The Health Benefits of Fuel Sulfur and Diesel Emissions Reduction

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Workshop on Fuel Efficiency Opportunities in São Paulo

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Contents

Major Vehicle/Fuel Emissions

Criteria Pollutants:

- Carbon Monoxide
- Nitrogen Oxides (NOx) and Hydrocarbons (HC) Precursors to Ozone and PM
- **Particulate Matter (PM)**
- **Diesel Exhaust**
- Lead
- Carbon Dioxide (GHG)

Air Toxics:

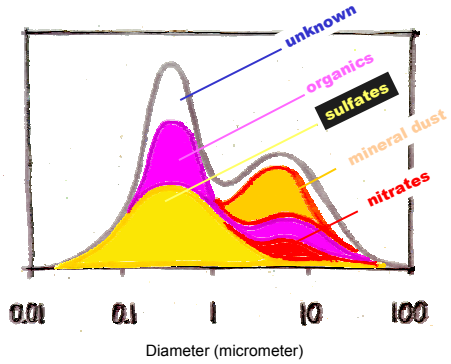
- Aldehydes
  - formaldehyde
  - acetaldehyde
  - others
- Benzene
- 1,3-butadiene
- Methanol
- Polycyclic organic matter (e.g. PAHs)

Effects of Air pollutants

Different Pollutants have Different Effects:

- Carbon Monoxide: circulatory system, heart
- Ozone: respiratory system, lung
- **PM: lung, cardiovascular effects**
- **Diesel exhaust, Air Toxics: cancer, respiratory effects**
- Lead: nervous system, brain
- Carbon Dioxide and Carbon Particles: climate change

ATMOSPHERIC AEROSOL
chemical composition



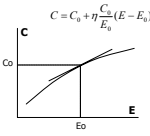
Source: *Frank Raes, JRC Ispra*

Frank Raes, JRC Ispra

PM2.5 composition in Santiago

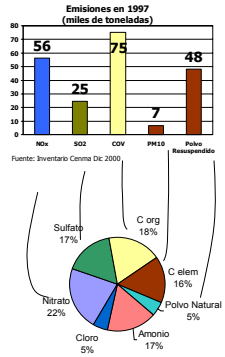
- El impacto de las emisiones de contaminantes primarios en el material particulado fino es muy diferente.
- Se usaron modelos roll-back con elasticidad menor que 1 para relacionar las emisiones con la fracción del PM2.5 correspondiente a cada contaminante (usando la asignación de CONAMA 2000)

$$C = C_0 + \eta \frac{C_0}{E_0}(E - E_0)$$



Donde C es la concentración de la fracción de PM2.5 asignada a cada contaminante primario

- No se considera explícitamente la existencia de un nivel background. Parte de ese efecto esta captado por la elasticidad menor que 1.
- Se consideró que 1/3 del Carbón orgánico proviene de compuestos orgánicos volátiles.



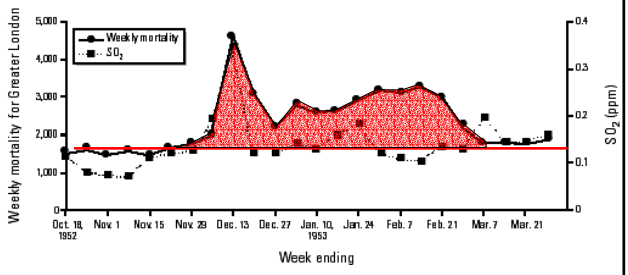
Health Effects of Criteria Pollutants

- Some Populations more sensitive than others
  - Children
  - Elderly
  - people with heart and lung disease
  - diabetics
- Asthma is growing
  - 150 million asthmatics worldwide
  - Increasing in most countries (2% to 5% per year)
  - Asthmatics much more sensitive to air pollution

PM Health Effects

- High levels of PM (e.g. 500 $\mu g/m^3$) have been known to cause premature death since long time ago:
  - e.g. London 1952; Donora, 1948

London, Winter 1953
Weekly mortality levels vs. SO_2 levels

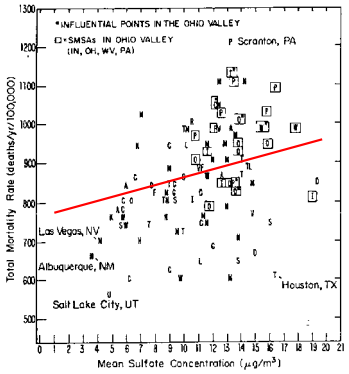


Source: Bell, M. L. and D. L. Davis (2001). "Reassessment of the lethal London fog of 1952: novel indicators of acute and chronic consequences of acute exposure to air pollution." *Environ Health Perspect* **109 Suppl 3**: 389-94.

