Diesel Particulate Matter in Underground Mines

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Aerosols and Gases Emitted by Diesel Engines in Occupational Settings

- Diesel-powered equipment is extensively used by a wide range of industries:
  - transportation;
  - construction;
  - mining…
- Emissions of carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, hydrocarbons, and particulate matter are of major concern.

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Diesel Particulate Matter (DPM)

- Nano, ultrafine, and fine aerosols emitted by diesel engines, collectively known as diesel particulate matter (DPM), are important contributors to the pollution of the workplace atmosphere.
- DPM primarily consists of an aggregated core of nano and ultrafine carbonaceous particles surrounded by core-bound or suspended hydrocarbons.
- Inorganic components such as sulfates and ash also contribute to DPM aerosols.
- DPM composition is dependant on a number of physical and chemical processes including:
  - engine operating condition;
  - engine design evolution;
  - aftertreatment technology (diesel particulate filters, diesel oxidation catalytic converters …);
  - fuel formulation;
  - etc.

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Diesels in Underground Mines

- Diesel in underground mining – unique challenges:
  - confined space;
  - harsh, rugged environment;
  - application specific operational and maintenance issues;
  - socioeconomic issues…
- These challenges result in higher concentrations of DPM in underground mines relative to other industries.
- Regulations:
  - In 2001 the Mine Safety and Health Administration (MSHA) promulgated a rule limiting the exposure of miners (66 FR 5706) in U.S. underground metal/nonmetal mines to DPM:
    - These limits were established on the technical feasibility of controlling DPM emissions rather than on a firm knowledge of the health risks associated with exposure to DPM.

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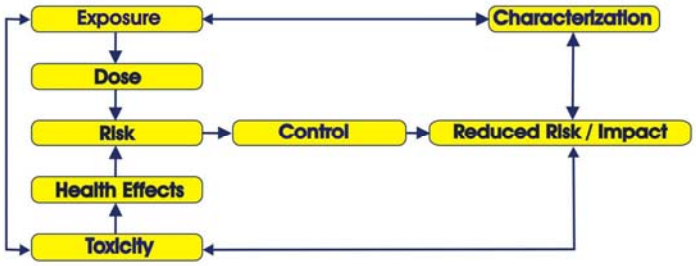
Addressing Occupational Impact of DPM

- Health risks associated with exposure to DPM are not completely understood and are currently the subject of extensive research



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Physical and Chemical Characterization of DPM

- Physical characteristics:
  - size;
  - surface area;
  - mass concentration;
  - number concentration;
  - morphology;
  - charge...
- Physical chemistry:
  - hydroscopicity;
  - hydrophilicity;
  - bioavailability;
  - acidity;
  - oxidant potential…
- Chemical composition:
  - elemental carbon;
  - organic carbons;
  - metals;
  - inorganic compounds…

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Effects of Control Technologies on Diesel Aerosols in Mine Air

- Field evaluations on the effects of selected engine modifications and control technologies on concentrations of DPM and gases in mine air conducted at the Stillwater Nye Mine in 2004 were used to study the effects of:
  - diesel particulate filter systems;
  - filtration systems with disposable filter elements;
  - alternative fuel formulations.

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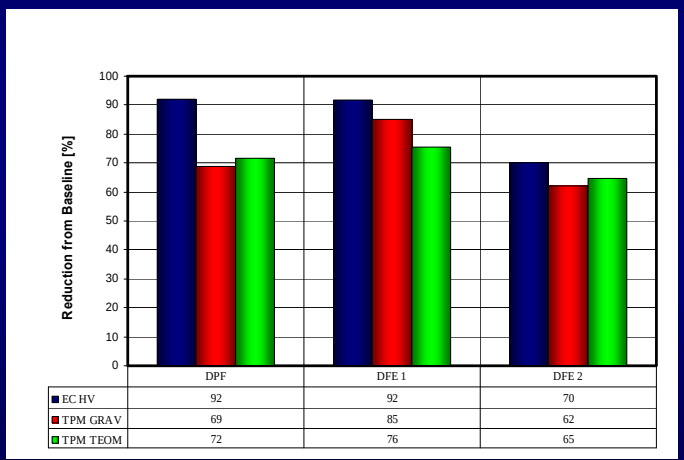
Effects of Filtration Systems on Diesel Aerosols in Underground Mine Air

- Diesel particulate filter (DPF) systems and disposable filter elements (DFEs) were found to be efficient in controlling DPM concentrations in mine air.



