Comments on the DEMS Exposure Assessment

Jonathan Borak, MD, FACOEM
Yale University

DEMS: Background

Diesel Exhaust in Miners Study

- NIOSH and NCI
- 8 US underground mines, 1947-1997
- Three principal components
  - quantitative estimate of historical DE exposure
  - two epidemiological studies
    - retrospective cohort mortality study
    - nested case-control study of lung cancer

DEMS: Background

Diesel Exhaust in Miners Study

- NIOSH and NCI
- 8 US underground mines, 1947-1997
- Three principal components
  - quantitative estimate of historical DE exposure
    - published as four reports
    - *Ann Occup Hyg* 54:728-788 (2010)
  - two epidemiological studies

DEMS: The Challenge

"... no standard for assessing the totality of DE exposure ..." [DEMS I]

- DE is a variable mixture
  - diesel particulate matter (DPM)
    - graphitic carbon core
    - adsorbed organic compounds

DEMS: The Challenge

"... no standard for assessing the totality of DE exposure ..." [DEMS I]

- DE is a variable mixture
  - diesel particulate matter (DPM)
  - gaseous emissions
    - NOx, CO, CO_2, aliphatic hydrocarbons

DEMS: The Challenge

Respirable Elemental Carbon (REC)

- REC: "primary surrogate" for DE
  - method was developed in mid-1990's
  - no historical REC data

DEMS: The Challenge

Respirable Elemental Carbon (REC)

- REC: "primary surrogate" for DE
  - method was developed in mid-1990's
  - no historical REC data
- Need to estimate historical REC levels

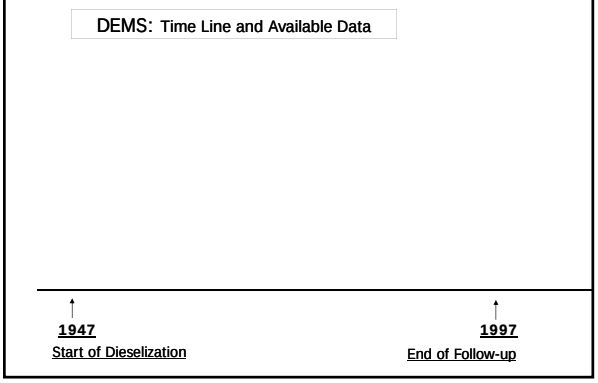
DEMS: The Challenge

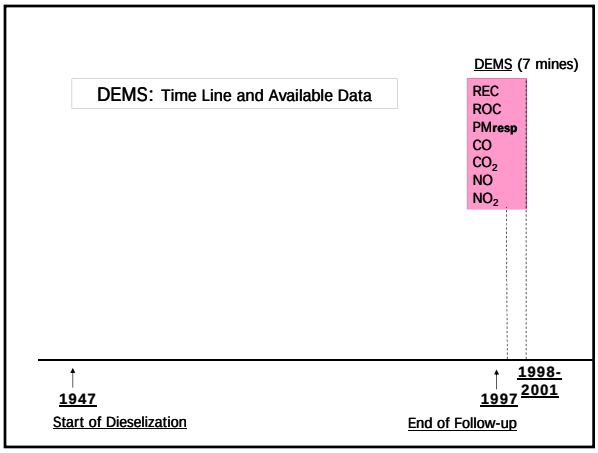
Respirable Elemental Carbon (REC)

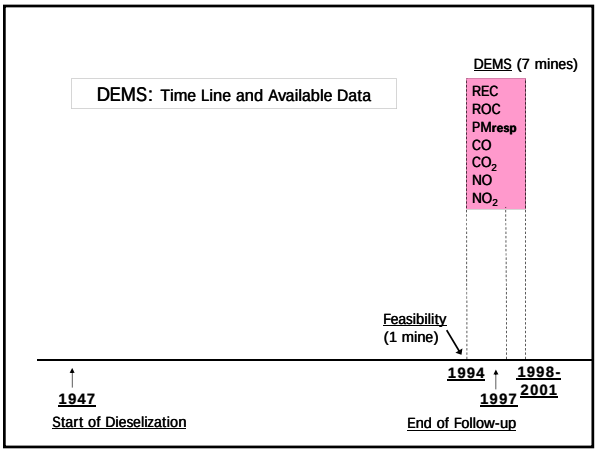
- REC: "primary surrogate" for DE
- Need to estimate historical REC levels
- Estimation was complicated
  - data deficiencies for other exposure metrics
  - changing diesel technology
  - changing mine production and methods
  - incomplete records

