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Risk factors associated with clinic visits during the 1999 forest fires near the Hoopa Valley Indian Reservation, California, USA

Tze-San Lee[a]*, Kenneth Falter[a1], Pamela Meyer[b], Joshua Mott[c] and Charon Gwynn[d]

[a]*Biometry Activity, CDC/NCEH/EHH, Mail Stop F-58, Chamblee, GA 30341, USA;* [b]*Office of The Director, CDC/CCEHIP, Mail Stop F-64, Chamblee, GA 30341, USA;* [c]*Epidemiology and Prevention Branch, CDC/NCIRD, Mail Stop A-32, Atlanta, GA 30333, USA;* [d]*Division of Epidemiology, NYC Department of Health and Mental Hygiene, New York, USA*

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Forest fires burned near the Hoopa Valley Indian Reservation in northern California from late August until early November in 1999. The fires generated particulate matter reaching hazardous levels. We assessed the relationship between patients seeking care for six health conditions and PM_{10} exposure levels during the 1999 fires and during the corresponding period in 1998 when there were no fires. Multivariate logistic regression analysis indicated that daily PM_{10} levels in 1999 were significant predictors for patients seeking care for asthma, coronary artery disease and headache after controlling for potential risk factors. Stratified multivariate logistic regression models indicated that daily PM_{10} levels in 1999 were significant predictors for patients seeking care for circulatory illness among residents of nearby communities and new patients, and for respiratory illness among residents of Hoopa and those of nearby communities.

Keywords: asthma; confounding variable; wildfires; Hoopa valley; interaction; logistic regression; PM_{10} levels; respiratory illness

Introduction

A series of lightning strikes on 23 August 1999 ignited several wildfires in the Shasta-Trinity National Forest in northern California. These fires burned for more than 10 weeks and spread over more than 135,000 acres of forest lands (*North Coast Journal* 1999). As the fire spread, it reached the border of the Hoopa Valley Indian Reservation in northern California. The residents of the Hoopa Valley Indian Reservation were exposed to varying levels of forest fire smoke from 23 August through 3 November 1999. Heavy smoke reduced visibility in the community of Hoopa, California, and raised the residents' concern about the potential impact on their health.

The major pollutant of concern from wildfires is particulate matter (PM). Particulates of aerodynamic diameter less than 10 microns (PM_{10}) are the components of smoke that pose the greatest health threat because they are small enough to evade the body's defensive mechanisms in the nose and throat. Consequently, they can reach

*Corresponding author. Email: tjl3@cdc.gov
[1]Retired

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the lungs and cause the most damage. Studies have reported health effects from exposure to PM_{10} in urban ambient pollution and among fire fighters exposed to smoke (Gallanter and Bozeman 2002). However, the components of the PM_{10} found in wildfire smoke could be different from those found in traffic and industrial pollution and therefore have different effects. Furthermore, studies of health effects associated with wildfires often focus on firefighters, a group that tends to be healthy and may not be representative of the typical resident in these communities. The health effects of residents in communities that experience high levels of particulates is not well documented.

Assessing the health effects of wildfires among residents of communities exposed to them is difficult because wildfires often occur in remote areas that are sparsely populated. Moreover, air quality monitors may not be available in those areas and residents may not have a single local health care center that serves the exposed community. This investigation offered a unique opportunity because Hoopa had both an air quality monitor and a single medical clinic that served the exposed population. The aim of this paper was to describe trends and identify predictors of patients seeking medical attention for specific conditions during the fires and during the corresponding time period in the year before the fires.

Methods

The Hoopa Valley Indian Reservation is located in the northeastern corner of rural Humboldt County in northern California. It lies approximately 50 miles inland from the Pacific Ocean and 300 miles north of San Francisco, California. The Reservation is nearly a square, with sides 12 miles in length, covering an area of approximately 144 square miles; it ranges in elevation from 320 to 5,000 feet. The 2000 U.S. Census indicated that there were 2,633 people residing on the Reservation.

