PM$_{2.5}$, Air Toxics, And Crankcase Emissions In The Truck Stop Environment

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Average Annual Daily Truck Traffic

Source: Federal Highway Administration (DOT) [www.dot.gov/freight/]
Average Annual Daily Truck Traffic …
Expected to Grow

Source: Federal Highway Administration (DOT) [www.dot.gov/freight/]
Tennessee Truck Traffic

AADTT: Average Annual Daily Truck Traffic

**1998**

**2020**

Estimated Average Annual Daily Truck Traffic: 1998

Estimated Average Annual Daily Truck Traffic: 2020
Aerial view looking South

- Region in non-attainment for PM$_{2.5}$, near non-attainment for ozone
Why study the Watt Road interchange?

- Confluence of I-40 and I-75 for twenty miles
- Heavy commercial truck traffic (~20K/day)
  - FHWA interested in traffic influences on PM
- Multiple over-nighting facilities for Class 8 trucks, including truck stop electrification
  - CMAQ project interested in seeing effects of TSE
- Proximity to ORNL/UT
Watt Road-Interstate 40/75 Interchange

Elevation Exaggeration=3x

Weigh Station

Watt Road-I-40/75 Interchange

Three Major Truckstops
Air Quality Studies: Location of Roadside, Truckstop, and Ridgetop (Background) Sampling Points

- **Roadside**
  - Elevation: 877 ft
- **Truckstop**
  - Elevation: 920 ft
- **Ridgetop (Background)**
  - Elevation: 1182 ft
- **Idleaire Installation**
Idling Trucks at Truckstops are Largest NOx and PM2.5 Contributor to Roadside Air Quality (Interstate Off Ramp)

- Combination of data used to determine contribution of idling trucks to air quality at ramp site near roadway
  - NOx, PM Monitoring
  - Meteorological Data
  - EPA’s MOBILE 6.2 Emission Factors

- Despite >20,000 Trucks per day traveling interstate near interchange...
  - 100s of Idling trucks dominate the NOx and PM2.5 right next to the interstate
  - Traffic on interstate free-flowing for this study
Hot Spot” of High Pollutant Levels Formed by Idling Trucks at Truck Stops Near Roadway

- Truckstops form “Hot Spots” of poor air quality
  - NOx, PM, MSATs elevated

- Boundary of “Hot Spot” difficult to define
  - Dependent on number of factors

- Recent health risk studies link higher risk to residency near roadways

- Further studies of “Hot Spots” warranted
  - Health impacts of 2007/10 technology introduction
Measured NO and NO$_2$ well above NAAQS for NO$_2$

Monthly Mean NO and NO2 Concentrations at Trailer #1

chart courtesy of Dr. Terry Miller, UT
Measured Formaldehyde exceeds minimum risk level often
Mobile Source Air Toxics: Air Quality Near Truckstops

- High Concentrations of Formaldehyde and Acetaldehyde observed at truckstop especially in winter

- Formaldehyde may transport to roadside and background in winter

![Graph showing concentrations of formaldehyde and acetaldehyde at different locations: Truckstop, Roadside, and Background. The graph indicates higher concentrations in winter compared to summer.]
Year-round PM$_{2.5}$ levels at the truckstop exceed EPA’s required annual average.
24-Average PM2.5 Concentrations at Trailer #2

Time (Hour)

24-Hour Average PM2.5 Concentration (µg/m³)

Diamonds: 24-Average PM2.5 Concentrations at Trailer #2
Mean Dp decreases when PM numbers increase, and vice versa.
Size distributions show 10-fold increase in nano-particles and combustion aerosols during overnight hours

~35 nm!
Winter OC & EC show more variation

Carbon Count (ug/m^3)

error bars represent +/- COV

Summer

Winter

day

night

Truck Stop OC

Truck Stop EC

Road OC

Road EC

Truck Stop OC

Truck Stop EC

Road OC

Road EC
• The concentration of three- and four-ring PAHs follows the trend of PM\textsubscript{2.5} concentration
• PAHs are typically associated with combustion aerosols like diesel PM
Lube-related alkanes heavy on some winter days

![Bar chart showing concentrations of various alkanes from 16 Feb to 4 Mar.](chart.png)

- n-Eicosane
- n-Heneicosane
- n-Docosane
- n-Tricosane
- n-Tetracosane
- n-Pentacosane
Fast forward to a new understanding of crankcase emissions

- Looking at evaluation methods for field-aged, retrofit DPF technology (EPA-OTAQ)

- Crankcase emissions difficult to measure
  - No vacuum or pressure can be exerted on the engine
  - Particle sizes go well beyond SMPS
  - Aerosol Particle Sizer very sensitive to concentration - >1000:1 dilution required

- Contribute directly to PM$_{2.5}$ as primary organic aerosol
Exhaust Sampling System

Engine: 1999 Cummins B5.9 Diesel

Sampler for crankcase PM

DPF
Crankcase Emissions Sampling System

Primary Dilution Tunnel
- 70 mm filters
- Isokinetic probe
- Room Air ~190 LPM
- Crankcase
- HEPA
- 198 LPM To Pump (Roots Blower)
- Manometer to ensure vacuum not exerted on crankcase
- 1.5 in.

Secondary Dilution Tunnel
- 99 LPM
- Mass Flow Controller
- HEPA-filtered air
- Draft tube
- Re=8500
- Isokinetic probe
- SMPS*: measures particles < 1 um
- Aerodynamic Particle Sizer**: measures particles > 1 um
- 5 LPM To Pump

* Scanning mobility particle sizer (SMPS): measures particles < 1 um
** Aerodynamic particle sizer: measures particles > 1 um
Crankcase PM Mass Emissions

Total crankcase PM emitted during FTP
Mass collected:
~ 63 mg each filter

Exhaust PM collected during FTP
Mass sampled:
~1.1 mg
Crankcase PM Mass Emissions for FTP Cycles

For hot FTP:
Crankcase emissions ~ 3 X greater than DPF treated exhaust emissions

Soluble organics ~90% of crankcase PM

Transient Test
Crankcase Emissions
Number-Size Distribution

1400 RPM, 300 ft lbs

Increased Backpressure

Engine Baseline

\( \mu_g = 114 \pm 2 \text{ nm} \)
\( C_{tot} = 2.9 \times 10^7 \text{#/cm}^3 \)

\( d_p > 540 \text{ nm} \)
\( C_{tot} = 1.8 \times 10^6 \)

Backpressure 280 mbar at rated speed (1400 RPM)

\( \mu_g = 159 \pm 2 \text{ nm} \)
\( C_{tot} = 1.4 \times 10^8 \text{#/cm}^3 \)

\( d_p > 540 \text{ nm} \)
\( C_{tot} = 1.1 \times 10^7 \)
Summary

- Winter temperatures, overnight stays influenced PM2.5
  - higher in truck stop, despite heavy truck traffic on I-40
- OC/EC dominated by biogenics in summer levels of both EC and OC higher in winter
  - much more variability in winter
- Lube and PAH important in PM$_{2.5}$ at the truck stop
- Formaldehyde levels can get high in winter
  - strongly dependent on temperature/mixing
- Crankcase PM
  - mass emissions ~ 3 X greater than DPF-out PM emissions over FTP
  - For $d_p > 540$ nm, total number concentration was about $1 \times 10^7$ for case of elevated backpressure