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IMPACT OF LOW EMISSION ENGINES ON MINE AIR QUALITY:

PHYSICAL MEASURMENTS

W. F. Watts, S. T. Bagley and D. B. Kittelson

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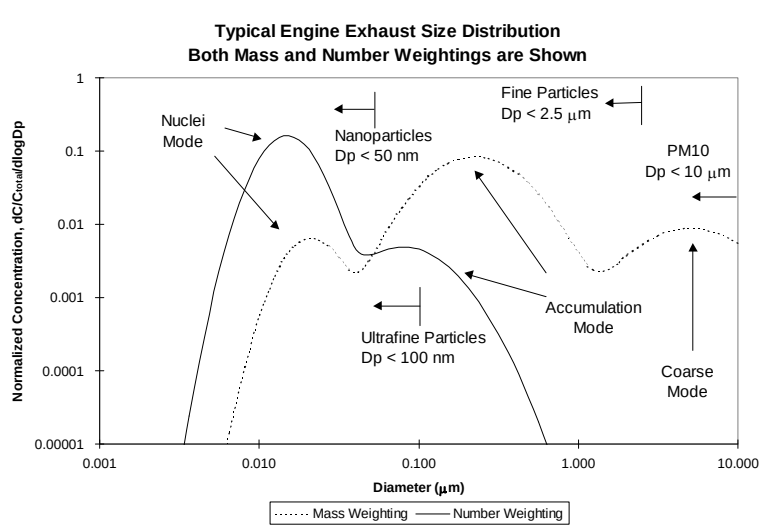
OUTLINE

- **Objectives**
- **Background**
- **Approach**
- **Mine description**
- **Instrumentation and methods**
- **Results**
- **Summary**

OBJECTIVES

- Evaluate the impact of low emission electronically controlled diesel engines versus older technology on mine air quality.
  - Determine diesel particulate matter (DPM)
    - Physical characteristics
    - Biological activity
    - Chemical composition
- Determine if low emission engine technology introduces any potential health concerns.

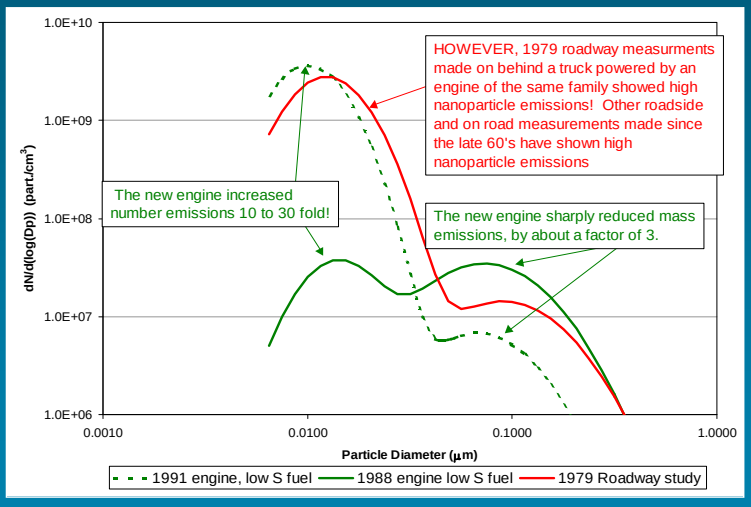
BACKGROUND



NANOPARTICLES

- There is limited evidence that nanoparticles (Dp < 50 nm) are a health concern.
- Difficulties are associated with quantifying nanoparticles.
  - Often > 90% of particle number are formed during exhaust dilution.
  - Large changes in of particle number may result from small changes dilution and sampling conditions.
- Reported that reductions in mass emissions were accompanied by an increase in particle number emissions (Bagley, *et al.*, 1996).

NUMBER SIZE DISTRIBUTION DATA FROM HEI REPORT AND 1979 CRC ROADWAY STUDY



Sources: Kittelson, 2000 Royal Society, Bagley *et al.*, 1996 and Kittelson, *et al.* 1988

KEY QUESTIONS

- Do low emission, electronically controlled Diesel engines fueled with low sulfur (34 ppm S) fuel produce more nanoparticles than older style mechanically controlled engines?
- Do these engines introduce potentially new health concerns into the mine environment?

APPROACH

- Pre-mine visit followed by a 2 week study
  - Week 1 – Evaluate mechanically fuel injected engines.
  - Week 2 – Evaluate electronically fuel injected engines.
  - Collect area samples "upwind" and "downwind" of Diesel activity, on the Diesel equipment, and a limited number of operator samples.
  - Normalize data - number of loaded trucks passing the sampling stations daily.
- UMN responsible for collecting aerosol samples underground and physical characterization.
- MTU and the UWI responsible for biological and chemical analysis.

