Diesel Particulate in Mines – Current Knowledge and Solutions

Mining Health and Safety Conference

Workplace Safety North

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Presentation Overview

- Health concerns
- Diesel particulate matter (DPM) sampling and analysis
- Regulations and mine worker exposure
- Emissions control strategies
- Lessons learned

Diesel Exhaust Emissions – Definite Link to Cancer

June 2012 World Health Organization moved classification for diesel exhaust from Group 2A (probable carcinogen) to Group 1 (carcinogen)

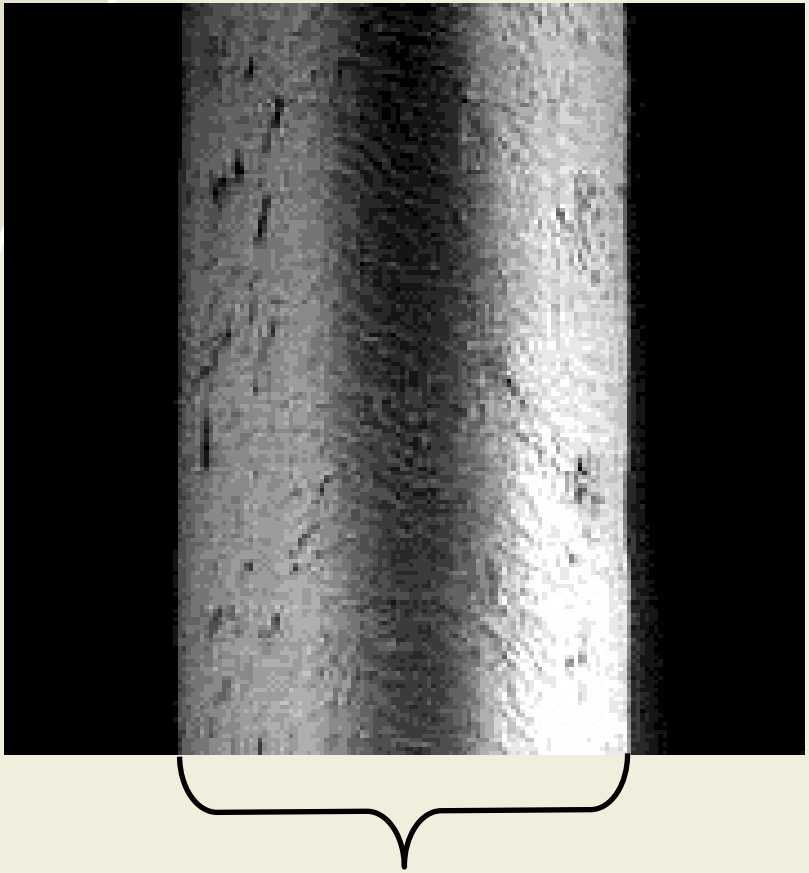
World Health Organization

Source: Reuters, London, June 12th 2012

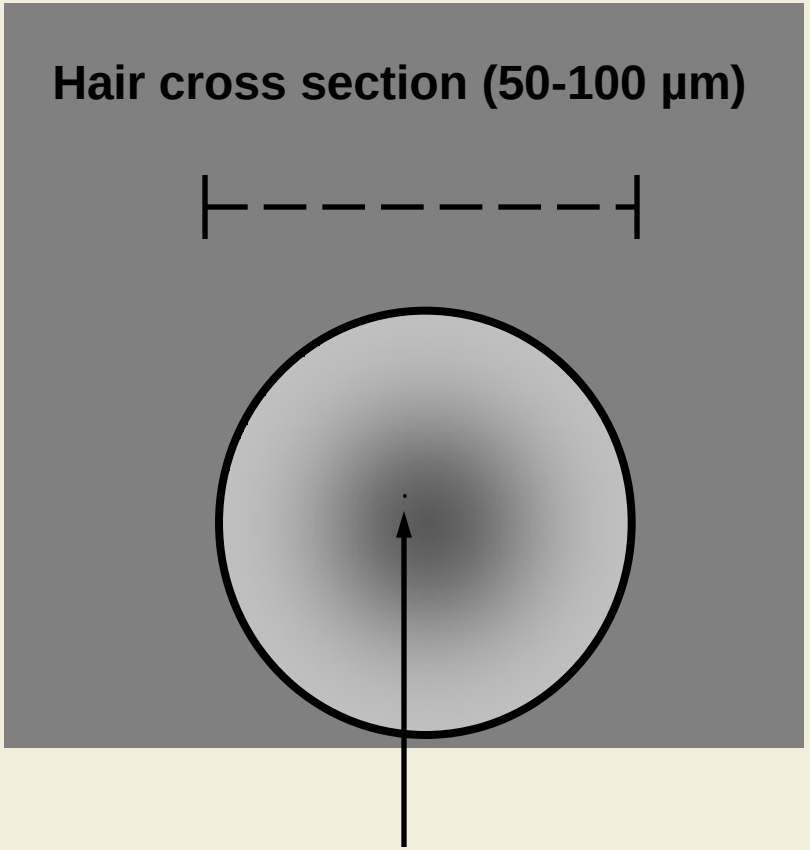
The Case of Claude Fortin

- Fortin was an U/G gold miner (25 years)
- An active non-smoker
- Diagnosed with lung cancer, passes away December 25th 2009
- 2103 Québec superior court upholds the regulators assertion that this represents an occupational disease
- This is a first…

