Supplemental Materials

Wildfires and the changing landscape of air pollution-related health burden

Ruwan Thilakaratne,[1,2] Sumi Hoshiko,[2] Andrew Rosenberg,[2] Thomas Hayashi,[3] Joseph Ryan Buckman,[1,2] Ana G. Rappold[4*]

Authors' affiliation

[1]California Department of Public Health/Cal EIS Program, Richmond, California, USA

[2]Environmental Health Investigations Branch, California Department of Public Health, Richmond, California, USA

[3]Sequoia Foundation, La Jolla, California, USA

[4]Center for Public Health and Environmental Assessment, United States Environmental Protection Agency, Durham, North Carolina, USA

*Corresponding author:

Ana G. Rappold, PhD

Center for Public Health and Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

Research Triangle Park, NC, USA

Rappold.ana@epa.gov

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Appendix. Methodology for statistical models used to derive cardiorespiratory health risk estimates associated with fine particulate matter ($PM_{2.5}$) in California, and estimation of health burden attributable to $PM_{2.5}$.

Statistical models

We used Poisson regression to model the outcome data, as preliminary models did not indicate the presence of over- or under-dispersion. We adjusted for several time-varying confounders of the association between $PM_{2.5}$ and the outcomes, chosen *a priori*: heat index, a summary measure of temperature and relative humidity, modeled as a natural cubic spline with two equally spaced internal knots; and day-of-the-week, modeled as six indicator variables with Sunday as the reference day. The temperature and relative humidity data were acquired from the National Oceanic and Atmospheric Administration (NOAA), and a validated formula was used to combine these variables to produce heat index.[1] A random intercept for each zip code was included to account for differing morbidity rates in the outcomes.

Additionally, we removed seasonal and long-term trends in $PM_{2.5}$ concentrations to account for confounding by unmeasured common determinants of $PM_{2.5}$ and outcome time trends, using linear regression with natural cubic spline smoothing functions of time and treating residuals as the detrended exposure. For purposes of eliminating confounding, spline smoothness should be determined by the exposure time series rather than the outcome time series.[2] Prior to $PM_{2.5}$ modeling, concentrations were grouped by the 16 California climate zones (https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and) to achieve better homogeneity of $PM_{2.5}$ time series. To determine spline smoothness for a given climate zone, we averaged $PM_{2.5}$ values to each day, thus averaging across zip codes in the climate zone, before linear regression modeling, in order to establish a stable time series representing typical time trends in $PM_{2.5}$ in the climate zone. We then fit climate zone-specific linear regression models using between 1 and 8 degrees of freedom per year, and selected the optimal spline degrees of freedom for detrending to use for the climate zone based on best model fit, as measured by the lowest Bayesian information criterion (BIC) value. Subsequently, the selected number of degrees of freedom was used in a linear regression of the raw, non-averaged $PM_{2.5}$ values for the climate zone, and model residuals were retained as the exposure for health outcome models. This process was repeated for all climate zones to obtain detrended $PM_{2.5}$ for the state. We used distributed lag models to account for the lagged effects of $PM_{2.5}$ by including additional linear terms for $PM_{2.5}$ lags, resulting in distributed lag models. The lag period was selected on BIC separately for each outcome, with candidate lags ranging from same-day (lag 0) to all lags from same-day through six days prior (lag 0-6) (selected lags are noted in the main text).

To model outcome variability, we used natural cubic spline smoothing functions of time for the health outcome time series. We chose four degrees of freedom per year *a priori*[3] which accounts for trends of three months or longer.