The Hoopa Tribal Council requested the assistance of the Centers for Disease Control and Prevention (CDC) in understanding health effects resulting from forest fires so the Council and Clinic Medical Director could use this information to enhance emergency response for future fires. During the fires when PM_{10} levels were reaching hazardous levels, the Northern California Indian Development Council (NCIDC) offered hotel vouchers to the Hoopa residents to encourage residents to leave. The NCIDC provided estimates of the number of Hoopa residents who stayed at hotels from week 9 through week 11.

Data collection

The sole provider of medical care on the Hoopa Reservation was the medical clinic. The nearest hospitals were located on the coast which was 50 miles away. The clinic maintained an electronic database, developed by the Indian Health Service, of all patient encounters. Diagnoses were recorded and coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). The number of patients who visited the clinic could be counted because each patient had a unique identification number. Data were abstracted from the records of clinic visits made during the weeks of the fires in 1999 and the corresponding time period one year prior to the fires in 1998. Four possible risk factors were assessed: age, residence, sex, and number of each patient's clinic visits in 1998 for the same health condition. Six health conditions that were suspected to be aggravated by forest fire smoke were investigated: asthma (ICD-9-CM: 493.0–493.99), circulatory-only illness (ICD-9-CM: 390.0–459.99) with no respiratory illness (denoted as circulatory), coronary artery disease (CAD) (ICD-9-CM: 414.0–436.99), headache (ICD-9-CM: 784.0), diabetes (ICD-9-CM: 250.0–250.99), and respiratory-only illness (ICD-9-CM: 460.0–519.9) with no circulatory illness (denoted as respiratory illness). Visits for all other conditions were categorized as other conditions to assess trends during and before the fires. The PM_{10} data were collected by the Hoopa's Tribal Environmental Protection Agency (TEPA), which used a tapered element oscillating microbalance ambient particulate monitor that measured PM_{10} concentrations on an hourly basis.

Data analysis

We analyzed the data on PM_{10} levels and patients who visited the clinic during the 12-week period between 17 August and 4 November 1999, and during the corresponding period in 1998 when there were no fires. We calculated a daily [hourly-average] PM_{10} level for each day and a weekly average PM_{10} level for each week to examine possible associations with health outcomes.

Residence status was defined as follows: *residents* (patients with addresses listed as Hoopa Valley East, Hoopa Valley West, and other Hoopa areas); *nearby* (patients with addresses listed in the surrounding communities of Burnt Ranch/Salyer, Salyer Area, Weitchpec, and Willow Creek Area); and *non-residents* (patients with all other entries for addresses) – probably firefighters deployed to the area. Data from patients with unknown residence (431 patients in 1998 and 410 patients in 1999) were excluded from all summaries and analyses.

We used a Chi-square test to assess the homogeneity in any categorical risk factor between the years of 1998 and 1999 (Fleiss 1981). To assess correlations for each year between patients seeking care for each of the selected health outcomes each week during the fires and the weekly average of PM_{10} levels during the corresponding period, we calculated Pearson correlations.

Multivariate analysis

We used logistic regression models to assess the relationship between patients seeking care for each of the selected health conditions and ambient PM_{10} levels and controlled for the patient's age, residence, sex, and number of each patient's clinic visits in 1998 for a specific condition. The unit of analysis was the patient. The referent groups for age, gender, residence, and number of clinic visits in 1998 were chosen, respectively, to be 50+ years old, males, the Hoopa's residents, and 0 visits. To alleviate a violation of the normality assumption, the [natural] logarithm of daily PM_{10} levels [$\ln(PM_{10})$] was used as an exposure variable in the logistic models because it more closely approximated a normal distribution. Mean, median, and mode of daily PM_{10} levels were 66.1, 30.4, and 17.4, whereas they were 3.5, 3.4, and 2.9 for the $\ln(PM_{10})$. To assess if a risk factor was a confounding variable, we employed the hierarchical backward elimination procedure (Kleinbaum and Klein 2002). After identifying confounding variables, a stratified analysis on each confounding variable was followed. Then, for each health condition, the adjusted odds ratio and its 95% confidence interval were estimated.