Source: Le Devoir, January 25th 2013



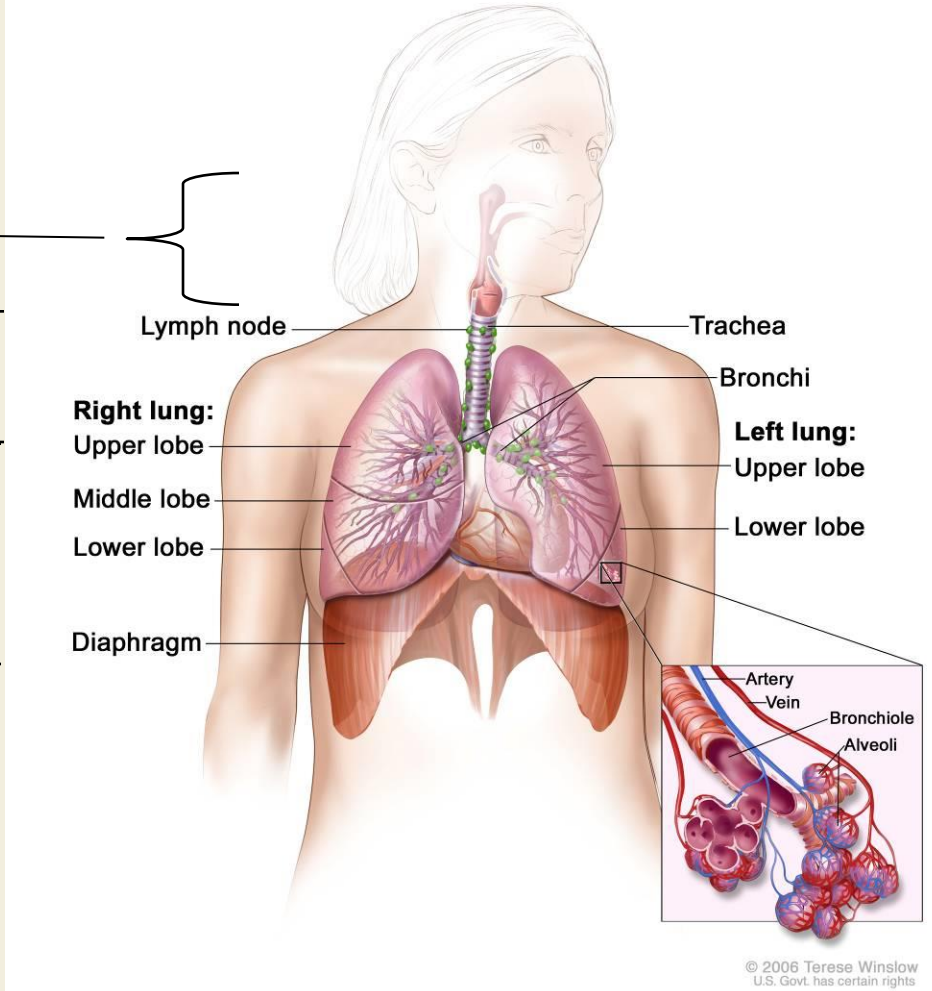
Human Hair
(50-100 µm diameter)



