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)

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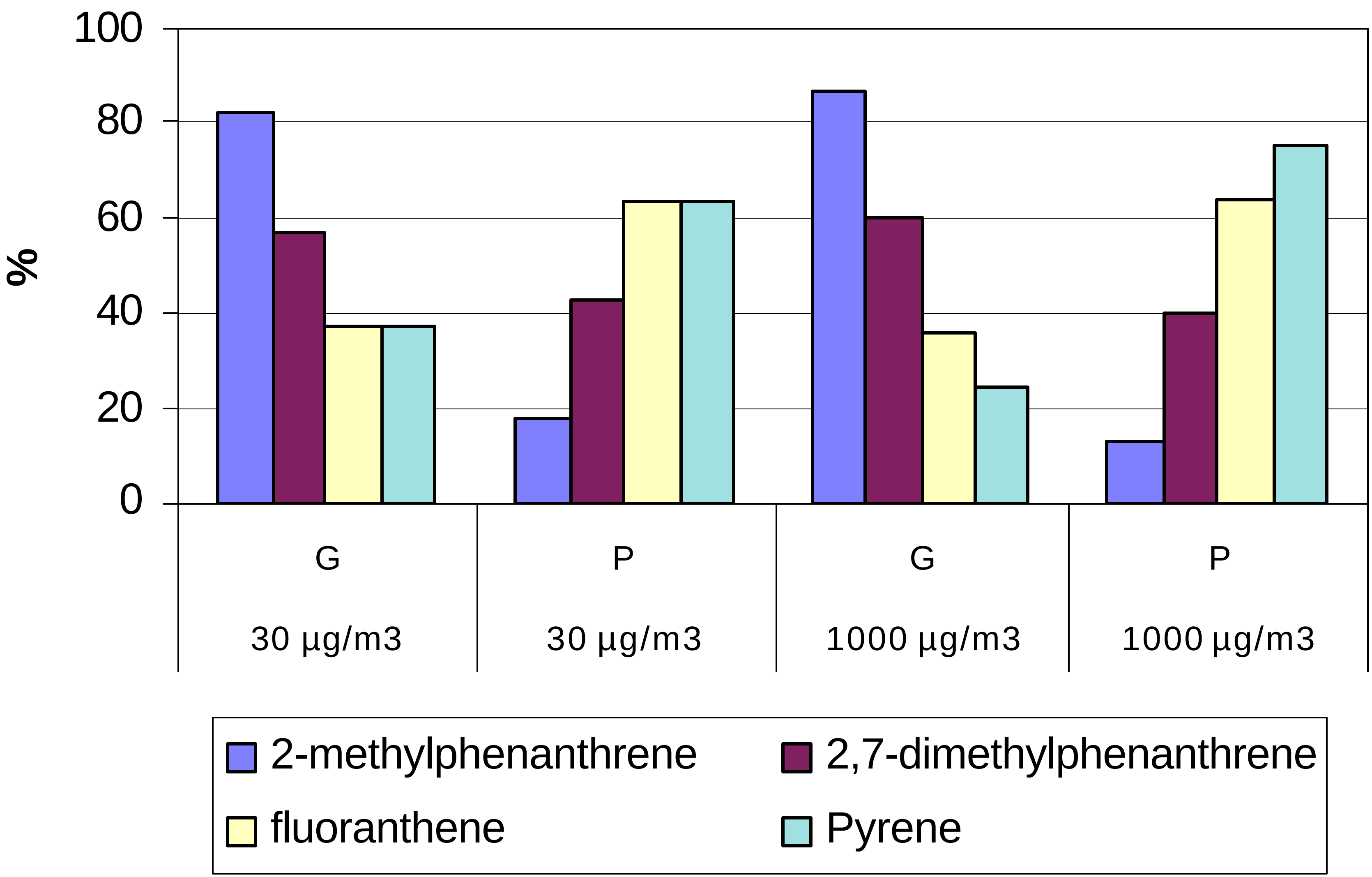
PURPOSES

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)



APPROACH

- **PM & SVOC samples were collected from in-use light- and medium-duty vehicles at SWRI**

  Normal-emitters at 72º and 30º

  High-emitters at 72º

  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

			%PM	%SVOC
Diesel				
Current Technology				
	72^{o}	D	64	36
	30^{o}	D_{30}	64	36
High-Emitter		HD	54	46
Gasoline				
Average				
	72^{o}	G	16	84
	30^{o}	G_{30}	24	76
White Smoker		WG	76	24
Black Smoker		BG	18	82