PM Health Effects

- Recent studies in North and South America, Europe, Asia, have found association of PM with death at much lower levels
  - → No evidence of a "threshold" (safe level)
- However, to date, a plausible biological mechanism for these effects has not been found.

SO_4 and long-term mortality rates



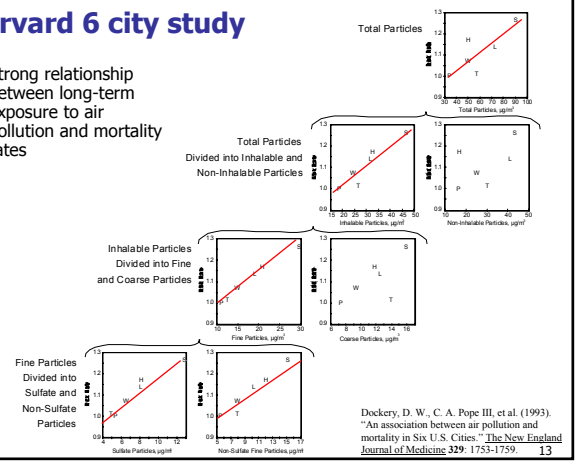
Source: Ozkaynak, H. and G. D. Thurston (1987). "Associations Between 1980 U.S. Mortality Rates and Alternative Measures of Airborne Particle Concentration." Risk Analysis **7**(4): 449-461.

Harvard Six Cities Study

- > 8 000 individuals followed for 16 years
- Individual measurements every 6 months
- Difference between Portaga, OR and Steubenville, OH
  - All cause mortality: 26%
  - RSP mortality
  - CVD mortalit
- Life expectancy
- St 1/5 box by day

Harvard 6 city study

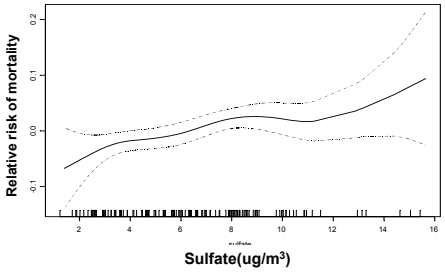
Strong relationship between long-term exposure to air pollution and mortality rates



Dockery, D. W., C. A. Pope III, et al. (1993). "An association between air pollution and mortality in Six U.S. Cities." The New England Journal of Medicine **329**: 1753-1759.

Effects of Sulfate on Premature Mortality

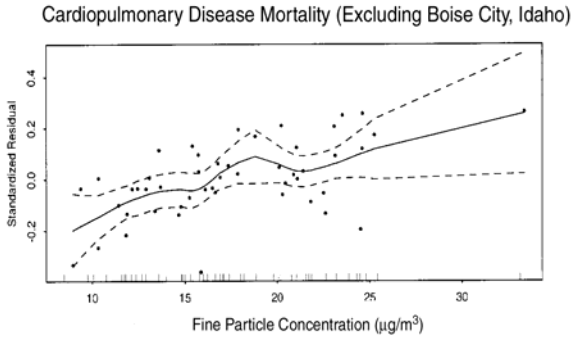
Source: HEI Reanalysis of the American Cancer Society Study (Krewski 2000)



- **Recent time series studies shown a significant increase in risk of death associated to various forms of PM**

Impacts of $PM_{2.5}$ on Heart and Lung Mortality

(Source: HEI Reanalysis of the American Cancer Society Study (Krewski 2000)

