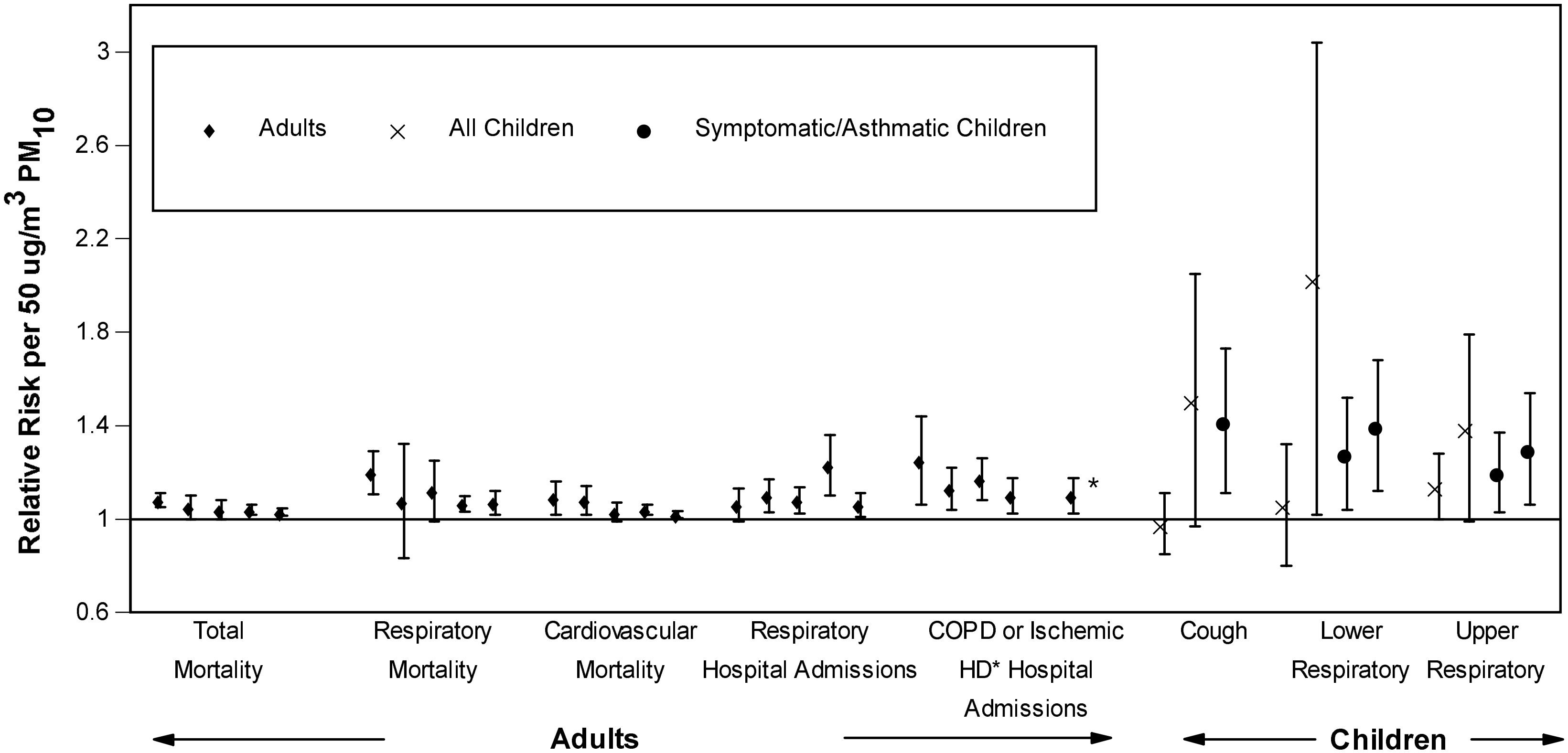
FIGURE V-2. **Relationship Between Relative Risk per 50 ug/m3 PM_{10} and Specific Causes of Mortality and Morbidity in Adults and Children.**



<u>Total, Respiratory and Cardiovascular Mortality</u>

1. Pope et al. (1992)
2. Schwartz (1993)
3. Styer et al. (1995)
4. Ostro et al. (1995a)
5. Ito and Thurston (1996)

<u>Respiratory Hospital Admissions</u>

1. Schwartz (1995) New Haven, CT
2. Schwartz (1995) Tacoma, WA
3. Schwartz (1996) Spokane, WA
4. Thurston et al. (1994) Toronto, Canada

<u>COPD or Ischemic Heart Disease (HD) Hospital Admissions</u>

1. Schwartz (1994f), Minneapolis, MN
2. Schwartz (1994c), Birmingham, AL
3. Schwartz (1996), Spokane WA
4. Schwartz (1994d), Detroit, MI

*5. Schwartz and Morris (1995), Detroit, MII, Ischemic HD

<u>Cough, Lower Respiratory, and Upper Respiratory</u>

1. Hoek and Brunekreef (1993)
2. Schwartz et al. (1994)
3. Pope et al. (1991), asthmatic children
4. Pope and Dockery (1992), symptomatic children

Table E-1. Potential Concentration Cutpoints of Interest for Assessing the Sensitivity of Risk Estimates Derived from Short-Term Exposure Studies

	TOTAL MORTALITY		HOSPITAL ADMISSIONS		RESPIRATORY SYMPTOMS	
Alternative Approaches	Conc. (µg/m³)	Reference	Conc. (µg/m³)	Reference	Conc. (µg/m³)	Reference
PM_{10} STUDIES						
Lower Limit of Detection	20 21	Pope & Kalkstein, 1996 Schwartz, 1994g	19 30	Schwartz, 1994e Schwartz & Morris, 1996	13	Schwartz et al., 1994
Minimum Mean Concentration	30	Schwartz et al., 1996a	36	Schwartz, 1994f	30*	Schwartz et al., 1994
Visual Interpretation	37 42 43*** 34-57***	Pope et al., 1992 Samet et al., 1995 Cifuentes and Lave, 1996 Samet et al., 1995	37	Schwartz, 1994d	-	
$PM_{2.5}$ STUDIES						
Lower Limit of Detection	9	Schwartz, et al., 1996a	13**	Burnett et al., 1995	12	Schwartz et al., 1994
Minimum Mean Concentration	18	Schwartz, et al., 1996a	19 15**	Thurston et al., 1994 Burnett, et al., 1995	18*	Schwartz et al., 1994
Visual Interpretation	29*** 22-36***	Cifuentes and Lave, 1996 Samet et al., 1995	-		-	

Footnotes:
- * Median estimate.
- ** Converted from sulfate data.
- *** Converted from TSP data. Range for Samet et al., 1995 reflects elderly and all mortality results, respectively.