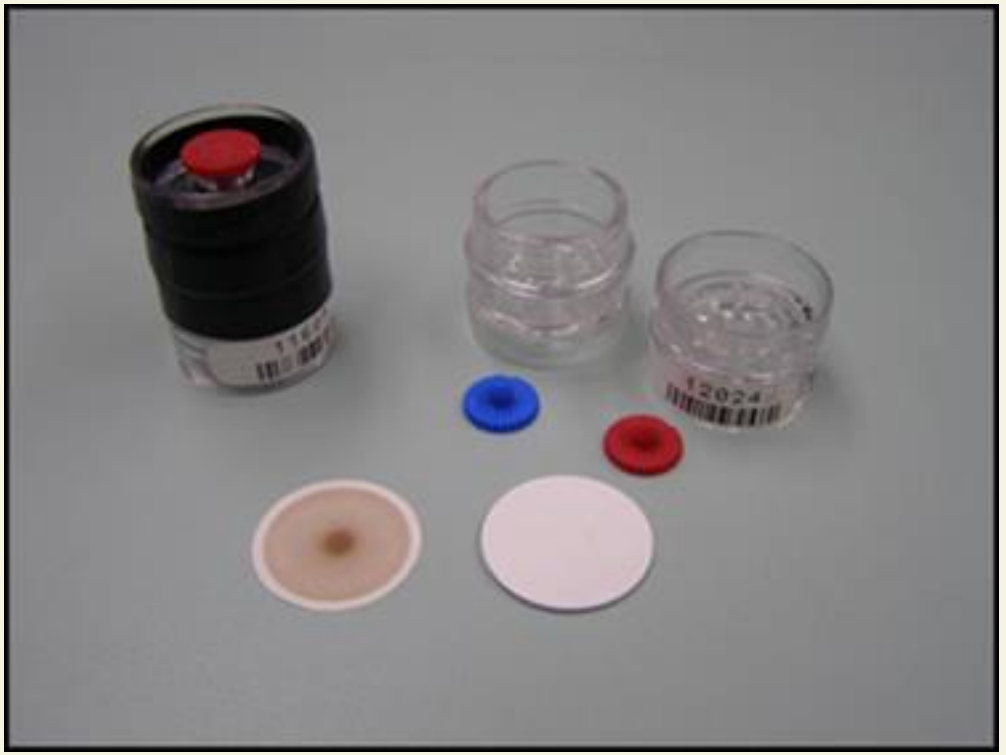
PM0.1 (0.1 µm)

Particulate deposition

- Nose and throat remove particles greater than 10 μm
- Trachea and upper bronchi remove particles 2.5 μm to 10 μm
- Particles between 0.1 μm and 2.5 μm are deposited in bronchioles and alveoli
- Particles less than 0.1 μm reach all areas of lung and to some degree diffuse into body tissues



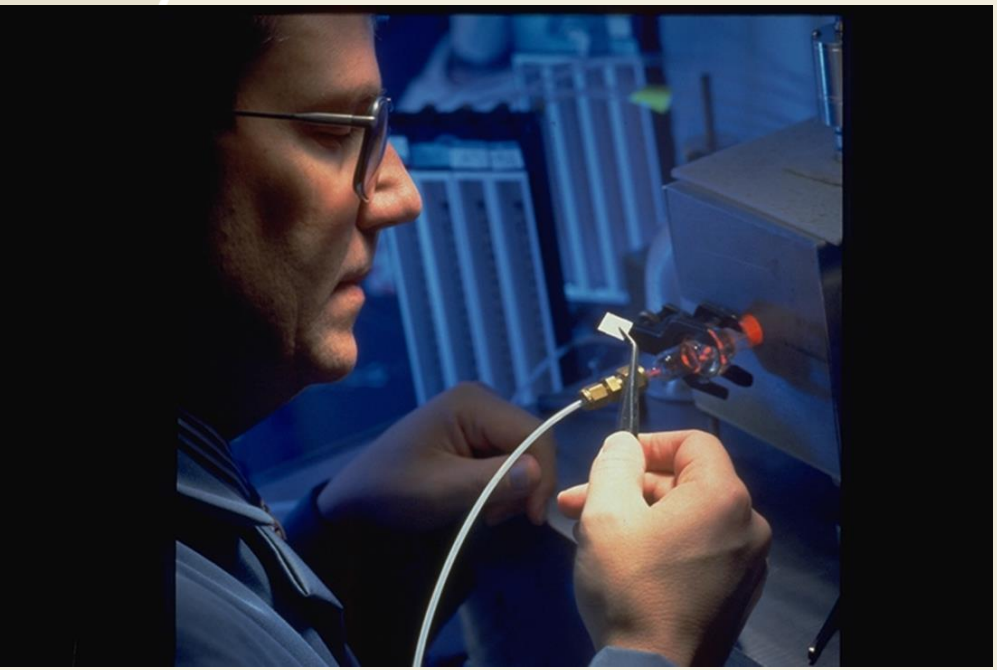
Diesel Particulate Sampling and Analysis



DPM Analytical Method

- NIOSH 5040 method:
  - Also known as the elemental carbon method
  - Adopted by Saskatchewan, Ontario, Québec, NL
  - Mentioned by name in the MSHA DPM ruling for the U.S.

