Biodiesel and Renewable Diesel Emissions Study
VOC, Carbonyl & N₂O Emissions

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Acknowledgements

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Organic Analysis

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## Engines and Fuels

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<td>EGR</td>
<td>ULSD diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100), Renewable diesel (R20, R50, R100)</td>
<td>VOC Carbonyl N2O</td>
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<td>2006 International ISM 370</td>
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<td>ULSD diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100),</td>
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<tr>
<td>2008 Freightliner Mercedes Benz MBE 4000</td>
<td>DOC, DPF, EGR</td>
<td>ULSD diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100),</td>
<td>VOC Carbonyl</td>
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Emissions Analyses

- Speciated non-methane hydrocarbons (NMHC)
- Carbonyl compounds
- Nitrous Oxide (N2O)
## Instrumentation

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<td>Tedlar Bag</td>
<td>Gas Chromatograph (GC) with flame ionization detector (FID)</td>
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<td>Carbonyls</td>
<td>DNPH* Cartridge</td>
<td>High performance liquid chromatograph (HPLC) with UV detector</td>
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<td>$\text{N}_2\text{O}$</td>
<td>Tedlar Bag</td>
<td>Fourier transform infrared spectrometer (FTIR)</td>
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* Sampling cartridge impregnated with 2,4-dinitrophenylhydrazine
Speciated Non-Methane Hydrocarbon Analysis

- Tedlar bag samples analyzed by 2 GC/FIDs, connected in parallel
  - Light-end GC: C1 to C5 HCs
  - Mid-range GC: C6 to C12 HCs
- Liquid nitrogen trapping of sample yields FID detection limits to very low ppbC
Speciated Non-Methane Hydrocarbon Analysis

- Compounds reported for this study:
  - 1,3-butadiene
  - benzene
  - toluene
  - ethylbenzene
  - \textit{m-}/\textit{p-}xylene
  - styrene
  - \textit{o-}xylene
Toxic VOC - Soy Biodiesel

ULSD Benzene

1,3-Butadiene
Benzene
o-Xylene

mg/mile
Toxic VOC - Animal Biodiesel

ULSD Benzene

1,3-Butadiene
Benzene
o-Xylene

mg/mile
Toxic VOC-C15

UDDS

Cruise
Toxic VOC - MBE4000

UDDS

Cruise
NITROUS OXIDE ANALYSIS

• Tedlar bag samples analyzed by Fourier transform infrared spectroscopy (FTIR)
  – 10-Meter, folded path IR cell
\( \text{N}_2\text{O} – \text{C15 Engine} \)
Carbonyl Analysis (Aldehydes and Ketones)

- Carbonyl group derivatized by DNPH in sampling cartridge*
- Cartridges flushed with solvent to extract carbonyl compounds
- Solution analyzed by high performance liquid chromatograph (HPLC) with UV detection
Carbonyl Analysis (Aldehydes and Ketones)

• This method measures:
  – formaldehyde
  – acetaldehyde
  – acrolein*
  – 10 Other carbonyls (to C$_6$)
Carbonyl - ULSD

The graph represents the concentration of carbonyl emissions in micrograms per mile (µg/mile) for different test conditions and fuel samples. The x-axis includes various test conditions and fuel samples, while the y-axis shows the concentration levels. The graph compares emissions from different sources, including formaldehyde, acetaldehyde, acrolein, and a sum of all carbonyls.
Carbonyl - Soy Biodiesel
Carbonyl - Animal Biodiesel

ULSD Carbonyl Sum

Formaldehyde
Acetaldehyde
Acrolein
Sum

mg/mile

A20 A50 A100 A20 A50 A100 A20 A50 A100 A20 A50 A100 A20 A50 A100
C15 ISM MBE4000 C15 ISM MBE4000
UDDS MBE4000 Cruise-50
Carbonyl-C15

**UDDS**

**Cruise**
Carbonyl-MBE4000

UDDS Crane

Cruise
Summary - VOC

- **Soy Biodiesel**
  - No significant VOC increase versus ULSD Fuel
  - No trend with regard to increasing Biodiesel fractions

- **Animal Biodiesel**
  - Modest VOC decrease versus ULSD Fuel
  - VOC reduced with increasing Biodiesel fractions

- **Renewable Biodiesel**
  - Modest VOC decrease in UDDS cycle versus ULSD fuel but not in cruise
  - VOC reduced with increasing Biodiesel fraction in UDDS but not in cruise
Summary – N2O

• No significant change in N2O emissions is observed for any fuel blend
Summary - Carbonyl

• Soy Biodiesel
  – No significant changes versus ULSD Fuel
  – No trend with regards to increasing Biodiesel fractions

• Animal Biodiesel
  – Modest decrease versus USLD Fuel in UDDS Cycle only
  – emissions reduced with increasing Biodiesel fractions.

• Renewable Biodiesel
  – No significant changes versus ULSD
Summary - Engines

• VOC
  – C15 and ISM engines perform similarly to each other under all fuel scenarios
  – MBE4000 emits $\sim <1/10^{th}$ of the average of C15 and ISM engines

• Carbonyls
  – C15 and ISM engines perform similarly to each other under all fuel scenarios
  – MBE4000 emits $\sim <1/6^{th}$ of the average of C15 and ISM engines