Table VIII-1. Comparison of Residential Visibility Valuation Study Results

Study	City	Mean WTP ($1990)	Starting VR (miles)	Ending VR (miles)	b coefficient	WTP for 20% changes VR (3)
Eastern CVM Studies						
	Atlanta and	Unadj. $39	17.6	20	305	$56
McClelland et	Chicago	Partial $25			196	$36
al.[5]		Full $18			140	$26
	Chicago	-$318	9	4	367	$67
		$305	9	18		
Tolley et al.[6]		$379	9	30		
	Atlanta	-$265	12	7	414	$75
		$255	12	22		
Tolley et al[6]		$381	12	32		
	Boston	-$196	18	13	372	$68
		$187	18	28		
Tolley et al[6]		$231	18	38		
	Mobile	-$212	10	5	275	$68
		$227	10	20		
Tolley et al[6]		$266	10	30		
	Washington, DC	-$314	15	10	560	$102
		$323	15	25		
Tolley et al[6]		$410	15	35		
		-$78	9	4	106	$17
	Cincinnati	$77	9	19		
Tolley et al[6]		$86	9	29		
		-$134	13	8	226	$41
	Miami	$120	13	19		
Tolley et at[6]		$141	13	29		
		$175	11.4	16.4	531	$97
	Cincinnati					
Rae[7]						
California CVM Studies						
		$115	2	12	105	$19
	Los Angeles	$294	2	28		
Brooksire et al.[8]		$161	12	28		
		-$186	18.6	16.3	1172	$214
	San Francisco	$109	16.3	18.6		
Loehman et al[9]						
						$216-$579
California Property Value Study						$437-$487
	Los Angeles					
Trijonis et al[10]	San Francisco					
Trijonis et al[10]						

Note: VR - Visual Range

Source: Chestnut et al., 1994.

Table VIII-2

Average Natural Background Levels of Aerosols and Light Extinction

	Average Concentration East $\mu g/m^3$	Average Concentration West $\mu g/m^3$	Error Factor	Extinction Efficiencies[a] m_2/g	Extinction Contributions East Mm^{-1}	Extinction Contributions West Mm^{-1}
Fine Particles ($\leq$2.5µm)						
Sulfates (as NH_4HSO_4	0.2	0.1	2	2.5	0.5	0.2
Organics	1.5	0.5	2	3.75	5.6	1.9
Elemental Carbon	0.02	0.02	2-3	10.5	0.2	0.2
Ammonium Nitrate	0.1	0.1	2	2.5	0.2	0.2
Soil dust	0.5	0.5	1.5-2	1.25	0.6	0.6
Water	1.0	0.25	2	5	5.0	1.2
Coarse Particles (2.5-10µm)	3.0	3.0	1.5-2	0.6	1.8	1.8
			Rayleigh Scatter		12	11
				Total	26$\pm$7	17$\pm$2.5

[a]The extinction efficiencies are based on the literature review by Trijonis et al. (1986 & 1988). All the extinction efficiencies represent particle scattering, except for elemental carbon where the 10.5 m^2/g value is assumed to consist of 9 m^2/g absorption and 1.5 m^2/g scattering. Note that the 0.6 m^2/g value for coarse particles is a "pseudo-coarse scattering efficiency" representing the total scattering by all ambient coarse particles (2.5 µm) divided by the coarse particle mass between 2.5 and 10 µm.

Table VIII-3. Dry particle light extinction efficiency values used in 1993 analysis of IMPROVE data.

Aerosol Constituent	Extinction Efficiency (in m^2/g)
Sulfates	3.0
Organics	3.0
Elemental carbon	10.0
Nitrates	3.0
Soil dust	1.0
Coarse particles	0.6

Source: Sisler et al., 1993

Table VIII-4. Comparison of total light extinction to estimated natural light extinction
for several eastern and western locations.

REGION	TOTAL LIGHT EXTINCTION 1988-1994 (in Mm^{-1})		VISUAL RANGE (in km)	
	Annual	Summer	Annual	Summer
Eastern U.S., estimated natural light extinction	**26 +/- 7**	**NA**	**150+/- 45**	**NA**
Appalachian	126	182	31	21
Boundary Waters	62	63	63	62
Northeast	77	95	51	41
Washington, D.C.	177	207	22	19
Western U.S., estimated natural light extinction	**17 +/- 2.5**	**NA**	**230 +/- 40**	**NA**
Colorado Plateau	32	33	122	119
Cascades	74	73	53	54
Southern California	74	87	53	45
Northern Rockies	57	48	69	82

Sources: Sisler et al., 1996; NAPAP 1991.

Table VIII-5

Visibility Model Results:
Anthropogenic Light Extinction Budgets[a]

	East[b]	Southwest[c]	Northwest[d]
Sulfates	65	39	33
Organics	14	18	28
Elemental carbon	11	14	15
Suspended dust	2	15	7
Nitrates	5	9	13
Nitrogen dioxide	3	5	4

[a]Percentage contribution by specific pollutant to anthropogenic light extinction in three regions of the United States.