TOXICITY EVALUATIONS

Bacterial mutagenicity

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

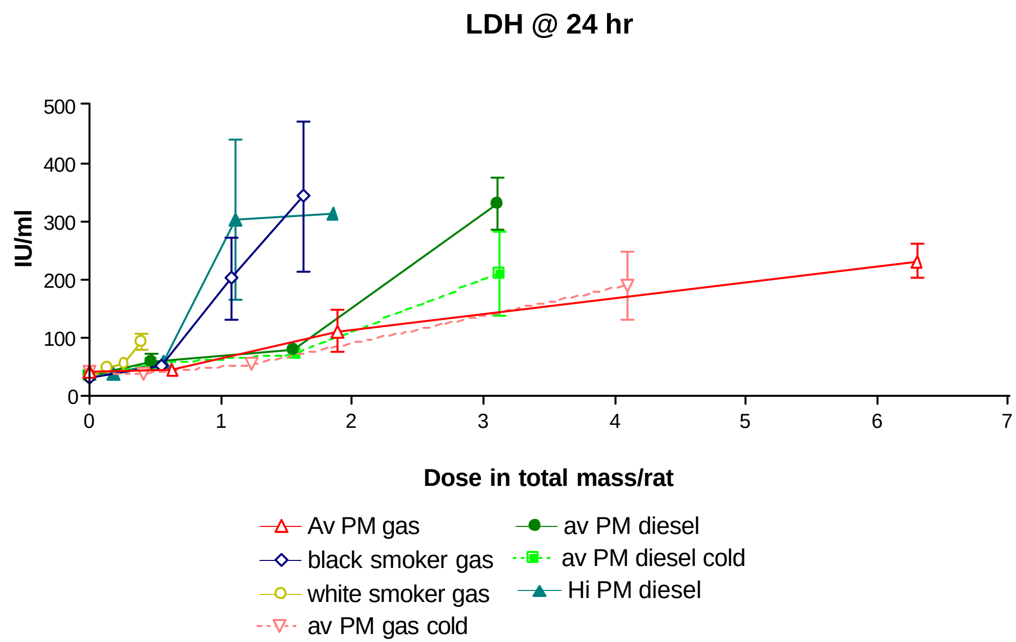
Rat lung exposed by instillation

- **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



2. Slope factors were derived from fitted functions

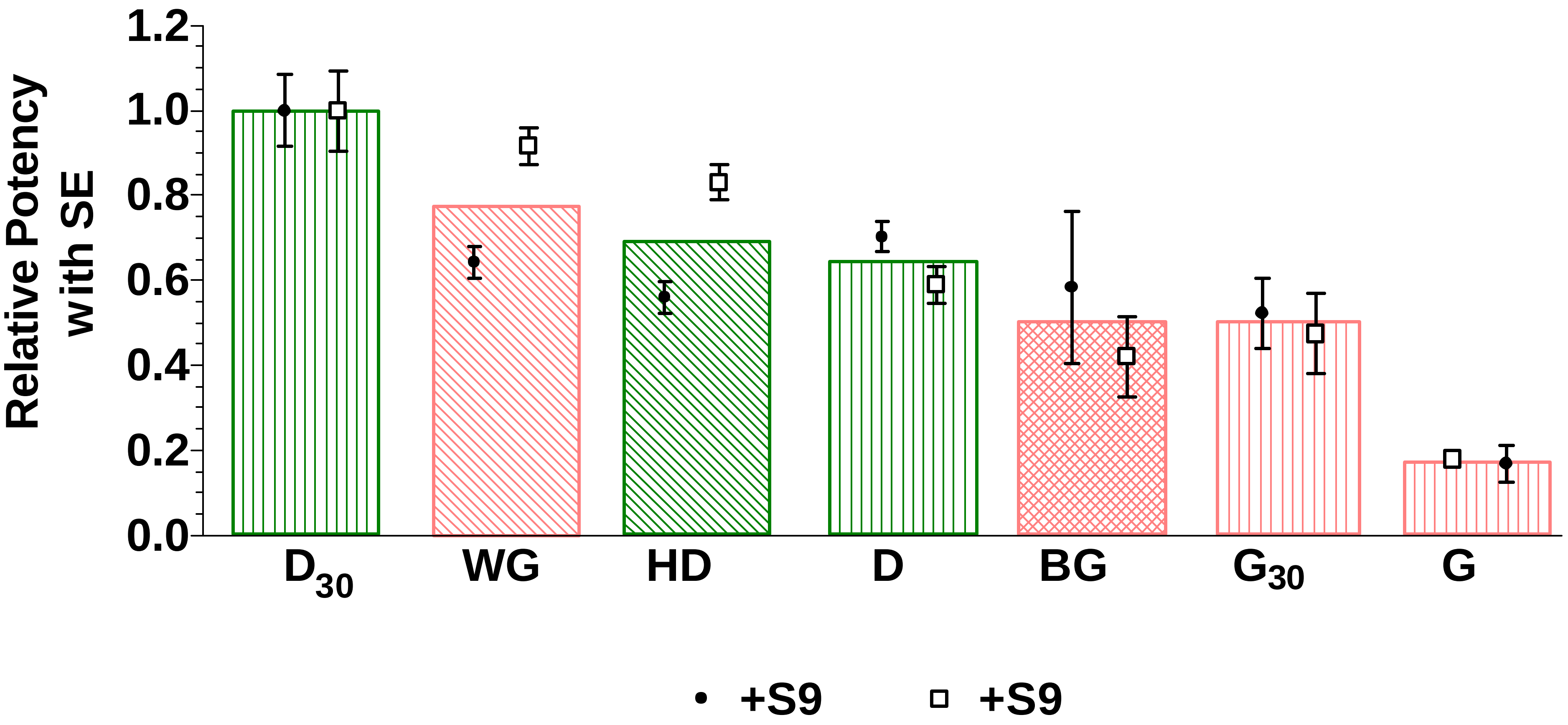
Log-normal functions were fitted to dose-response curves (except Ames

