DIESEL EXHAUST: A COMPARISON OF STANDARDS AND SAMPLING METHODS

Presented by
Tammy Edwards and Jena Brunson, MPH
Naval Medical Center Portsmouth
Industrial Hygiene Department

Disclaimer

The views expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense or the United States Government.

WHAT IS DIESEL EXHAUST

- Diesel exhaust is a complex mixture hundreds of combustion products of diesel fuel
  - Two main components – gas and particulate (DPM)

- The exact composition of the mixture depends on the engine types (heavy-duty, light-duty), engine operating conditions (idle, accelerate, decelerate) and fuel formulations (high/low sulfur fuel).

GASES

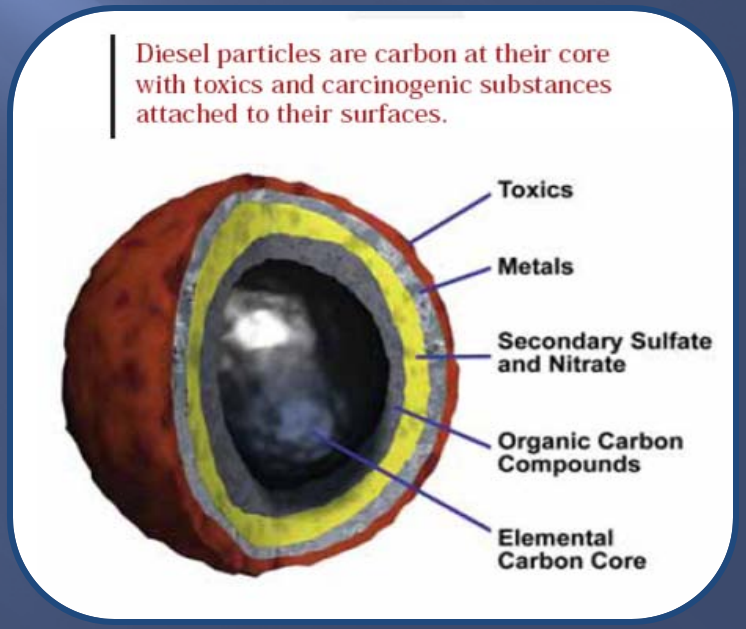
- Gases – carbon monoxide, carbon dioxide, oxygen, oxides of nitrogen, water vapor, sulfur compounds, and numerous low-molecular-weight hydrocarbons

  - Several of the hydrocarbons are individually toxic aldehydes, benzene, polycyclic aromatic hydrocarbons (PAHs), 1,3-butadiene, etc.

PARTICULATES

- Particulate – Diesel Particulate Matter (DPM)
  - Less than 1μm in diameter
  - Highly respirable

Organic and elemental carbon account for approximately 80% of the total particulate matter mass.



EFFECTS OF EXPOSURE TO DIESEL EXHAUST

Acute - eye, throat, and bronchial irritation, allergenic responses, and asthma-like symptoms

Chronic – Premature death from cardiovascular, cardiopulmonary and respiratory causes, lung cancer

IS DIESEL EXHAUST A CARCINOGEN?

- 1988 NIOSH - Potential occupational carcinogen
- 1989 IARC - 2A – Probably carcinogenic to humans
- 2000 National Toxicology Program/US Dept of Health and Human Services ROC12 - Reasonably anticipated to be a human carcinogen
- 2002 EPA - Likely to be carcinogenic to humans by inhalation
- OSHA - Select Carcinogen

March 2012 NCI Study

- NCI/NIOSH/CDC/NIH
- 20 year study
- 12000 non-metal mine workers
- Sampled elemental carbon as the best index for diesel exhaust