[b]Based on Table 9, Table 18, Figure 45, Appendix A, and Appendix E of NAPAP Visibility SOS/T Report (Trijonis et al., 1990). It is assumed that sulfates (3% natural) account for 60% of non-Rayleigh extinction, organics (33% natural) account for 18%, elemental carbon (3% natural) accounts for 10%, suspended dust (50% natural) accounts for 4%, nitrates (10% natural) account for 5%, and nitrogen dioxide (10% natural) accounts for 3%.

[c]Based on Table 9, Table 18, Figure 45, Appendix A, and Appendix E of the NAPAP Visibility SOS/T Report (Trijonis et al., 1990). It is assumed that sulfates (10% natural) account for 33% of non-Rayleigh extinction, organics (33% natural) account for 20%, elemental carbon (10% natural) accounts for 12%, suspended dust (50% natural) accounts for 23%, nitrates (105 natural) account for 8%, and nitrogen dioxide (10% natural) accounts for 4%.

[d]Extinction efficiencies (relative to organics are chosen as 1.5 for sulfates, 2.5 for elemental carbon, 0.3 for fine crustal materials, and 1.5 for nitrates (Trijonis et al., 1988, 1990). Coarse dust extinction is assumed to be three times fine dust extinction (Trijonis et al., 1988, 1990). Natural aerosol particle fractions are assumed to be one-tenth for sulfates, one-third for organics one-tenth for elemental carbon, one-half for crustal materials, and one-tenth for nitrates. These assumptions are applied using the fine mass concentrations in Trijonis et al., (1990). The percentage contribution for

nitrogen dioxide is assumed to be 4%.

Source: NRC, 1993.

Table VIII-6. Percentage Contribution by Source Category to Fine Particle (and Precursor) Emissions in the East, Southwest, and Northwest

EAST	SOx	Organic Particles	VOC's	Elementa l Carbon	Suspended Dust	NH3	NOx
Electric utilities	78.0	--	--	--	--	--	39
Diesel-fueled mobile sources	1.5	--	--	47	--	--	16
Gasoline vehicles	1.0	34	31	29	--	--	26
Petroleum and chemical industries	4.5	--	11	--	--	--	--
Industrial coal combustion	7.0	--	--	--	--	--	--
Residential wood burning	--	20	13	15	--	--	--
Fugitive dust (on-road/off-road traffic)	--	--	--	--	100	--	--
Feedlots and livestock waste mgmt.	--	--	--	--	--	66	--
Miscellaneous	8.0	46	45	9	--	34	19

SOUTHWEST	SOx	Organic Particles	VOC's	Elementa l Carbon	Suspended Dust	NH3	NOx
Electric utilities	33	--	--	--	--	--	19
Diesel-fueled mobile sources	12	5	--	52	--	--	23
Gasoline vehicles	5	38	42	31	--	--	32
Petroleum and chemical industries	22	--	12	--	--	--	--
Copper smelters	19	--	--	--	--	--	--
Fugitive dust (on-road/off-road traffic)	--	--	--	--	100	--	--
Residential wood burning	--	8	5	6	--	--	--
Feedlots and livestock waste mgmt.	--	--	--	--	--	75	--
Miscellaneous	9	49	41	11	--	25	26

NORTHWEST	SOx	Organic Particles	VOC's	Elementa l Carbon	Suspended Dust	NH3	NOx
Electric utilities	30	--	--	--	--	--	8
Diesel-fueled mobile sources	12	--	--	37	--	--	29
Gasoline vehicles	4	15	31	16	--	--	36
Petroleum and chemical industries	19	--	10	--	--	--	--
Residential wood burning	--	22	25	22	--	--	--
Forest management burning	--	45	13	20	--	--	--
Fugitive dust (on-road/off-road traffic)	--	--	--	--	100	--	--
Feedlots and livestock waste mgmt.	--	--	--	--	--	81	--
Primary metallurgical process	8	--	15	--	--	--	--
Organic solvent evaporation	--	--	15	--	--	--	--
Miscellaneous	27	18	6	5	--	19	27

Source: NRC, 1993.

Table VIII-7. Percentage contributions of aerosol constituents to annual average total light extinction in the Washington, D.C. and southern California areas.

Location	Sulfate	Nitrate	Organics	Elemental Carbon	Soil and Coarse
Wash, DC	49	16	16	11.9	6.9
So. Calif.	14	44	18	9.0	13.9

Source: Sisler et al., 1993

TABLE V-3. ESTIMATED MORTALITY INCREASE PER 50 μg/m^3 INCREASE IN 24-h PM_{10} CONCENTRATIONS FROM U.S. STUDIES (After CD, Table 13-3)

Study Location	RR (± CI) Only PM in Model	RR (± CI) Other Pollutants in Model	Reported PM_{10} Levels Mean (Min/Max)[†]
Increased Total Acute Mortality			
Six Cities[a]		—	
Portage, WI	1.04 (0.98, 1.09)	—	18 (±11.7)
Boston, MA	1.06 (1.04, 1.09)	—	24 (±12.8)
Topeka, KS	0.98 (0.90, 1.05)	—	27 (±16.1)
St. Louis, MO	1.03 (1.00, 1.05)	—	31 (±16.2)
Kingston/Knoxville, TN	1.05 (1.00, 1.09)	—	32 (±14.5)
Steubenville, OH	1.05 (1.00, 1.08)	—	46 (±32.3)
St. Louis, MO[c]	1.08 (1.01, 1.12)	1.06 (0.98, 1.15)	28 (1/97)
Kingston, TN[c]	1.09 (0.94, 1.25)	1.09 (0.94, 1.26	30 (4/67)
Chicago, IL[h]	1.04 (1.00, 1.08)	—	37 (4/365)
Chicago, IL[g]	1.03 (1.02, 1.04)	1.02 (1.01, 1.04)	38 (NR/128)
Utah Valley, UT[b]	1.08 (1.05, 1.11)	1.19 (0.96, 1.47)	47 (11/297)
Birmingham, AL[d]	1.05 (1.01, 1.10)	—	48 (21, 80)
Los Angeles, CA[f]	1.03 (1.00, 1.055)	1.02 (0.99, 1.036)	58(15/177)

References:

[a]Schwartz et al. (1996a).
[b]Pope et al. (1992, 1994)/O_3.
[c]Dockery et al. (1992)/O_3.
[d]Schwartz (1993).
[g]Ito and Thurston (1996)/O_3.
[f]Kinney et al. (1995)/O_3, CO.
[h]Styer et al. (1995).