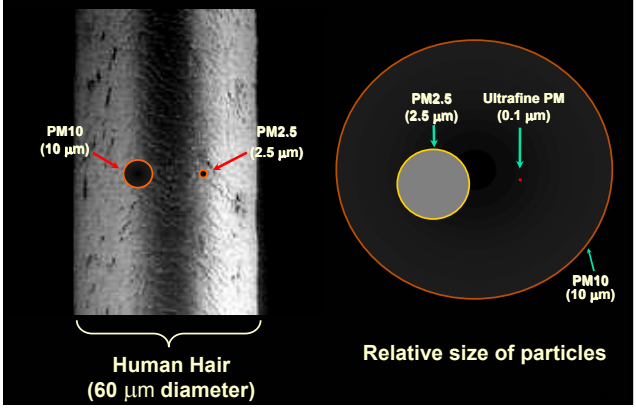


PM_{10} Study in Europe

(Lancet Medical Journal – September 2, 2000)

- ~6% of all deaths from PM_{10}
- ~40,000 deaths per year in Austria, France, Switzerland; 2 times traffic fatalities
- Motor Vehicles Responsible For ~50%
- People in Cities Die ~18Months Earlier Than They Otherwise Would
- Over 300,000 cases of chronic bronchitis; 500,000 asthma attacks; 16 million lost person days of activity
- Health Costs From Traffic Pollution ~1.7% of total GDP

Comparison of PM10, PM2.5, and Ultrafine PM



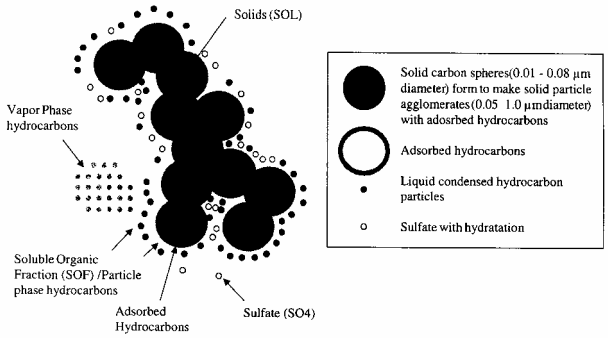
Concern Over Ultrafine PM Reinforced

- Daily Mortality in Erfurt Germany
  - Health Effects of Ultrafine & Fine PM Comparable
  - Effects of Ultrafines Depend on Number and Surface Area
  - Since 91/92 PM Mass Has Declined
  - Since 91/92 very small particles (.01-.03) increased

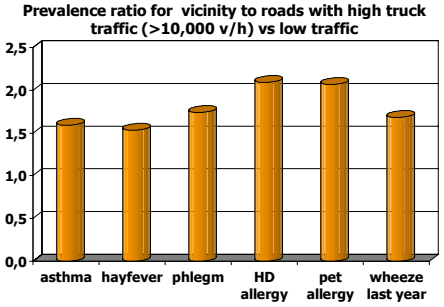
Diesel Health Effects

- Diesel Engines have substantial advantages over Otto engines:
  - Higher fuel efficiency
  - Lower CO and CO2 emissions
- However, they also emit high levels of :
  - PM, NOx, and chemicals attached to the particles (e.g. PAHs)
- Two major types of health effects :
  - acute effects (e.g. exacerbating asthma)
  - cancer effects

Diesel Particulate Matter



Diesel Effects on Childhood Illness
Association between truck traffic and symptoms



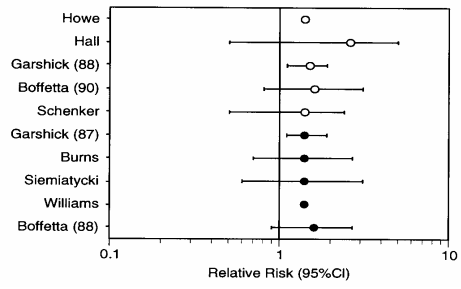
- Source: Brunekreef, B., N. A. Janssen, J. de Hartog, H. Harssema, M. Knape and P. van Vliet (1997). "Air pollution from truck traffic and lung function in children living near motorways." *Epidemiology* 8(3): 298-303

Assessing Diesel Cancer Risk

- Some 30 studies of lung cancer effects on workers
- Consistent small (20-40%) increase in lung cancer associated with exposure
- Some questions about each study
- WHO, IARC*, and U.S. agencies have concluded that diesel is a *"probable human carcinogen"*
- California Air Resources Board listed Diesel Exhaust as a "Toxic Air Pollutant" in 1998