Formally, the distributed lag model is:

$$Y_{ij} \sim Poisson(\mu_{ij})$$

$$\log(\mu_{ij}) = \beta_{0\mathrm{j}} + \sum_{\mathrm{l=0}}^{\mathrm{L}} \beta_l\, detrended\ PM_{2.5_{(i-l)j}} + NCS\big(heat\ index_{ij}, 3\big) + \sum\nolimits_{m=1}^{6} \beta_m DOW_i + NCS(date_i, 36)$$

$$\beta_{0\mathrm{j}} = \beta_0 + u_j$$

where Y_{ij} is the number of cardiorespiratory ED visits or hospitalizations on day i in zip code j, assumed to be distributed Poisson with rate parameter μ_{ij}; β_{0j} is the random intercept for zip code j; β_l is the log-relative risk for a one-unit increase in detrended $PM_{2.5}$ for lag l; "NCS (heat index, 3)" is a natural cubic spline of heat index composed of three functions evenly spaced over the heat index distribution; DOW stands for day-of-week, with β_m the log-relative risk for day m compared to Sunday; "NCS (date, 36)" is a natural cubic spline of time composed of 36 cubic functions evenly spaced over the 9-year study period, resulting in 4 functions per year. β_0 is the grand intercept and u_j is the random component of the intercept for zip code j. Distributed lag models were constructed using the R package *dlnm*.4

We calculated and reported the cumulative percent change in risk for each outcome associated with ΔPM μg/m3 increase in PM2.5. The cumulative relative risk (cRR) over the lag period and corresponding 95% confidence interval were calculated as $(\text{cRR} - 1) \times 100\%$, where $\text{cRR} = \exp(\Delta PM * \sum_{l=0}^{L} \beta_l)$ with confidence intervals corresponding to $\exp(\Delta PM * (\sum_{l=0}^{L} \beta_l \pm 1.96\, SD_{\sum_{l=0}^{L} \beta_l})$ and percent change in risk was subsequently derived as follows:

$$\%\, change\ in\ risk = (cRR - 1) \times 100\%$$

Additionally, relative risks were estimated within demographic subgroups (age, race/ethnicity, sex) using the subgroup-specific outcome time series and natural cubic spline of time, with other model specifications remaining the same. Relative risk estimates were not calculated by geographic factors.

All associations were reported per 10 μg/m3 increase in $PM_{2.5}$ for the best-fitting lag for each outcome.

Health burden estimation

We used the health outcome models to calculate the number of excess cardiorespiratory ED visits or hospitalizations (collectively referred to as "events") attributable to total ambient $PM_{2.5}$ and $PM_{2.5}$ associated with wildland fire smoke. To do this, we used the models to predict the expected number of events on each zip code-day given covariate values on each zip code-day at the observed level of $PM_{2.5}$ concentrations and in the counterfactual scenario where PM2.5 is set to 0. Using the best fit model for each outcome, we calculated excess cardiorespiratory ED visits and HAs attributable to total ambient PM2.5 and to PM2.5 on smoke days. First, we estimated the expected number of events on each ZIP-day when counterfactually setting the PM2.5 concentration to zero (Y0), holding all other variables at their observed levels. The attributable number of ED visits and HAs was calculated as a product: Y0 × (RR0 -1) $\times$ 100%. We then calculated burden rates per 100,000 persons, statewide and within demographic, geographic, or temporal strata. To obtain statewide burden rates, we added each ZIP-code level annual burden, divided by the 2010 census California population size, and multiplied by 100,000. To obtain subgroup burden rates, we calculated the subgroup- specific annual burden in each ZIP code using the subgroup-specific $PM_{2.5}$ risk estimates, added these, and then divided this value by the 2010 census subgroup population size. To obtain the burden rate by geographic characteristics (urbanicity and long term air quality) we added the overall burden rates across zip codes with the same geographic characteristics and divided by the corresponding population size.

To calculate the expected number of events on each ZIP-day when counterfactually setting PM2.5 equal to zero (Y_0) we had to create a new variable called Residual $PM_{2.5}^{*}$. As PM2.5 residuals were calculated by subtracting expected concentrations from observed, PM2.5 residuals under the counterfactual scenario were calculated by subtracting expected concentrations from 0, as in:

$$\text{Residual } PM_{2.5} = \text{Observed } PM_{2.5} - \text{Expected } PM_{2.5}$$

$$\text{Residual PM}_{2.5}^{*} = 0 - \text{Expected PM}_{2.5}$$

References

1. Anderson GB, Bell ML, Peng RD. Methods to Calculate the Heat Index as an Exposure Metric in Environmental Health Research. *Environmental Health Perspectives*. 2013;121(10):1111-1119. doi:10.1289/ehp.1206273