[†]Min/Max 24-h PM_{10} in parentheses unless noted otherwise as standard deviation (± S.D), 10 and 90 percentile (10, 90). NR = not reported.
[*]Means of several cities.

TABLE 13-4. EFFECT ESTIMATES PER VARIABLE INCREMENTS IN 24-h CONCENTRATIONS OF FINE PARTICLE INDICATORS ($PM_{2.5}$, $SO_4^=$, H^+) FROM U.S. AND CANADIAN STUDIES

Acute Mortality	Indicator	RR (± CI) per 25 μg/m^3 PM Increase	Reported PM Levels Mean (Min/Max)†
Six City[A]			
Portage, WI	$PM_{2.5}$	1.030 (0.993, 1.071)	11.2 (±7.8)
Topeka, KS	$PM_{2.5}$	1.020 (0.951, 1.092)	12.2 (±7.4)
Boston, MA	$PM_{2.5}$	1.056 (1.038, 1.0711)	15.7 (±9.2)
St. Louis, MO	$PM_{2.5}$	1.028 (1.010, 1.043)	18.7 (±10.5)
Kingston/Knoxville, TN	$PM_{2.5}$	1.035 (1.005, 1.066)	20.8 (±9.6)
Steubenville, OH	$PM_{2.5}$	1.025 (0.998, 1.053)	29.6 (±21.9)
Increased Hospitalization			
Ontario, CAN[B]	$SO_4^=$	1.03 (1.02, 1.04)	R = 3.1-8.2
Ontario, CAN[C]	$SO_4^=$	1.03 (1.02, 1.04)	R = 2.0-7.7
	O_3	1.03 (1.02, 1.05)	
NYC/Buffalo, NY[D]	$SO_4^=$	1.05 (1.01, 1.10)	NR
Toronto[D]	H^+ (Nmol/m^3)	1.16 (1.03, 1.30)*	28.8 (NR/391)
	$SO_4^=$	1.12 (1.00, 1.24)	7.6 (NR, 48.7)
	$PM_{2.5}$	1.15 (1.02, 1.78)	18.6 (NR, 66.0)
Increased Respiratory Symptoms			
Southern California[F]	$SO_4^=$	1.48 (1.14, 1.91)	R = 2-37
Six Cities[G] (Cough)	$PM_{2.5}$	1.19 (1.01, 1.42)**	18.0 (7.2, 37)***
	$PM_{2.5}$ Sulfur	1.23 (0.95, 1.59)**	2.5 (3.1, 61)***
	H^+	1.06 (0.87, 1.29)**	18.1 (0.8, 5.9)***
Six Cities[G] (Lower Resp. Symp.)	$PM_{2.5}$	1.44 (1.15-1.82)**	18.0 (7.2, 37)***
	$PM_{2.5}$ Sulfur	1.82 (1.28-2.59)**	2.5 (0.8, 5.9)***
	H^+	1.05 (0.25-1.30)**	18.1 (3.1, 61)***
Decreased Lung Function			
Uniontown, PA[E]	$PM_{2.5}$	PEFR 23.1 (-0.3, 36.9) (per 25 μg/m^3)	25/88 (NR/88)

References:
[A]Schwartz et al. (1996a)
[B]Burnett et al. (1994)
[C]Burnett et al. (1995) O_3
[D]Thurston et al. (1992, 1994)
[E]Neas et al. (1995)
[F]Ostro et al. (1993)
[G]Schwartz et al. (1994)

†Min/Max 24-h PM indicator level shown in parentheses unless otherwise noted as (± S.D.), 10 and 90 percentile (10,90) or R = range of values from min-max, no mean value reported.
*Change per 100 nmoles/m^3
**Change per 20 μg/m^3 for $PM_{2.5}$; per 5 μg/m^3 for $PM_{2.5}$ sulfur; per 25 nmoles/m^3 for H^+.
***50th percentile value (10,90 percentile)

TABLE 13-5. EFFECT ESTIMATES PER INCREMENTS[a] IN ANNUAL MEAN LEVELS OF FINE PARTICLE INDICATORS FROM U.S. AND CANADIAN STUDIES

Type of Health Effect & Location	Indicator	Change in Health Indicator per Increment in PM[a]	Range of City PM Levels Means ($\mu g/m^3$)
Increased total chronic mortality in adults		Relative Risk (95% CI)	
Six City[b]	$PM_{15/10}$	1.42 (1.16-2.01)	18-47
	$PM_{2.5}$	1.31 (1.11-1.68)	11-30
	$SO_4^=$	1.46 (1.16-2.16)	5-13
ACS Study[c] (151 U.S. SMSA)	$PM_{2.5}$	1.17 (1.09-1.26)	9-34
	$SO_4^=$	1.10 (1.06-1.16)	4-24
Increased bronchitis in children		Odds Ratio (95% CI)	
Six City[d]	$PM_{15/10}$	3.26 (1.13, 10.28)	20-59
Six City[e]	TSP	2.80 (1.17, 7.03)	39-114
24 City[f]	H^+	2.65 (1.22, 5.74)	6.2-41.0
24 City[f]	$SO_4^=$	3.02 (1.28, 7.03)	18.1-67.3
24 City[f]	$PM_{2.1}$	1.97 (0.85, 4.51)	9.1-17.3
24 City[f]	PM_{10}	3.29 (0.81, 13.62)	22.0-28.6
Southern California[g]	$SO_4^=$	1.39 (0.99, 1.92)	—
Decreased lung function in children			
Six City[d,h]	$PM_{15/10}$	NS Changes	20-59
Six City[e]	TSP	NS Changes	39-114
24 City[i,j]	H^+ (52 nmoles/m^3)	−3.45% (-4.87, -2.01) FVC	—
24 City[i]	$PM_{2.1}$ (15 $\mu g/m^3$)	−3.21% (-4.98, -1.41) FVC	—
24 City[i]	$SO_4^=$ (7 $\mu g/m^3$)	−3.06% (-4.50, -1.60) FVC	—
24 City[i]	PM_{10} (17 $\mu g/m^3$)	−2.42% (-4.30, -.0.51) FVC	—