NIOSH 5040 Method



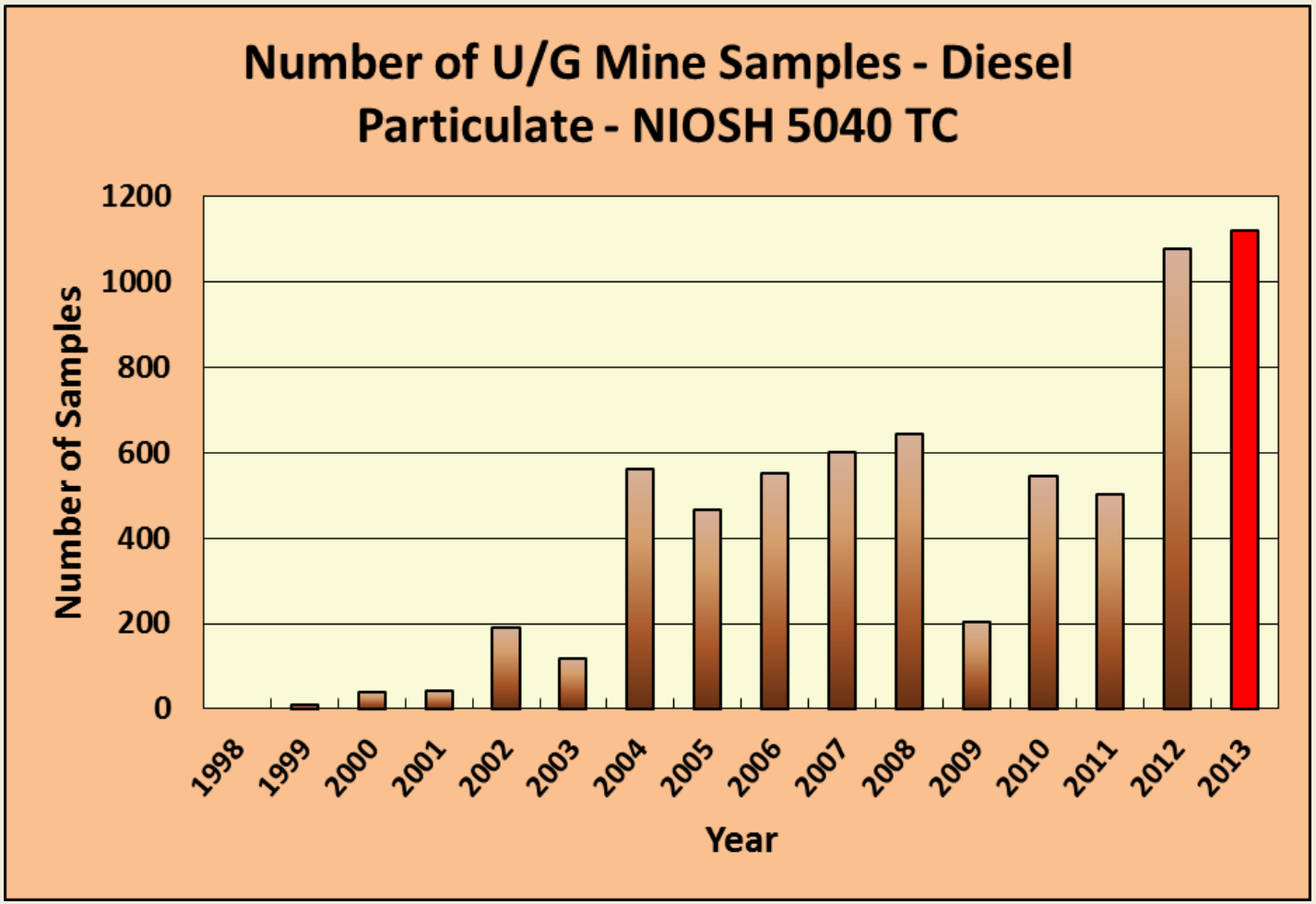
- Detection limit: 0.001 mg (elemental carbon) and 0.005 mg (organic carbon)
- Principle of analysis: two-phase heating of sample with measurement of combustion generated gases