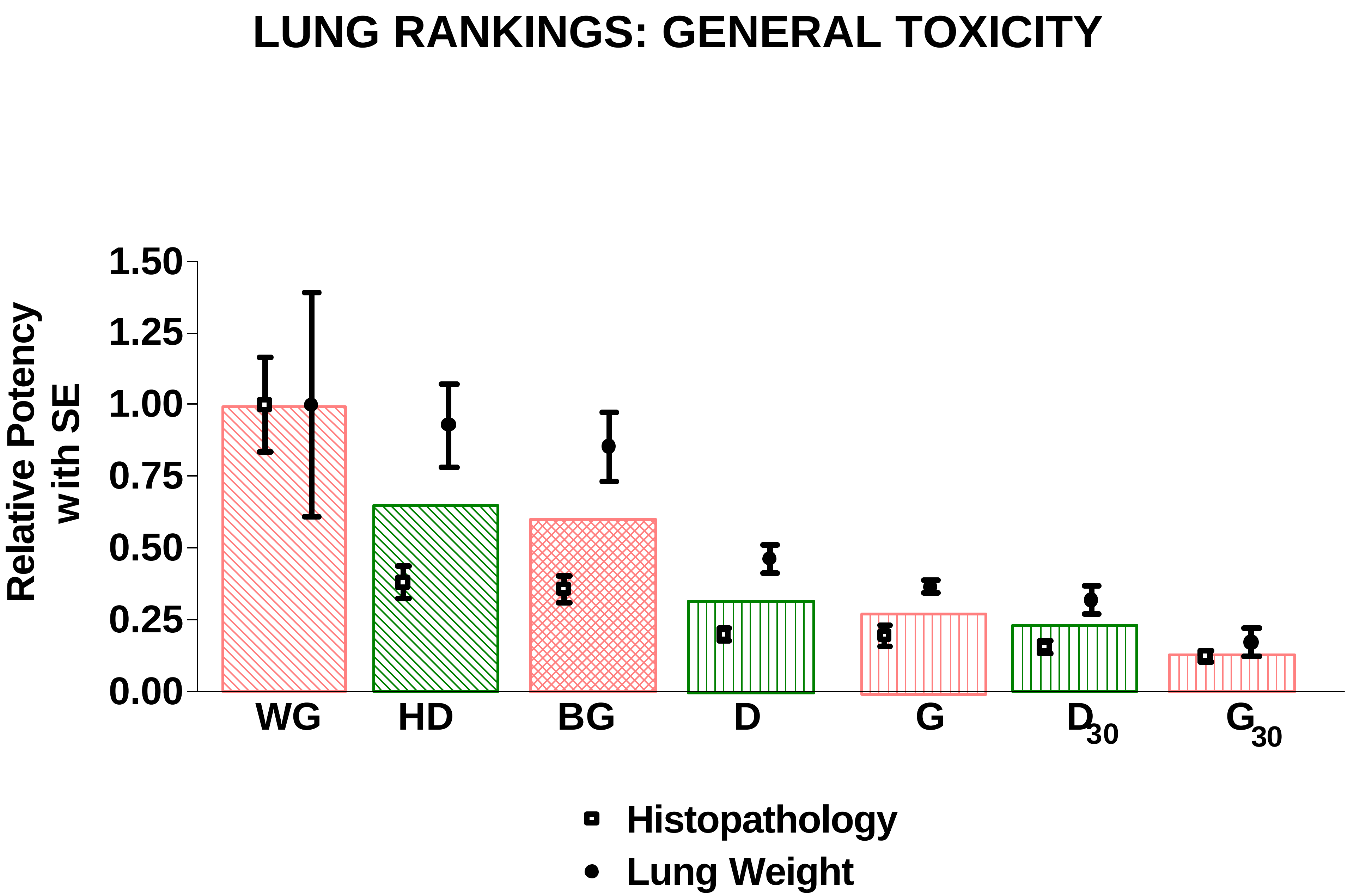
log y = c + [b x dose]