* IARC = International Agency for Research on Cancer

Lung Cancer Studies in Railroad Workers HEI,1995



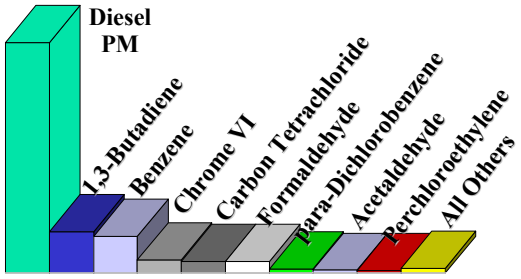
All studies indicate an increase in lung cancer for exposed vs. unexposed workers

Selected Cancer Potencies Approved By The Scientific Review Panel From 1984 To 1998

Compound	Unit Risk ($\mu g/m^3)^{-1}$	Range ($\mu g/m^3)^{-1}$
Dioxins	3.8×10^{1}	2.4×10^{1} to 3.8×10^{1}
Chromium VI	1.5×10^{-1}	1.2×10^{-2} to 1.5×10^{-1}
Cadmium	4.2×10^{-3}	2.0×10^{-3} to 1.2×10^{-2}
Inorganic Arsenic	3.3×10^{-3}	6.3×10^{-4} to 1.3×10^{-2}
Benzo[a]pyrene	1.1×10^{-3}	1.1×10^{-3} to 3.3×10^{-3}
Diesel Exhaust	**3×10^{-4}**	**1.3×10^{-4} to 2.4×10^{-3}**
Nickel	2.6×10^{-4}	2.1×10^{-4} to 3.7×10^{-3}
1,3-Butadiene	1.7×10^{-4}	4.4×10^{-6} to 3.6×10^{-4}
Ethylene Oxide	8.8×10^{-5}	6.1×10^{-5} to 8.8×10^{-5}

Source: Table 2. Findings of the Scientific Review Panel On **The Report on Diesel Exhaust** As Adopted at the Panel's April 22, 1998 Meeting http://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm

Relative Cancer Risks From Air Pollutants in Los Angeles

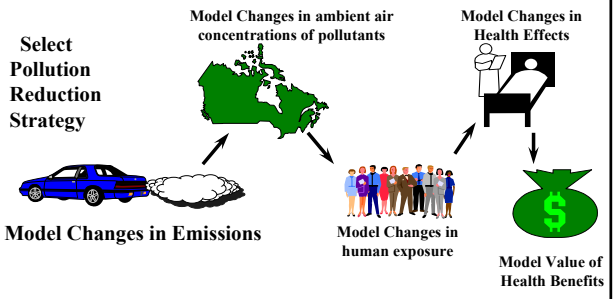


Based on ARB monitoring data 1995 - 1997

Estimating the health benefits of reducing fuel sulfur and diesel emissions

- Canada
- USA
- Santiago, Chile
- Potential for Latin America

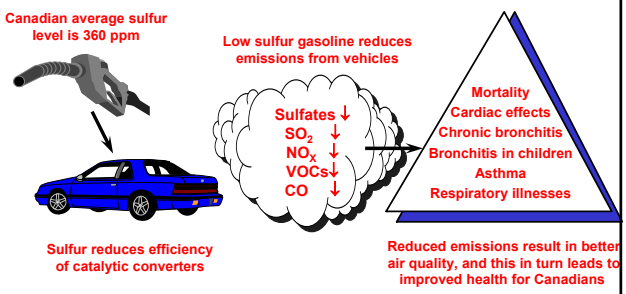
Integrating Science & Policy:
How to Evaluate a Emissions Control Strategy?



Assessing the Health Benefits of Canadian Gasoline Sulfur Rules

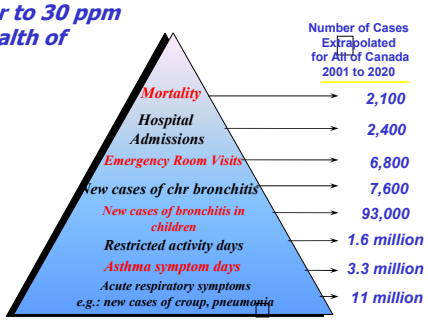
- Canada implemented a substantial reduction in sulfur in gasoline:
  - From 360 ppm to 30 ppm
- Designed to
  - reduce direct emissions, and
  - improve effectiveness of catalytic converters
- Independent analysis of health benefits conducted by Health Canada