Legend:

EC – elemental carbon

HV – high volume sampling

TPM – total particulate matter

GRAV – gravimetric analysis

TEOM – tapered element oscillating microbalance

NOTE: The baseline was established with a vehicle equipped with a muffler.

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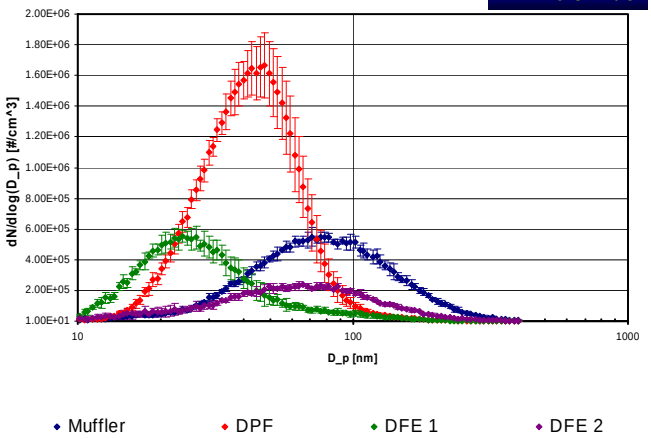
Effects of Filtration Systems on Size Distribution and Number Concentrations of Diesel Aerosols in Underground Mine Air

VR≈19.3 m^3/s



Exhaust Config.	Average GM 1	Average GM 2
	nm	nm
Muffler	34.2	86.0
DPF	42.5	-
DFE 1	24.2	68.3
DFE 2	35.8	73.6

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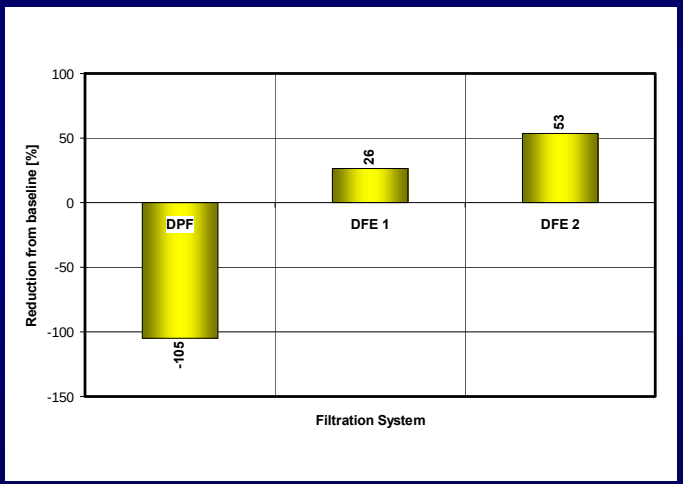
Effects of Filtration Systems on Total Number of Diesel Aerosols in Underground Mine Air



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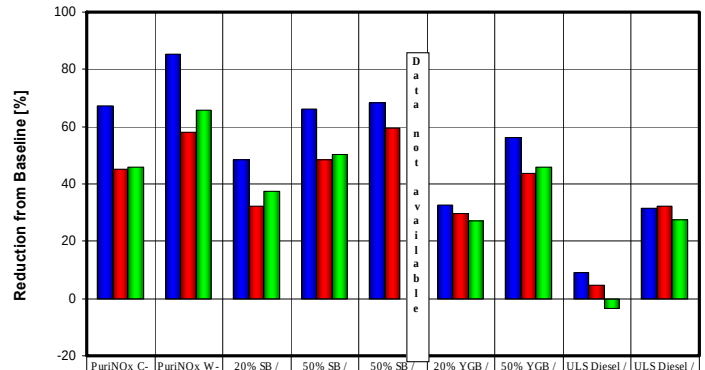
Effects of Alternative Fuels on Diesel Aerosols in Underground Mine Air

- Water-in-diesel fuel emulsions and biodiesel blends were also found to be effective technologies for controlling EC and DPM emitted by diesel-powered mining equipment.



	PuriNOx C-W / Muffler	PuriNOx W-W / Muffler	20% SB / Muffler	50% SB / Muffler	50% SB / DOC	20% YGB / Muffler	50% YGB / Muffler	ULS Diesel / Muffler	ULS Diesel / DOC
EC HV	67	85	49	66	68	33	56	9	32
TPM GRAV	45	58	32	48	60	30	44	5	32
TPM TEOM	46	66	37	50		27	46	-3	27

NOTE: The baseline was established with a vehicle equipped with a muffler and operated with #1 diesel.