Results

Clinic patients

The total number of patients who visited the clinic during the 12 weeks of the 1999 fires (n = 1,882) represented a 15% increase over the number of patients during the corresponding 12 weeks of 1998 (n = 1,632) (Table 1). The majority of the 250 new patients seeking medical care during the 1999 fires were residents of Hoopa (75.5%),

Table 1. Characteristics of patients and their reasons for seeking care at the clinic during the fires in 1999 and the corresponding time in the 1998 when there were no fires, Hoopa, California.

	1998	1999	
Variable	No. (%)	No. (%)	*p*-value
Total number of patients	1,632 (100%)	1,882 (100%)	
Sex			0.015
Male	728 (44.6%)	917 (48.7%)	
Female	904 (55.4%)	965 (51.3%)	
Age			<0.004
0–19	600 (36.8%)	628 (33.4%)	
20–49	661 (40.5%)	875 (46.5%)	
50+	371 (22.7%)	379 (20.1%)	
Residency			<0.006
Resident	1458 (89.3%)	1677 (89.1%)	
Nearby	155 (9.5%)	157 (8.3%)	
Non-resident	19 (1.2%)	48 (2.6%)	
Number of patients seeking care for selected conditions			<0.0001
Asthma	37 (5.0%)	125 (6.6%)	
Circulatory	165 (22.4%)	162 (15.9%)	
CAD	82 (11.1%)	57 (5.6%)	
Diabetes	96 (13.0%)	113 (11.1%)	
Headache	27 (3.7%)	37 (3.6%)	
Respiratory	331 (44.9%)	528 (51.7%)	
Number of visits by condition			<0.0001
Asthma	58 (5.2%)	174 (10.2%)	
Circulatory	259 (23.4%)	378 (22.4%)	
CAD	128 (11.5%)	89 (5.3%)	
Diabetes	180 (16.2%)	285 (16.9%)	
Headache	32 (2.9%)	47 (2.8%)	
Respiratory	452 (40.8%)	718 (42.5%)	
Week of patient's first clinic visit			<0.0001
1	351 (21.5%)	267 (14.2%)	
2	297 (18.2%)	324 (17.2%)	
3	176 (10.8%)	243 (12.9%)	
4	148 (9.1%)	161 (8.6%)	
5	179 (11.0%)	159 (8.4%)	
6	108 (6.6%)	115 (6.1%)	
7	85 (5.2%)	110 (5.8%)	
8	74 (4.5%)	106 (5.6%)	
9	68 (4.2%)	105 (5.6%)	
10	56 (3.4%)	105 (5.6%)	
11	62 (3.8%)	108 (5.7%)	
12	28 (1.7%)	79 (4.2%)	

male (75.6%), ages 20–49 years (85.6%) and sought care for respiratory conditions including asthma. In contrast, there was a reduction in the number of patients with circulatory conditions, including CAD, and other conditions during the fires.

PM_{10} levels

The weekly average PM_{10} concentrations were higher in 1999 than 1998 for all weeks except the first week (Table 2). Maximum PM_{10} concentrations were higher in 1999 than 1998 for hourly (996.3 $\mu g/m^3$ vs. 175 $\mu g/m^3$), daily average (619.8 $\mu g/m^3$ vs.175 $\mu g/m^3$) and weekly average (363.3 $\mu g/m^3$ vs. 26.8 $\mu g/m^3$) levels. There were no days in 1998 that exceeded 150 $\mu g/m^3$ for a 24-h average concentration, the national air quality standard for PM_{10} at the time (USEPA 2007). However, daily average PM_{10} levels exceeded 150 $\mu g/m^3$ on 12 days in 1999 during the period of fires. The weekly average PM_{10} concentrations were not significantly correlated with number of visits for specific conditions.

We also examined the number of clinic visits for patients who sought care for specific conditions during each of the 12 weeks to assess whether higher weekly average PM_{10} levels might trigger symptoms for specific health outcomes. Statistically significant differences were found for clinic visits for all health conditions except headache by week between 1998 and 1999 (Table 2). Estimates of the number of Hoopa residents who stayed at coastal hotels were 66 during week 9, 444 during week 10, and 313 during week 11.

