IMPACT OF MOBILE SOURCE EMISSIONS ON HEALTH: WHAT CAUSES WHAT?

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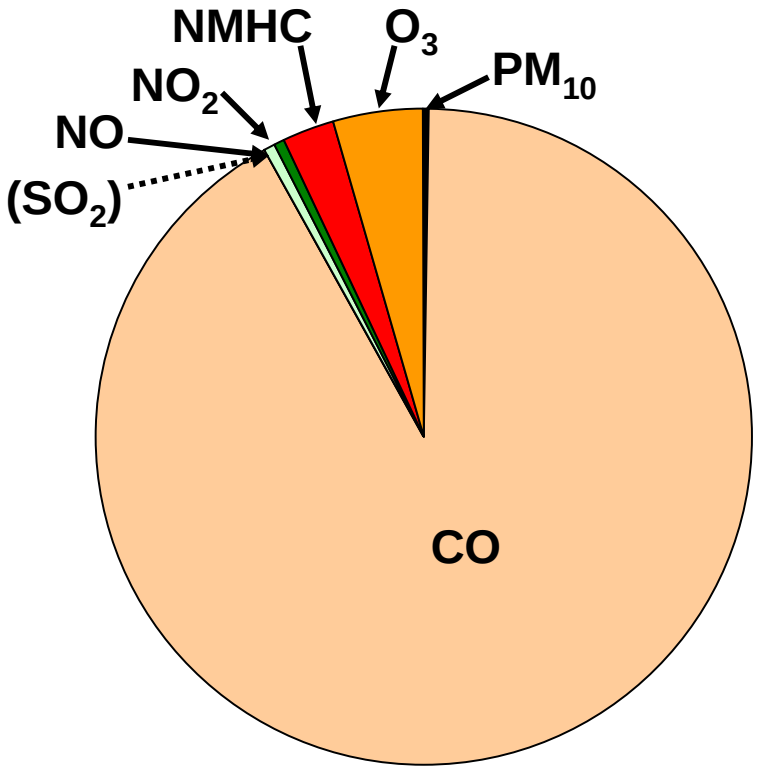
NERC – because you never breathe only one pollutant!

ENVIRONMENTAL AIR POLLUTION AND MOBILE SOURCE EMISSIONS ARE VERY COMPLEX MIXTURES

Mass Composition of Air Pollution in Central Los Angeles*

2005 Annual Average



PM and VOC contain 100s of compounds!

*Does not include O_2, CO_2, H_2O, or CH_4

Data provided by Phil Fine, SCAQMD

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"WHAT CAUSES WHAT" IS A KEY QUESTION FOR MULTI-POLLUTANT AIR QUALITY MANAGEMENT

Which air contaminants cause which health effects, and which are the most toxic ?

When (and how) can we lump pollutants for regulatory purposes ?

Are there combinations of air contaminants that have health significance ?

and then .....

What practical changes in air quality would give the greatest, most cost-effective health benefit ?

What are the relative importances of different sources ?

Are regulations actually reducing health burdens ?

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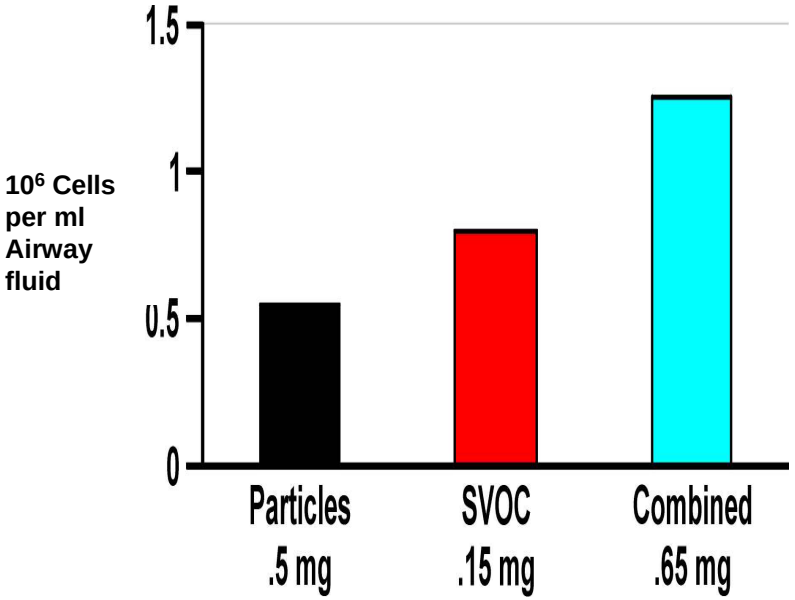
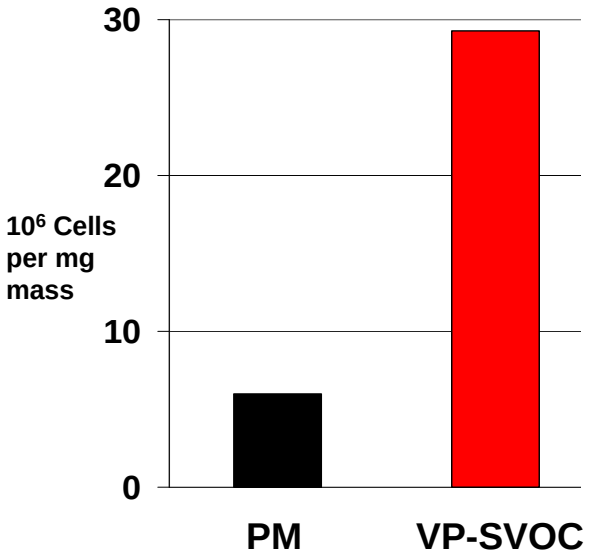
TUNNEL STUDY REVEALED IMPORTANCE OF VAPOR-PHASE SEMI-VOLATILE ORGANIC COMPOUNDS