-Results: 3-fold increase in lung cancer overall

5-fold increase in lung cancer for heavily exposed

7-fold increase for non-smokers/heavily exposed

DIESEL EXHAUST STANDARDS

- EPA
- OSHA
- ACGIH
- MSHA

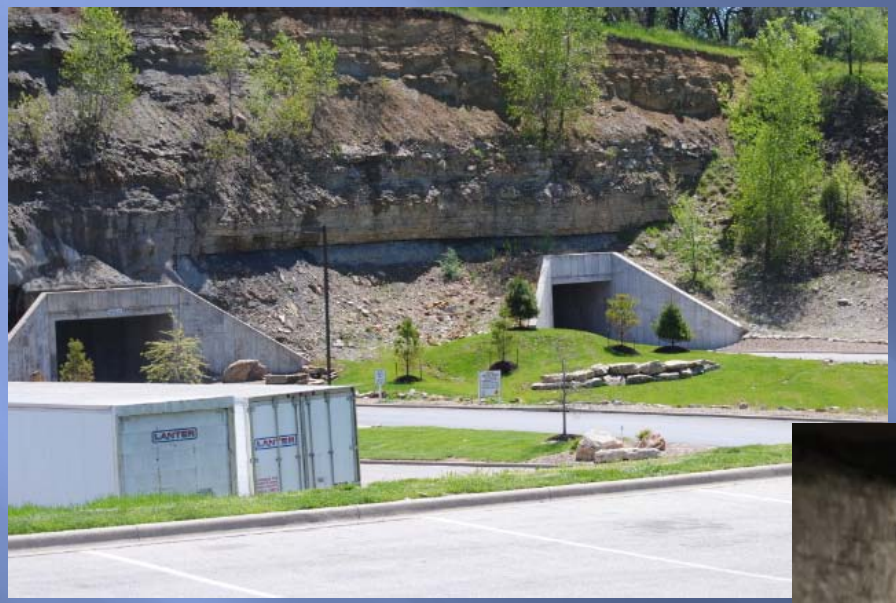
EPA STANDARDS

- 2002 EPA's Inhalation Reference Concentration, which estimates a safe daily exposure level during a lifetime is 5 µg/m3 (0.005 mg/m3).

OSHA PEL's

- OSHA does not have a PEL for diesel exhaust
  - Regulates as the individual constituents
    - Benzene
    - Carbon dioxide
    - Carbon monoxide
    - Formaldehyde
    - Nitrogen dioxide
    - Sulfur dioxide
    - PAH's
    - etc…

Trip down memory lane



ACGIH TLV

- Listed as a notice of intended changes in 2001
  - 0.02 mg/m^3 (as elemental carbon)
  - A2 carcinogen - Suspected Human Carcinogen
- Withdrawn in 2003 ?????

MSHA STANDARDS

- Regulates occupational settings for the mining industry
- 2008 - PEL of 160 µg/m3 (0.16 mg/m3) of total carbon for metal/non-metal mines
- MSHA requires specific size selective sampling media to reduce interferences from tobacco smoke, drill oil mist, and mineral ore founds in mines
- NIOSH method 5040

At last a standard –

WHAT'S NEXT?

Enter Ms. Jena Brunson – aspiring Industrial Hygienist and Master Student in need of a capstone project

HOW TO SAMPLE

DPM cassette with jeweled impactor

OR

Quartz cassette

What's the difference?

Official MSHA method:

- DPM cassette with a Precision-jeweled Impactor
  - Heat-treated quartz filter
  - Impactor with precision sapphire orifices screens out particles ≥ 1.0 µm such as coal dust

Alternative method for non-mine settings:

- Preloaded Cassette, Quartz
  - Heat-treated quartz filter

Both methods can by analyzed using NIOSH Method 5040

Why do we care?