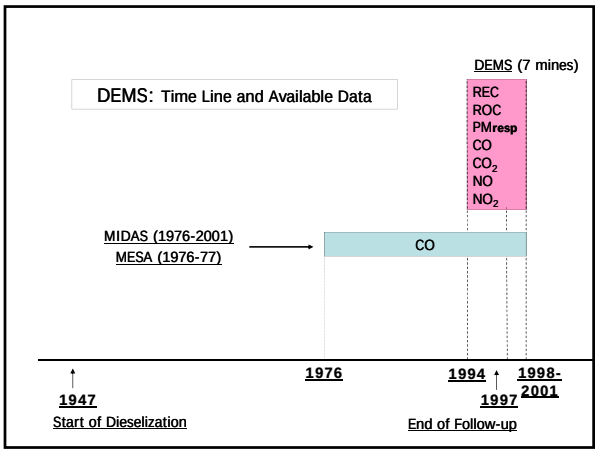
DEMS:

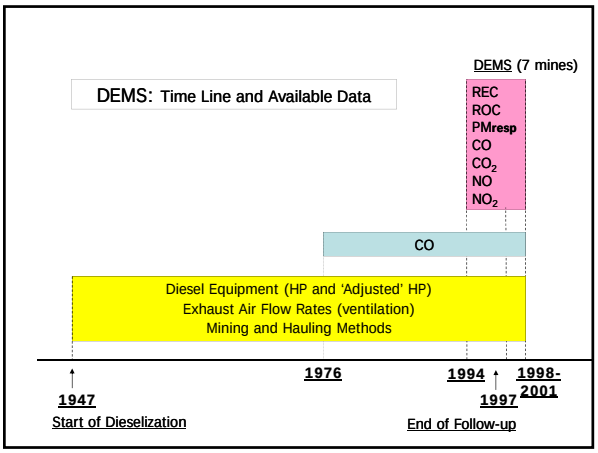
Time Line and Available Data











The Reconstruction

1. Determine REC-CO correlation (1998-01)

The Reconstruction

1. Determine REC-CO correlation (1998-01)
2. Estimate 1976-1994 REC levels using historical CO levels

The Reconstruction

1. Determine REC-CO correlation (1998-01)
2. Estimate 1976-1994 REC levels using historical CO levels
3. Estimate 1947-1976 CO levels based on
   a) diesel fleet HP
   b) hours of equipment use
   c) mine ventilation rates

The Reconstruction

1. Determine REC-CO correlation (1998-01)
2. Estimate 1976-1994 REC levels using historical CO levels
3. Estimate 1947-1976 CO levels based on
   a) diesel fleet HP
   b) hours of equipment use
   c) mine ventilation rates
4. Estimate 1947-1976 REC levels using estimated CO levels

Reconstruction Concerns

- Concerns about CO data
- Concerns about the REC-CO correlation
- Concerns about use of "Fleet HP"

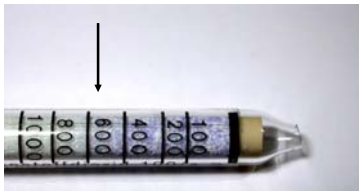
Concerns about CO data

Numbers of CO measurements in the Historical Reconstruction

Survey	Personal Samples	Area Samples
DEMS (1998-2001)	0	208
Feasibility (1994)	0	25
MIDAS (1976-2001)	46	9,746
MESA (1976-77)	0	1,099
"Other"	0	46
Total	46	11,124

Concerns about CO data

- Vast majority were obtained using colorimetric tubes



Concerns about CO data

CO Colorimetric Tubes are Imprecise

- Precision Certification
  - 25-125 ppm ..... ± 25%
  - 12.5-25 ppm ..... ± 35%
  - Not certified < 5 ppm (ANSI/ISEA)

"At best indicator tubes may be regarded as only range finding and approximate in nature"

Stern and Mansdorf, 1999

Concerns about CO data

CO Colorimetric Tubes are Imprecise

In 1976, WHO recommend colorimetric tubes "only for estimating the concentration of CO at concentrations > 5 mg/m^3" **[4.35 ppm]**

WHO, 1976

CO Levels (ppm) in the 7 Mines

Mine	Geometric Mean	Geometric SD
Mine A	4.5	3.7
Mine B	3.5	1.7
Mine D	1.9	2.3
Mine E	3.1	1.6
Mine G	0.4	2.6
Mine H	0.8	4.6
Mine I	2.5	3.0