- PM (filter mass) and vapor-phase SVOC (PUF/XAD trap) from "truck" bore of Baltimore harbor traffic tunnel
- Instilled the 2 phases, separately and combined, into rat lungs
- Measured Inflammatory responses in lung 24 hr later





Per unit of mass, the vapor-phase SVOC was ~ 5x more toxic than PM !

Seagrave et al., *Toxicologist* 60:192, 2001

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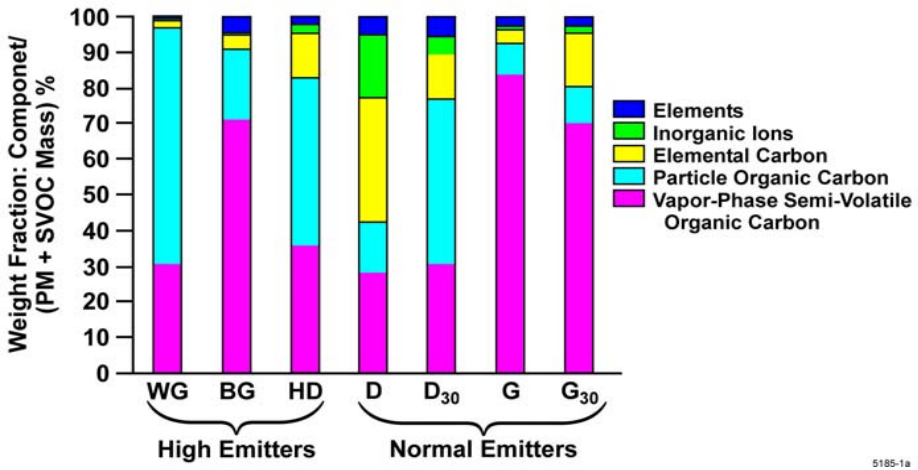
TOXIC COMPONENTS OF VEHICLE EMISSIONS?

- PM and vapor-phase SVOCs from in-use vehicles on city cycle
- Analyzed composition in detail
- Instilled combined fractions into rat lungs, and measured inflammation at 24 hr
- Used multivariate statistical analysis to relate composition to relative potency

Samples

Gasoline (5)	G
Gasoline 30º	G_{30}
White smoker gas.	WG
Black smoker gas.	BG
Diesel (3)	D
Diesel 30º	D_{30}
High-emitter diesel	HD

