Biography

Dr Amu Amukelani Portia Manyike-Modau is a significant figure in the field of occupational health, specifically addressing the impact of diesel emissions in the mining sector in South Africa. She has a Medical Science background and holds multiple degrees in Medical Physiology, Public Health, Occupational Hygiene, Mine Environmental Engineering, and Occupational Health and Safety Management. She transitioned early in her career to mining and has over 17 years of experience in Occupational Health and Hygiene, both at the operational and corporate levels. She has worked in various mining commodities, including gold, Platinum, Chrome, Nickel, and Coal. She currently holds an Executive position at African Rainbow Minerals leading strategies and providing oversight on SHERQ programs for ARM operations. She participates in various advisory and technical committees for the South African Mining Industry. She is also an academic researcher, associated with the University of Witwatersrand, Johannesburg, and has a strong focus on Public Health and Occupational Hygiene. She recently completed her PhD, with a thesis titled "Characterisation of emissions and exposure to diesel engine exhaust in trackless mobile machinery in underground South African Platinum Mines: Evaluating strategies to prevent and control exposure". This indicates her expertise in understanding and mitigating health risks in mining environments, particularly related to diesel exhaust. This study strategically assists the South African Mining Industry with a policy to regulate and reduce DPM exposure to underground miners.

Research and Publications: Her research has contributed to peer-reviewed journals, and she has presented at international conferences.

Conference Engagements: She has been a plenary speaker at events like the SAIOH (South African Institute for Occupational Hygiene) 2024 Annual Scientific Conference, discussing topics like air quality improvement in workplaces.

MINERALS COUNCIL
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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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Managing Diesel Particulate Matter Exposure in Underground Mines: A Comprehensive, Integrated Approach

Dr Amu Manyike_Modau (PhD)

Employer: African Rainbow Minerals
Affiliation: *The University of Witwatersrand*
Mine Ventilation Society Fellow
SAIOH

Annual Mine Dust Conference
25 July 2025

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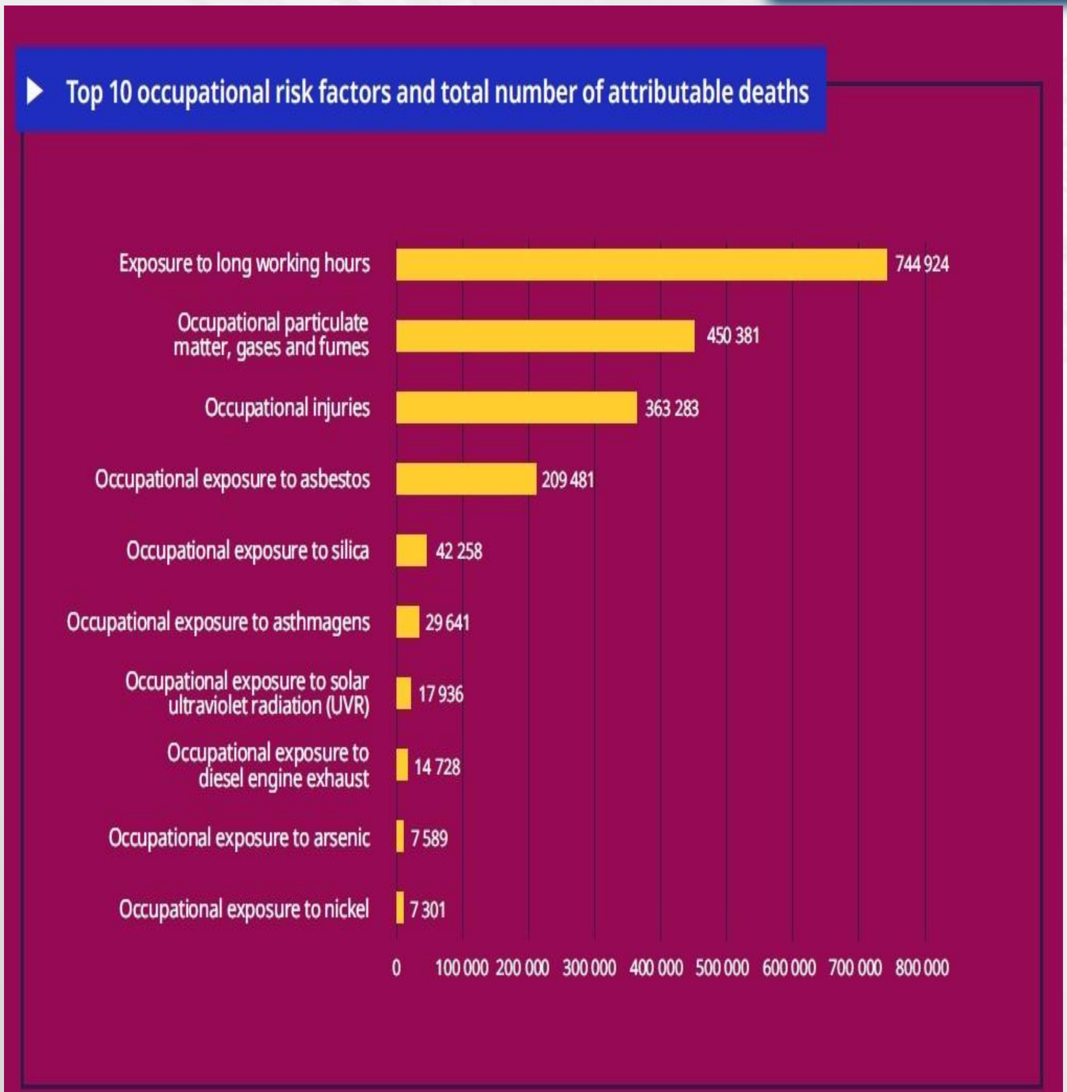
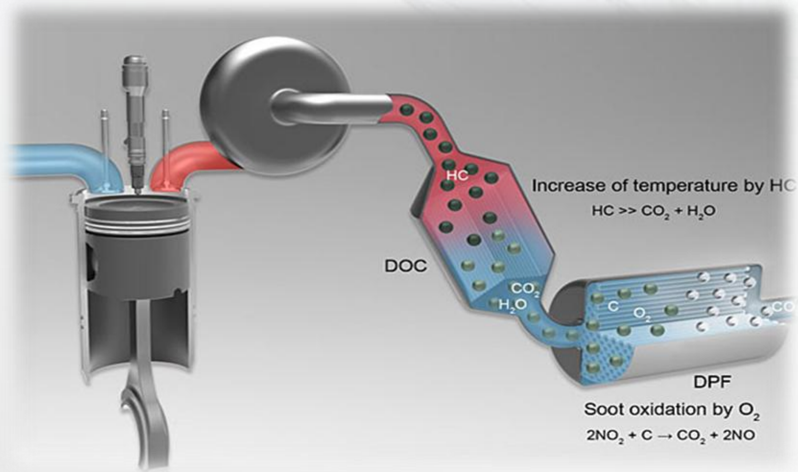
Background.