2. Dominici F, McDermott A, Hastie TJ. Improved Semiparametric Time Series Models of Air Pollution and Mortality. *Journal of the American Statistical Association*. 2004;99(468):938–948,. doi:10.1198/016214504000000656

3. Peng RD, Dominici F, Louis TA. Model choice in time series studies of air pollution and mortality. *Journal of the Royal Statistical Society*. 2006;169:179–203. doi:10.1111/j.1467-985X.2006.00410.x

4. Gasparrini A, Armstrong B, Scheipl F. *Dlnm: Distributed Lag Non-Linear Models*.; 2021. Accessed December 27, 2021. https://CRAN.R-project.org/package=dlnm

Figure E1. Annual $PM_{2.5}$ attributable fraction (A) and percent of $PM_{2.5}$ burden on days with wildfire smoke (B), for hospital admissions related to asthma, chronic obstructive pulmonary disease (COPD), respiratory disease, and cardiovascular disease, California, 2008-2016.

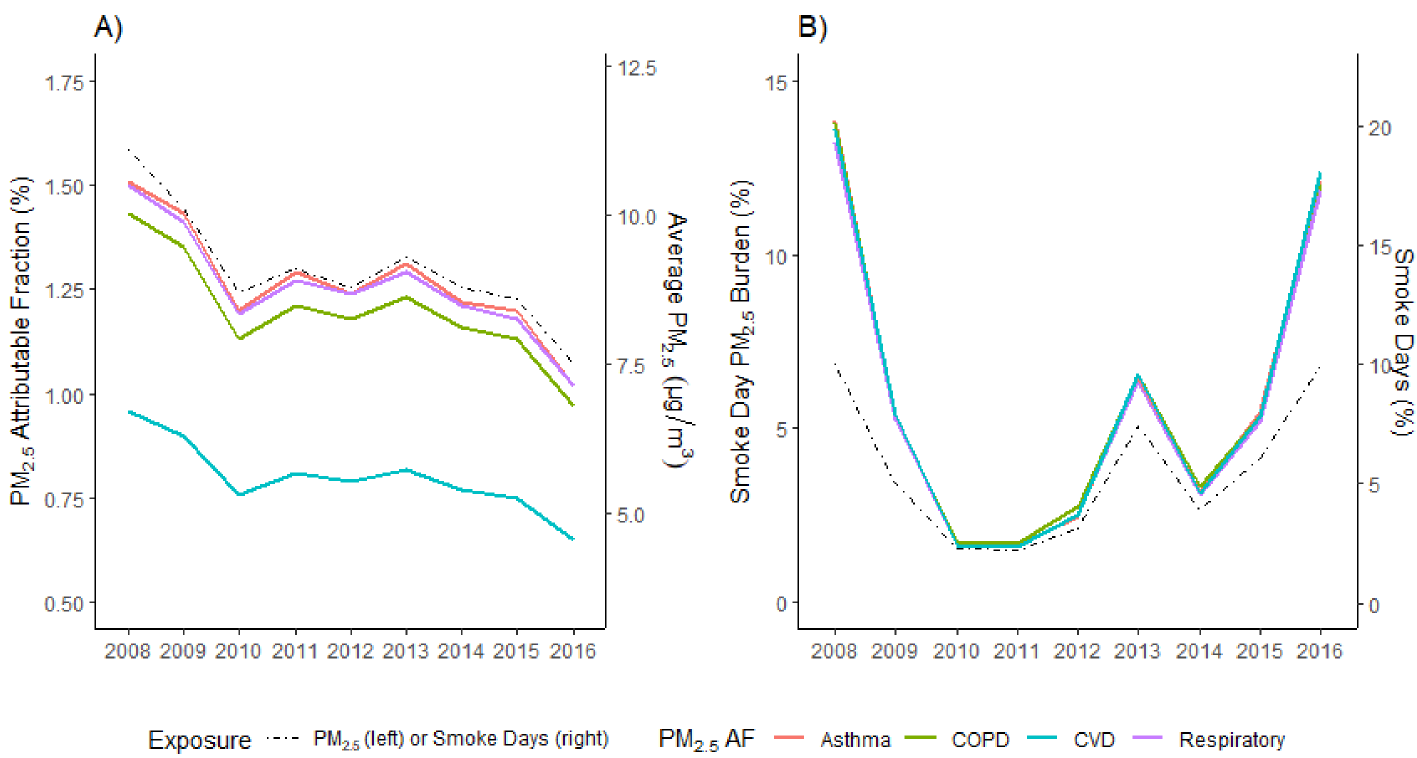

Figure E2. $PM_{2.5}$ attributable rate of cardiorespiratory-related hospital admissions per 100,000 people on days affected by smoke, cumulatively over 2008-2016, at ZIP code resolution, for (A) asthma, (B) chronic obstructive pulmonary disease (COPD), (C) respiratory disease, and (D) cardiovascular (CV) disease. Color gradient is determined by the following percentile ranges of the ZIP code-level rates: 0-50, 50-75, 75-95, 95-99, and 99-100. Black boundaries denote counties.

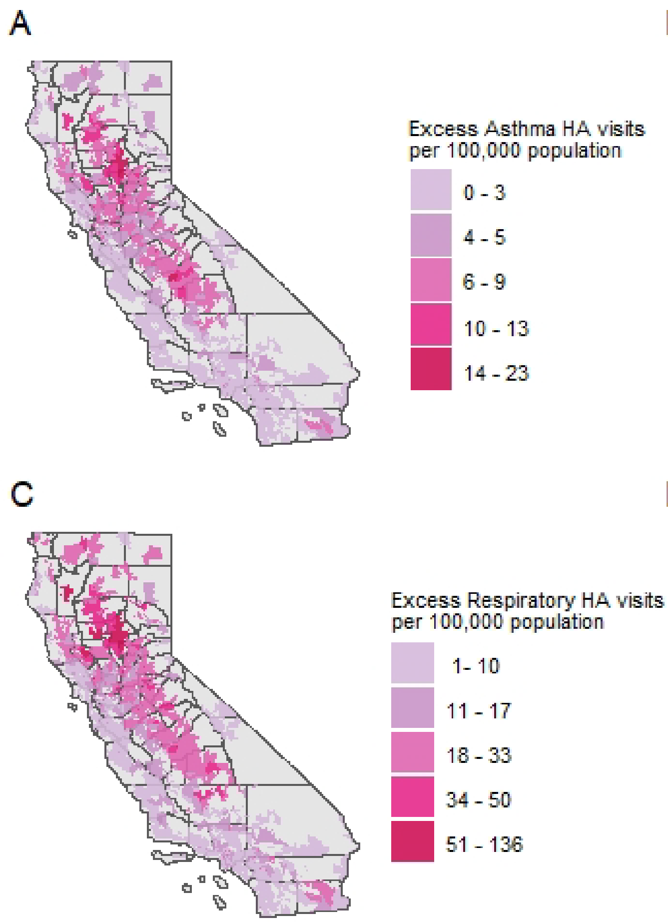