MINE DESCRIPTION

- Underground domal salt mine on Louisiana's gulf coast
- Room and pillar mining method
  - 1500 ft level
  - Pillars are 100 x 100 ft on 150 ft center
  - Rooms are developed 25 ft high and later benched
  - Salt mined 5 days/wk, 3 shifts/day, limited production on weekends
  - Production varied < 10 % during the period of the study
  - 220,000 cfm of ventilation air entering mine
  - Approximately 10,000 total horsepower underground
  - Mine temperature 37 – 42 ^{o}C at the sampling locations

DIESEL TEST EQUIPMENT

Equipment type	Approximate year of manufacture	Model	Engine	Horsepower	Enclosed cab and AC
30 t truck	1990	769 C	3408 C DITA	425	N
30 t truck	1998	769 D	3408 F HEUI	450	Y
Front-end-loader	1990	988 B	3408 C DITA	425	N
Front-end-loader	1998	988 F	3408 F HEUI	450	Y

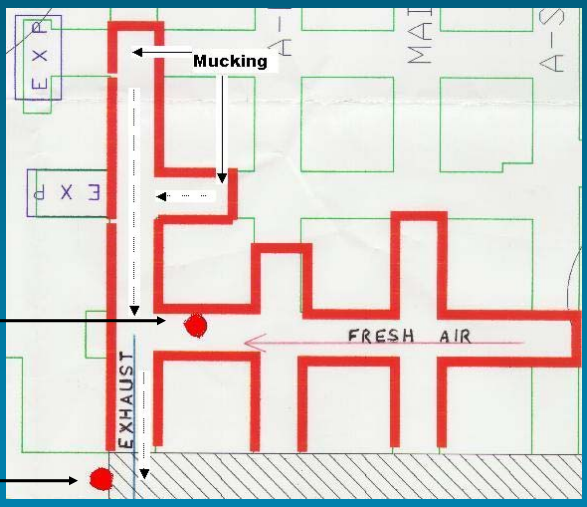
DITA - Direct injection, turbocharged, aftercooled with mechanical fuel injection
HEUI - Hydraulic electric unit injector, turbocharged and aftercooled

- 34 ppm S fuel used
- No emission control devices used in the mine.

SAMPLING LOCATIONS

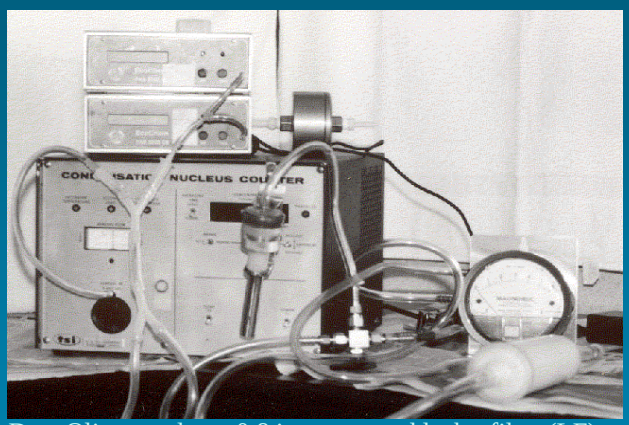
Upwind

Downwind



NEAR REAL-TIME INSTRUMENTATION

- **TSI 3020 Condensation Particle Counter (CPC) – number concentration**
- **Diffusion Charger (DC) –surface area concentration**
- **Photoelectric Aerosol Sensor (PAS) – photoemission intensity**
- **Data logged every 10 s**



Dorr Oliver cyclone, 0.8 impactor and leaky-filter (LF) dilutor used with CPC, DC and PAS.
Average LF dilution ratio 14.5:1

FILTER BASED INSTRUMENTATION

- **Size Selective (SS) sampling with gravimetric analysis for DPM**
- **Elemental Carbon (EC) sampling using NIOSH method 5040**
- **High Volume (HV) sampling with slotted inertial impactors with 50% cut points at 3.5, 2.0 and 0.95 µm for chemical and biological analysis**

A MOUDI and Nano-MOUDI (NM) were also operated - unsuccessfully

SAMPLE MATRIX

Sample type	Number of Days	Location		
		Upwind	Vehicle	Downwind
HV	10	2	NA	4
SS	10	3	3	3
EC	10	3	3	3
MOUDI and NM	10	1	NA	2

- A limited number of SS and EC samples were collected in the vehicle cabs.
- 10 dynamic blanks were collected to correct for organic carbon (OC) adsorption on the EC filters.
- Lab blank, 8 x 10 in Pallflex filters, were also submitted with the HV samples.

