Particulate Emissions from Biodiesel Blends
Measurement and Trends

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Breathing easy in VT
Why care about air quality at UVM?

CHECK ENGINE

IF IT AIN'T BROKE DON'T FIX IT.
FALSE.
IMPROVEMENT IS ALWAYS POSSIBLE.
VT is not immune to poor air quality.
Global Community

Air Quality Index (AQI) Values

<table>
<thead>
<tr>
<th>AQI Range</th>
<th>Levels of Health Concern</th>
</tr>
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<tbody>
<tr>
<td>0 to 50</td>
<td>Good</td>
</tr>
<tr>
<td>51 to 100</td>
<td>Moderate</td>
</tr>
<tr>
<td>101 to 150</td>
<td>Unhealthy for Sensitive Groups</td>
</tr>
<tr>
<td>151 to 200</td>
<td>Unhealthy</td>
</tr>
<tr>
<td>201 to 300</td>
<td>Very Unhealthy</td>
</tr>
<tr>
<td>301 to 500</td>
<td>Hazardous</td>
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</tbody>
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The map illustrates the air quality index values across different countries.
Particulate Matter (PM)

“A complex mixture of extremely small particles and liquid droplets” (US EPA)
PM & Health: Smaller is Worse

- Class 1 Carcinogen
- No evidence of safe exposure level

(WHO, 2013)
Major Sources: Vehicles

Source: Deutsche Bank
Diesel Particulate Matter (DPM)

Product of unburned hydrocarbons

Gas-phase hydrocarbons (organic carbon) nucleate to form particles...

... or adsorb to soot

Solid, elemental carbon cores (i.e., soot)

SEM image of DPM (Boehmann et al., 1999)
Emissions Standards: Timeline

Standards reached through development of “clean diesel technology”

- Particulate Filters
- Ultra Low Sulfur Diesel
Biodiesel Shown to Reduce PM

Possible reasons why:

- **Oxygen content of biodiesel**
- Absence of sulfur
- Advanced start of combustion/injection

(U.S. EPA, 2002a)

(Lapuerta et al., 2007)
Biodiesel & PM: Evidence

(Giakoumis et al., 2012)

Light-duty diesel studies:

<table>
<thead>
<tr>
<th></th>
<th>Increases</th>
<th>Decreases</th>
<th>Both*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Drive Cycles

**Steady-State**

**Transient**
Research Objective 1

Quantify PM emissions from a light-duty diesel engine on a transient drive-cycle as a function of biodiesel blend percentage.
Biodiesel Blends

- Ultra Low Sulfur Diesel (ULSD)
- Two Biodiesel Feedstocks
  - From waste vegetable oil (WVO) & soy oil (SOY)
- BXX% Blends: B0, B10, B20, B50, B100
Results: PM

The graph shows the relationship between Biodiesel Percentage (BXXX) and PM$_{Grav}$ (mg/m$^3$). Error bars are ±1 StDev. The x-axis represents the Biodiesel Percentage (BXXX), and the y-axis represents PM$_{Grav}$ (mg/m$^3$). The ratio to B0 (Mean of All B0) is also indicated on the right y-axis. The graph includes data points for WVO (△) and SOY (○).
PM Measurement

**Gravimetric Method**

Operational Definition:

“mass collected on a filter” under specified conditions

(Swanson et al., 2012)
Gravimetric Error

Current PM emissions too low to measure well with filters
Particle Size Distribution

Low \quad ← \quad \text{Number} \quad → \quad \text{High}

Small \quad ← \quad \text{Particle Diameter} \quad → \quad \text{Large}
New Method: IPSD (Integrated Particle Size Distribution)

**Basic procedure**

1. Measure particle size distribution (PSD) by number
2. Assume spherical particles to calculate volume
3. Apply size dependent density values to calculate mass

\[
m = \rho V
\]

mass = density \times volume

\[
d/2 = r
\]

\[
V = \frac{4}{3} \pi r^3
\]
Research Objective 2

Evaluate IPSD method for different biodiesel feedstocks and blends

PM_{IPSD} vs. PM_{Gravimetric}

1:1 match?
Thank You

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