Table E1. Diagnostic codes used to identify cardiorespiratory-related emergency department visits and hospital admissions in a study of the acute cardiorespiratory health burden attributable to air pollution and wildfire smoke in California, 2008-2016.

Outcome	Constituent Conditions	ICD-9-CM	ICD-10-CM
Cardiovascular disease	Hypertension	401-405	I10-I16
	Myocardial infarction	410	I21, I22
	Ischemic heart disease	410-411,413	I20-I24
	Pulmonary embolism	415	I26
	Dysrhythmia and conduction disorder	426-427	I44-I49
	Heart failure	428	I50
	Peripheral arterial disease	444	I74
Respiratory disease	Asthma	493	J45
	COPD	491-492, 496	J41-J44
	Pneumonia	480-486	J12-J18
	Other non-cardiac chest pain or respiratory syndrome	786	R04-R07, R09
Asthma	-	493	J45
COPD	-	491-492, 496	J41-J44

COPD: chronic obstructive pulmonary disease; ICD-9-CM: International Classification of Diseases 9th revision Clinical Modification; ICD-10-CM: International Classification of Diseases 10th revision Clinical Modification

Table E2. Annual Hospital Admission burden rates per 100,000 people for asthma, chronic obstructive pulmonary disease, respiratory disease, and cardiovascular disease, California, 2008-2016. Rates are given for the whole population and by demographic and geographic characteristics and expressed per 100,000 people in the subgroup. Percentage of visits shared by subpopulation are given in parentheses. California 2010 population fraction estimates are provided in the second column for reference.