Effects of Sulfur in Gasoline on Health



Health Effects Consensus Findings
(Independent Expert Panel)

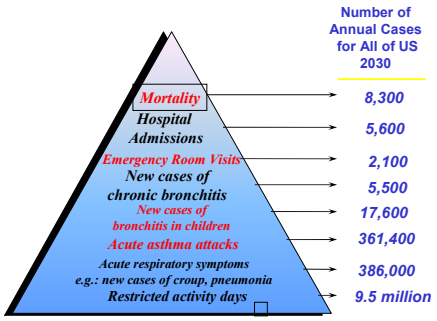
Reducing sulphur to 30 ppm improves the health of Canadians:



Assessing Health Benefits of US. Diesel Fuel and Technology Rules

- New US EPA rules to reduce diesel fuel sulfur and engine emissions
  - Fuel sulfur from 500 ppm to 15 ppm in 2006
  - Reduced PM and NOx emissions in 2007, 2010
- EPA conducted extensive Regulatory Impact Analyses (2000)
- Accepted by US Office of Management and Budget

Estimates of benefits

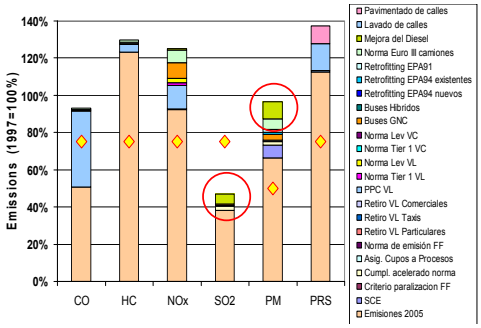


Source: US EPA RIA, 2000

Health benefits of sulfur reduction in Santiago, Chile

- The reduction of sulphur in diesel was considered in the 1997 Decontamination Plan of Santiago
- The reduction considered was from 1200 to 500 ppm S and from 32 to 9% in aromatics (later it was reduced to 250 by the State Petroleum Co)
- This resulted in a reduction of emissions of 60% for SO2, 20% for PM, and 1.1% for NOx
- The cost of the reduction was estimated by ENAP at Ch$10-15 per liter (6.4 to 10 USc/gl)
- The B/C ratio was estimated at **3.0 (2.0 – 3.8)**

Estimated Emission reductions by 2005



Reduction of S in diesel has a big share of emissions reductions:

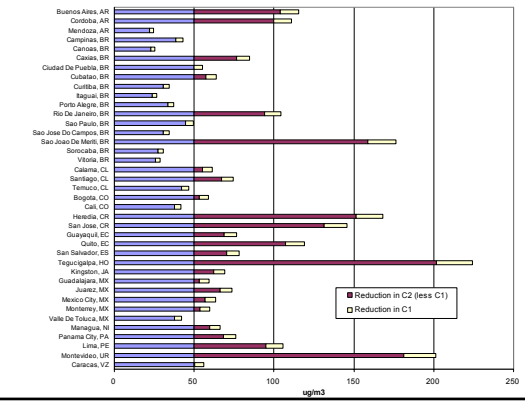
About 70% of SO2 reductions

About 30% of PM reductions

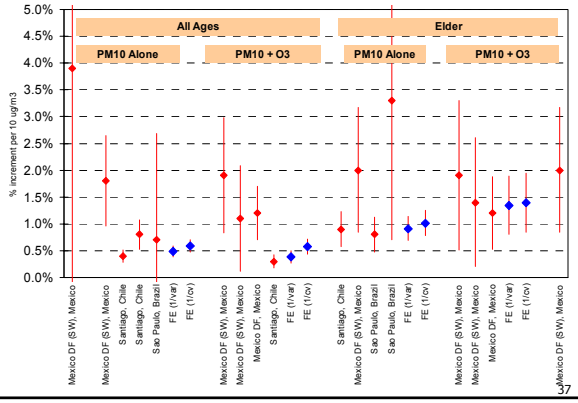
Health benefits: Potential for Latin-America

- We performed an analysis of health effects for 40 cities inLA
- Only PM concentrations considered.
- Draft results from Cifuentes, L., A. Krupnick, R. O'Ryan and M. Toman) (2004). Urban Air Quality And Human Health In Latin America And The Caribbean, Working paper:September 2004.