Composition



Seagrave et al. *Toxicol. Sci.* 70: 212-226, 2002

Zielinska et al., *J. Air Waste Man. Assoc.* 54: 1138-1150, 2004

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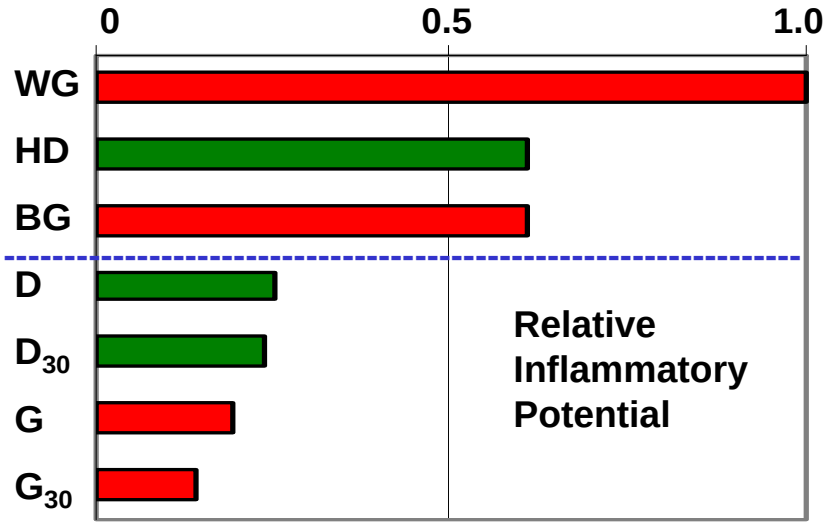
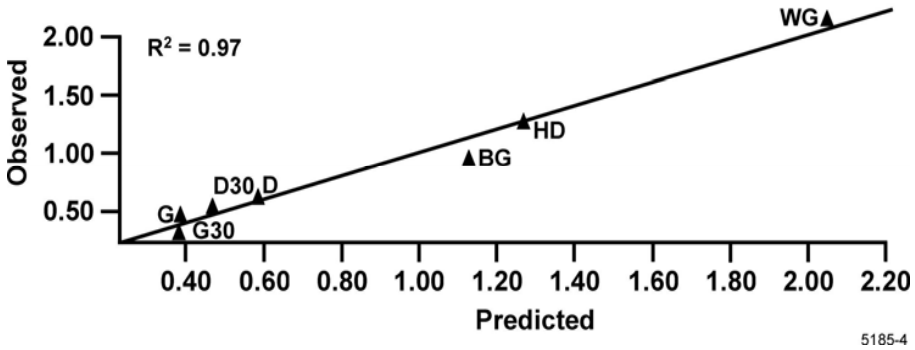
POTENCY VARIED 5-FOLD, AND TOXICITY WAS LINKED TO COMPOSITION





Emissions from high-emitters were more toxic per unit of mass !

Hopanes & steranes, markers of crankcase lube oil on PM, were most closely linked to toxicity !

Same results from high-emitter, normal-emitter, and new technology CNG buses

McDonald et al., *Environ Health Perspect.* 112: 1527-1538, 2004
Seagrave et al., *Toxicol. Sci.* 87:323-241, 2005

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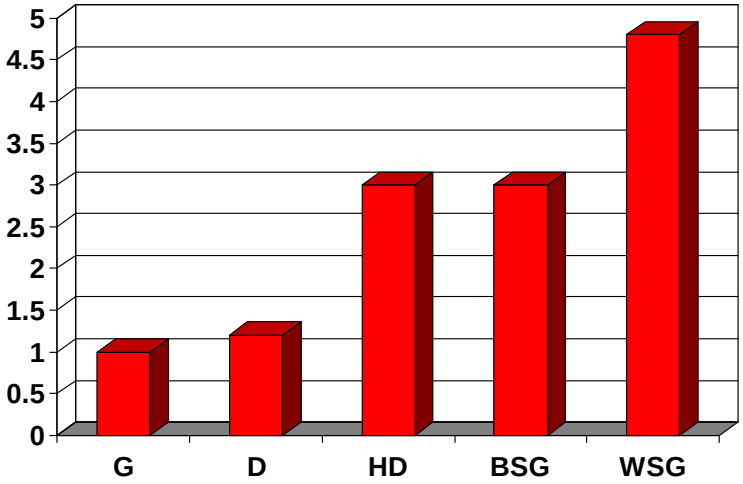
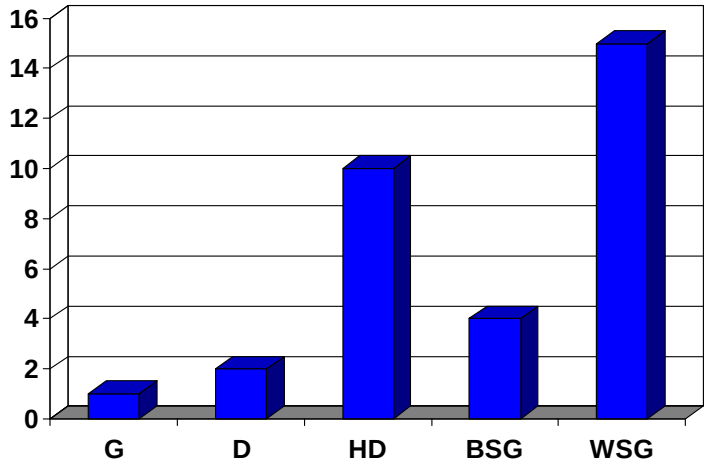
HIGH-EMITTERS ARE KEY TO REDUCING HAZARD