	CA Population[b] (%)	Asthma Rate (%)	COPD Rate (%)	Respiratory Rate (%)	Cardiovascular Rate (%)
N (2008-2016)	37,366,938	1,845,439	2,416,963	6,268,847	11,763,547
Annual Visit Rate		559	732	1,900	3,564
Age Group					
0-4	6.8%	453 (5.5)	NC	970 (3.5)	NC
5-18	19.6%	259 (9.1)	NC	336 (3.5)	NC
19-64	62.1%	479 (53.2)	380 (32.3)	1,300 (42.5)	2,254 (39.3)
65+	11.4%	1,580 (32.2)	4,343 (67.6)	8,423 (50.5)	18,764 (60.0)
Race/Ethnicity[a]					
White	40.3%	664 (47.8)	1,217 (67.0)	2,589 (54.9)	4,781 (54.1)
Black	5.9%	1,476 (15.6)	1,373 (11.1)	3,871 (12.0)	6,729 (11.1)
Hispanic	37.7%	328 (25.0)	256 (13.2)	1,102 (21.9)	2,104 (22.3)
Asian	13.3%	371 (7.8)	321 (5.8)	1,081 (7.6)	2,382 (8.9)
Native American	0.4%	485 (0.3)	511 (0.3)	1,389 (0.3)	2,382 (0.3)
Other	2.4%	661 (2.8)	682 (2.2)	2,196 (2.8)	4,223 (2.8)
Sex					
Male	49.7%	408 (36.3)	748 (50.8)	1,780 (46.6)	3,490 (48.7)
Female	50.3%	708 (63.7)	717 (49.2)	2,018 (53.4)	3,638 (51.3)
Urbanicity					
Urban	94.4%	560 (94.6)	711 (91.7)	1,878 (93.3)	3,553 (94.1)
Rural	5.6%	540 (5.4)	1,084 (8.3)	2,260 (6.7)	3,751 (5.9)
Long-term Air Quality					
<12 μg/m³	83.3%	547 (76.6)	729 (77.9)	1,859 (76.6)	3,504 (76.9)
12+ μg/m³	16.7%	600 (23.4)	745 (22.1)	2,037 (23.4)	3,771 (23.0)

CA: California; COPD: chronic obstructive pulmonary disease; NC: not calculated due to low counts
[a]Race/Ethnicity: White, Black, Asian, Native American, and Other categories are exclusive of Hispanic or Latino
[b]Estimates of demographic characteristics for the state of California are for the year 2010 and were derived from several data sources. Race/Ethnicity, sex, and age estimates are from the California Department of Finance. Urbanicity estimates are from the United States Department of Agriculture Rural-Urban Commuting Area Codes. Long-term air quality was determined by long-term averages of ZIP code-level satellite-based estimates of fine particulate matter ($PM_{2.5}$) on days when no wildland fire smoke was observed.

Table E3. Annual Hospital Admission rates per 100,000 people for asthma, chronic obstructive pulmonary disease (COPD), respiratory disease, and cardiovascular disease, attributed to $PM_{2.5}$ exposure, California, 2008-2016. Annual rates (95% confidence intervals) are given for the whole population and by demographic and geographic characteristics and expressed per 100,000 people in the subgroup. $PM_{2.5}$ attributable fraction is given in parentheses.