CO Levels in MIDAS and MESA

- CO area levels taken in the face area and used for underground prediction models
  - 1975-79: "typically" from 1-2 ppm
  - 1980s: "typically" from 1-3 ppm
  - 1990s: "typically" <1 ppm

Concerns about the REC-CO correlation

The CO-REC correlation

Correlation was "Moderate"

- Pearson correlation coefficient for 168 DEMS production face samples: $r_p = 0.41$

Correlation Coefficients: REC vs. CO
(log transformed)

Mine	Correlation Coefficient	# of Sample Pairs
Seven mines	**0.41**	**168**
Mine A	0.49	26
Mine B	0.77	23
Mine D	0.62	19
Mine E	0.74	26
Mine G	0.44	23
Mine H	0.40	25
Mine I	0.05	29

The CO-REC correlation

Correlation was "Moderate"

- Pearson correlation coefficient for 168 DEMS production face samples: $r_p = 0.41$
- "Weakest" correlation of the gaseous DE components measured
  - NO: $r_p = 0.72$
  - CO_2: $r_p = 0.66$
  - NO_2: $r_p = 0.52$

CO-REC correlation in diesel engine emissions

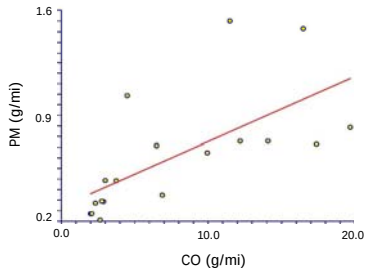
Correlation in Diesel Emissions

- 18 transit buses
- Controlled test conditions
  - chassis dynamometer
  - standardized test cycles
  - engines operating properly
- No exhaust after-treatment devices
- PM vs. CO: $r^2 = 0.43$

Hesterberg, 2008

Correlation for Diesel Emissions

- 18 transit buses - PM vs. CO: $r^2 = 0.43$



Hesterberg, 2008

Concerns about "Fleet HP"

Concerns about "Fleet HP"

- Data limitations

"diesel-powered equipment … inventories generally were available for a few years in the 1970s and the 1990s but rarely in the 1980s."

[DEMS IV]

Concerns about "Fleet HP"

Emissions vary under different work conditions

Concerns about "Fleet HP"

- HP is a weak predictor of DE
  - Emissions depend on speed and load

Concerns about "Fleet HP"

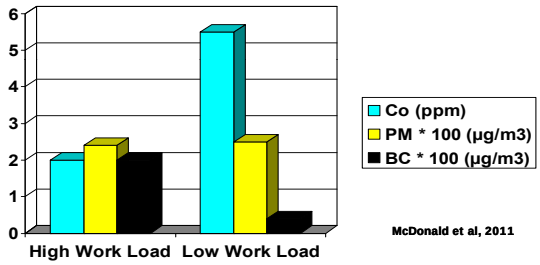
- HP is a weak predictor of DE
  - Emissions depend on speed and load
  - High fuel consumption/work is associated with ↑PM output and ↓CO output

Concerns about "Fleet HP"

- HP is a weak predictor of DE
  - Emissions depend on speed and load
  - High fuel consumption/work is associated with ↑PM output and ↓CO output
  - Low fuel consumption/work is associated with ↓PM output and ↑CO output

Concerns about "Fleet HP"

CO, PM and Black Carbon do not trend under different work conditions



Concerns about "Fleet HP"

Emissions vary across engines
(even for the same models)

Concerns about "Fleet HP"

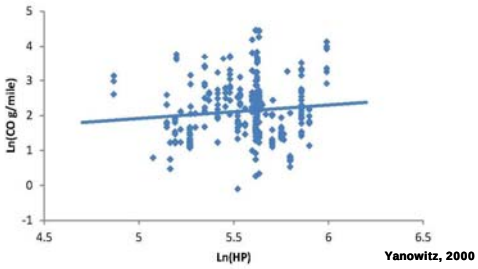
Yankowitz 2000

"Further evidence supporting the historical extrapolation approach" [DEMS III]

- chassis dynamometer data
- 20 different studies
- >250 heavy-duty diesel vehicles
  - model years: 1974 to 1997
  - Mileage: <1000 to 750,000+
- different work conditions

HP does NOT predict CO

HP and CO do not trend:
303 vehicle tests



Yanowitz, 2000