Used slope value b ± SE to compare potencies

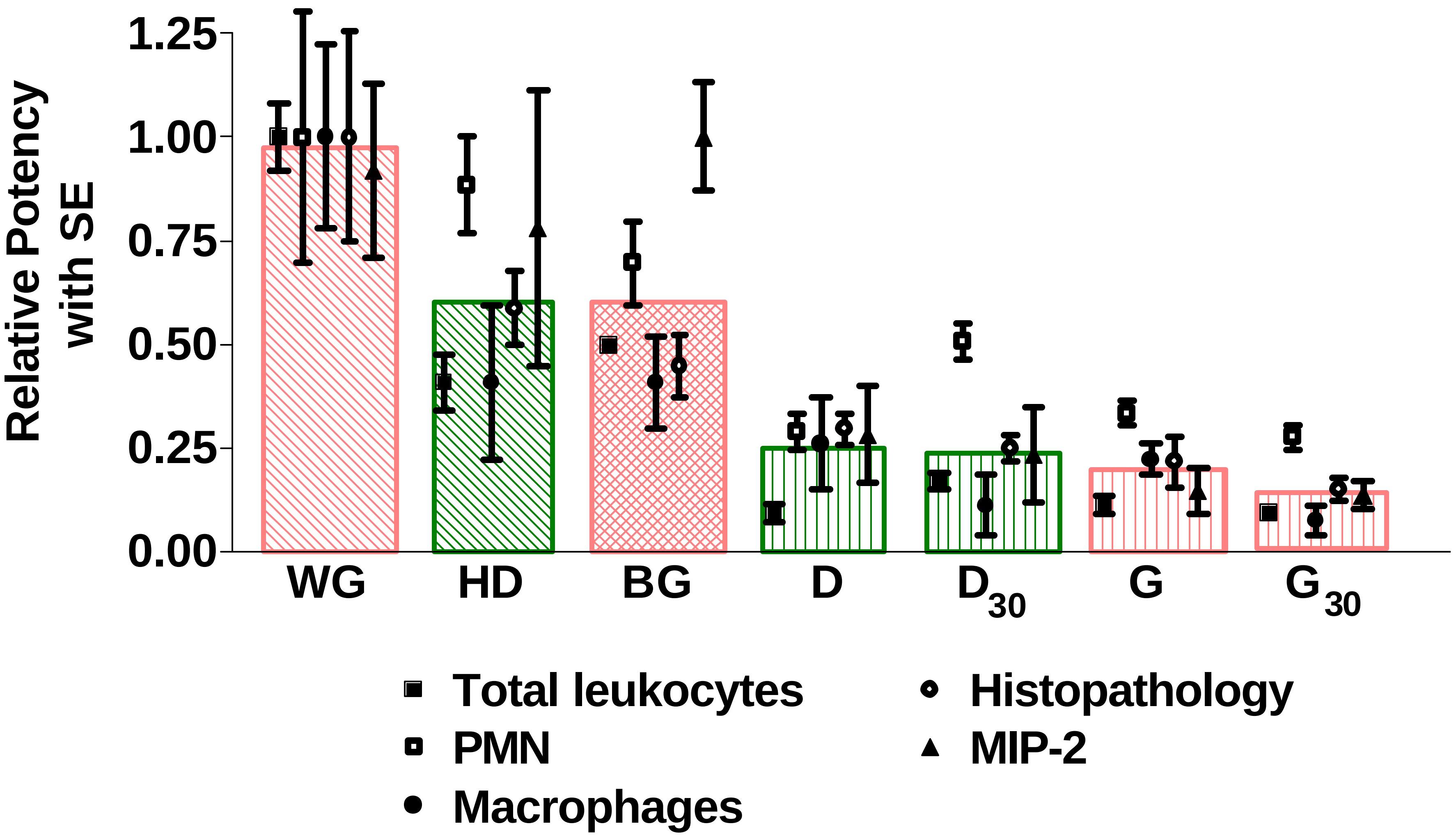
Used multiple comparison to test significance of differences in slope