Multivariate analysis

The results of the multivariate analysis for each of the six health conditions are shown in Table 3. No statistically significant interaction terms were identified for asthma, CAD, diabetes or headache. PM_{10} levels in 1999 were significant predictors for patients seeking care for asthma, (OR = 1.77, 95% CI: 1.51–2.09), CAD (OR = 1.48, 95% CI: 1.11–1.97) and headache (OR = 1.74, 95% CI: 1.32–2.29) after controlling for age group, sex and clinic visits for the same condition during the corresponding period in 1998. In contrast, PM_{10} levels in 1999 were not significant predictors for patients seeking care for diabetes (OR = 1.21, 95% CI: 0.96– 1.52) after controlling for age group, sex and clinic visits for the same condition during the corresponding period in 1998.

Circulatory illness

Both residence and the number of clinic visits in 1998 were confounders, so logistic analyses for circulatory illness were stratified by these variables. PM_{10} levels were not statistically significant predictors of seeking care for circulatory illness during the fires among Hoopa residents (OR = 1.13, 95% CI: 0.94–1.37) or non-residents (OR = 0.54, 95% CI: 0.01–38.5) after controlling for age group, sex and prior visits in 1998. Yet, among residents of nearby communities, exposure to PM_{10} levels in 1999, was significant but protective for seeking care for circulatory illness (OR = 0.10, 95% CI: 0.03–0.41) during the 1999 fires.

In the stratified analysis by number of clinic visits in 1998, among patients who had at least one visit in 1998, daily exposure to PM_{10} levels in 1999 was not a predictor for seeking care for circulatory illness (OR = 0.92, 95% CI: 0.66–1.28)

Table 2. Number of weekly clinic visits for patients seeking care for selected health conditions and weekly average PM_{10} level during the 1999 fires and the corresponding period in the prior year, Hoopa, CA, 1998–1999.

Week of fire	PM_{10} concentration ($\mu g/m^3$) Weekly average		Number (%) for the total number of clinic visits											
			Asthma		Circulatory		CAD		Diabetes		Headache		Respiratory	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
1	15.5	12.8	5 (8.6)	6 (3.4)	77 (29.7)	44 (11.6)	33 (25.8)	14 (15.7)	37 (20.6)	111 (38.9)	5 (15.6)	2 (4.3)	50 (11.1)	38 (5.3)
2	20.2	30.0	12 (20.7)	16 (9.2)	49 (18.9)	52 (13.8)	27 (21.1)	11 (12.4)	37 (20.6)	46 (16.1)	2 (6.3)	5 (10.6)	64 (14.2)	39 (5.4)
3	26.8	31.0	0 (0.0)	15 (8.6)	26 (10.0)	41 (10.8)	6 (4.7)	13 (14.6)	28 (15.6)	17 (6.0)	3 (9.4)	4 (8.5)	34 (7.5)	66 (9.2)
4	20.6	66.1	5 (8.6)	19 (10.9)	14 (5.4)	33 (8.7)	11 (8.6)	4 (4.5)	19 (10.6)	10 (3.5)	0 (0.0)	2 (4.3)	47 (10.4)	50 (7.0)
5	17.5	48.6	5 (8.6)	4 (2.3)	22 (8.5)	36 (9.5)	11 (8.6)	18 (20.2)	14 (7.8)	23 (8.1)	4 (12.5)	1 (2.1)	31 (6.9)	78 (10.9)
6	12.8	38.1	7 (12.1)	15 (8.6)	11 (4.2)	19 (5.0)	6 (4.7)	5 (5.6)	9 (5.0)	12 (4.2)	3 (9.4)	2 (4.3)	42 (9.3)	62 (8.6)
7	12.9	164.6	2 (3.4)	16 (9.2)	15 (5.8)	14 (3.7)	10 (7.8)	6 (6.7)	9 (5.0)	26 (9.1)	3 (9.4)	5 (10.6)	42 (9.3)	57 (7.9)
8	12.5	59.0	7 (12.1)	14 (8.0)	7 (2.7)	13 (3.4)	4 (3.1)	3 (3.4)	9 (5.0)	12 (4.2)	1 (3.1)	2 (4.3)	36 (8.0)	69 (9.6)
9	14.5	57.9	6 (10.3)	12 (6.9)	9 (3.5)	10 (2.6)	0 (0.0)	4 (4.5)	4 (2.2)	6 (2.1)	4 (12.5)	3 (6.4)	32 (7.1)	62 (8.6)
10	19.8	363.3	4 (6.9)	33 (19.0)	13 (5.0)	8 (2.1)	8 (6.3)	3 (3.4)	6 (3.3)	9 (3.2)	3 (9.4)	8 (17.0)	30 (6.6)	78 (10.9)
11	13.8	59.5	2 (3.4)	16 (9.2)	14 (5.4)	15 (4.0)	9 (7.0)	3 (3.4)	7 (3.9)	9 (3.2)	3 (9.4)	7 (14.9)	24 (5.3)	61 (8.5)
12			3 (5.2)	8 (4.6)	2 (0.8)	93 (24.6)	3 (2.3)	5 (5.6)	1 (0.6)	4 (1.4)	1 (3.1)	6 (12.8)	20 (4.4)	58 (8.1)
	1998 vs. 1999		$p = 0.005^{+}$		$p < 0.0001$		$p = 0.005^{+}$		$p = 0.002$		$p = 0.31^{+}$		$p < 0.0001$	