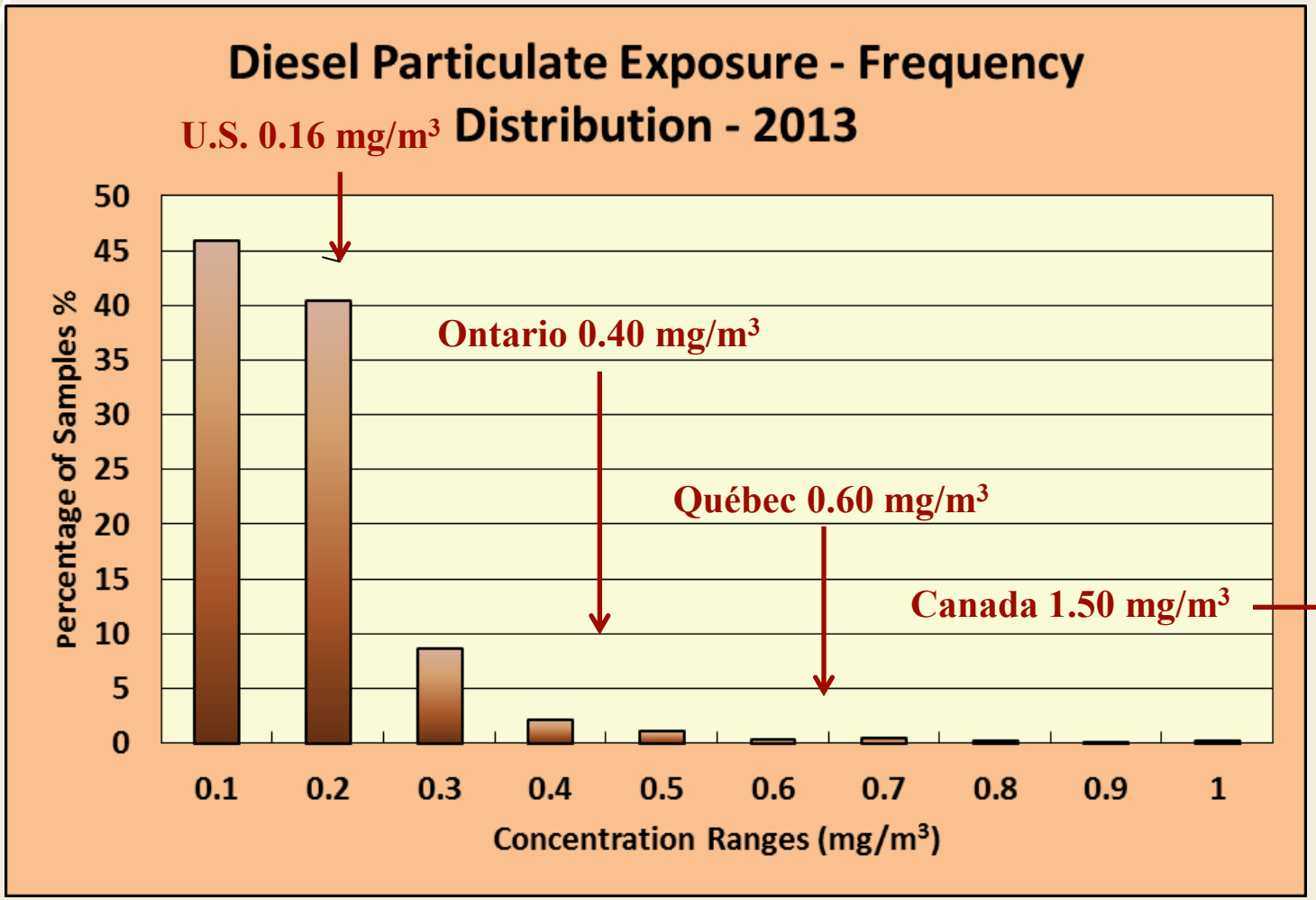
DPM Regulation and Miner Exposure Data

DPM Exposure Limits

- Canada - 1.5 mg/m^3 (early1990's)
- Québec - 0.6 mg/m^3 (Spring 2003*)
- Ontario - 0.4 mg/m^3 (January 2012)
- MSHA – American mines 0.16 mg/m^3

