

Addendum to the BenMAP User's Manual Appendices (October 2012)

Created 1/11/2013

The purpose of this addendum is to update the BenMAP User's Manual Appendices to incorporate the information applied in the 2012 PM NAAQS RIA (U.S. EPA, 2012).

Appendix E: Particulate Matter Health Impact Functions in U.S. Setup

E.1 Long-term Mortality

Table E-1. Health Impact Functions for Particulate Matter and Long-Term Mortality

Effect	Author	Year	Location	Age	Metric	Beta	Std Err	Form	Notes
Mortality, All Cause	Lepeule et al.	2012	6 Cities	25-99	Annual	0.013103	0.000107	Log-linear	

E.1.7 Lepeule et al. (2012)

Lepeule et al. (2012) evaluated the sensitivity of previous Six Cities results to model specifications, lower exposures, and averaging time using eleven additional years of cohort follow-up that incorporated recent lower exposures. The authors found significant associations between PM_{2.5} exposure and increased risk of all-cause, cardiovascular and lung cancer mortality. The authors also concluded that the concentration-response relationship was linear down to PM_{2.5} concentrations of 8 µg/m³, and that mortality rate ratios for PM_{2.5} fluctuated over time, but without clear trends, despite a substantial drop in the sulfate fraction.

E.2 Chronic / Severe Illness

Table E-6. Health Impact Functions for Particulate Matter and Chronic Illness

Effect	Author	Year	Location	Age	Metric	Beta	Std Err	Form	Notes
Stroke	Miller et al.	2007	36 U.S. Metropolitan Cities	50-79	D24HourMean	0.0247	0.0116	Log-linear	

E.2.2 Adjustment (Update): Based on recent data from the Agency for Healthcare Research and Quality's Healthcare Utilization Project National Inpatient Sample database (AHRQ, 2009), we identified death rates for adults hospitalized with acute myocardial infarction stratified by age (e.g., 1.852% for ages 18–44, 2.8188% for ages 45–64, and 7.4339% for ages 65+). These rates show a clear downward trend over time between 1994 and 2009 for the average adult and thus replace the 93% survival rate previously applied across all age groups from Rosamond et al. (1999).

E.4.4 Miller et al. (2007)

Miller et al. (2007) examined the effects of long-term exposure to PM_{2.5} with cardiovascular events in postmenopausal women (50-79 years old) in 36 U.S. metropolitan cities from 1994-1998. In particular, coronary heart disease, cerebrovascular disease, myocardial infarction, coronary revascularization, and

stroke were examined as the cardiovascular outcomes. 65,893 women without previous cardiovascular disease were assessed in relation to their exposure to PM_{2.5} using the monitor located nearest to each woman's residence. After adjusting for age, race, smoking status, educational level, household income, body-mass index, diabetes, hypertension, and hypercholesterolemia, hazard ratios were estimated for the first cardiovascular event. Each increase of 10 µg/m³ of PM_{2.5} was associated with a 24% increase in the risk of any cardiovascular event (95% CI: 1.09-1.41) and a 76% increase in the risk of death from cardiovascular disease (95% CI: 1.25-2.47). Also, the risk of cerebrovascular events was associated with increased levels of PM_{2.5} with a hazard ratio of 1.35 (95% CI: 1.08-1.68).

Cardiovascular Events, Stroke

In a single-pollutant model the coefficient and standard error were estimated from the hazard ratio (1.28) and 95% confidence interval (95% CI: 1.02-1.61) for a 10 µg/m³ increase in the annual mean PM_{2.5} concentration in postmenopausal women 50-79 years old (Miller et al., 2007, Table 3).