$439 for a box of 10

$43.90 each

$156 for a box of 50

$3.12 each

Hypothesis

- There will not be a statistically significant difference in the results of the two sampling methods
  - there are no expected interferences such as coal dust, tobacco smoke, and mineral ore

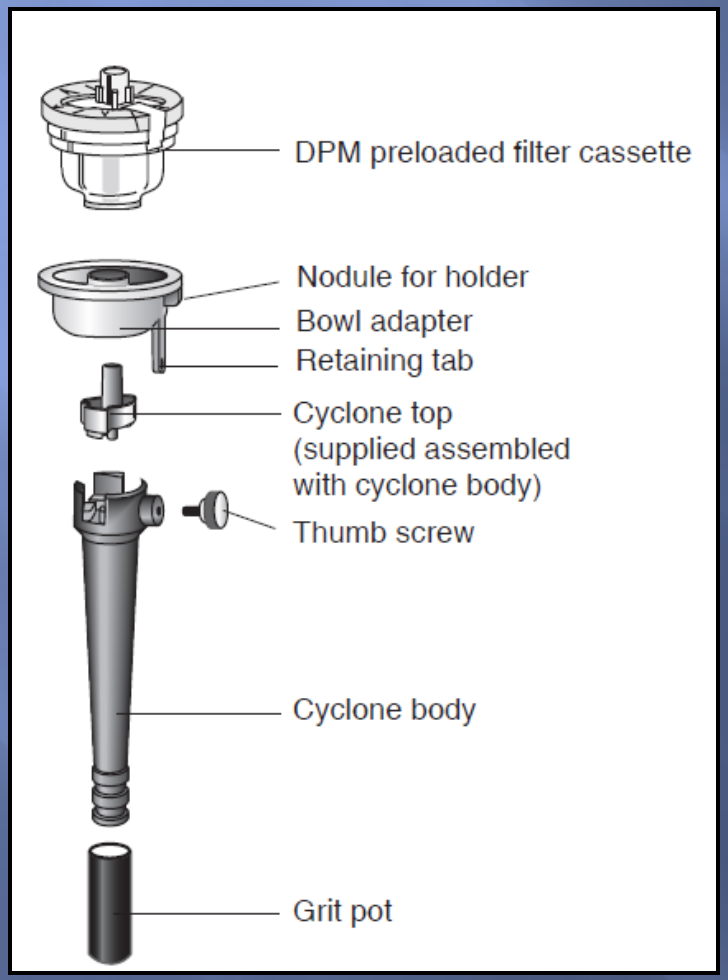
P100 FIRE PUMP

Testing P-100 Fire Pumps

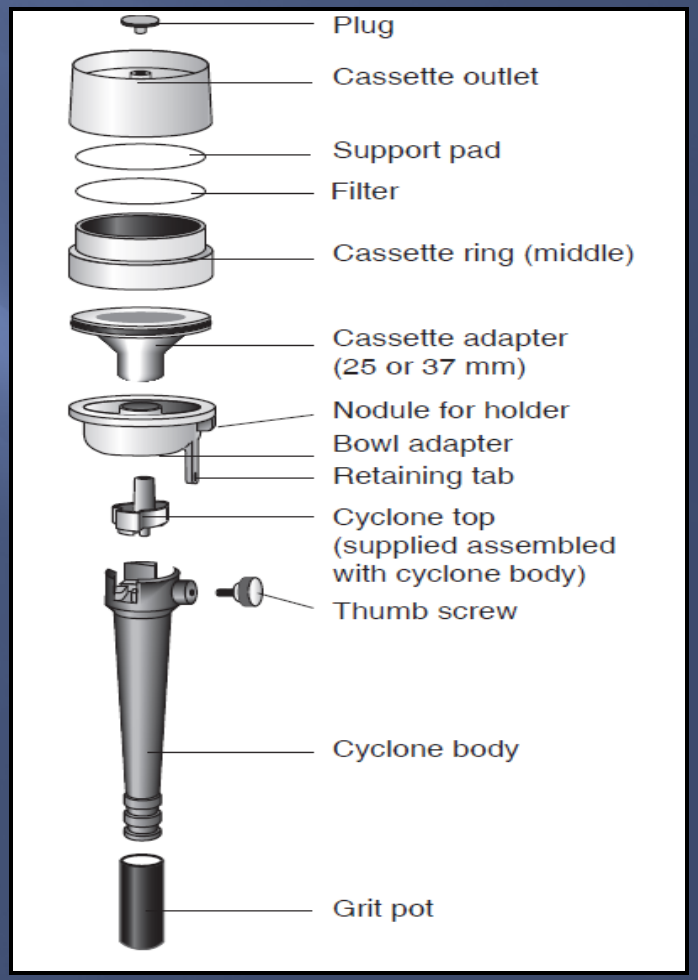
- Testing involves 2 workers who work within 1-5 feet of fire pump exhaust as they bend over pump to make adjustments
- Each test lasts a minimum of 30 minutes
- Tests are performed outdoors
  - Will we even get positive results?