NUMBER OF TRUCKS PER DAY

Week 1		Week 2	
Date	N	Date	N
21-Feb	24	28-Feb	28
22-Feb	24	Feb-29	34
23-Feb	25	1-Mar	50
24-Feb	37	2-Mar	32
25-Feb	23	3-Mar	59
Average	26.6	Average	40.6

N = number of round trips per day by 30 t haul trucks
Data used to normalize and weight the average concentrations.

UPWIND CONCENTRATIONS

Parameter	Week 1		Week 2		Significantly different
	Avg	SD	Avg	SD	
EC, mg/m^3	1.11	0.07	0.29	0.03	Y
OC, mg/m^3	0.26	0.04	0.13	0.03	Y
TC, mg/m^3	1.39	0.10	0.41	0.06	Y
< 0.8, mg/m^3	1.44	0.06	1.02	0.12	Y
RD, mg/m^3	2.41	0.38	1.78	0.53	Y

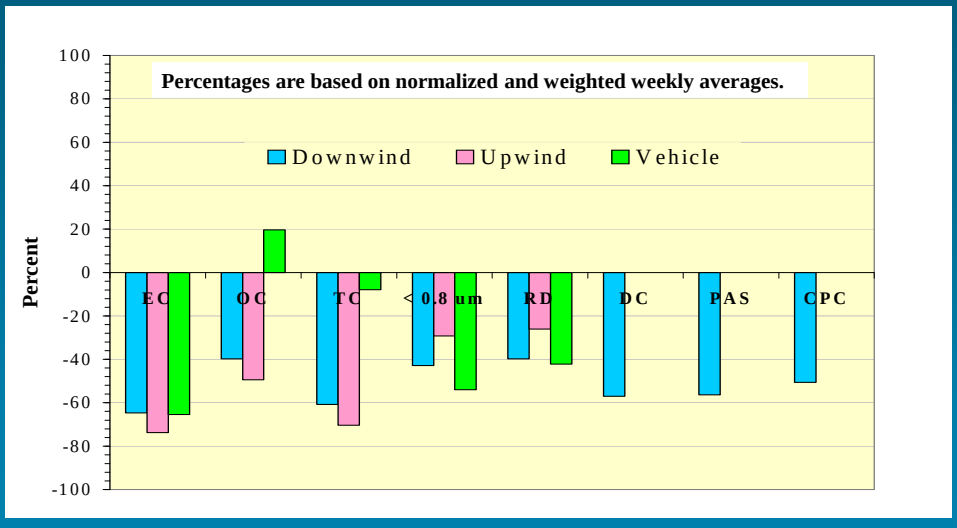
- Concentrations are normalized and weighted.

DOWNWIND CONCENTRATIONS

Parameter	Week 1		Week 2		Significantly different
	Avg	SD	Avg	SD	
EC, mg/m^3	0.92	0.01	0.33	0.00	Y
OC, mg/m^3	0.27	0.02	0.16	0.00	Y
TC, mg/m^3	1.39	0.04	0.55	0.01	Y
< 0.8, mg/m^3	1.63	0.16	0.93	0.06	Y
RD, mg/m^3	2.79	0.25	1.68	0.09	
CPC, $part/cm^3$	2.9E+05	2.3E+04	1.5E+05	2.2E+04	Y
DC, fA	219	22	94	9	Y
PAS, ng/m^3	373	34	163	20	Y

- Concentrations are normalized and weighted.

PERCENT REDUCTION



CAB AND OPERATOR SAMPLES

Parameter	No Cab			Cab		
	N	Avg	SD	N	Avg	SD
EC, mg/m^3	2	0.49	0.33	10	0.07	0.04
OC, mg/m^3	2	0.35	0.19	10	0.27	0.06
TC, mg/m^3	2	0.84	0.51	10	0.34	0.08
< 0.8, mg/m^3	2	1.63	0.06	10	0.42	0.19
RD, mg/m^3	2	2.37	0.19	10	0.93	0.34

- Haul trucks with cabs were air conditioned.

SUMMARY

- **Electronically controlled engines**
  - **Did not increase nanoparticle concentrations**
  - **Reduced TC and EC concentrations by about 60 %**
  - **Reduced near real-time instrument (CPC, DC, PAS) concentrations between 50 - 60 %**
- **No evidence suggesting new health concerns were introduced into the mine**
- **The complete report is available at www.deep.org**