E.3 Hospitalizations

Table E-7. Health Impact Functions for Particulate Matter and Hospital Admissions

Effect	Author	Year	Location	Age	Metric	Beta	Std Err	Form	Notes
All Respiratory	Kloog et al.	2012	New England	65-99	D24HourMean	0.0007	0.0010	Log-linear	

E.3.11 Kloog et al. (2012)

Kloog et al. (2012) examined the relationship between both short-term and long-term PM_{2.5} exposure and emergent hospital admissions for respiratory (ICD-9 codes 460-519) and cardiovascular (ICD-9 codes 390-429) diseases in the New-England states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. The study used hospital admission data from the U.S. Medicare program for only patients that were at least 65 years old. Short-term exposure models looked at the mean 24-hour PM_{2.5} concentration on the day of a patient's hospital admission, while long-term exposure was defined to be the mean PM_{2.5} concentration over the entire study period (2000-2006). Results of the study showed an association between PM_{2.5} and hospital admissions for all disease types in both the short and long term.

Hospital Admissions, Respiratory (ICD Codes 460-519)

In a single pollutant model for patients over the age of 65, the coefficient and standard error were estimated from the percent change (0.70%) and 95% confidence interval (0.35%-1.05%) for a 10 µg/m³ increase in same day (0 lag) 24-hour mean PM_{2.5} concentration.

E.4 Emergency Room Visits

Table E-8. Health Impact Functions for Particulate Matter and Emergency Room Visits

Effect	Author	Year	Location	Age	Metric	Beta	Std Err	Form	Notes
Asthma	Glad et al.	2012	Pittsburgh, PA	18-64	D24HourMean	0.0052	0.0032	Logistic	All Races
Cardiovascular	Mathes et al.	2011	Detroit, MI	2-18	D24HourMean	0.0039	0.0011	Logistic	all year

Cardiovascular	Tolbert et al.	2007	Atlanta, GA	0-99	D24HourMean	0.0005	0.0005	Log-linear	
Cardiovascular	Metzger et al.	2004	Atlanta, GA	0-99	D24HourMean	0.0032	0.0011	Log-linear	

E.4.4 Glad et al. (2012)

Glad et al. (2012) examined the relationship between air pollution and emergency department visits for asthma (ICD-9 code 493) in six Pittsburgh, PA hospitals between 2002 and 2005. The study includes a total of 6,979 individuals with a primary discharge diagnosis of asthma. Using a case-crossover methodology, which controls for the effects of subject-specific covariates such as gender and race, a 2.5% increase was observed in asthma ED visits for each 10 ppb increase in the 1-hour maximum ozone level on day 2 (odds ratio [OR] = 1.025, $p < 0.05$). Particulate matter with an aerodynamic diameter $\leq 2.5\mu\text{m}$ ($\text{PM}_{2.5}$) had an effect both on the total population on day 1 after exposure (1.036, $p < 0.05$), and on African Americans for day-1 lag (OR = 1.055; 95% CI, 1.001–1.112), day-2 lag (OR = 1.067; 95% CI, 1.015–1.122), day-3 lag (OR = 1.053; 95% CI, 1.002–1.106), and the 6-day average (OR = 1.088; 95% CI, 1.001–1.184). $\text{PM}_{2.5}$ had no significant effect on Caucasian Americans alone. The disparity in risk estimates by race may reflect differences in residential characteristics, exposure to ambient air pollution, or a differential effect of pollution by race.

Emergency Room Visits, Asthma (ICD-9 Code 493) – by Age and Racial Group

In a single pollutant model for patients of all ages and all races, the coefficient and standard error were estimated from the odds ratio (1.04) and 95% confidence interval (0.984 – 1.10) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 3).

In a single pollutant model for African American patients of all ages, the coefficient and standard error were estimated from the odds ratio (1.088) and 95% confidence interval (1.001 – 1.184) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 3).

In a single pollutant model for Caucasian American patients of all ages, the coefficient and standard error were estimated from the odds ratio (0.975) and 95% confidence interval (0.904 – 1.053) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 3).

In a single pollutant model for patients of ages 18-64 and all races, the coefficient and standard error were estimated from the odds ratio (1.053) and 95% confidence interval (0.988– 1.122) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 4).