RELATIVE INFLAMMATORY EFFECT PER UNIT OF MASS

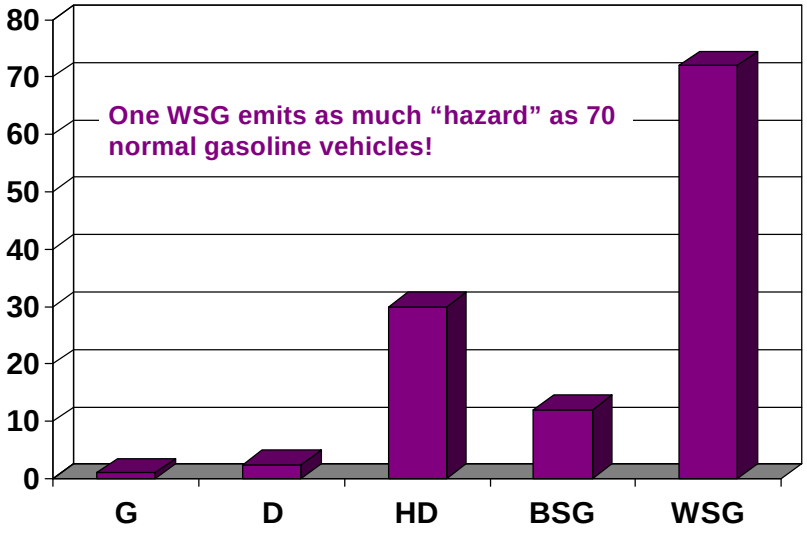


RELATIVE EMISSION RATES



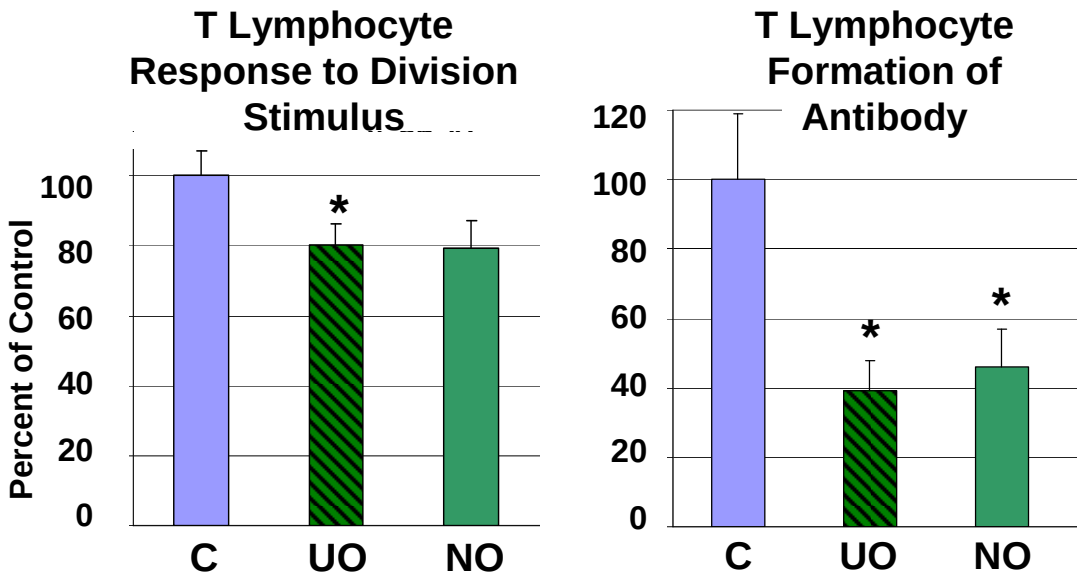
"Normal gasoline" set to 1.0

"RELATIVE INFLAMMATORY HAZARD" PER UNIT OF VEHICLE TRAVEL



CAN OIL NANOPARTICLES AFFECT IMMUNE RESPONSES OUTSIDE THE LUNG?

- Exposed mice by inhalation for 7 days to 20 nm particles of used (UO) and new (NO) diesel crankcase oil at 1 million particles/cc
- Examined function of lymphocytes from the spleen



High concentrations of nanoparticles can have widespread effects on the immune system!

Would lower concentrations do this?

Mitchell et al. new data, and McDonald et al. *Toxicologist* 96:230, 2007

NERC STUDIES OF COMPONENTS RESPONSIBLE FOR HEALTH EFFECTS OF WHOLE COMBUSTION EMISSIONS

Diesel:

2000 Cummins 5.9L 6 cyl. on HD certification cycle

Circa 2000-2006 D-2 certification fuel (370 ppm S)

Shell Rotella-T crankcase oil

Hardwood Smoke:

Uncertified heating stove on 6 hr heating cycle

Oak at 20% moisture

Flue at constant draft

Gasoline:

1996 GM 4.3L V6 on California UDC, 2 cold starts

2002 U.S. average RUL fuel

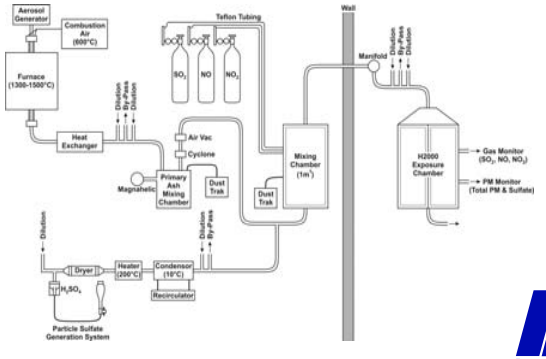
Pennzoil 10w-30 crankcase oil

Simulated "Downwind" Coal:

Powder River Basin sub-bituminous

Electric furnace + added SO_4, NOx, SO_2

Steady-state



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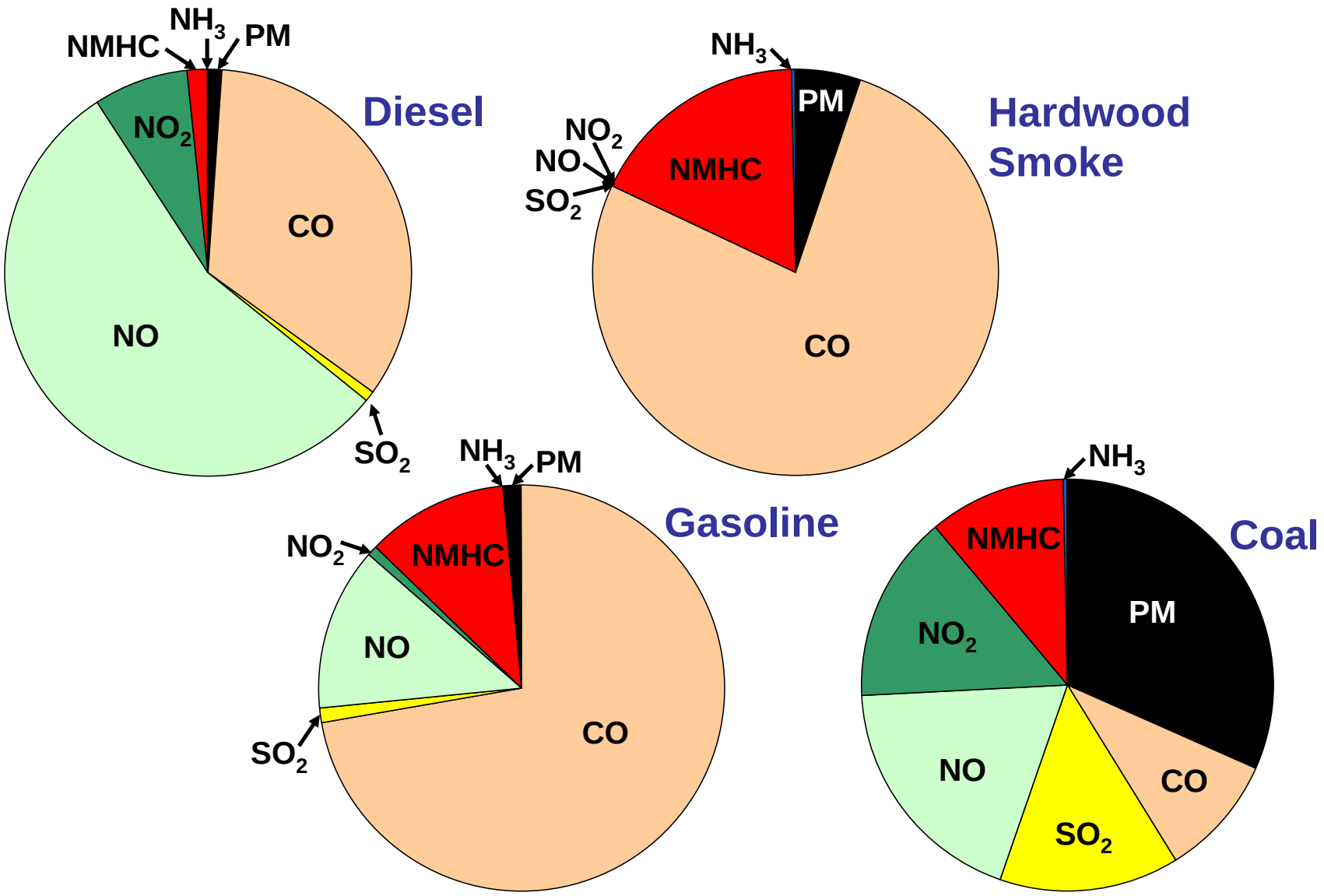
NERC EXPOSURE ATMOSPHERES