$^{+}$The Chi-square test may not be valid because some of the cell sample sizes are less than five.

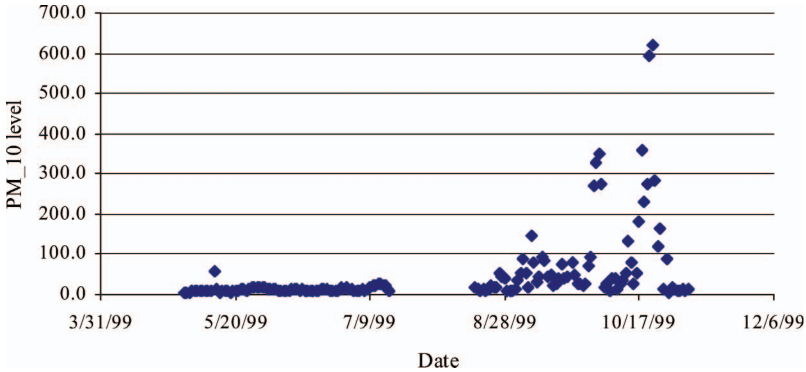

Figure 1. Daily average PM_{10} levels from 1 May until 4 November 1999.

during the fires after controlling for age group, sex and resident status. However, among patients who had no visits in 1998, exposure to PM_{10} levels in 1999 was protective (OR = 0.21, 95% CI: 0.05–0.81) after controlling for age group, sex and resident status.

Respiratory illness

Because there was significant interaction between ln(PM_{10}) and residence, this analysis was stratified by resident status. Among Hoopa residents, and nearby residents, PM_{10} levels in 1999 were predictive of seeking care for respiratory illness 1999 (Hoopa residents: OR = 1.36, 95% CI: 1.24–1.50, nearby-residents: OR = 1.51, 95% CI: 1.04–2.20), among non-residents, exposure to PM_{10} levels in 1999 was not predictive of seeking care for respiratory illness after controlling for age, sex, and the clinic visits for respiratory illness in 1998.

Discussion

In Hoopa, the greatest increase in clinic visits during the fires was for treatment of respiratory conditions. This finding is consistent with other studies on the health impact of wildfire smoke. One study of emergency department visits during wildfires found visits increased by 91% for asthma and 132% for bronchitis with acute exacerbation (Centers for Disease Control and Prevention [CDC] 1999). The Malaysia hospitalization time series analyses suggested that fire-related increases in hospital admissions were more evident for patients with adverse respiratory conditions than for circulatory conditions (Mott et al. 2005). The same study found 90% of respondents surveyed reported adverse respiratory symptoms; severity of respiratory problems was associated with a history of asthma.

The finding that fewer patients sought care for circulatory conditions during the fires compared with the previous year may be due to preventive actions taken. For example, when PM_{10} concentrations reached high levels, the medical director and clinic staff examined patient records and compiled a list of patients likely to be vulnerable to smoke exposure. The list included patients with certain circulatory or

Table 3. Adjusted odds ratios [95% confidence intervals (CI)] for ln(PM_{10}), and potential risk factors as predictors for patients seeking care for selected conditions in 1999, Hoopa, California.

