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Regulatory Impact Analysis for the Proposed Revisions to the National Ambient Air Quality Standards for Particulate Matter

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Table 5-6. **Health Endpoints and Epidemiological Studies Used to Quantify Health Impacts in the Main Analysis[a]**

Endpoint	Study	Study Population	Risk Estimate (95th Percentile Confidence Interval)[a]
Premature Mortality			
Premature mortality—cohort study, all-cause	Krewski et al. (2009)	>29 years	RR = 1.06 (1.04 – 1.06) per 10 $\mu g/m^3$
	Laden et al. (2006)	>24 years	RR = 1.16 (1.07 – 1.26) per 10 $\mu g/m^3$
Premature mortality, total exposures	$PM_{2.5}$ Expert Elicitation (Roman et al., 2008)	>24 years	Varies by expert
Premature mortality—all-cause	Woodruff et al. (1997)	Infant (<1 year)	OR = 1.04 (1.02 – 1.07) per 10 $\mu g/m^3$
Chronic Illness			
Nonfatal heart attacks	Peters et al. (2001)	Adults (>18 years)	OR = 1.62 (1.13 – 2.34) per 20 $\mu g/m^3$
	Pooled estimate:		
	Pope et al. (2006)		β = 0.00481 (0.00199)
	Sullivan et al. (2005)		β = 0.00198 (0.00224)
	Zanobetti et al. (2009)		β = 0.00225 (0.000591)
	Zanobetti and Schwartz (2006)		β = 0.0053 (0.00221)
Hospital Admissions			
Respiratory	Zanobetti et al. (2009)—ICD 460-519 (All respiratory)	>64 years	β=0.00207 (0.00446)
	Moolgavkar (2000)—ICD 490–496 (Chronic lung disease)	18–64 years	1.02 (1.01—1.03) per 36 $\mu g/m^3$
	Babin et al. (2007)—ICD 493 (asthma)	<19	β=0.002 (0.004337)
Cardiovascular	*Pooled estimate:*	>64 years	
	Zanobetti et al. (2009)—ICD 390-459 (all cardiovascular)		β=0.00189 (0.000283)
	Peng et al. (2009)—ICD 426-427; 428; 430-438; 410-414; 429; 440-449 (Cardio-, cerebro- and peripheral vascular disease)		β=0.00068 (0.000214)
	Peng et al. (2008)—ICD 426-427; 428; 430-438; 410-414; 429; 440-449 (Cardio-, cerebro- and peripheral vascular disease)		β=0.00071 (0.00013)
	Bell et al. (2008)—ICD 426-427; 428; 430-438; 410-414; 429; 440-449 (Cardio-, cerebro- and peripheral vascular disease)		β=0.0008 (0.000107)
	Moolgavkar (2000)—ICD 390–429 (all cardiovascular)	20–64 years	RR=1.04 (t statistic: 4.1) per 10 $\mu g/m^3$
Asthma-related ER visits	*Pooled estimate:*	All ages	
	Mar et al. (2010)		RR = 1.04 (1.01 – 1.07) per 7 $\mu g/m^3$
	Slaughter et al. (2005)		RR = 1.03 (0.98 – 1.09) per 10 $\mu g/m^3$

(continued)

Table 5.B-7. Unit Values for Hospital Admissions in BenMAP 4.0.51 (Abt Associates, 2011)[a]

End Point	ICD Codes	Age Range *min.*	Age Range *max.*	Mean Hospital Charge (2000$)	Mean Length of Stay (days)	Total Cost of Illness (Unit value in 2000$)
HA, All Cardiovascular	390–429	18	64	$26,654	4.12	$27,119
HA, All Cardiovascular	390–429	65	99	$24,893	4.88	$25,444
HA, All Respiratory	460–519	65	99	$20,667	6.07	$21,351
HA, Asthma	493	0	64	$9,723	3.00	$10,051
HA, Chronic Lung Disease	490–496	18	64	$12,836	3.90	$13,276

[a] National average median daily wage is $112.86 (2000$).

Table 5.B-8. Unit Values for Hospital Admissions in BenMAP 4.0.43 (Abt Associates, 2010)[a]

End Point	ICD Codes	Age Range *min.*	Age Range *max.*	Mean Hospital Charge (2000$)	Mean Length of Stay (days)	Total Cost of Illness (Unit value in 2000$)
HA, All Cardiovascular	390–429	20	64	$22,300	4.15	$22,778
HA, All Cardiovascular	390–429	65	99	$20,607	5.07	$21,191
HA, All Respiratory	460–519	65	99	$17,600	6.88	$18,393
HA, Asthma	493	0	64	$7,448	2.95	$7,788
HA, Chronic Lung Disease	490–496	20	64	$10,194	$5.92	$15,375

[a] National average median daily wage is $115.20 (2000$).

Table 5.B-9. Change in Monetized Hospitalization Benefits for 12/35

Endpoint	2000 AHRQ (millions of 2006$)	2007 AHRQ (millions of 2006$)	Percent Change
Respiratory hospital admissions	$2.3	$2.4	3.4%
Cardiovascular hospital admissions	$3.1	$3.2	2.1%
Work loss days	$6.7	$6.7	0.02%

* All estimates rounded to two significant digits.