- ✓ Death by Occupational injuries – 32,6%
- ✓ Health Related Death – 66%
- ✓ Exposure to occupational particulate matter, gases, and fumes - 450,000 associated deaths,



Adapted from ILO 2023



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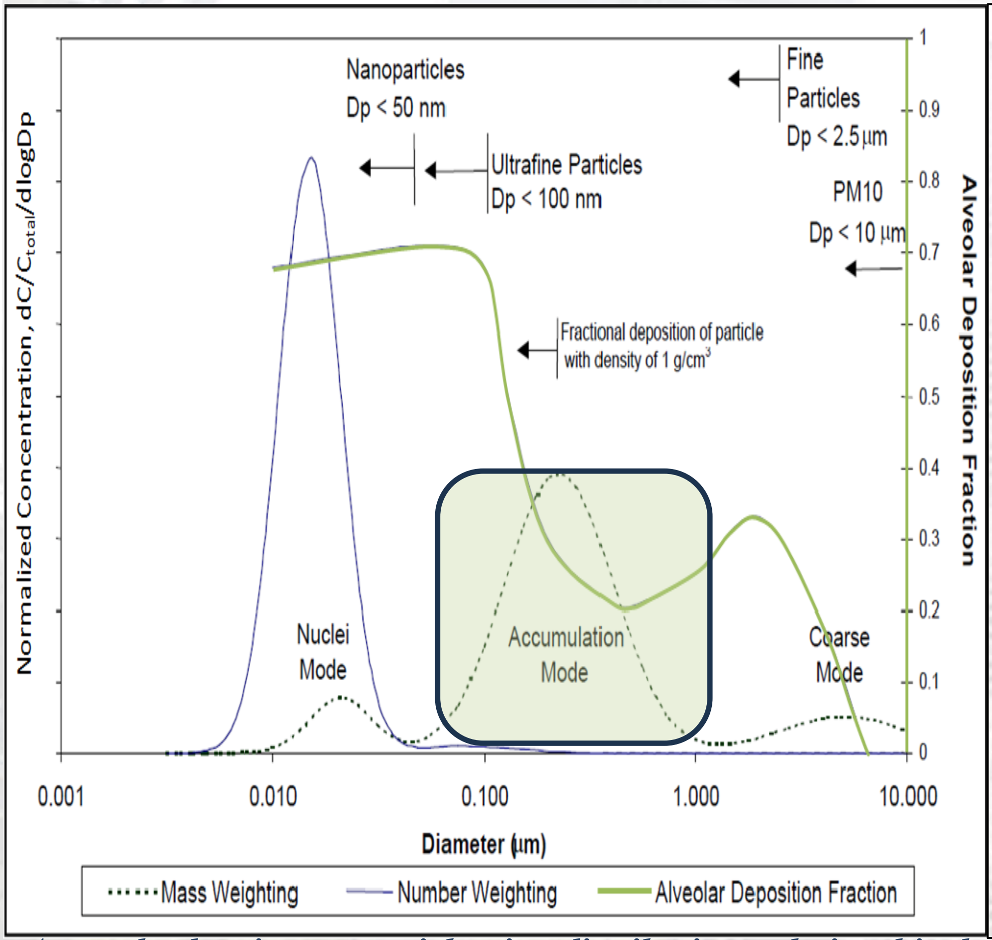
Diesel Engine Exhaust (DEE).



- ✓ 2012 - DEE classification class I (IARC)
- ✓ Characterisation of DEE
  - ✓ Gaseous component
  - ✓ Particulate component
- ✓ Health Effects – Acute and Chronic - linked to lung cancer, asthma, COPD, and DNA damage
- ✓ PM1<1µm: Ultrafine-sized
- ✓ PM2.5<2.5 µm: Respirable
- ✓ PM10 <10 µm: inhalable

A graph showing a particle size distribution relationship between various diesel particulate matter particle metrics (number, surface, and mass) and the deposition of particles in the tracheobronchial and alveolar regions of the human lung(Adapted from Myung 2012)