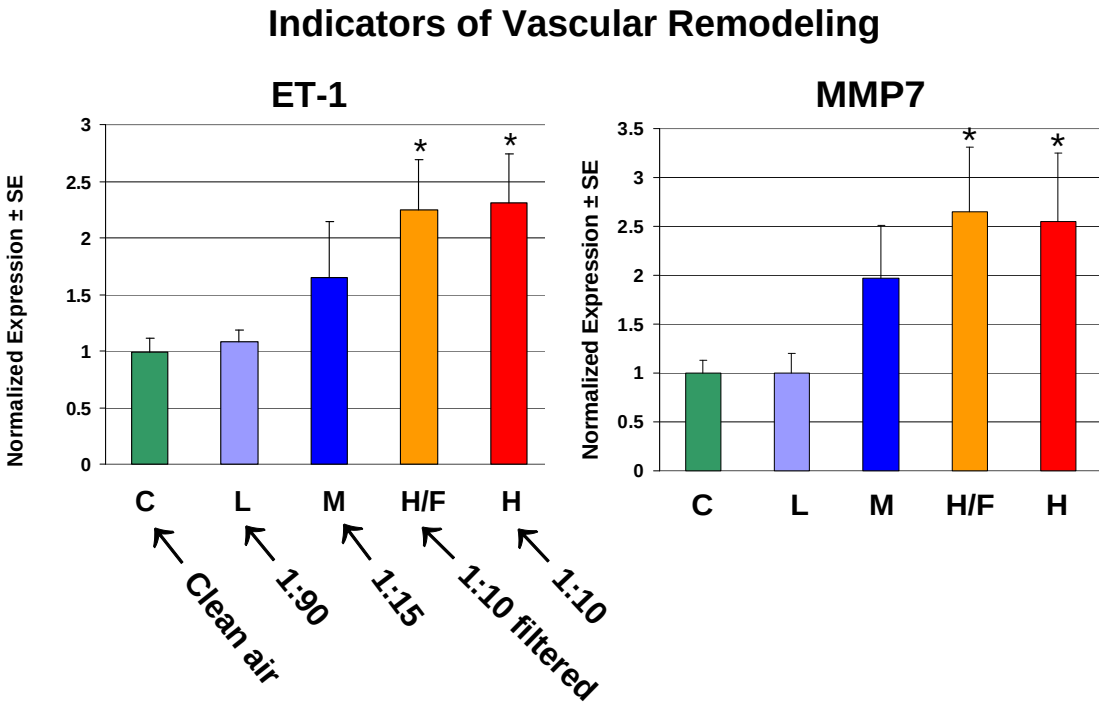
(Proportional Mass Composition, less O_2, CO_2, H_2O, and CH_4)



EFFECTS OF GASOLINE EMISSIONS ON VESSELS

- Fed atherosclerosis-prone mice high-fat diet and exposed for 7 weeks
- Measured indicators of oxidative stress and remodeling in aorta

1. Clear evidence of effects in vessels outside the lung !
2. Non-PM components drove these effects !
3. No significant effects at typical exposure levels



What caused it – NOx? CO? VOCs?

Lund et al. *Toxicol. Sci.* 95:485-494, 2007

NO AND CO CAUSED SOME, BUT NOT ALL, EFFECTS

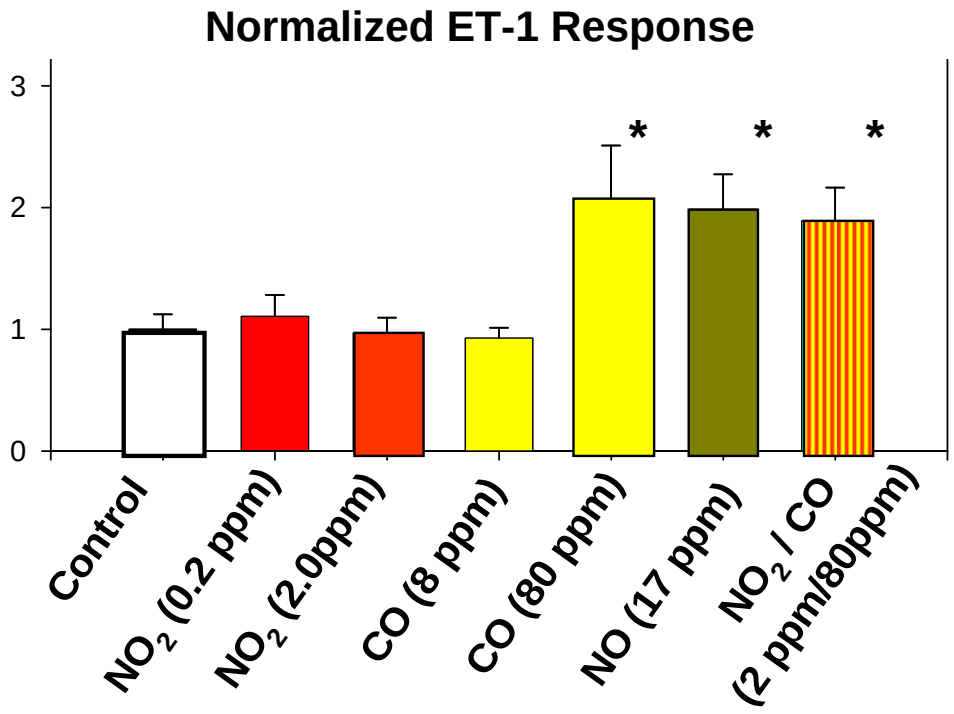
- **Plausible biological mechanisms suggested that NO, NO_2, or CO might cause the vascular effects**

- **Exposed mice to these gases at the high and low concentrations in the gasoline study**

1. **CO and NO <u>did</u> reproduce effects on some responses**
2. **NO_2 was <u>not</u> a cause**
3. **CO and NOx <u>did not</u> reproduce effects on some other responses**

What components caused the other effects? *(VOCs?)*

What levels are safe?