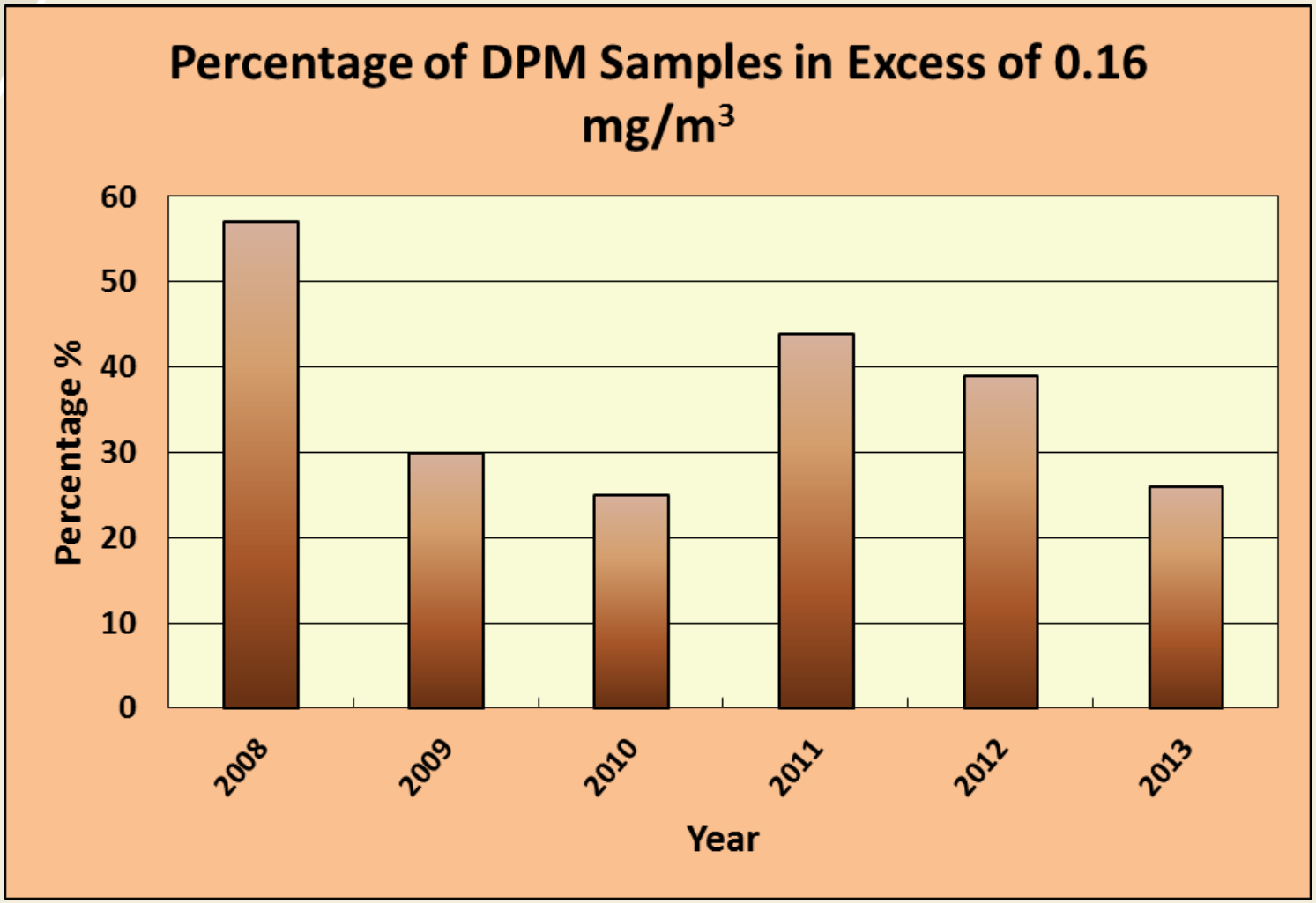
* Now 0.4 mg/m^3


Number of U/G Mine Samples - Diesel Particulate - NIOSH 5040 TC
Number of Samples
1200
1000
800
600
400
200
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year


Diesel Particulate Exposure - Frequency Distribution - 2013
U.S. 0.16 mg/m3
Ontario 0.40 mg/m3
Québec 0.60 mg/m3
Canada 1.50 mg/m3
Percentage of Samples %
50
45
40
35
30
25
20
15
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Concentration Ranges (mg/m3)

Percentage of Samples in Excess of Various Exposure Limits – 2013 Canadian Underground Mine Data (1064 samples)

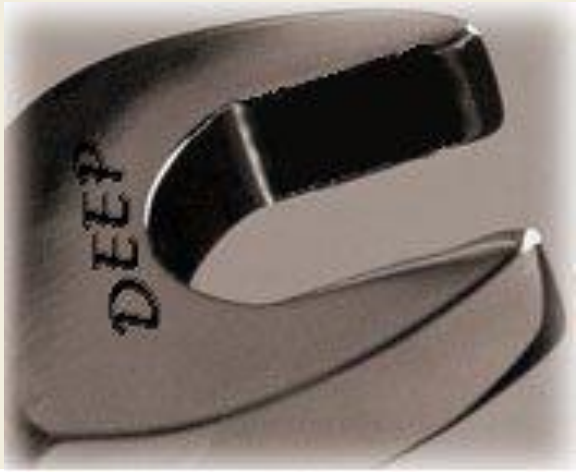
Exposure limit (mg/m^3)	% of samples in excess of limit
1.5 (Canada)	0
0.6 (Québec)	1.5
0.4 (Ontario)	3
0.16 (USA – MSHA)	26


Percentage of DPM Samples in Excess of 0.16 mg/m3
Percentage %
60
50
40
30
20
10
0
2008
2009
2010
2011
2012
2013
Year

