COMPARATIVE TOXICITY OF COMBINED PARTICLE AND SEMI-VOLATILE ORGANIC FRACTIONS OF GASOLINE AND DIESEL EMISSIONS

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(With lots of help from our friends at NREL, SWRI, and DRI)
PURPOSES

1. Develop strategy for comparing toxicity of collected emission samples without conducting inhalation studies
   - Use lung, cultured cells, and bacterial mutagenicity
   - Test combined particles (PM) and semi-volatile organic compounds (SVOCs)
   - Evaluate relative toxicity per unit of collected mass

2. Compare toxicity of normal and high-emitting in-use gasoline and diesel emissions
   - Compare relative toxicity per unit of collected mass
   - Evaluate correlations between chemistry and toxicity
   - Establish baseline for testing other emission cases
     - New diesel and gasoline technologies
     - Natural gas and other alternate fuels
     - Other source emissions
HEAVY ORGANICS IN FRESH EMISSIONS ARE PARTITIONED BETWEEN VAPOR AND PARTICLE PHASES

e.g., NERC Exposure (2000 Cummins B 5.9L on HD cycle & nat’l. cert. fuel)

![Bar chart showing partitioning of heavy organics between vapor and particle phases for different concentrations and compounds.](chart.png)
APPROACH

• PM & SVOC samples were collected from in-use light- and medium-duty vehicles at SWRI
  Normal-emitters at $72^\circ$ and $30^\circ$
  High-emitters at $72^\circ$
  Vehicles on chassis dynamometers, Unified Driving Cycle Filter (PM) and PUF-XAD (SVOC) samples

• Samples were extracted from collection media and analyzed chemically at DRI
  Chemistry not discussed today

• PM and SVOC fractions were re-combined in original emission ratios and the toxicity of PM+SVOC mass was tested at LRRI
  1. Instilled into rat lungs
  2. Ames Salmonella bacterial mutagenicity (TA98 and TA100)
  3. Mixed with cell culture medium (not discussed today)
VEHICLES

Current Technology Diesel
1998 Mercedes Benz E300
1999 Dodge Ram 2500
2000 Volkswagen Beetle

High-emitter diesel
1991 Dodge Ram 2500

Average Gasoline
1982 Nissan Maxima
1993 Mercury Sable
1994 GMC 1500
1995 Ford Explorer
1996 Mazda Millenia

White-smoker gasoline
1990 Mitsubishi Montero

Black-smoker gasoline
1976 Ford F-150
# PM & SVOC AS PERCENTAGE OF TOTAL MASS

<table>
<thead>
<tr>
<th></th>
<th>%PM</th>
<th>%SVOC</th>
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<tbody>
<tr>
<td><strong>Diesel</strong></td>
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<tr>
<td>Current Technology</td>
<td></td>
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<tr>
<td>72°</td>
<td>D</td>
<td>64</td>
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<tr>
<td>30°</td>
<td>D₃₀</td>
<td>64</td>
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<tr>
<td><strong>High-Emitter</strong></td>
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<tr>
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<td><strong>Gasoline</strong></td>
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<tr>
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<tr>
<td>72°</td>
<td>G</td>
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</tr>
<tr>
<td>30°</td>
<td>G₃₀</td>
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<td><strong>White Smoker</strong></td>
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<tr>
<td>WG</td>
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<td>76</td>
</tr>
<tr>
<td><strong>Black Smoker</strong></td>
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<td></td>
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<tr>
<td>BG</td>
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TOXICITY EVALUATIONS

Bacterial mutagenicity

TA100 (+-S9)  frame shift and base pair substitution

Rat lung exposed by instillation

General Toxicity (overall response)

Histopathology (total of all changes)
Lung weight

Inflammation (influx of inflammatory cells)

Inflammatory cells in histopathology
Bronchoalveolar lavage (lung washing, BAL):
   Total leukocytes (WBC)
   Polymorphonuclear leukocytes (PMN)
   Macrophages
   Chemical inflammatory signal (MIP-2)

Cytotoxicity (tissue damage)

Tissue damage in histopathology
BAL lactate dehydrogenase (LDH)
BAL protein
RESPONSES WERE RANKED BY THE SLOPES OF DOSE-RESPONSE CURVES

1. Responses were measured at multiple doses
   Toxicity was reflected by steepness of the dose-response curve

   ![Graph of LDH @ 24 hr showing dose-response curves for different types of gas and PM.

   Dose in total mass/rat
   - Av PM gas
   - Av PM gas cold
   - Black smoker gas
   - Av PM diesel
   - Av PM diesel cold
   - White smoker gas
   - Hi PM diesel
   - Av PM gas cold

2. Slope factors were derived from fitted functions
   Log-normal functions were fitted to dose-response curves (except Ames)
   \[ \log y = c + [b \times \text{dose}] \]
   Used slope value \(b \pm \text{SE}\) to compare potencies
   Used multiple comparison to test significance of differences in slope
BACTERIAL MUTAGENICITY RANKINGS: TA100
LUNG RANKINGS: GENERAL TOXICITY

Relative Potency with SE

- Histopathology
- Lung Weight
LUNG RANKINGS: CYTOTOXICITY

Relative Potency with SE

- LDH
- Histopathology
- Protein

WG  BG  HD  D  D_30  G  G_30
SUMMARY OF RESULTS

1. There was good concordance among the multiple parameters within each class of lung toxicity
   
   Lends confidence to rankings
   
   Suggests that fewer parameters are necessary

2. The rankings for the three classes of lung toxicity were very similar
   
   WG > HD, BG > others

3. Cold operation (30°) caused little difference in lung toxicity, but tended to slightly increase mutagenicity of both gasoline and diesel
CONCLUSIONS & IMPLICATIONS

1. Per unit of mass emitted, the toxicity of PM+SVOC from these populations of normal-emitter gasoline and diesel vehicles was similar

   Can probably compare health hazards adequately on basis of mass emissions (emissions rate x VMT x proximity)

2. The toxicity of PM+SVOC emissions from both gasoline and diesel high-emitters is greater than the toxicity of emissions from normal-emitters

   High-emitters contribute a disproportionate share of health hazard

3. Operating temperature did not affect toxicity very much

   May not need to compare gasoline & diesel at multiple temperatures

4. The lung assay gave convincingly consistent rankings

   Cultured cell results (not shown today) did not agree well with lungs