Campen, Lund et al., new unpublished results

BENEFITS OF EMISSION REDUCTIONS: Effect of "Retrofit" with PM Trap and Low-Sulfur Fuel

Compared effects of exhaust from diesel engine under 2 conditions:

350 ppm S pre-2007 certification fuel
No after-treatment

15 ppm S fuel (BP-15)
Catalyzed PM trap

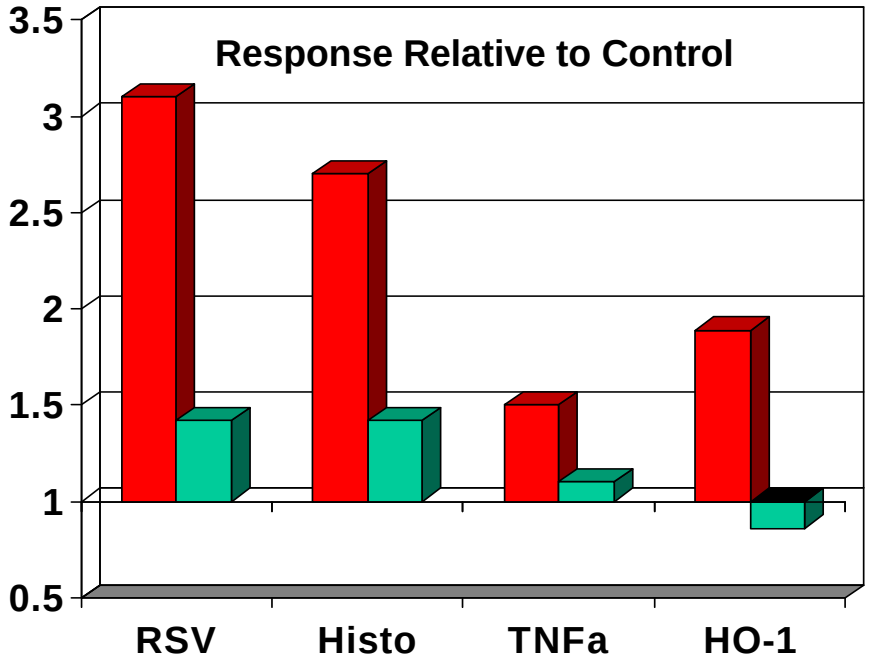
- **Yanmar YDG5500E diesel generator at constant (full) load and dilution**
- **Exposed mice 7 days**
- **Measured:**

  Clearance of Respiratory Syncytial Virus (RSV)

  Histopathology (HISTO)

  Pro-inflammatory cytokine (TNFα)

  Indicator of oxidative tissue stress (heme-oxygenase-1 [HO-1])



Health effects were eliminated or reduced to non-significant levels !

McDonald et al. *Aerosol Sci. Technol*. 38: 62-78, 2004
McDonald et al., *Environ. Health Perspect.* 112: 1307, 2004

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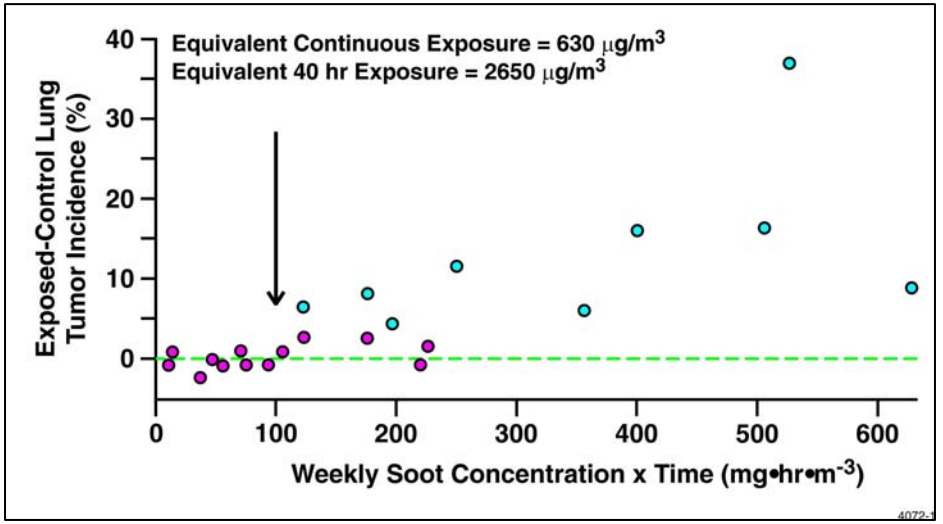
EVALUATING EFFECTS OF EMISSIONS FROM HEAVY-DUTY DIESEL ENGINES MEETING 2007 STANDARDS