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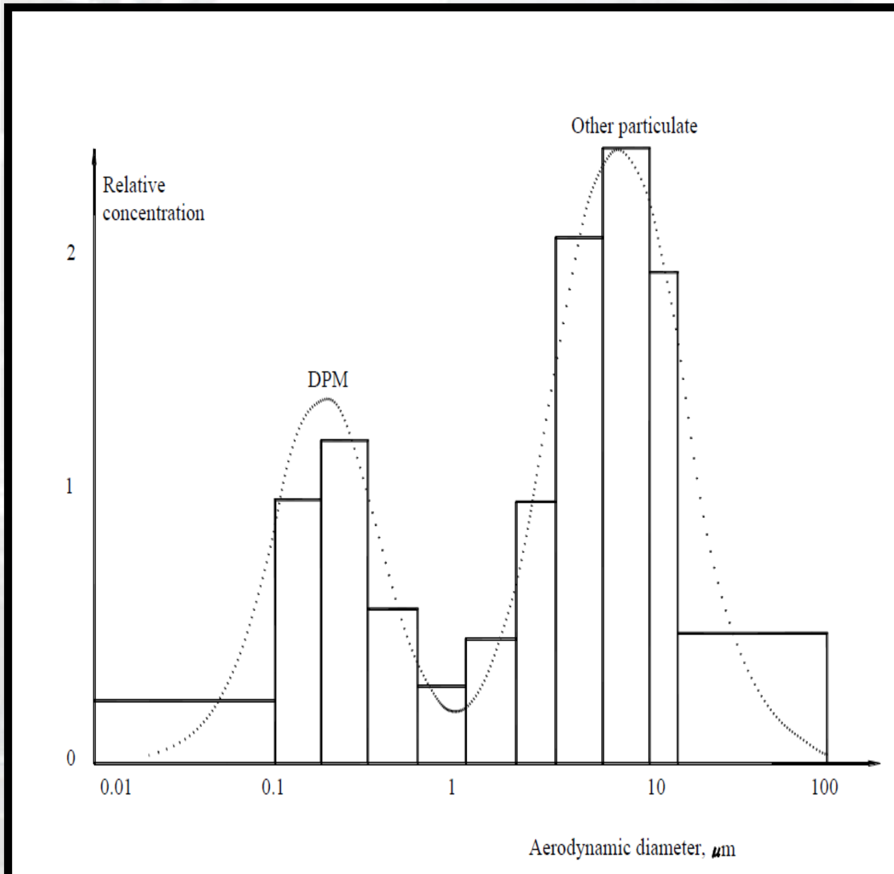
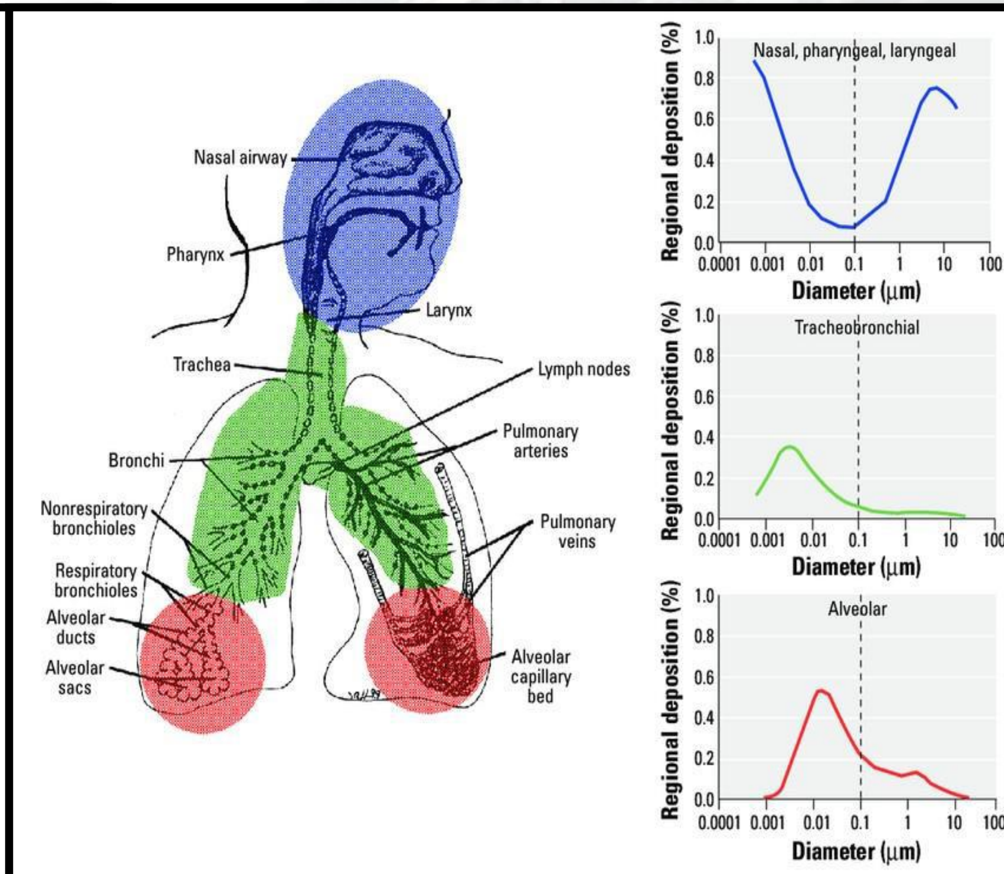
Particulate Matter Aerodynamics





Distribution of DPM Versus other Mining Particles (Adapted from Dong et al. 2011)

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Regulatory Framework

Regulator/Agency	Date	Exposure Limit	DEE particulate surrogate
South Africa	***2025***	***0.1 mg/m3***	***EC***
Swiss MAK Exposure limits	2001	0.1 mg/m3	EC
Australia	2020	0.1 mg/m3	EC
Canada (Ontario)	2011	0.4 mg/m3	TC
Mine Safety & Health Administration (USA)	2008	0.16 mg/m3, 0.123 mg/m3 EC	TC & EC
Germany, Tunnelling	1996	0.3 mg/m3	EC
Germany Other applications	1996	0.1 mg/m3	EC
ACGIH	2001	0.02 mg/m3	EC
EU European Union	***2023/2024***	***0.05mg/m3***	***EC***

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Sources of DPM at Mines

DPM is primarily generated by the combustion of diesel fuel in diesel-powered machinery, which is extensively used in underground mines

- Equipment type
- Lubricating oils
- Confined spaces
- Old engine technology
- Development ends
- Fuel/Air ratio
- Turbocharging
- Fuel Injection
- Blind headings
- Poor fuel quality
- Poor ventilation
- Traffic bottlenecks
- Maintenance bays
- Engine Age
- High Equipment density
- Engine idling
- Ineffective maintenance

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Case Study: South African Platinum Mine

A quantitative, quasi-experimental study designed with an intervention component, was conducted in two Platinum underground mines in South Africa