5.B.5 Long-term $PM_{2.5}$ Mortality Estimates using Cohort Studies in California

In Chapter 5, we described the multi-state cohort studies we used to estimate the $PM_{2.5}$-related mortality (i.e., Krewski et al., 2009; Laden et al., 2006), as well as summarized the effect estimates for additional cohort studies. In this appendix, we provide additional information about cohort studies in California.[1] As shown in Table 5.x in the health benefits chapter, a large percentage of the monetized human health benefits associated with the illustrative control strategy to attain the alternative combination of standards are projected to occur in California. Specifically, for an annual $PM_{2.5}$ standard of 12 $\mu g/m^3$ in conjunction with retaining the 24-hour standard of 35 $\mu g/m^3$, 70% of the total monetized benefits were estimated to occur in California and 98% for an annual $PM_{2.5}$ standard of 13 $\mu g/m^3$. For this reason, we determined that it was appropriate to consider the sensitivity of the benefits results using effect estimates for cohorts in California specifically. Although we have not calculated the benefits results using these cohort studies, it is possible to use the effect estimates themselves to determine how much the monetized benefits in California would have changed if we used effect estimates from the California cohorts. Each of the California cohort studies are summarized in the PM ISA (and thus not summarized here) with the exception of the Ostro et al. (2010, 2011) studies, which we describe below. Table 5.B.10 provides the effect estimates from each of these cohort studies for all-cause, cardiovascular, cardiopulmonary, and ischemic heart disease (IHD) mortality for each of the California cohort studies.

Ostro et al. (2010) characterize the risk of premature death associated with long-term exposure to $PM_{2.5}$ in California among a cohort of about 134,000 current and former female public school professionals (i.e., the California Teacher's Study (CTS)). In this prospective cohort study, Ostro and colleagues estimated long-term PM exposure to several PM constituents, including elemental carbon, organic carbon, sulfates, nitrates, iron, potassium, silicon and zinc. In an erratum, Ostro et al. (2011) modified their approach to assigning $PM_{2.5}$ levels to the cohort populations, noting that they "reanalyzed the CTS data using time-dependent pollution metrics—in which the exposure estimates for everyone remaining alive in the risk set were recalculated at the time of each death—in order to compare their average exposures up to that time with that of the individual who had died. In this way, decedents and survivors comprising the risk set had similar periods of pollution exposure, without subsequent pollution trends influencing the surviving women's exposure estimates." This change in assumption attenuated the hazard ratios significantly, though hazard ratios remained significant for cardiovascular mortality and total $PM_{2.5}$ mass and certain constituents, nitrate and sulfate; no association was observed between all-cause mortality and total $PM_{2.5}$ mass or its constituents. The authors note that these revised results are generally consistent with other long-term PM cohort studies, including the ACS and H6C studies.

[1] In addition to cohorts studies conducted in California, we have also identified a cross-sectional studies (Hankey et al., 2012). However, we have not summarized that study here.

Table 5.B-10. Summary of Effect Estimates From Associated With Change in Long-Term Exposure to $PM_{2.5}$ in Recent Cohort Studies in California

		Hazard Ratios per 10 μg/m³ Change in $PM_{2.5}$ (95th percentile confidence interval)		
Authors	Cohort	All Causes	Cardiopulmonary	Ischemic Heart Disease
McDonnell et al. (2000)[a]	Adventist Health Study (AHS) cohort (age > 27)	1.09 (.98–1.24)	N/A	N/A
Jerrett et al. (2005)[b]	Subset of the ACS cohort living in the Los Angeles metropolitan area (age > 30)	1.15 (1.03–1.29)	1.10 (0.94–1.28)	1.32 (1.03–1.29)
Chen et al. (2005)[c]	Adventist Health Study (AHS) cohort living in San Francisco, South Coast (i.e., Los Angeles and eastward), and San Diego air basins (age > 25)	N/A	N/A	1.42 (1.06–1.90)
Enstrom et al. (2005)[d]	California Prevention Study (age >65)	1.04 (1.01–1.07)	N/A	N/A
Krewski et al. (2009)[e]	Subset of the ACS cohort living in the 5-county Los Angeles Metropolitan Statistical Area (age > 30)	1.42 (1.26–1.27)	1.11 (0.95–1.23)	1.32 (1.06–1.64)
Ostro et al. (2010)[c]	California Teacher's study. Current and former female public school professionals (age > 22)	1.84 (1.66–2.05)	2.05 (1.80–2.36)	2.89 (2.27–3.67)
Ostro et al. (2011)[c,f]		1.06 (0.96–1.16)	1.19 (1.05–1.36)	1.55 (1.24–1.93)

[a] Table 3, adjusted for 10 μg/m³ change in $PM_{2.5}$.

[b] Table 1. 44 individual-level co-variates + all social (i.e., ecologic) factors specified (principal component analysis).

[c] Women only.

[d] Represents deaths occurring from 1973–1982, but no significant associations were reported with deaths in later time periods. The PM ISA (U.S. EPA, 2009) concludes that the use of average values for California counties as exposure surrogates likely leads to significant exposure error, as many California counties are large and quite topographically variable.

[e] Table 23. 44 individual-level co-variates + all social (i.e., ecologic) factors specified.

[f] Erratum Table 2.

As shown in Table 5.B.10, most of the cohort studies conducted in California report central effect estimates similar to the (nation-wide) all-cause mortality risk estimate we applied from Krewski et al. (2009) and Laden et al. (2006) albeit with wider confidence intervals. A couple cohort studies conducted in California indicate higher risks than the risk estimates we applied.

5.B.6 References

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