Advanced Collaborative Emissions Study (ACES)

Long-term exposure of rats to high concentrations of pre-1990 diesel emissions caused lung tumors

- Only at 100x common exposure levels
- Mice and hamsters did not get tumors
- Determined to be an effect of "overloading" with PM



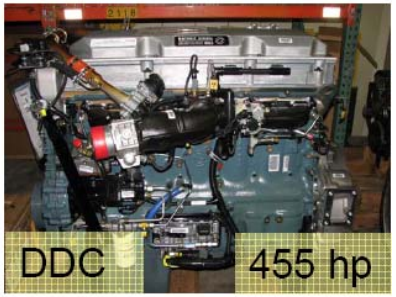
Newer engines are much cleaner, and especially with PM traps and low sulfur fuel

Does exposure at highest practical concentration cause the effects observed in the old studies?

ACES STRATEGY AND STATUS

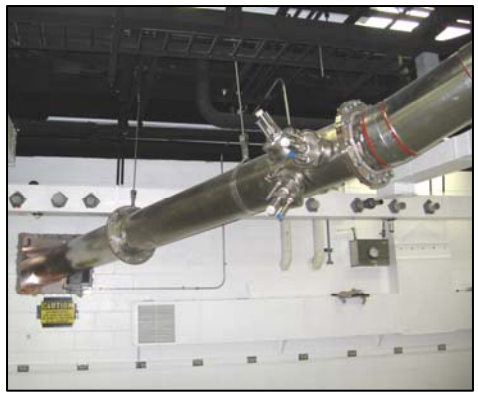
1. **Compare emissions from four HD 2007-compliant engines**
   - **All with OEM PM traps and same fuel and lube oil**

2. **Select one engine for the animal study**
   - **Health Effects Institute is coordinating selection**
   - **Selection to be made next month**

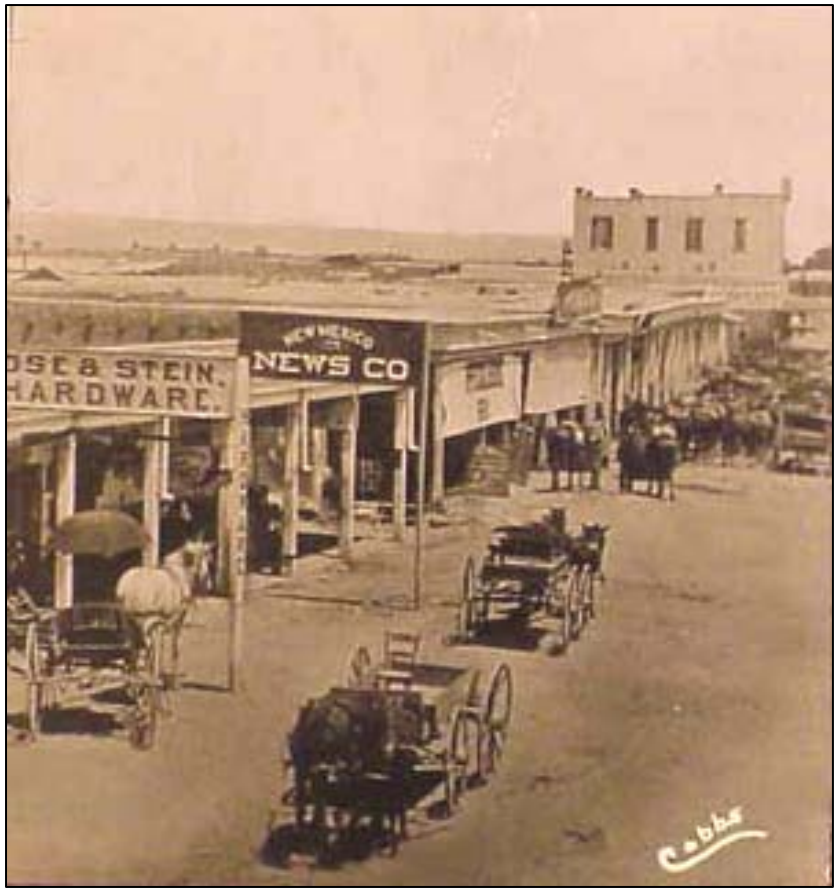


3. **Conduct animal study at LRRI**
   - **Expect to start exposures in January**
   - **Final results not available until late 2011**

Engine-exposure facility at LRRI is nearly complete



MOBILE SOURCES ARE BECOMING CLEANER!



Albuquerque, NM in 1800s

Cumbres & Toltec Railroad, Chama, NM
(still in operation for tourists)