01
Collect point source tailpipe diesel particulate concentration

02
Measure personal exposure post intervention

03
Build scenario-based intervention to model DPM dispersion

04
Evaluate effectiveness of control-Integrated Approach

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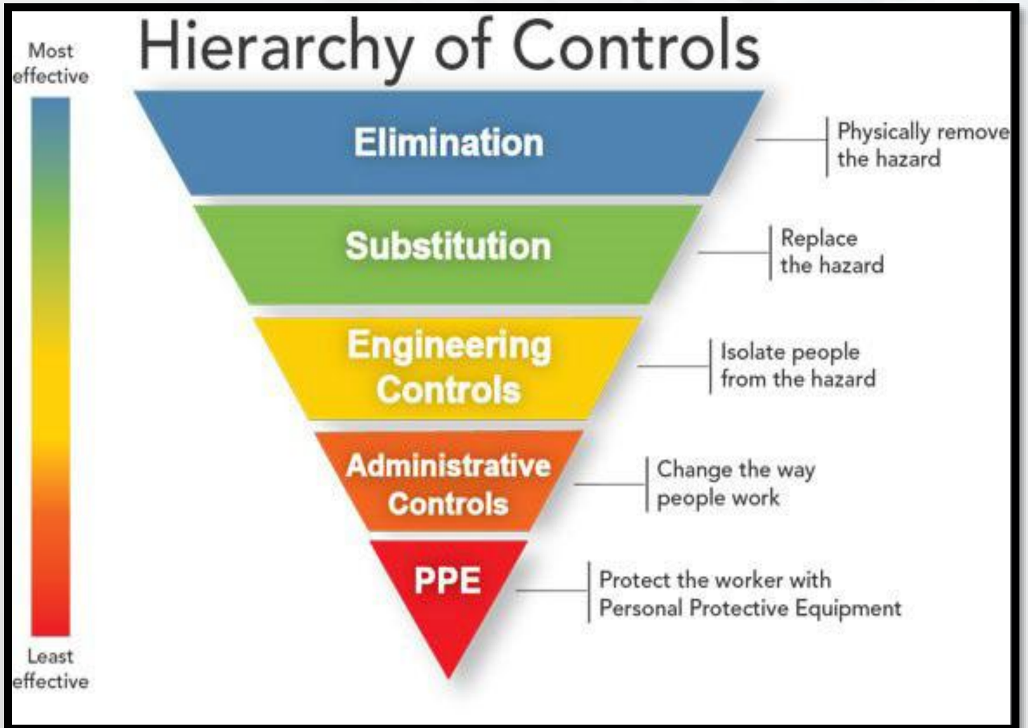
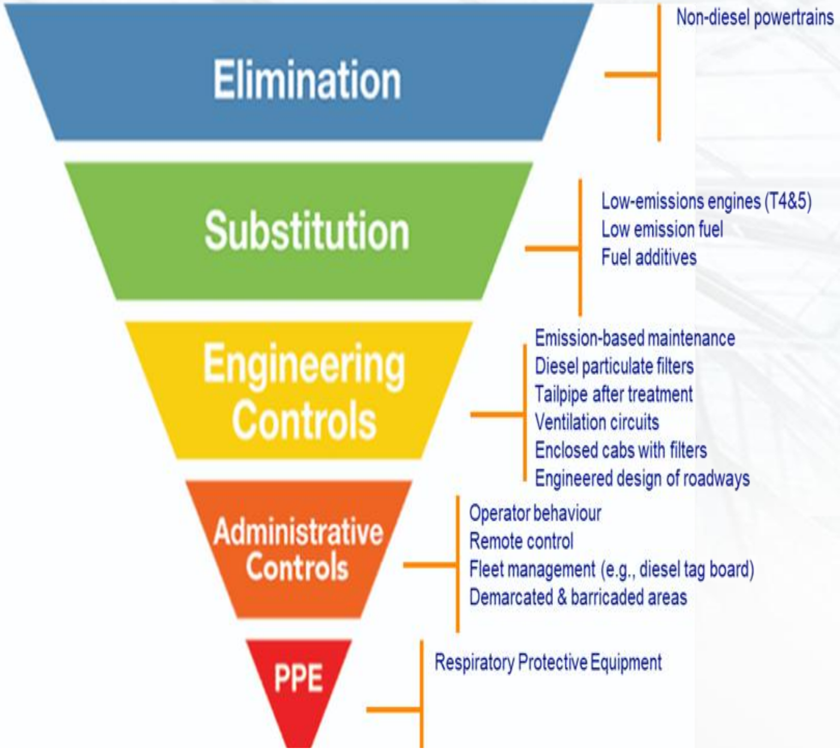
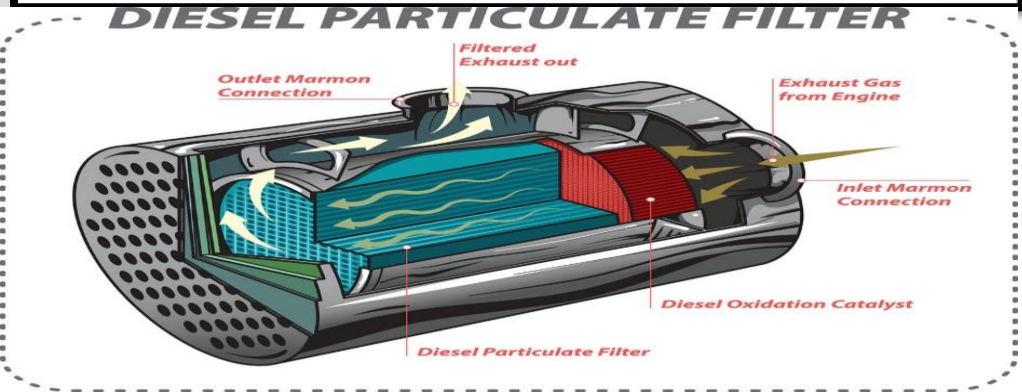
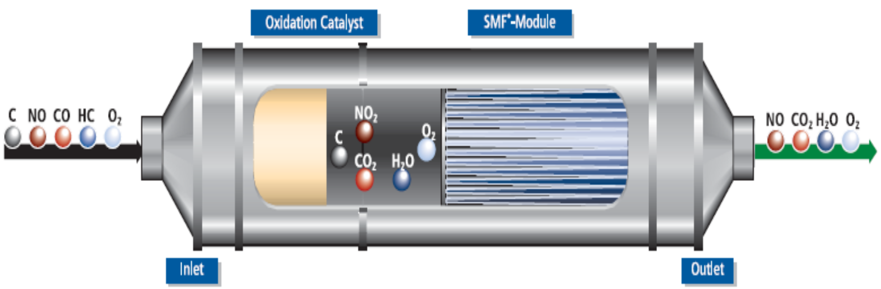
Hierarchy of Controls