[a]Estimates calculated annual-average PM increments assume: a 100 $\mu g/m^3$ increase for TSP; a 50 $\mu g/m^3$ increase for PM_{10} and PM_{15}; a 25 $\mu g/m^3$ increase for $PM_{2.5}$; and a 15 $\mu g/m^3$ increase for $SO_4^=$, except where noted otherwise; a 100 nmole/m^3 increase for H^+.
[b]Dockery et al. (1993)
[c]Pope et al. (1995)
[d]Dockery et al. (1989)
[e]Ware et al. (1986)
[f]Dockery et al. (1996)
[g]Abbey et al. (1995a,b,c)
[h]NS Changes = No significant changes.
[i]Raizenne et al. (1996)
[j]Pollutant data same as for Dockery et al. (1996)

TABLE V-4. COMPARISON OF TOTAL MORTALITY WITH AGE- AND CAUSE-SPECIFIC MORTALITY FOR SHORT-TERM EXPOSURE STUDIES

Study	Total Mortality, Relative Risk per 50 μg/m^3 PM10	Age- and Cause-specific Mortality per 50 μg/m^3 PM10
Respiratory Related		
Utah Valley, Pope et al. (1992)	1.08 (1.05 - 1.11)	1.20 (1.11 - 1.29)
Chicago, Styer et al. (1995)	1.04 (1.00 - 1.08)	1.12 (0.99 - 1.26)
Chicago, Ito and Thurston (1996)	1.03 (1.01, 1.04)	1.07 (1.02, 1.12)
Birmingham, Schwartz (1993)*	1.05 (1.01 - 1.10)	1.08 (0.88 - 1.32)
Santiago, Chile, Ostro et al. (1995a)	1.04 (1.035 - 1.06)	1.06 (1.03 - 1.10)
Elderly		
Chicago, Styer et al. (1995)	1.04 (1.00 - 1.08)	1.08 (1.03 - 1.13)
Santiago, Chile, Ostro et al. (1995a)	1.04 (1.035 - 1.06)	1.05 (1.03 - 1.06)
Cardiovascular Related		
Utah Valley, Pope et al. (1992)	1.08 (1.05 - 1.11)	1.09 (1.02 - 1.17)
Chicago, Styer et al. (1995)	1.04 (1.00 - 1.08)	1.03 (0.98 - 1.09)
Chicago, Ito and Thurston (1996)	1.03 (1.01 - 1.04)	1.02 (1.00 - 1.03)
Birmingham, Schwartz (1993)	1.05 (1.01 - 1.10)	1.08 (1.02 - 1.14)
Santiago, Chile, Ostro et al. (1995a)	1.04 (1.035 - 1.06)	1.04 (1.02 - 1.06)

* The Schwartz (1993) study was of COPD.

TABLE V-5. RELATIVE RISK BETWEEN THE MOST POLLUTED AND LEAST POLLUTED CITIES FOR FOR TOTAL POPULATION AND FORMER AND CURRENT SMOKERS IN THE PROSPECTIVE COHORT STUDIES

A) Harvard Six City Study, Dockery et al. (1993)

Endpoint	Total Population RR*	Non-Smokers RR*	Former Smokers RR*	Current Smokers RR*	No Occupational Exposure RR*
Total Mortality	1.26 (1.08 - 1.47)	1.19 (0.90 - 1.57)	1.35 (1.02 - 1.77)	1.32 (1.04 - 1.68)	1.17 (0.93 - 1.47)
Cardiopulmonary Disease	1.37 (1.11 - 1.68)	---	---	---	---
Lung Cancer	1.37 (0.81 - 2.31)	---	---	---	---

The results (and 95 percent confidence intervals) were reported in the paper between the city with the highest level of $PM_{2.5}$ (Steubenville, OH, average 29.6 $\mu g/m^3$) and the lowest level of $PM_{2.5}$ (Portage, WI, 11.0 $\mu g/m^3$).

B) American Cancer Society Study, Pope et al. (1995)

Endpoint	Total Population RR**	Non-Smokers RR**	Current and Former Smokers RR**
Total Mortality	1.17 (1.09 - 1.26)	1.22 (1.07 - 1.39)	1.15 (1.05 - 1.26)
Cardiopulmonary	1.31 (1.17 - 1.46)	1.43 (1.18 - 1.72)	1.24 (1.08 - 1.42)
Lung Cancer	1.03 (0.80 - 1.33)	0.59 (0.23 - 1.52)	1.07 (0.82 - 1.39)

The results (and 95 percent confidence intervals) were reported in the paper between the city with the highest and the lowest level of $PM_{2.5}$ of the 47 cities examined.

* Per 18.6 $\mu g/m^3$ increase in $PM_{2.5}$.