PM10 levels in Latin American Cities



Meta-analysis of the effects of PM10 All Cause Mortality



Reduction in Premature Mortality

Annual standard attainment in these 40 cities would reduce 16 500 deaths each year

City	Baseline Effects (1)	Reduction in number of premature deaths	
		C1 - 10% reduction	C2 - Annual PM10 Standard
		E2	E2
Buenos Aires, AR	70,518	848	4,666
Cordoba, AR	10,275	118	631
Mendoza, AR	6,360	16	
Rio De Janeiro, BR	28,327	309	1,573
Sao Paulo, BR	32,415	170	
Calama, CL	701	1	2
Santiago, CL	24,991	52	172
Temuco, CL	1,242	2	
Bogota, CO	25,656	158	241
Cali, CO	16,136	71	
Heredia, CR	379	7	44
San Jose, CR	1,190	18	113
Guayaquil, EC	7,875	63	214
Quito, EC	5,551	69	387
San Salvador, ES	1,855	15	54
Tegucigalpa, HO	7,829	182	1,306
Kingston, JA	6,031	44	119
Guadalajara, MX	14,959	149	227
Juarez, MX	4,834	60	193
Mexico City, MX	111,076	1,182	2,425
Monterrey, MX	13,009	132	219
Valle De Toluca, MX	4,969	35	
Managua, NI	3,155	22	53
Panama City, PA	7,599	60	205
Lima, PE	23,653	261	1,341
Montevideo, UR	12,715	266	1,864
Caracas, VZ	7,417	43	45
Total	489,090	4,574	16,538

Summary Impacts

	Endpoint Group	10%	Std
E2 - LA CR Data	**Mortality (short-term ex**	**4.635**	**16.274**
	Hospital Admissions	2.294	8.558
	Emergency Room Visits	6.146	21.114
	Medical Visits	53.362	191.063
E3 - USA CR Data	**Mortality (long-term exp**	**7.686**	**30.981**
	Chronic Bronchitis	8.250	28.187
	Hospital Admissions	17.267	59.933
	Emergency Room Visits	2.545	7.765
	Restricted Activity Days	19.317.591	58.334.031
	Symptoms	17.835.366	51.498.723
	Work Loss Days	3.828.729	11.651.257
	Symptoms	39.993.758	113.118.911
	Restricted Activity Days	21.402.882	68.765.033

Benefits by City

City	C2 - Annual PM10 Standard			
	M US$		As % of income	
	LA	USA	LA	USA
Buenos Aires, AR	3.421	**60.099**	8,0%	**140,5%**
Sao Paulo, BR	-	-	-	-
Calama, CL	1	**29**	0,0%	**0,1%**
Santiago, CL	109	**2.044**	0,3%	**4,8%**
Bogota, CO	121	**3.240**	0,3%	**7,6%**
Heredia, CR	11	**380**	0,0%	**0,9%**
San Jose, CR	45	**1.182**	0,1%	**2,8%**
Guayaquil, EC	83	**2.201**	0,2%	**5,1%**
Quito, EC	142	**3.963**	0,3%	**9,3%**
San Salvador, ES	17	**513**	0,0%	**1,2%**
Tegucigalpa, HO	77	**6.616**	0,2%	**15,5%**
Juarez, MX	98	**1.295**	0,2%	**3,0%**
Mexico City, MX	1.227	**17.494**	2,9%	**40,9%**
Monterrey, MX	111	**1.453**	0,3%	**3,4%**
Panama City, PA	59	**1.439**	0,1%	**3,4%**
Lima, PE	442	**14.116**	1,0%	**33,0%**
Total	9.049	**177.358**	1,9%	**38,0%**

Conclusions

- There are a variety of health effects caused by vehicle emissions, including cancer, premature death, and increased hospitalization.
- Key effects include:
  - Effects on mortality from particulate matter emissions
  - Effects on asthma and cancer from diesel emissions
- Health benefit analyses in Canada and the US have shown substantial health and monetary benefits from reducing sulfur and diesel emissions overall
- The potential for benefits from reductions in sulfur in Latin America is potentially very high

Thanks!