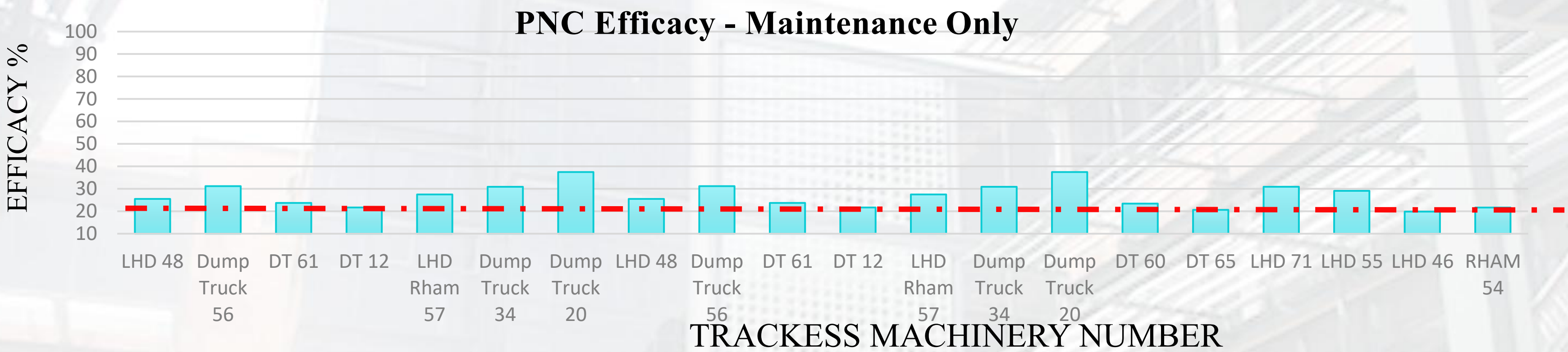


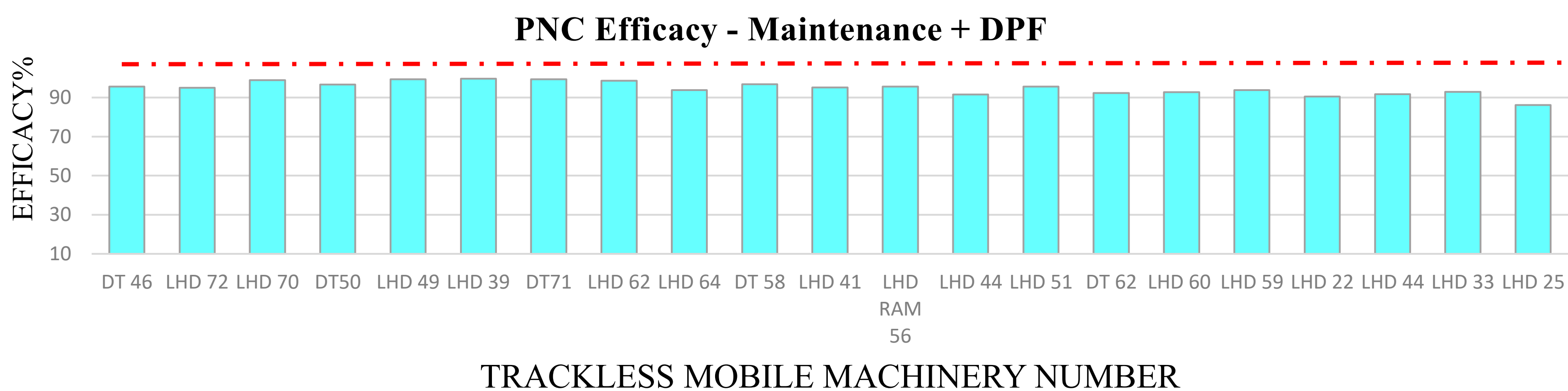






Results - Tailpipe





Efficacies after the intervention for machines that underwent maintenance only & machines that underwent maintenance and retrofitted with DPF; efficacy is presented in percentage reduction. The dashed line shows the group average.

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Dispersion and Ventilation Input Parameters

Dispersion parameters:

- The first step was to determine the engine-out emission rate based on the engine flow rate,

  Emission cumulative strength (mg/s) = particle concentration (mg/m^3) X (Engine airflow rate (l/s)*1000

- The following assumptions were made:
  - The 90th percentile was calculated (mass and gas concentrations)
  - EC was assumed to be 50% of the total engine-out emission
  - Normal conditions were assumed
  - Number of machines and operation mode determined

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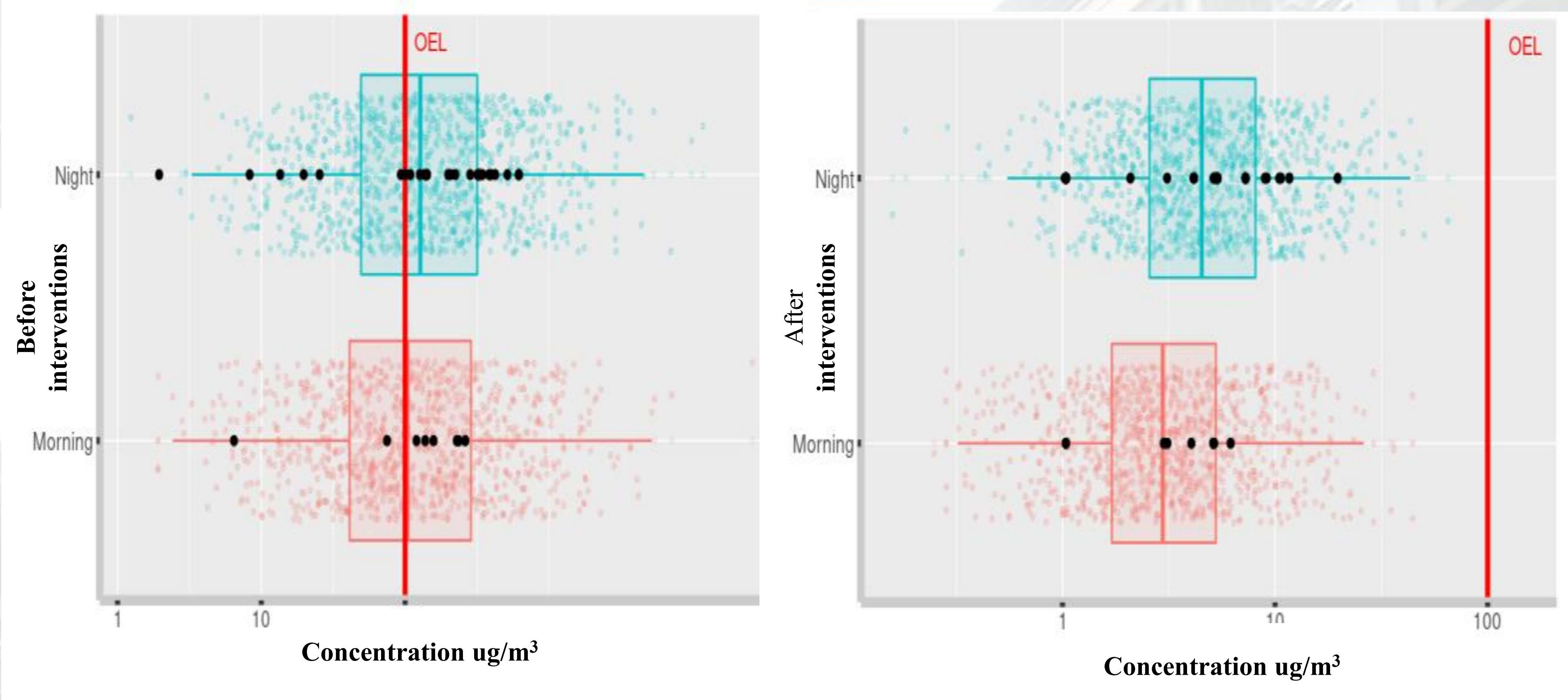
Results - Personal Exposure to EC