In a single pollutant model for African American patients of ages 18-64, the coefficient and standard error were estimated from the odds ratio (1.095) and 95% confidence interval (0.995– 1.205) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 4).

In a single pollutant model for Caucasian American patients of ages 18-64, the coefficient and standard error were estimated from the odds ratio (0.992) and 95% confidence interval (0.908– 1.084) for a $10\ \mu\text{g}/\text{m}^3$ increase in 24-hour mean $\text{PM}_{2.5}$ concentration averaged over lags 0-6 days (Glad et al., 2012, Table 4).

E.4.5 Mathes et al. (2011)

Mathes et al. (2011) examined the association between particulate matter (PM_{2.5}), hospitalization/emergency department visits for cardiovascular disease in 11 New York City hospitals between the years of 2004 and 2006. The study divided ED visits into two categories: Syndrome 1 (ICD-9 codes 410-429), and Syndrome 2 (ICD-9 codes 405-441). The authors only included emergency department records for patients over the age of 40, and excluded records which were missing a chief complaint description. Three Poisson-generalized linear models were used to show temporal differences: a cold season model (October – March), a warm season model (April-September), and an all-year model. Models were also included to test for day-of-week and holiday patterns. All models included lag periods of 0, 1, 2, and 3 days. Results of the study showed the strongest associations between PM_{2.5} and CVD health outcomes in cold season models that used same-day PM_{2.5} concentrations.

Emergency Department Visits, Cardiovascular (ICD-9 Codes 405-441, 785-786)¹ – by Season

In a single pollutant model for patients over the age of 40, the coefficient and standard error were estimated from the percent excess risk (0.8%) and 95% confidence intervals (0.0%, 1.6%) for a 10 µg/m³ increase in same day 24-hour mean PM_{2.5} concentration all year (results obtained through communication with the first author).

In a single pollutant model for patients over the age of 40, the coefficient and standard error were estimated from the percent excess risk (2.1%) and 95% confidence intervals (0.9%, 3.3%) for a 10 µg/m³ increase in same day 24-hour mean PM_{2.5} concentration in the cold season during October through March (Mathes et al., 2011, Page 6).

In a single pollutant model for patients over the age of 40, the coefficient and standard error were estimated from the percent excess risk (0.6%) and 95% confidence intervals (-0.5%, 1.6%) for a 10 µg/m³ increase in 24-hour mean PM_{2.5} concentration of lag 3-day in the warm season during April through September (results obtained through communication with the first author).

E.4.6 Metzger et al. (2004)

Metzger et al. (2004) examined the relationship between emergency room visits for cardiovascular conditions and ambient air pollution (NO₂, CO, organic carbon, elemental carbon, oxygenated hydrocarbons, SO₂, O₃, PM₁₀, and coarse PM) in Atlanta, Georgia from January 1, 1993 to August 31, 2000. Poisson generalized linear models controlling for long-term temporal trends and meteorological conditions with cubic splines were used to evaluate the relative risk of all cardiovascular disease (ICD-9 codes 410-414, 427-428, 433-437, 440, 443-444, 451-453), dysrhythmia (ICD-9 code 427), congestive heart failure (ICD-9 code 428), and peripheral and cerebrovascular disease (ICD-9 codes 433-437, 440, 443-444, and 451-453) emergency room visits associated with air pollution. Using a 3-day moving average in single-pollutant models, they found that cardiovascular disease visits were associated with daily 1-hour maximum NO₂ and CO and 24-hour average PM_{2.5}, organic carbon, elemental carbon and oxygenated hydrocarbons, with a secondary analysis indicating the strongest effect for same-day pollution levels. SO₂ and O₃ were not found to be associated with an increase in emergency room visits for cardiovascular disease.

Emergency Room Visits, All Cardiovascular (ICD-9 codes 410-414, 427-428, 433-37, 440, 443-444, 451-453)

¹ This outcome is labeled as Syndrome 2 ED visits in the paper.