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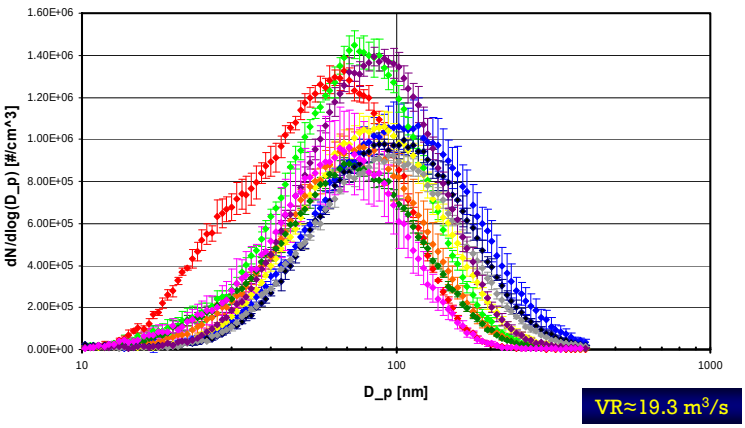
Effects of Alternative Fuels on Size Distribution and Number Concentrations of Diesel Aerosols in Underground Mine Air



VR≈19.3 m^3/s

- #1 Diesel with Muffler
- PuriNOx Warm-Weather with Muffler
- 50% Soy Biodiesel with Muffler
- ULS Diesel with Muffler
- 20% Yellow Grease Biodiesel with Muffler
- PuriNOx Cold-Weather with Muffler
- 20% Soy Biodiesel with Muffler
- 50% Soy Biodiesel with DOC
- ULS Diesel with DOC
- 50% Yellow Grease Biodiesel with Muffler

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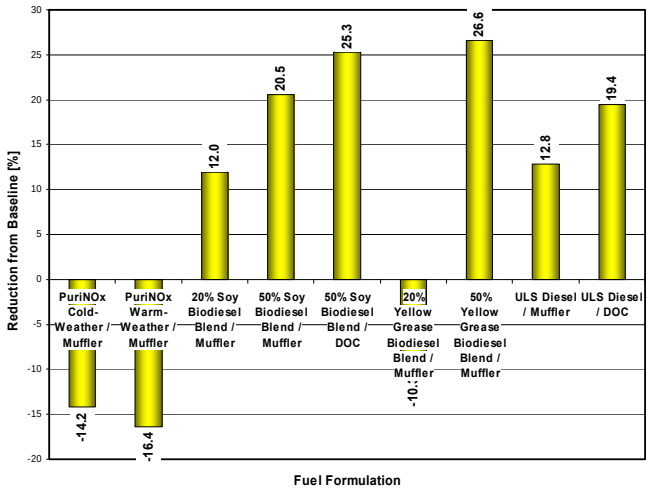
Effects of Alternative Fuels on Total Number of Diesel Aerosols in Underground Mine Air



Fuel/Exhaust Configuration	Average GM nm
#1 Diesel / Muffler	95.1
PuriNOx Cold-Weather/ Muffler	68.4
PuriNOx Warm-Weather / Muffler	54.9
20% Soy Biodiesel Blend / Muffler	80.6
50% Soy Biodiesel Blend / Muffler	70.3
50% Soy Biodiesel Blend / DOC	67.0
20% Yellow Grease Biodiesel Blend / Muffler	81.0
50% Yellow Grease Biodiesel Blend / Muffler	61.4
ULS Diesel / Muffler	93.0
ULS Diesel / DOC	89.3