	Asthma Rate (%)	COPD Rate (%)	Respiratory Rate (%)	Cardiovascular Rate (%)
N (2008-2016)	23,316 (18,401, 28,250)	28,836 (23,192, 34,500)	78,719 (69,581, 87,875)	94,014 (81,203, 106,845)
Annual $PM_{2.5}$ Burden Rate	7 (1.3)	9 (1.2)	24 (1.3)	28 (0.8)
Age Group				
0-4	13 (2.8)	NC	26 (2.7)	NC
5-18	3 (1.2)	NC	2 (0.6)	NC
19-64	5 (1.0)	5 (1.4)	16 (1.2)	16 (0.7)
65+	24 (1.5)	50 (1.2)	106 (1.3)	177 (0.9)
Race/Ethnicity[a]				
White	8 (1.2)	14 (1.1)	28 (1.1)	35 (0.7)
Black	11 (0.8)	16 (1.2)	38 (1.0)	35 (0.5)
Hispanic	5 (1.5)	5 (1.4)	19 (1.7)	25 (1.2)
Asian	7 (1.9)	5 (2.1)	18 (1.7)	27 (1.1)
Native American	7 (1.4)	4 (0.8)	21 (1.5)	53 (2.2)
Other	17 (2.5)	17 (2.5)	38 (1.7)	41 (1.0)
Sex				
Male	5 (1.3)	7 (1.0)	21 (1.2)	25 (0.7)
Female	9 (1.3)	10 (1.4)	27 (1.3)	32 (0.9)
Urbanicity				
Urban	7 (1.3)	9 (1.2)	24 (1.3)	29 (0.8)
Rural	5 (0.8)	8 (0.7)	18 (0.8)	19 (0.5)
Long-term Air Quality				
<12 $\mu g/m^3$	6 (1.1)	8 (1.1)	21 (1.1)	25 (0.7)
12+ $\mu g/m^3$	10 (1.7)	12 (1.6)	34 (1.7)	39 (1.0)

CA: California; COPD: chronic obstructive pulmonary disease; NC: not calculated due to low counts
[a]Race/Ethnicity: White, Black, Asian, Native American, and Other categories are exclusive of Hispanic or Latino
Urbanicity estimates are from the United States Department of Agriculture Rural-Urban Commuting Area Codes. Long-term air quality is determined by long-term averages of ZIP code-level satellite-based estimates of $PM_{2.5}$ on days when no wildland fire smoke was observed.

Table E4. Excess asthma-related emergency department visits associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

Asthma Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	8,763	7,564 (86.32)	1,198 (13.67)	2.60%
2009	10,091	9,551 (94.65)	541 (5.36)	2.46%
2010	9,346	9,174 (98.16)	171 (1.75)	2.09%
2011	11,205	11,009 (98.25)	196 (1.72)	2.25%
2012	12,024	11,707 (97.36)	318 (2.64)	2.14%
2013	13,559	12,676 (93.49)	884 (6.52)	2.28%
2014	14,179	13,696 (96.59)	482 (3.40)	2.11%
2015	15,199	14,341 (94.35)	858 (5.65)	2.09%
2016	13,127	11,608 (88.43)	1,519 (11.57)	1.76%
Total	107,493	101,326 (94.26)	6,167 (5.74)	2.15%

Table E5. Excess chronic obstructive pulmonary disease (COPD)-related emergency department visits associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

COPD Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	1,613	1,340 (83.08)	272 (16.86)	1.58%
2009	1,685	1,591 (94.42)	94 (5.58)	1.43%
2010	1,619	1,584 (97.84)	35 (2.16)	1.23%
2011	2,023	1,982 (97.97)	41 (2.03)	1.33%
2012	2,162	2,086 (96.48)	75 (3.47)	1.26%
2013	2,431	2,244 (92.31)	187 (7.69)	1.36%
2014	2,448	2,343 (95.71)	105 (4.29)	1.25%
2015	2,753	2,564 (93.13)	189 (6.87)	1.23%
2016	2,885	2,522 (87.42)	363 (12.58)	1.05%
Total	19,619	18,256 (93.05)	1,361 (6.94)	1.27%

Table E6. Excess respiratory disease-related emergency department visits associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

