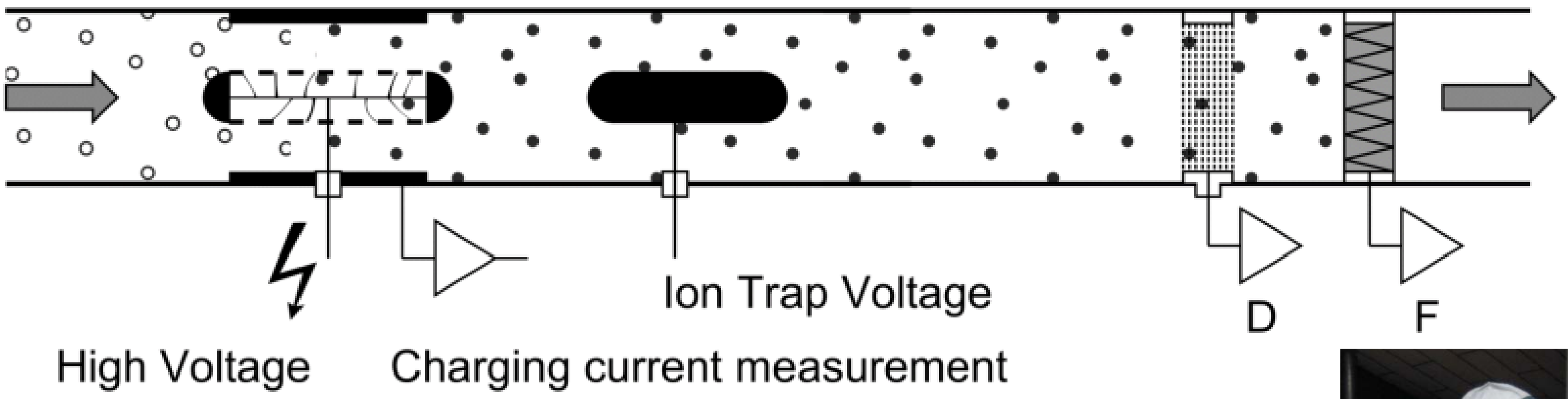
- Existing exposure metrics are inadequate
- There appears to no one single adequate metric

Additional info not in presentation, use if time

- HEPA filters
  - High efficiency particulate air, must remove (from the air that passes through) 99.97% of particles that have a size of 0.3 µm
  - The 0.3 µm is 300 nm, much bigger than nDPM (50 – 70nm)
  - HEPA filters are not the solution
- ALARP / ALARA
  - As low as reasonably possible / achievable
  - Cannot apply to nDPM.   At this time there is no clear dose level
- Elemental carbon is the current criteria @ 0.1 mg / m^3
  - This is now obsolete and has no coherent justification. You cannot use it

Diffusion Charging by TESTO and NANEOS

for Laboratory, PEMS, Maintenance and Personal Sampling



Why should we introduce DPF ? Question of Swiss government 2002

1. because of the health effects of solid nanosize particles at the working place and in the public

2. because of the impact of black carbon nanoparticles on global warming

3. because the Benefit/Cost of DPF is > 10 which means that the society is gaining money by this investment, reducing health cost