Sampling Assembly

DPM Cassette and GS-1 Cyclone assembly



Three-piece quartz cassette and GS-1 Cyclone assembly



Figures taken from SKC Operating Instructions for the DPM Cassette

It looked like this…

- Sampled side-by-side using both the DPM with jeweled impactor and the quartz cassette, both with the GS-1 cyclone

What we accomplished

- Sampling between February 2009 and August 2011
- Collected 11 sample pairs
- Only one pump “fatality” during the study
- I graduated!

Results

Sampling Date	Official Method:DPM Cassette (mg/m^3)	Alternate Method:3-piece quartz filter (mg/m^3)
10 August 2011	0.0219	0.0219
4 August 2011	0.0250	0.0106
12 April 2011	0.0520	0.0570
12 April 2011	0.0289	0.0289
14 September 2011	0.1626	0.1406
2 April 2010	0.1000	0.1250
2 April 2010	0.1100	0.0900
6 March 2009	0.1100	0.1100
6 March 2009	0.1500	0.1100
27 February 2009	0.0848	0.6290
27 February 2009	0.1900	0.2210

Wilcoxon Matched Pairs Test

- Determines whether the difference between the medians of the two groups of results is statistically significant

Analysis of Results

Wilcoxon Matched Pairs Test

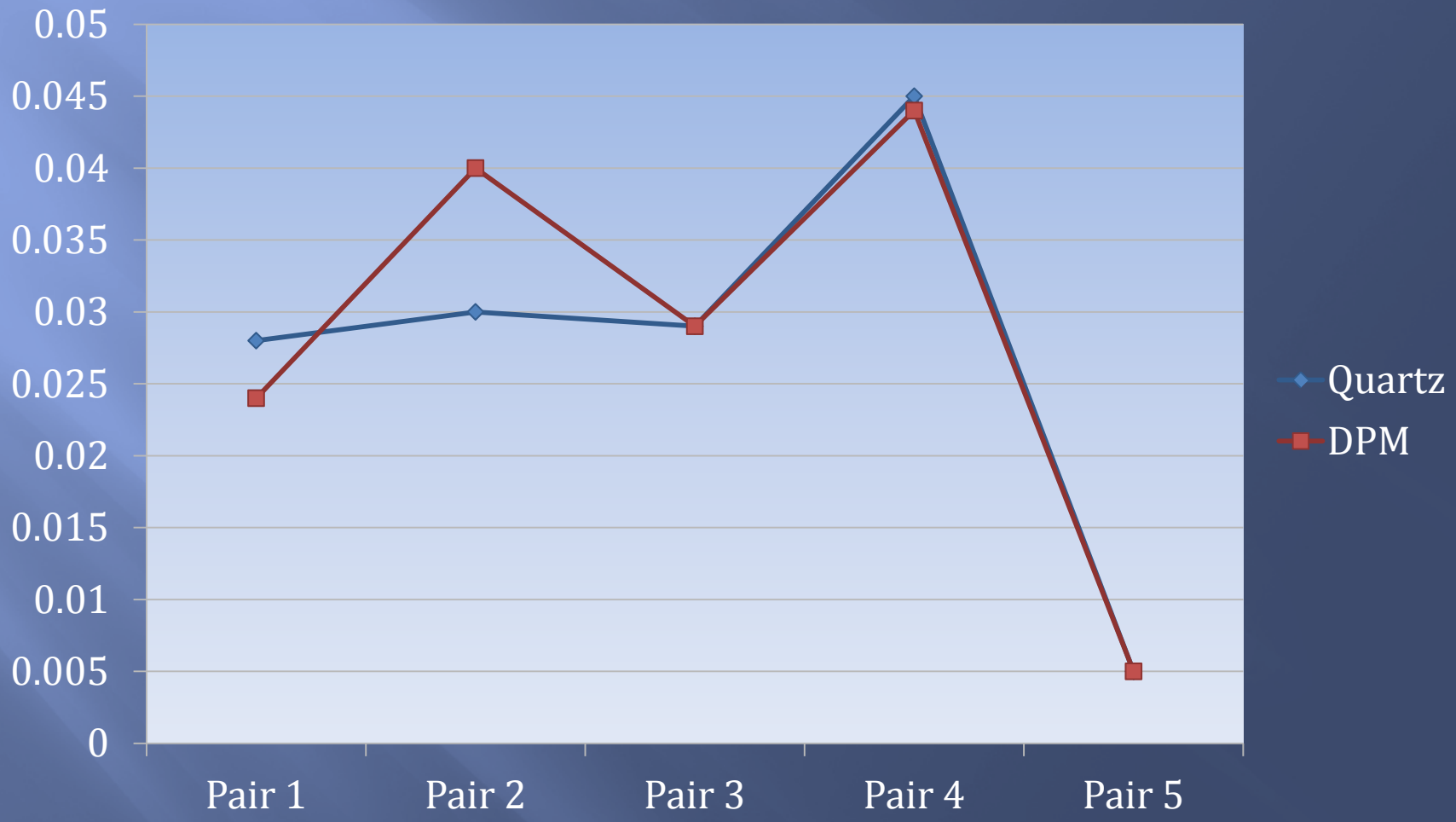
Sampling Date	Official Method (mg/m^3)	Alternate Method (mg/m^3)	Difference Score	Assigned Rank
10 August 2011	0.0219	0.0219	0	---