All-cause Respiratory Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	27,645	23,785 (86.58)	3,860 (13.96)	2.65%
2009	30,669	29,005 (94.83)	1,664 (5.43)	2.49%
2010	27,149	26,664 (98.27)	485 (1.79)	2.11%
2011	31,336	30,798 (98.31)	538 (1.72)	2.26%
2012	32,963	32,078 (97.39)	884 (2.68)	2.17%
2013	36,731	34,358 (93.90)	2,373 (6.46)	2.31%
2014	37,432	36,189 (96.80)	1,243 (3.32)	2.15%
2015	40,794	38,533 (94.81)	2,261 (5.54)	2.11%
2016	37,543	33,238 (89.04)	4,305 (11.47)	1.79%
Total	302,262	284,648 (94.17)	17,613 (5.83)	2.19%

Table E7. Excess cardiovascular disease-related emergency department visits associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

All-cause CVD Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	10,636	9,033 (84.93)	1,603 (15.07)	1.06%
2009	11,484	10,833 (94.33)	652 (5.68)	0.99%
2010	11,186	10,973 (98.10)	213 (1.90)	0.84%
2011	13,710	13,467 (98.23)	243 (1.77)	0.90%
2012	14,694	14,280 (97.18)	414 (2.82)	0.86%
2013	16,387	15,235 (92.97)	1,152 (7.03)	0.91%
2014	16,912	16,314 (96.46)	598 (3.54)	0.84%
2015	18,112	17,020 (93.97)	1,092 (6.03)	0.83%
2016	16,787	14,686 (87.48)	2,101 (12.52)	0.71%
Total	129,908	121,841 (93.79)	8,068 (6.21)	0.86%

Table E8. Excess asthma-related hospital admissions associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

Asthma Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	2,789	2,403 (86.16)	386 (13.84)	1.51%
2009	2,784	2,637 (94.72)	147 (5.28)	1.43%
2010	2,423	2,382 (98.31)	41 (1.69)	1.20%
2011	2,603	2,560 (98.35)	43 (1.65)	1.29%
2012	2,515	2,453 (97.53)	62 (2.47)	1.24%
2013	2,674	2,502 (93.57)	172 (6.43)	1.31%
2014	2,564	2,482 (96.80)	82 (3.20)	1.22%
2015	2,680	2,533 (94.51)	147 (5.49)	1.20%
2016	2,283	2,006 (87.87)	277 (12.13)	1.02%
Total	23,315	21,958 (94.18)	1,357 (5.82)	1.26%

Table E9. Excess chronic obstructive pulmonary disease (COPD)-related hospital admissions associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

COPD Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	3,702	3,192 (86.22)	510 (13.78)	1.43%
2009	3,483	3,300 (94.75)	183 (5.25)	1.35%
2010	3,053	3,000 (98.26)	53 (1.74)	1.13%
2011	3,268	3,212 (98.29)	56 (1.71)	1.21%
2012	3,125	3,039 (97.25)	86 (2.75)	1.18%
2013	3,194	2,985 (93.46)	210 (6.57)	1.23%
2014	2,921	2,824 (96.68)	97 (3.32)	1.16%
2015	3,068	2,903 (94.62)	165 (5.38)	1.13%
2016	3,021	2,656 (87.92)	364 (12.05)	0.97%
Total	28,835	27,111 (94.02)	1,724 (5.98)	1.19%

Table E10. Excess all-cause respiratory-related hospital admissions associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

All-cause Respiratory Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	10,256	8,900 (86.78)	1,356 (13.22)	1.50%
2009	9,881	9,361 (94.74)	520 (5.26)	1.41%
2010	8,492	8,353 (98.36)	139 (1.64)	1.19%
2011	8,961	8,815 (98.37)	146 (1.63)	1.27%
2012	8,572	8,354 (97.46)	218 (2.54)	1.24%
2013	8,786	8,230 (93.67)	556 (6.33)	1.29%
2014	8,143	7,890 (96.89)	253 (3.11)	1.21%
2015	8,352	7,915 (94.77)	437 (5.23)	1.18%
2016	7,276	6,412 (88.13)	864 (11.87)	1.02%
Total	78,719	74,230 (94.30)	4,489 (5.70)	1.26%

Table E11. Excess all-cause cardiovascular hospital admissions associated with particulate matter of diameter less than 2.5 microns ($PM_{2.5}$) exposure on smoke days and non-smoke days, fraction of excess visits attributable to non-smoke days and smoke days, and total $PM_{2.5}$ -attributable fraction ($PM_{2.5}$ AF) in California, 2008-2016.