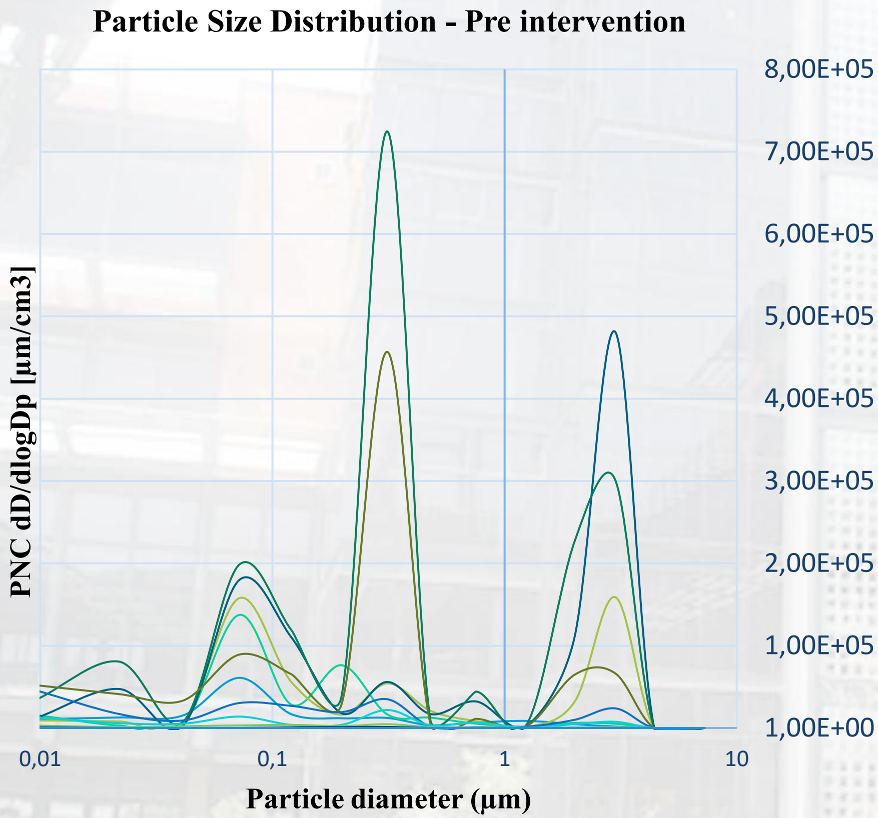


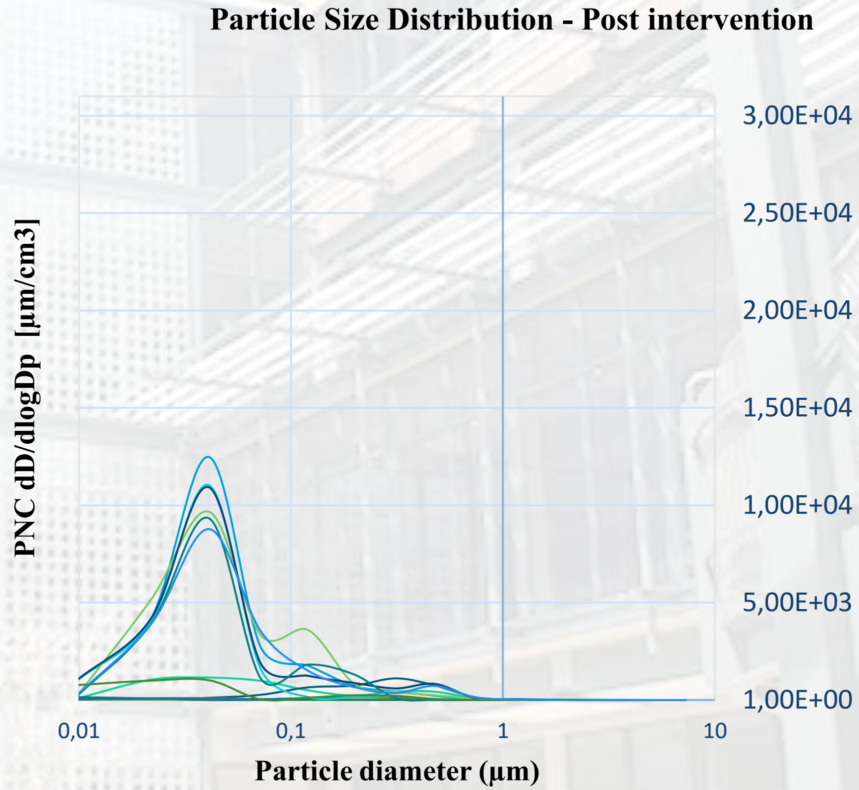
Comparison of elemental carbon (EC) concentrations before and after the intervention; baseline data consists of retrospective 2019 data and the after-intervention data taken after the installation of DPFs in all TMM at the mine N = (34)

GM Before = 130[84-190] *GM After = 4.1[3.2-5.3]*

GSD Before = 3.9[3.1-5.4] *GSD After = 2.3[2-2.9]*

Results – Particle Size Distribution





Particle size distributions of the 13 TMMs under study before and after intervention at 1000 hourly maintenance.

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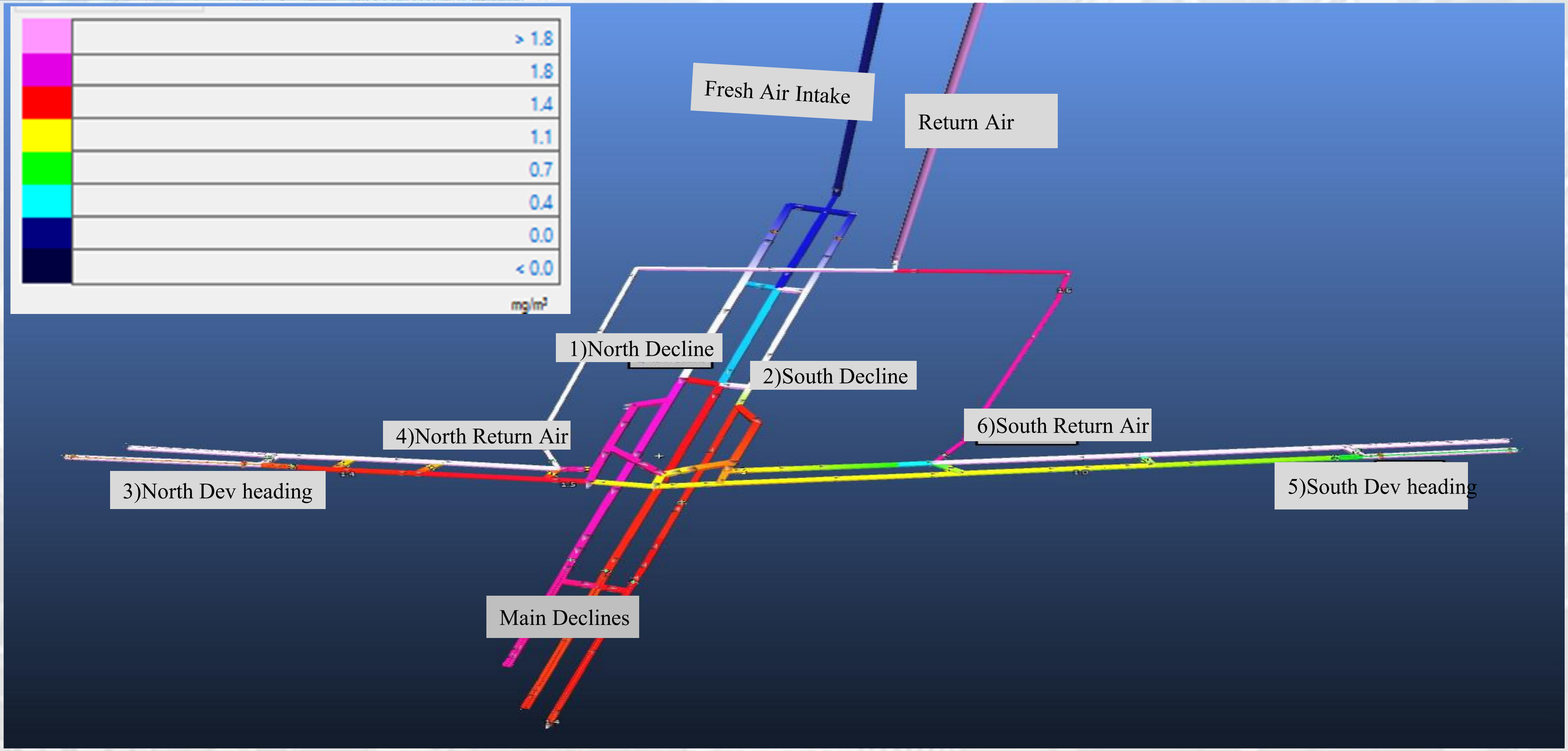
Base Case – Ventilation without Interventions