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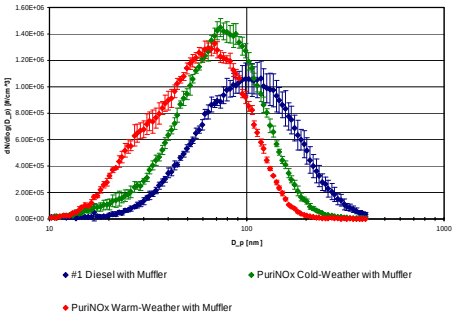
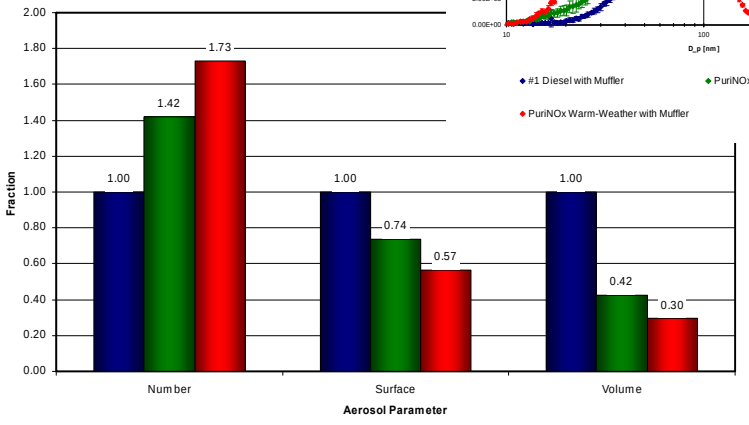
Effects of Fuel Formulations on Relative Deposition of Aerosols in the Human Respiratory Tract (ICRP 66) during Light Exercise - Total Respiratory Tract





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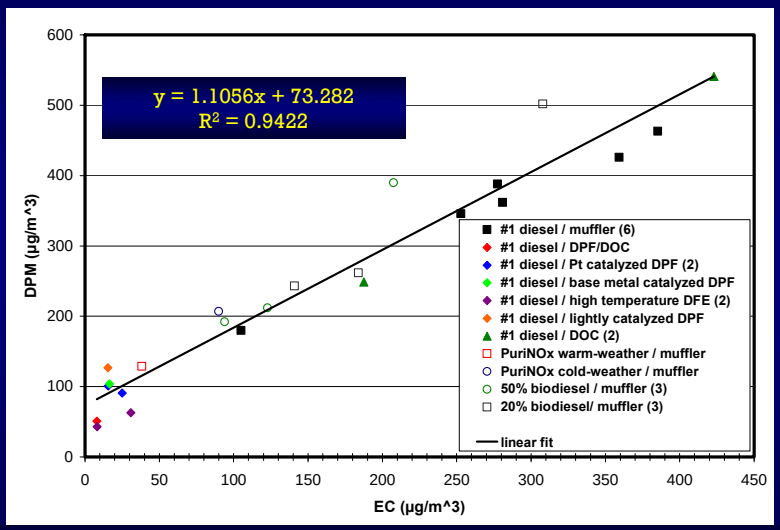
Relationship Between Measured DPM and EC Concentrations in Mine Air



NOTE: These concentrations are not normalized to a single ventilation rate.

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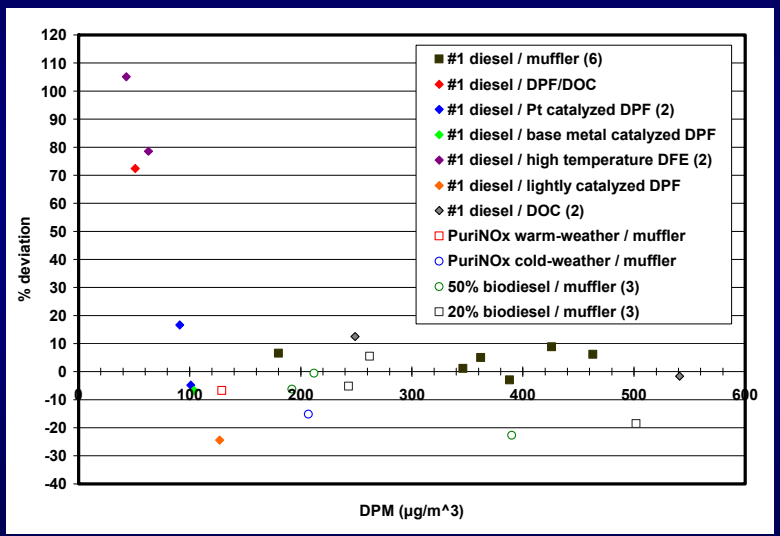
Deviation Between Measured DPM and EC Concentrations in Mine Air at Concentrations



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Concluding Remarks

- Despite substantial progress in diesel research over the past decades, DPM remains a poorly understood health concern and requires further study.
- More work on the physical and chemical characterization and the toxicity of DPM is needed to understand its complex nature and mechanisms of injury.
- The effects of control technologies and strategies on DPM and noxious gases in mine air needs to be fully understood.
- The existing methods of monitoring exposure to DPM should be complemented with measurements of:
  - particle number;
  - particle surface area;
  - size distribution of particles
  - oxidative potential…
- More data, more questions…

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