**Per 24.5 $\mu g/m^3$ increase in $PM_{2.5}$.

TABLE V-6. ESTIMATED INCREASED HOSPITAL ADMISSIONS FOR THE ELDERLY PER 50 $\mu g/m^3$ INCREASE IN 24-h PM_{10} CONCENTRATIONS FROM U.S. AND CANADIAN STUDIES

(After CD, Table 13-3)

Study Location	RR (± CI) Only PM in Model	RR (± CI) Other Pollutants in Model	Reported PM_{10} Levels Mean (Min/Max)[†]
Respiratory Disease			
Toronto, CAN[I]	1.23 (1.02, 1.43)[‡]	1.12 (0.88, 1.36)[‡]	30-39[*]
Tacoma, WA[J]	1.10 (1.03, 1.17)	1.11 (1.02, 1.20)	37 (14, 67)
New Haven, CT[J]	1.06 (1.00, 1.13)	1.07 (1.01, 1.14)	41 (19, 67)
Cleveland, OH[K]	1.06 (1.00, 1.11)	—	43 (19, 72)
Spokane, WA[L]	1.08 (1.04, 1.14)	—	46 (16, 83)
COPD			
Minneapolis, MN[N]	1.25 (1.10, 1.44)	—	36 (18, 58)
Birmingham, AL[M]	1.13 (1.04, 1.22)	—	45 (19, 77)
Spokane, WA[L]	1.17 (1.08, 1.27)	—	46 (16, 83)
Detroit, MI[O]	1.10 (1.02, 1.17)	—	48 (22, 82)
Pneumonia			
Minneapolis, MN[N]	1.08 (1.01, 1.15)	—	36 (18,58)
Birmingham, AL[M]	1.09 (1.03, 1.15)	—	45 (19, 77)
Spokane, WA[L]	1.06 (0.98, 1.13)	—	46 (16, 83)
Detroit, MI[O]	—	1.06 (1.02, 1.10)	48 (22, 82)
Ischemic HD			
Detroit, MI[P]	1.02 (1.01, 1.03)	1.02 (1.00, 1.03)	48 (22, 82)

References:

[I]Thurston et al. (1994)/O_3.
[J]Schwartz (1995)/SO_2.
[K]Schwartz et al. (1996b).
[L]Schwartz (1996).
[M]Schwartz (1994e)
[N]Schwartz (1994f).
[O]Schwartz (1994d).
[P]Schwartz and Morris (1995)/O_3, CO, SO_2 .

[†]Min/Max 24-h PM_{10} in parentheses unless noted otherwise as standard deviation (± S.D), 10 and 90 percentile (10, 90). NR = not reported.
Means of several cities.
[‡]RR refers to total population, not just>65 years

TABLE V-7. ESTIMATED LUNG FUNCTION CHANGES AND RESPIRATORY SYMPTOMS PER 50 $\mu g/m^3$ INCREASE IN 24-h PM_{10} CONCENTRATIONS FROM U.S. AND CANADIAN STUDIES (After CD, Table 13-3)

Study Location	RR (± CI) Only PM in Model	RR (± CI) Other Pollutants in Model	Reported PM_{10} Levels Mean (Min/Max)[†]
Increased Respiratory Symptoms			
<u>Lower Respiratory</u>			
Six Cities[Q]	2.03 (1.36, 3.04)	Similar RR	30 (13,53)
Utah Valley, UT[R]	1.28 (1.06, 1.56)[τ]	—	46 (11/195)
	1.01 (0.81, 1.27)[π]		
Utah Valley, UT[S]	1.27 (1.08, 1.49)	—	76 (7/251)
<u>Cough</u>			
Denver, CO[X]	1.09 (0.57, 2.10)	—	22 (0.5/73)
Six Cities[Q]	1.51 (1.12, 2.05)	Similar RR	30 (13, 53)
Utah Valley, UT[S]	1.29 (1.12, 1.48)	—	76 (7/251)
Decrease in Lung Function			
Utah Valley, UT[R]	55 (24, 86)[**]	—	46 (11/195)
Utah Valley, UT[S]	30 (10, 50)[**]	—	76 (7/251)
Utah Valley, UT[W]	29 (7,51)[***]	—	55 (1,181)

References:

[Q]Schwartz et al. (1994).
[R]Pope et al. (1991).
[S]Pope and Dockery (1992).
[T]Schwartz (1994g)
[W]Pope and Kanner (1993)
[X]Ostro et al. (1991)

[†]Min/Max 24-h PM_{10} in parentheses unless noted otherwise as standard deviation (± S.D), 10 and 90 percentile (10, 90). NR = not reported.
[τ]Children.
[π]Asthmatic children and adults.
Means of several cities.
[**]PEFR decrease in ml/sec.
[***]FEV_1 decrease.

TABLE V-8. MORBIDITY EFFECTS ESTIMATES PER INCREMENTS[a] IN ANNUAL MEAN LEVELS OF FINE/THORACIC PARTICLE INDICATORS FROM U.S. AND CANADIAN STUDIES (After CD, Table 13-5).

Type of Health Effect & Location	Indicator	Change in Health Indicator per Increment in PM[a]	Range of City PM Levels Means ($\mu g/m^3$)
Increased bronchitis in children		Odds Ratio (95% CI)	
Six City[d]	$PM_{15/10}$	3.26 (1.13, 10.28)	20-59
Six City[e]	TSP	2.80 (1.17, 7.03)	39-114
24 City[f]	H^+	2.65 (1.22, 5.74)	6.2-41.0
24 City[f]	$SO_4^=$	3.02 (1.28, 7.03)	18.1-67.3
24 City[f]	$PM_{2.1}$	1.97 (0.85, 4.51)	9.1-17.3
24 City[f]	PM_{10}	3.29 (0.81, 13.62)	22.0-28.6
Southern California[g]	$SO_4^=$	1.39 (0.99, 1.92)	—
Decreased lung function in children			
Six City[d,h]	$PM_{15/10}$	NS Changes	20-59
Six City[e]	TSP	NS Changes	39-114
24 City[i,j]	H^+ (52 nmoles/m^3)	−3.45% (-4.87, -2.01) FVC	—
24 City[i]	$PM_{2.1}$ (15 $\mu g/m^3$)	−3.21% (-4.98, -1.41) FVC	—
24 City[i]	$SO_4^=$ (7 $\mu g/m^3$)	−3.06% (-4.50, -1.60) FVC	—
24 City[i]	PM_{10} (17 $\mu g/m^3$)	−2.42% (-4.30, -.0.51) FVC	—