Health conditions	Risk factor	% with illness (*n*)	Odds ratio (95% CI)
Asthma[a]			
	ln(PM_{10}) [adjusted]		1.77* (1.51–2.09)
	Age		
	0–19	6.7 (627)	1.39 (0.77–2.51)
	20–49	7.4 (876)	1.40 (0.80–2.44)
	50+	9.5 (379)	Ref
	Residency		
	Nearby	5.1 (157)	0.70 (0.32–1.52)
	Non-resident	4.2 (48)	0.64 (0.15–2.74)
	Resident	6.9 (1677)	Ref
	Sex		
	Male	5.0 (917)	Ref
	Female	8.2 (965)	1.77* (1.19–2.63)
	# visits in 1998		
	0	6.0 (1854)	Ref
	1+	50.0 (28)	16.7* (7.39–38.0)
Circulatory[b]			
Residence = Hoopa			
	ln(PM_{10}) [adjusted]		1.13 (0.94–1.37)
	Age		
	0–19	0.5 (586)	0.02* (0.01–0.07)
	20–49	5.7 (778)	0.22* (0.14–0.34)
	50+	29.7 (313)	Ref
	Sex		
	Male	8.6 (825)	Ref
	Female	8.1 (852)	0.85 (0.57–1.27)
	# visits in 1998		
	0	5.1 (1553)	Ref
	1+	49.2 (124)	6.18* (3.86–9.89)
Residence = nearby			
	ln(PM_{10}) [adjusted]		0.10* (0.03–0.41)
	Age		
	0–19	0.0 (31)	–[#]
	20–49	5.9 (68)	0.15* (0.03–0.73)
	50+	27.6 (58)	Ref
	Sex		
	Male	10.8 (65)	Ref
	Female	14.1 (92)	2.79 (0.64–12.1)
	# visits in 1998		
	0	6.5 (139)	Ref
	1+	61.1 (18)	193.3* (15.0–1000.0)
Residence = non-resident			
	ln(PM_{10}) [adjusted]		0.54 (0.01–38.5)
	Age		
	0–19	0.0 (11)	–[#]
	20–49	3.5 (29)	–[#]
	50+	12.5 (8)	Ref
	Sex		
	Male	3.7 (27)	Ref
	Female	4.8 (21)	–[#]

(*continued*)

Table 3. (*Continued*).

Health conditions	Risk factor	% with illness (*n*)	Odds ratio (95% CI)
	# visits in 1998		
	0	2.1 (47)	Ref
	1+	100.0 (1)	–#
# visits in 1998 = 0			
	$\ln(PM_{10})$ [adjusted]		0.21* (0.05–0.81)
	Age		
	0–19	0.3 (626)	0.01* (0.003–0.05)
	20–49	4.1 (838)	0.16* (0.10–0.26)
	50+	19.3 (275)	Ref
	Residency		
	Nearby	6.5 (139)	20.6 (0.33–1270.1)
	Non-resident	2.1 (47)	5.52 (0.001–41460.8)
	Resident	5.1 (1553)	Ref
	Sex		
	Male	5.2 (845)	Ref
	Female	5.0 (894)	0.74 (0.47–1.18)
# visits in 1998 = 1+			
	$\ln(PM_{10})$ [adjusted]		0.92 (0.66–1.28)
	Age		
	0–19	50.0 (2)	1.02 (0.06–17.7)
	20–49	40.5 (37)	0.40* (0.17–0.95)
	50+	54.8 (104)	Ref
	Residency		
	Nearby	61.1 (18)	1.36×10^{7} (0.02–1.05×10^{16})#
	Non-resident	100.0 (1)	42367.2 (0.0–1.0×10^{100})#
	Resident	49.2 (124)	Ref
	Sex		
	Male	48.6 (72)	Ref
	Female	53.5 (71)	1.40 (0.68–2.91)
CAD[a]			
	$\ln(PM_{10})$ [adjusted]		1.48* (1.11–1.97)
	Age		
	0–19	0.3 (628)	0.06* (0.01–0.24)
	20–49	0.9 (874)	0.15* (0.06–0.36)
	50+	12.4 (380)	Ref
	Residency		
	Nearby	2.6 (157)	0.41 (0.13–1.32)
	Non-resident	2.1 (48)	1.39 (0.17–11.1)
	Resident	3912 (1677)	Ref
	Sex		
	Male	3.8 (917)	Ref
	Female	2.3 (965)	0.73 (0.38–1.39)
	# visits in 1998		
	0	1.4 (1813)	Ref
	1+	46.4 (69)	20.9* (10.0–43.5)
Diabetes[a]			
	$\ln(PM_{10})$ [adjusted]		1.21 (0.96–1.52)
	Age		
	0–19	0.0 (628)	–#
	20–49	4.9 (875)	0.50* (0.29–0.83)
	50+	18.5 (379)	Ref
	Residency		