Visual dynamic simulation representation: a colour-coded diesel particulate dispersion dynamic model within the ventilation district, from the highest to lowest diesel particulate concentrations at the base case, before any intervention on the machines.

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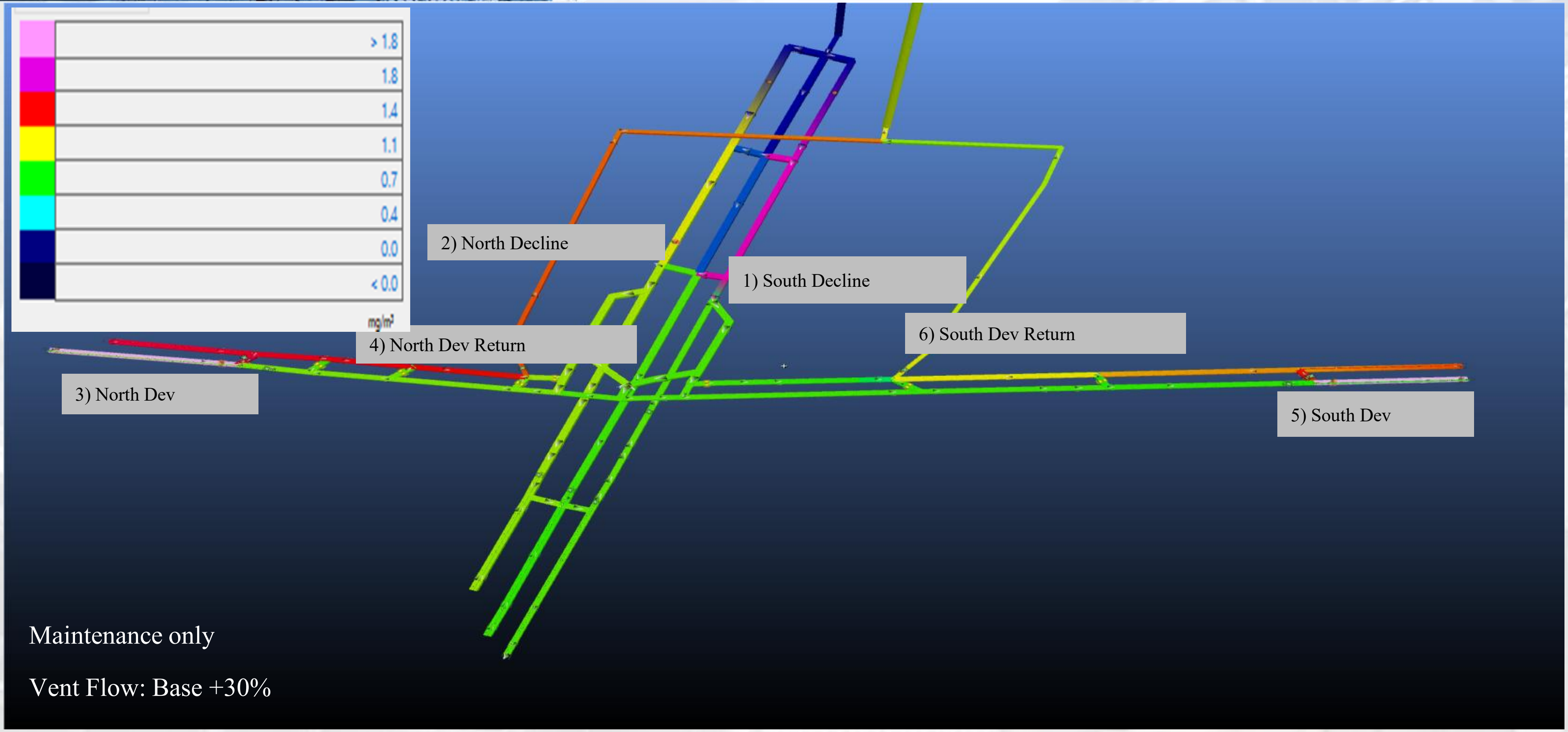
Ventilation Alterations Interventions



The DPM slightly decreased as ventilation increased from 10-30%. At a 10% increase, a slight green shift was observed, showing a concentration reduction towards 0.7mg/m3.

However, the pollutant concentration reached its limit at 0.7mg/m3, which is still higher than the recommended action limit for DPM