[a]Estimates calculated annual-average PM increments assume: a 100 $\mu g/m^3$ increase for TSP; a 50 $\mu g/m^3$ increase for PM_{10} and PM_{15}; a 25 $\mu g/m^3$ increase for $PM_{2.5}$; and a 15 $\mu g/m^3$ increase for $SO_4^=$, except where noted otherwise; a 100 nmole/m^3 increase for H^+.
[d]Dockery et al. (1989)
[e]Ware et al. (1986)
[f]Dockery et al. (1996)
[g]Abbey et al. (1995a,b,c)
[h]NS Changes = No significant changes.
[i]Raizenne et al. (1996)
[j]Pollutant data same as for Dockery et al. (1996)

TABLE V-10. QUANTITATIVE COHERENCE OF ACUTE MORTALITY AND HOSPITALIZATION STUDIES (CD, Table 13-8)

Age Group	Health Endpoint	Population Annual Baseline Per Million Total Population	Population Daily Baseline Per Million Total Population	PM_{10} Lag Time	Excess Risk per 50 $\mu g/m^3$ PM_{10} Incr.	Possible Number of PM-Related Events Per Day Per 1 Mil. Pop. for 50 $\mu g/m^3$ PM_{10} Increment
Whole Population						
All	Total mortality	8,603[1]	23.6	<2d	0.03[2]	0.7
				3-5d	0.06[2]	1.5
	Total hospit.	124,110[3]	340.0	-	-	-
All	Resp. mortality	676[1]	1.85	3-5d	0.19[4]	0.3
	Total resp. hospitalization	12,180[3]	33.4	<2d	0.06[5]	2.0
All	Cardiovascular mortality	3,635[1]	10.0	3-5d	0.09[4]	0.9
	Heart disease hospitalization	21,310[3]	58.4	<2d	0.04[6]	2.3
Elderly						
65+	Total mortality	6,201[7]	17.0	2d	0.06[8]	1.0[8]
	Total hospit.	42,845[9]	117.4	-	-	-
65+	Total resp. hospitalization	5,101[9]	14.0	≤1d	0.08[5]	1.1
	Pneumonia hospit.	2,335[9]	6.4	≤1d	0.08[10]	0.5
	COPD hospit.	2,560[11]	7.0	≤1d	0.16[5]	1.1
	Heart disease hospitalization	13,502[9]	37.0	≤1d	0.06[6]	2.2

[1]From National Center for Health Statistics (1993).
[2]From EPA meta-analyses, Table 12-30, models without copollutants.
[3]From Table 12-6, based on first-listed diagnoses for discharges.
[4]From Pope et al. (1991), Schwartz (1993) for Utah Valley and Birmingham, variance-weighted average, Table 12-4.*
[5]From Table 12-8, average.*
[6]From Table 12-11.*
[7]Assuming elderly as 12.6% of 1991 U.S. population.
[8]Based on different set of studies than for above whole population (ALL), i.e., 65+ PM mortality risk from Saldiva et al. (1994) and Ostro et al. (1996) variance-weighted average; Section 12.3.*
[9]From Table 12-6,* assuming 12.6%, age 65+.
[10]From Table 12-10,* average.
[11]From 1992 detailed tables; excludes asthma (ICD 493).
*All Table references to Chapter 12 of the CD.

TABLE V-11. SHORT-TERM EXPOSURE EPIDEMIOLOGICAL STUDIES OF MORTALITY USING OPTICAL FINE PARTICLE INDICATORS*

City	Study Years	Indicator	Reference
Acute Mortality			
London	1963-1972,winters 1965-1972, winters	BS	Thurston et al., 1989 Ito et al., 1993
Athens	1975-1987 July, 1987 1984-1988	BS	Katsouyanni et al., 1990 Katsouyanni et al., 1993 Touloumi et al., 1994
Los Angeles	1970-1979 1970-1979	KM	Shumway et al., 1988 Kinney and Ozkaynak, 1991
Santa Clara	1980-1986, winters	COH	Fairley, 1990

*BS, KM, COH are optical measurements that are most directly related to elemental carbon concentrations, but only indirectly to mass (See Appendix B). Site specific calibrations and/or comparisons of such optical measurements with gravimetric mass measurements in the same time and city are needed to make inferences about particle mass. Both the nature of the monitor inlet and the fact that elemental carbon particles are found in the fine fraction mean such measurements reflect variations in fine particle mass (if calibrated) or in that portion of fine particles indexed by elemental carbon (largely primary combustion particles). Comparisons between the respective optical measurements and mass measurements were made for the historical London winters (EPA, 1982a), the Athens studies (Katsouyanni et al., 1995), and Santa Clara (Fairly, 1990). Such comparisons were not reported for the Los Angeles study using KM, but the same investigators also reported significant associations between mortality and PM gravimetric mass in Los Angeles (Kinney et al., 1995).