(*continued*)

Table 3. (*Continued*).

Health conditions	Risk factor	% with illness (*n*)	Odds ratio (95% CI)
	Nearby	3.2 (157)	0.38 (0.13–1.15)
	Non-resident	0.0 (48)	–[#]
	Resident	6.4 (1677)	Ref
	Sex		
	Male	6.1 (917)	Ref
	Female	5.9 (965)	1.15 (0.68–1.93)
	# visits in 1998		
	0	2.6 (1795)	Ref
	1+	77.0 (69)	61.0* (33.0–113.8)
Headache[a]			
	$\ln(PM_{10})$ [adjusted]		1.74* (1.32–2.29)
	Age		
	0–19	0.8 (628)	0.38 (0.12–1.19)
	20–49	2.7 (875)	1.21 (0.53–2.76)
	50+	18.5 (379)	Ref
	Residency		
	Nearby	1.3 (157)	0458 (0.11–1.93)
	Non-resident	0.0 (48)	–[#]
	Resident	2.1 (1677)	Ref
	Sex		
	Male	1.0 (917)	Ref
	Female	2.9 (965)	2.90* (1.34–6.25)
	# visits in 1998		
	0	1.8 (1859)	Ref
	1+	13.0 (23)	7.36* (1.94–28.0)
Respiratory[b]			
Residence = Hoopa			
	$\ln(PM_{10})$ [adjusted]		1.36* (1.24–1.50)
	Age		
	0–19	32.0 (584)	1.74* (1.24–2.43)
	20–49	29.7 (780)	1.63* (1.18–2.25)
	50+	21.1 (313)	Ref
	Sex		
	Male	25.5 (825)	Ref
	Female	32.3 (852)	1.36* (1.09–1.70)
	# visits in 1998		
	0	27.0 (1457)	Ref
	1+	41.8 (220)	1.97* (1.45–2.66)
Residence = nearby			
	$\ln(PM_{10})$ [adjusted]		1.51* (1.04–2.20)
	Age		
	0–19	16.1 (31)	0.86 (0.26–2.81)
	20–49	19.1 (68)	0.86 (0.35–2.13)
	50+	20.7 (58)	Ref
	Sex		
	Male	15.4 (65)	Ref
	Female	21.7 (92)	1.41 (0.60–3.34)
	# visits in 1998		
	0	18.5 (146)	Ref
	1+	27.3 (11)	1.71 (0.41–7.16)
Residence = non-resident			
	$\ln(PM_{10})$ [adjusted]		0.58 (0.27–1.24)

(*continued*)

Table 3. (*Continued*).

Health conditions	Risk factor	% with illness (n)	Odds ratio (95% CI)
	Age		
	0–19	45.5 (11)	2.99 (0.33–26.9)
	20–49	20.7 (29)	1.15 (0.16–8.17)
	50+	25.0 (8)	Ref
	Sex		
	Male	18.5 (27)	Ref
	Female	38.1 (21)	2.09 (0.50–8.84)
	# visits in 1998		
	0	25.5 (47)	Ref
	1+	100.0 (1)	–#

[a]The reduced model contained only the main-effect terms; [b]the reduced model contained the interaction term for ln(PM_{10}) $\times$ residence in addition the main-effect terms; *statistically significant at the level of 0.05; #the validity of the model fit is questionable, because the frequency count is zero or very sparse in the category.