All-cause CVD Burden				
Year	**$PM_{2.5}$ burden**	**No smoke $PM_{2.5}$ burden (%)**	**Any smoke $PM_{2.5}$ burden (%)**	**Total $PM_{2.5}$ AF**
2008	12,081	10,442 (86.43)	1,639 (13.57)	0.96%
2009	11,539	10,914 (94.58)	625 (5.42)	0.90%
2010	10,006	9,841 (98.35)	164 (1.64)	0.76%
2011	10,691	10,518 (98.38)	174 (1.63)	0.81%
2012	10,342	10,079 (97.46)	263 (2.54)	0.79%
2013	10,588	9,893 (93.44)	695 (6.56)	0.82%
2014	9,944	9,633 (96.87)	311 (3.13)	0.77%
2015	10,097	9,557 (94.65)	540 (5.35)	0.75%
2016	8,726	7,643 (87.59)	1,083 (12.41)	0.65%
Total	94,014	88,520 (94.16)	5,494 (5.84)	0.80%

Table E12. Annual Hospital Admission rates per 100,000 people for asthma, chronic obstructive pulmonary disease (COPD), respiratory disease, and cardiovascular disease, attributed to $PM_{2.5}$ exposure on days where air quality was affected by wildfire smoke (smoke days), California, 2008-2016. Annual rates (95% confidence intervals) are given for the whole population and by demographic and geographic characteristics and expressed per 100,000 people in the subgroup. Wildfire smoke- $PM_{2.5}$ attributable fraction is given in parentheses.

	Asthma Rate (%)	COPD Rate (%)	Respiratory Rate (%)	Cardiovascular Rate (%)
N (2008-2016)	23,316 (18,401, 28,250)	28,836 (23,192, 34,500)	78,718 (69,581, 87,875)	94,014 (81,203, 106,845)
Annual $PM_{2.5}$ Burden Rate	7 (1.3)	9 (1.2)	24 (1.3)	28 (0.8)
Age Group				
0-4	13 (2.8)	NC	26 (2.7)	NC
5-18	3 (1.2)	NC	2 (0.6)	NC
19-64	5 (1.0)	5 (1.4)	16 (1.2)	16 (0.7)
65+	24 (1.5)	50 (1.2)	106 (1.3)	177 (0.9)
Race/Ethnicity[a]				
White	8 (1.2)	14 (1.1)	28 (1.1)	35 (0.7)
Black	11 (0.8)	16 (1.2)	38 (1.0)	35 (0.5)
Hispanic	5 (1.5)	5 (1.4)	19 (1.7)	25 (1.2)
Asian	7 (1.9)	5 (2.1)	18 (1.7)	27 (1.1)
Native American	7 (1.4)	4 (0.8)	21 (1.5)	53 (2.2)
Other	17 (2.5)	17 (2.5)	38 (1.7)	41 (1.0)
Sex				
Male	5 (1.3)	7 (1.0)	21 (1.2)	25 (0.7)
Female	9 (1.3)	10 (1.4)	27 (1.3)	32 (0.9)
Urbanicity				
Urban	7 (1.3)	9 (1.2)	24 (1.3)	29 (0.8)
Rural	5 (0.8)	8 (0.7)	18 (0.8)	19 (0.5)
Long-term Air Quality				
<12 $\mu g/m^3$	6 (1.1)	8 (1.1)	21 (1.1)	25 (0.7)
12+ $\mu g/m^3$	10 (1.7)	12 (1.6)	34 (1.7)	39 (1.0)

CA: California; COPD: chronic obstructive pulmonary disease; NC: not calculated due to low counts
[a]Race/Ethnicity: White, Black, Asian, Native American, and Other categories are exclusive of Hispanic or Latino
Urbanicity estimates are from the United States Department of Agriculture Rural-Urban Commuting Area Codes. Long-term air quality is determined by long-term averages of ZIP code-level satellite-based estimates of $PM_{2.5}$ on days when no wildland fire smoke was observed.