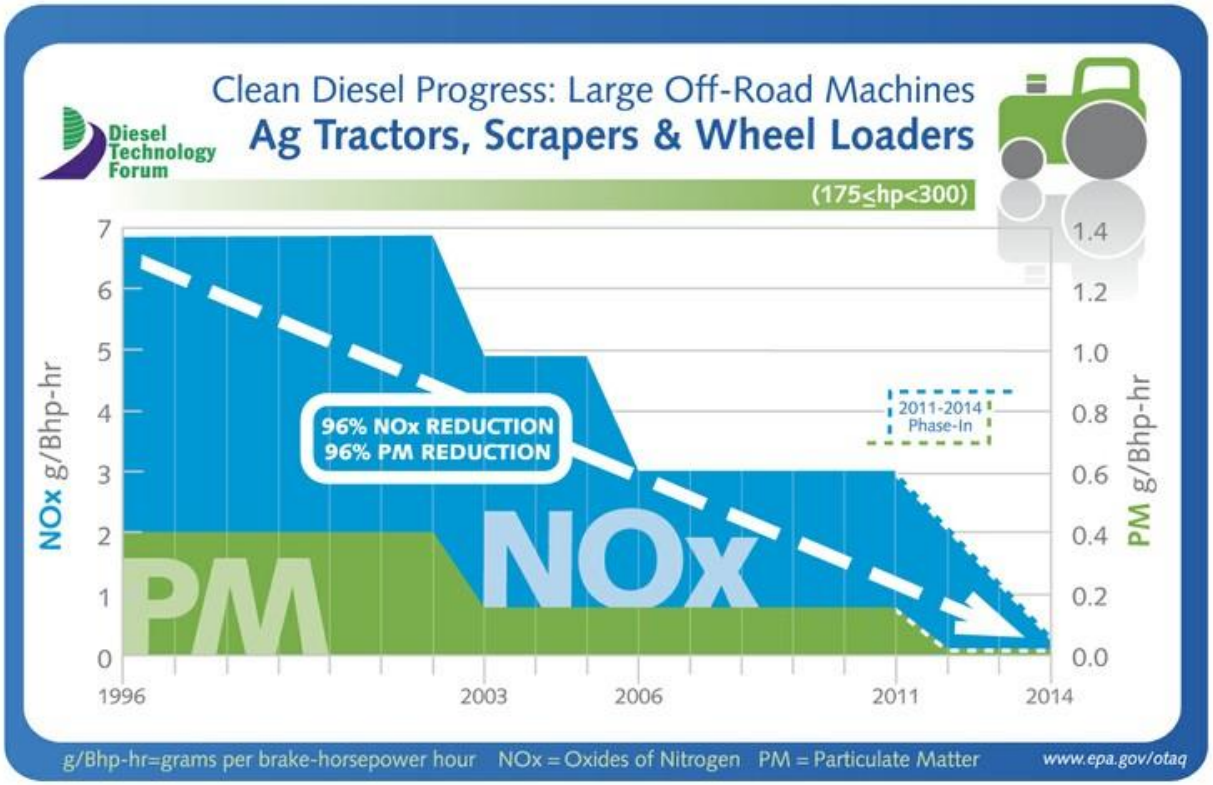
Emissions Control Strategies and Research

Solutions Toolbox – First and Foremost: Control at the Source

- Modern engines/certification
- Maintenance
- After-treatment technology
- Alternative energies



Clean Modern Engines



Certification for U/G Mine Engines

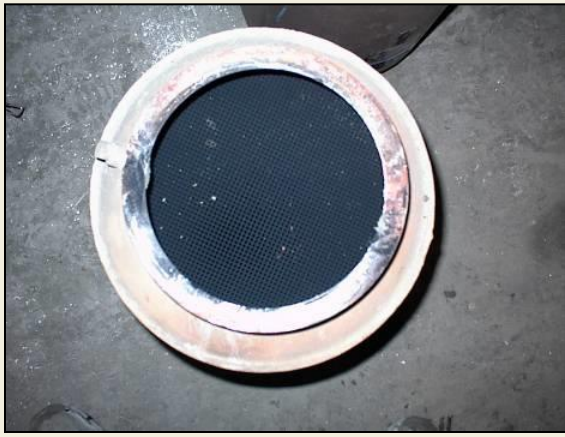
- Characterize engine emissions on laboratory dynamometer
- Determine ventilation volumes required to dilute to “safe” levels
- Used in some provincial regulation
- Used by all to select “cleaner” engines
- www.diesel.nrcan.gc.ca

Emissions Based Maintenance

- Underground mines require routine maintenance (250 hours)
- Maintain intake filters, leaks, exhaust, engine, cooling, etc. and **measure impact**
- Research showed 53% reductions in DPM exhaust concentration
- www.camiro.org/mining/diesel-emission-evaluation-program

Exhaust Treatment

- Catalytic converters – oxidation of CO to CO_2
- Particulate filters > 80% DPM reduction
- Advanced technology (selective catalytic reduction, SCR) > 70% NO_x reduction
- Combination of above, the only means of meeting new U.S. engine regulatory requirements (EPA Tier 4)