TABLE V-12. FINE PARTICLE INDICATOR ($PM_{2.5}$, $SO_4^=$, H^+) EFFECTS STUDIES FROM THE U.S. AND CANADA (CD, Tables 13-4, 12-2, 12-13)

	Indicator	RR (± CI) per 25 $\mu g/m^3$ PM Increase	PM Levels Mean (Min/Max)†
Acute Mortality			
Six City[A]			
Portage, WI	$PM_{2.5}$	1.030 (0.993, 1.071)	11.2 (±7.8)
Topeka, KS	$PM_{2.5}$	1.020 (0.951, 1.092)	12.2 (±7.4)
Boston, MA	$PM_{2.5}$	1.056 (1.038, 1.0711)	15.7 (±9.2)
St. Louis, MO	$PM_{2.5}$	1.028 (1.010, 1.043)	18.7 (±10.5)
Kingston/Knoxville, TN	$PM_{2.5}$	1.035 (1.005, 1.066)	20.8 (±9.6)
Steubenville, OH	$PM_{2.5}$	1.025 (0.998, 1.053)	29.6 (±21.9)
Increased Hospitalization			
Ontario, CAN[B]	$SO_4^=$	1.03 (1.02, 1.04)	Min/Max = 3.1-8.2
Ontario, CAN[C]	$SO_4^=$ O_3	1.03 (1.02, 1.04) 1.03 (1.02, 1.05)	Min/Max = 2.0-7.7
NYC/Buffalo, NY[D]	$SO_4^=$	1.05 (1.01, 1.10)	NR
Toronto, CAN[D]	H^+ (Nmol/m^3) $SO_4^=$ $PM_{2.5}$	1.16 (1.03, 1.30)* 1.12 (1.00, 1.24) 1.15 (1.02, 1.78)	28.8 (NR/391) 7.6 (NR, 48.7) 18.6 (NR, 66.0)
Increased Respiratory Symptoms			
Southern California[F]	$SO_4^=$	1.48 (1.14, 1.91)	R = 2-37
Six Cities[G] (Cough)	$PM_{2.5}$ $PM_{2.5}$ Sulfur H^+	1.19 (1.01, 1.42)** 1.23 (0.95, 1.59)** 1.06 (0.87, 1.29)**	18.0 (7.2, 37)*** 2.5 (3.1, 61)*** 18.1 (0.8, 5.9)***
Six Cities[G] (Lower Resp. Symp.)	$PM_{2.5}$ $PM_{2.5}$ Sulfur H^+	1.44 (1.15-1.82)** 1.82 (1.28-2.59)** 1.05 (0.25-1.30)**	18.0 (7.2, 37)*** 2.5 (0.8, 5.9)*** 18.1 (3.1, 61)***
Denver, CO[P] (Cough, adult asthmatics)	$PM_{2.5}$ $SO_4^=$ H^+	0.0012 (0.0043)*** 0.0042 (.00035)*** 0.0076 (0.0038)***	0.41 - 73 0.12 - 12 2.0 - 41
Decreased Lung Function			
Uniontown, PA[E]	$PM_{2.5}$	PEFR 23.1 (-0.3, 36.9) (per 25 $\mu g/m^3$)	25/88 (NR/88)
Seattle, WA[Q] Asthmatics	$b_{ext.}$ calibrated by $PM_{2.5}$	FEV1 42 ml (12,73) FVC 45 ml (20,70)	5/45

References:

[A]Schwartz et al. (1996a)
[B]Burnett et al. (1994)
[C]Burnett et al. (1995) O_3
[D]Thurston et al. (1992, 1994)
[E]Neas et al. (1995)
[F]Ostro et al. (1993)
[G]Schwartz et al. (1994)
[P]Ostro et al. (1991)
[Q]Koenig et al. (1993)

†Min/Max 24-h PM indicator level shown in parentheses unless otherwise noted as (± S.D.), 10 and 90 percentile (10,90).
*Change per 100 nmoles/m^3.
**Change per 20 $\mu g/m^3$ for $PM_{2.5}$; per 5 $\mu g/m^3$ for $PM_{2.5}$ sulfur; per 25 nmoles/m^3 for H^+.
***50th percentile value (10,90 percentile).
****Coefficient and SE in parenthesis.

TABLE V-14. ESTIMATED INCREASE IN DAILY MORTALITY, 95% C1, AND t STATISTIC BY CITY AND COMBINED ESTIMATE ASSOCIATED WITH A 10 μg/m^3 INCREASE IN PARTICULATE MASS CONCENTRATIONS. EFFECT OF EACH PARTICLE MASS MEASURE ASSOCIATIONS ESTIMATED SEPARATELY, CONTROLLED FOR LONG-TERM TRENDS AND WEATHER.

Study City	Correlation $PM_{2.5}$/CM	$PM_{2.5}$	CM	PM_{10}
Boston	0.23	2.2% (1.5%, 2.9%) t=6.31	0.2% (-0.6%, 1.2%) t=0.58	1.2% (0.7%, 1.7%) t=4.86
Knoxville	0.44	1.4% (0.2%, 2.6%) t=2.26	1.0% (-0.6%, 2.6%) t=1.20	0.9% (0.1%, 1.8%) t=2.21
St. Louis	0.45	1.1% (0.4%, 1.7%) t=3.17	0.2% (-0.7%, 1.1%) t=0.45	0.6% (0.1%, 1.0%) t=2.42
Steubenville	0.69	1.0% (-0.1%, 2.1%) t=1.79	2.4% (0.5%, 4.3%) t=2.43	0.9% (0.1%, 1.6%) t=2.17
Portage	0.32	1.2% (-0.3%, 2.8%) t=1.64	0.5% (-1.2%, 2.3%) t=0.57	0.7% (-0.4%, 1.7%) t=1.22
Topeka	0.29	0.8% (-2.0%, 3.6%) t=0.53	=1.3% (-3.3%, 0.6%) t=1.32	-0.5% (-2%, 0.9%) t=0.67
All Cities Combined				
Total Mortality		1.5% (1.1%, 1.9%) t=7.13	0.4% (-0.1%, 1.0%) t=1.48	0.8% (0.5%, 1.1%) t=5.84
Ischemic Heart Disease		2.1% (1.5%, 2.7%) t=7.12		
Chronic Obstructive Pulmonary Disease		3.3% (1.0%, 5.7%) t=2.79		