4 August 2011	0.0250	0.0106	0.0144	2
12 April 2011	0.0520	0.0570	-0.005	1
12 April 2011	0.0289	0.0289	0	---
14 September 2011	0.1626	0.1406	0.022	4
2 April 2010	0.1000	0.1250	-0.025	5
2 April 2010	0.1100	0.0900	0.02	3
6 March 2009	0.1100	0.1100	0	---
6 March 2009	0.1500	0.1100	0.04	7
27 February 2009	0.0848	0.6290	0.5442	8
27 February 2009	0.1900	0.2210	-0.031	6

Wilcoxon Matched Pairs Test

- Sum the ranks of the positive difference scores
  - $\sum P=2+3+4+7+8=24$
- Sum the ranks of the negative difference scores
  - $\sum N=1+5+6=12$
- Compare to the "W-statistic" of 10
  - $\sum N=12$ (smaller one, so use this)
  - If $\sum$ > W-statistic, the difference between the medians of the two groups is not statistically significant
  - Because 12 > 10 there is not a significant difference in total carbon results of the DPM Cassette compared to the three-piece quartz cassette

Results

(Positive Values only)



95 percentile

(Based on positive results only)

DPM cassette	Quartz cassette
0.095 mg/m^3	0.089 mg/m^3

Conclusions

- Navy should use the MSHA standard as a means of evaluating personnel exposure to diesel exhaust
- The use of the quartz filter is more economical and statistically similar to the DPM cassette with the jeweled impactor.

QUESTIONS?