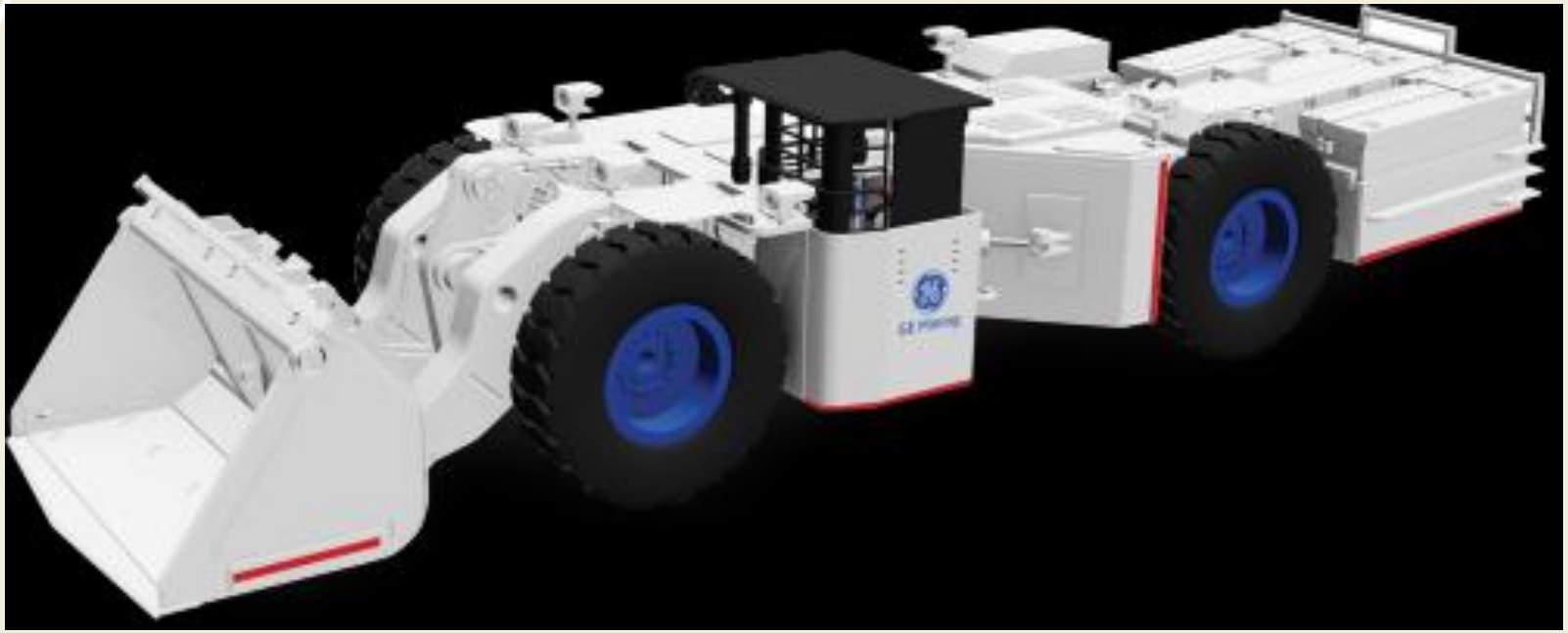
Alternative Energies

- Biodiesel
  - Can significantly reduce DPM
  - Can cause NO_2 to increase
- Diesel-Electric Hybrid Vehicles
  - 65% reduction in overall exhaust contamination
  - Fuel savings of 25% to 40%
- Hydrogen Fuel Cells
- Fully Electric Vehicles

RDH Mining – Haulmaster 800E

Pedno - Minautor

GE Mining – Battery Powered LHD



MINECAT – UT150 eMV

Papabravo – Badger EV-141 Crew

Other Mitigation Strategies:

- Sampling and monitoring
- Ventilation
- Training/technology transfer

Sampling & Monitoring

- Critical:
  - To meet regulation
  - To assess the impact of maintenance
  - To prove the impact and assess the cost benefit of engineering controls

Ventilation

- Maintain good ventilation systems and infrastructure
- Ventilation is indispensable but very costly – control at the source
- Underground as elsewhere it must be managed carefully

Training & Technology Transfer

- Make sure employees are aware of the risks and know how to eliminate or minimize exposure
- Share information
- http://mdec.ca

Lessons Learned

- Invest in the latest technology (modern engines, AC cabs, exhaust treatment)
- Regular emissions based vehicle maintenance
- Measure and monitor
- Ventilation (volume, distribution, maintenance)
- Employee training:
  - No unnecessary idling
  - Ensure equipment is working properly
  - Ensure ventilation is adequate
  - Report issues immediately

Thank you…

Merci!