In a single-pollutant model, the coefficient and standard error are estimated from the relative risk (1.033) and 95% confidence interval (95% CI: 1.01-1.056) for a 10 ug/m³ increase in daily 24-hour mean PM_{2.5} (Metzger et al., 2004, Table 4).

Emergency Room Visits, Congestive Heart Failure (ICD-9 code 428)

In a single-pollutant model, the coefficient and standard error are estimated from the relative risk (1.055) and 95% confidence interval (95% CI: 1.006-1.105) for a 10 ug/m³ increase in same-day daily 24-hour mean PM_{2.5} (Metzger et al., 2004, Table 4).

Emergency Room Visits, Dysrhythmia (ICD-9 codes 427)

In a single-pollutant model, the coefficient and standard error are estimated from the relative risk (1.015) and 95% confidence interval (95% CI: 0.976-1.055) for a 10 ug/m³ increase in same-day daily 24-hour mean PM_{2.5} (Metzger et al., 2004, Table 4).

Emergency Room Visits, Ischemic Heart Disease (ICD-9 codes 410-414)

In a single-pollutant model, the coefficient and standard error are estimated from the relative risk (1.023) and 95% confidence interval (95% CI: 0.983-1.064) for a 10 ug/m³ increase in same-day daily 24-hour mean PM_{2.5} (Metzger et al., 2004, Table 4).

Emergency Room Visits, Peripheral Vascular and Cerebrovascular Disease (ICD-9 codes 433-437, 440, 443-444, 451-453)

In a single-pollutant model, the coefficient and standard error are estimated from the relative risk (1.05) and 95% confidence interval (95% CI: 1.008-1.093) for a 10 ug/m³ increase in same-day daily 24-hour mean PM_{2.5} (Metzger et al., 2004, Table 4).

E.4.7 Tolbert et al. (2007)

Tolbert et al. (2007) examined the relationship between emergency room visits for respiratory (ICD-9 codes 493, 786.07, 786.09, 491, 492, 496, 460-465, 460.0, 477, 480-486, 466.1, 466.11, 466.19) and cardiovascular (ICD-9 codes 410-414, 427, 428, 433-437, 440, 443-445, 451-453) conditions and ambient air pollution (PM₁₀, O₃, NO₂, SO₂, CO, PM_{2.5}) in metropolitan Atlanta, Georgia from 1993-2004. Poisson generalized linear models were used to examine outcome counts in relation to 3-day moving average concentrations of the pollutants. For cardiovascular visits, associations were observed with CO, NO₂, and PM_{2.5} elemental carbon and organic carbon. In multi-pollutant models, CO was the strongest predictor. For respiratory visits, associations were observed with ozone, PM₁₀, CO, and NO₂ in single-pollutant models. In multi-pollutant models, PM₁₀ and ozone persisted as predictors, with ozone the stronger predictor. Caveats and considerations in interpreting the multi-pollutant model results were discussed.

Emergency Room Visits, Cardiovascular (ICD-9 codes 410-414, 427, 428, 433-437, 440, 443-445, 451-453)

In a single-pollutant model, the coefficient and standard error are estimated from the risk ratio (1.005) and 95% confidence interval (95% CI: 0.993-1.017) for a 10.96 ug/m³ increase in daily 24-hour mean PM_{2.5} across a 3-day moving average (Tolbert et al., 2007, Table 4).

Emergency Room Visits, All Respiratory (ICD-9 codes 460-465, 466.1, 466.11, 466.19, 477, 491, 492, 493, 496, 786.07, 786.09)

In a single-pollutant model, the coefficient and standard error are estimated from the risk ratio (1.005) and 95% confidence interval (95% CI: 0.995-1.015) for a 10.96 ug/m³ increase in daily 24-hour mean PM_{2.5} across a 3-day moving average (Tolbert et al., 2007, Table 4).

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