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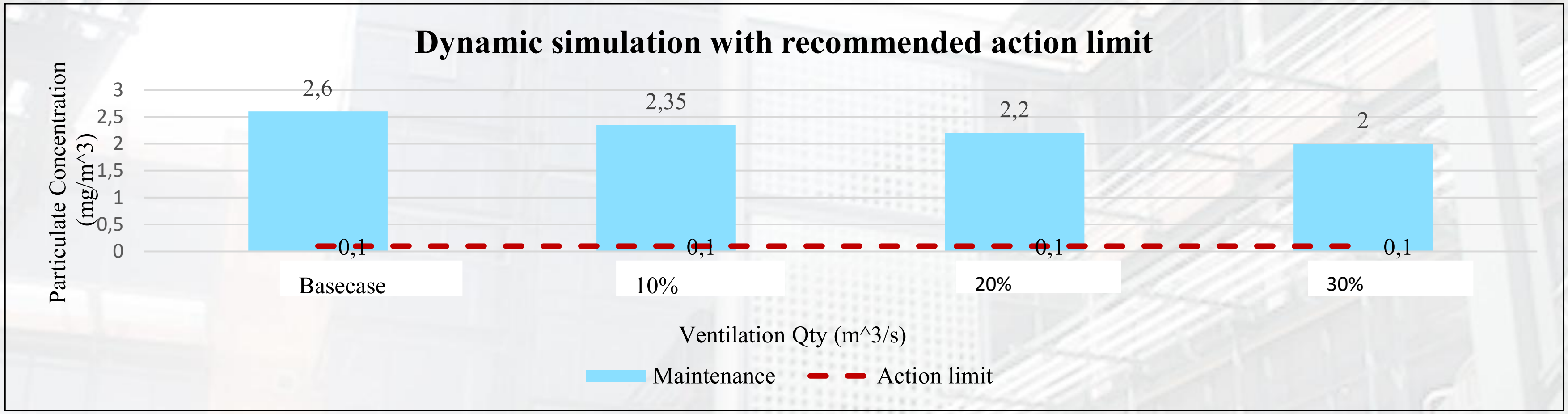
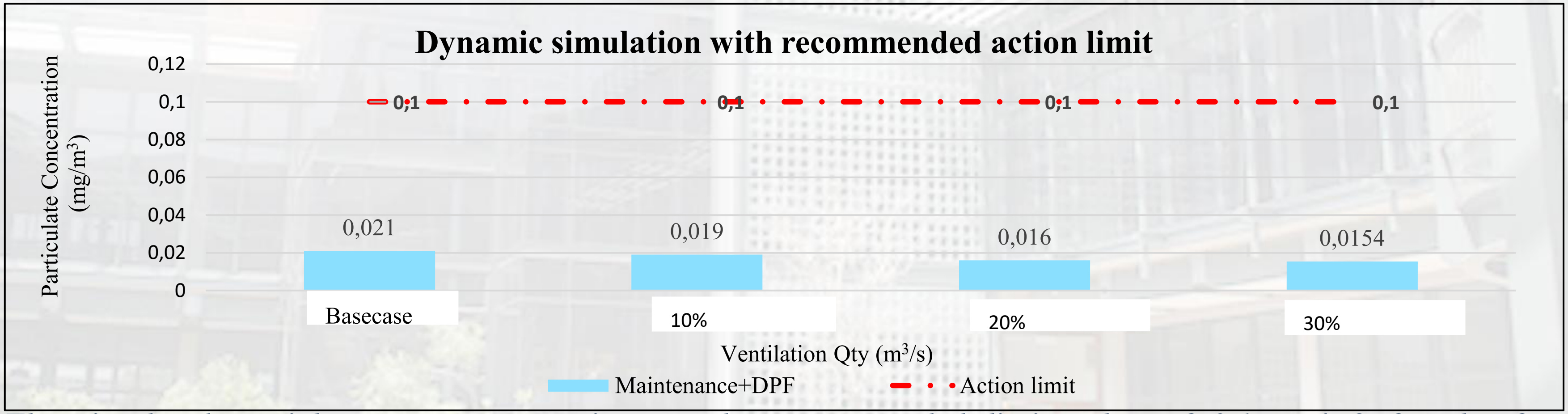
Dynamic Simulation for EC Concentration





The simulated particle mass concentration on the recommended limit value of 0.1 mg/m3 for the face development (location 3) at base-case and altered ventilation increases by 10%, 20%, and 30% for the two interventions.

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Shared Learnings

Ventilation Engineering planning remains key, viz;. Volumes Vs number of machines

Understand the Engine capacity vs size of DPF viz Sandvic 208

Managing potential fire hazard

- Pipe and DPF insulation around the exhaust is critical
- Roadway conditions – routing of ECU (service check)
- Underground Environmental conditions – humidity clogs the air filter
- Check for parasitic loads on the engine. This could cause machine power output issues and lead to over fueling

Maintenance challenges

- Emissions testing to establish engine health is critical post-intervention
- Treat the DPF system as an early warning system for system performance
- Training of the Engineering maintenance team, operators and VOHE teams

Integrated Approach: recommendations

Buy in from Corporate and Top Management

Develop DPM Risk Management Team: Engineers, VOHE Team, Maintenance team, SHE committee members, Safety team

Identify DPM sources

Compile a baseline risk assessment: EC, TC, Particle number (sampling machines, sampling methodology, real time monitors, maintenance themes)

Conduct a Bowtie and define critical controls

Develop DPM control and management SOP

Training and awareness campaigns

Develop Health surveillance and health monitoring

Evaluate and review against set OEL objectives

- Diesel vehicles tier 2
- Engine Age
- Engine maintenance status
- Operating mechanism/inefficiencies
- Exhaust filtration
- Sulphur content (effective in higher tier engines viz.; ≥Tier 2)
- Engine turbocharging

Source

Pathway

- Enclosed cabs with filters
- **Exhaust Filtration systems**
- Vehicle management system (automatic shutdown)
- **Dilution by ventilation**
- **Limit number of machinery allowed within a given volume of ventilation air**
- Restricting unnecessary idling

- *RPE*

Receptor

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Challenges and Gaps

Cumulative exposure

- ✓ This refers to the **total amount of a hazardous substance** (e.g., coal dust, diesel particulate matter, silica) that a miner inhales or is exposed to over time, often measured across their entire working life.

- ✓ This **cumulative exposure** plays a critical role in determining long-term health risks, including the development of occupational diseases like black lung disease (CWP), silicosis, and lung cancer.

A Coal Miner

- ❖ Respirable coal dust – Pneumoconiosis, COPD
- ❖ Crystalline silica – Silicosis, lung disease
- ❖ **Diesel Particulate matter** – Lung Cancer, Cardiovascular disease
- ❖ Gases (CH_4, CO, NOx) – Asphyxiation, toxic gas exposure
- ❖ Welding Fumes – Noise-Induced Hearing Loss

Critical Controls Management for DPM

- ✓ Low Sulphur content fuel
- ✓ Replacement of lower tier (1-2) with higher tier (3-4) more efficient engines
- ✓ Installation of exhaust aftertreatment – diesel particulate filters
- ✓ Ventilation design/dilution ventilation – modelling is key
  - ✓ 0.06 m3/s/kW dilution rate to be used when complying with the diesel particulate matter management program, including the use of higher tier engines, Tier 3 and 4 engines DPF and catalytic converters, 50 ppm diesel
  - ✓ 0.12 m3/s/kW if ventilation dilution is the only control
- ✓ Emission based maintenance program for all vehicles
- ✓ Limiting number of vehicles based on ventilation design

Tailpipe Benchmark Parameters

Before/After	Raw Gas	Conditioned Gas	%Change
Opacity (K-value)	1.2		
DPM (mg/m^3)	0.1 EC		
CO(ppm)	250		
CO_2(%)	3.6		
HC(ppm)	25		
NO_2(ppm)	150		
NO(ppm)	300		
NOx(ppm)	450		
O_2(%)	13		
CO/CO_2 (ratio)	≤5%		
Temperature			
Back pressure			

What is good enough?

No standardised method

Tailpipe emissions parameters: Adapted from Sibanye Stillwaters/Thesis Manyike_Modau

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Next Steps

In March 2025 - South Africa has established an OEL – 0.1mg/m^3 EC

SO WHAT

Documenting a best Practice or Not

Q & A

Sampling Equipment – Dekati ELPI+

Dekati ELPI+ Connections

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