BACTERIAL MUTAGENICITY RANKINGS: TA100

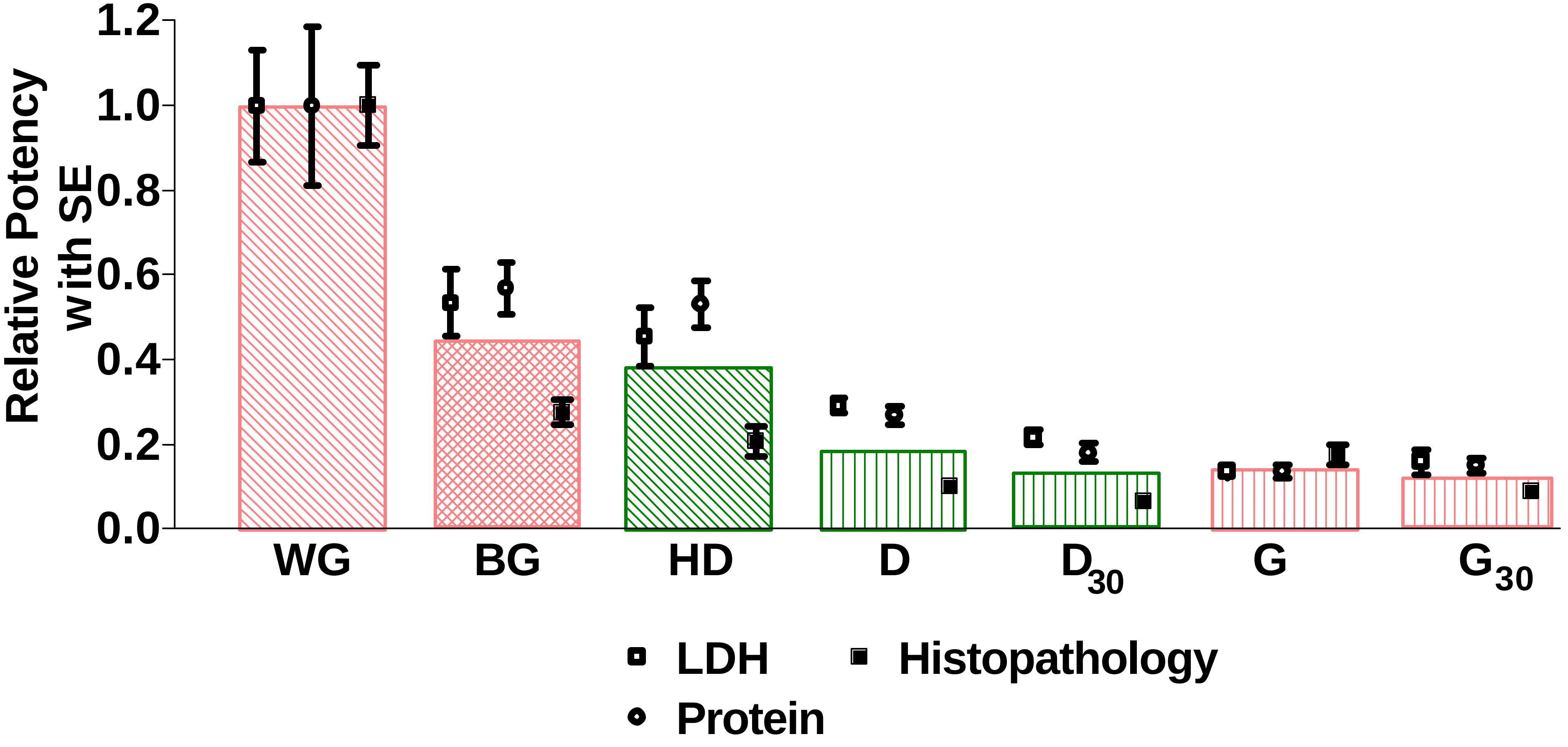



LUNG RANKINGS: GENERAL TOXICITY
Relative Potency with SE
1.50
1.25
1.00
0.75
0.50
0.25
0.00
WG
HD
BG
D
G
D30
G30
Histopathology
Lung Weight

LUNG RANKINGS: INFLAMMATION



LUNG RANKINGS: CYTOTOXICITY



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^{o}) 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