respiratory conditions, especially CAD and asthma. These patients were contacted and advised to evacuate. During week 10 it was estimated that 444 Hoopa residents stayed at coastal hotels. Consequently, the number of clinic visits probably underestimates the number of people who would have sought care at the clinic had they not evacuated. Some did not leave; many of those did not want to abandon animals. The medical clinic provided high efficiency particulate air (HEPA) cleaners to people remaining in their homes who were identified by the clinic staff as vulnerable. These preventive measures may have protected these patients, but we could not assess the effectiveness of these measures.

Health outcomes were not significantly correlated with weekly PM_{10} levels, but were significantly associated with daily PM_{10} levels in multivariate analysis. One explanation may be that weekly average PM_{10} levels mask some of the health effects from daily variations. The association between daily PM_{10} concentrations and health outcomes is consistent with several studies examining the relationship between health and PM_{10} produced by wildfires. In a study of the health effects of PM_{10} levels from tropical forest fires in Singapore, researchers found that an increase in PM_{10} levels from 50 to 150 $\mu g/m^3$ was significantly associated with an increase of 19% in asthma outpatient visits (Emmanuel 2000). A study of asthma and smoke pollution from bushfires in Australia found an increase in the number of asthma patients visiting the hospital on days when the PM_{10} level was above 40 $\mu g/m^3$ compared with days when the PM_{10} level was less than 10 $\mu g/m^3$ (Johnston et al. 2002). Another Australian bushfires study found no association between the bushfire period or PM_{10} levels and evening peak expiratory flow rates in children with wheeze. However, there was a significant negative association between PM_{10} levels and evening peak expiratory flow rates in a subgroup of children with bronchial hyper-reactivity (Jalaludin et al. 2000).

There was an increase in male patients visiting the clinic during the 1999 fires. There are several possible explanations. One is that, when people were advised to be evacuated from the town, many men stayed to carry out essential administrative and maintenance duties. Another possible reason is that some men stayed to fight the fires. Incomes in this community are low and some of the male residents decided to accept paid work to fight the fires.

There are several limitations on drawing inferences from this study. First, it was not possible to calculate population-based rates because people moved on and off the reservation during the fires. When the PM_{10} levels remained at hazardous levels for several days, the medical director advised evacuation to hotels in coastal towns. Because this was an emergency, energies were focused on helping people leave the reservation, and one California non-profit organization paid for hotel rooms for the residents. Unfortunately, there was no detailed documentation regarding who stayed in a hotel room and the dates of their stay. For example, a family may have gone to a hotel, but some men may have quickly returned to the reservation to work or provide care for the animals while other family members stayed at the hotel. The residents who stayed at their homes were advised to stay indoors when the particulate levels were high. Second, it was not possible to know what personal exposures actually were. Measurement error can result when the ambient PM_{10} level is substituted for personal exposure (Dominici et al. 2000). For example, the medical clinic provided HEPA cleaners to people whom the clinic staff identified as vulnerable; use of those air cleaners may have reduced exposures. The third limitation was that on several days the PM_{10} hourly concentrations likely underestimated the ambient level. The TEOM instrument was not calibrated to operate at such high concentrations of PM_{10}; this necessitated recalibrations and frequent filter changes during operation. On a couple of occasions, the TEOM was recalibrated to >500 $\mu g/m^3$ and later to $>1{,}000$ $\mu g/m^3$; therefore the true PM_{10} concentrations on these days are not known.

Wildfires are a growing natural hazard in most regions of the United States (United States Geological Survey [USGS] 2006). An increase in summer drying over the interior of the United States and of other mid-altitude continents during the twenty-first century is predicted, according to scientists brought together by the United Nations and the World Meteorological Organization to assess the current and future condition of Earth's climate (Working Group on Wildland Fires 2001). More research is needed to better understand the underlying mechanisms of wildfire smoke exposure, particularly on those individuals at greatest risk, so that more precise human health risks can be defined and appropriate interventions developed and implemented (Zelikoff et al. 2002).

Conclusion

Multivariate analyses suggest that exposure to the higher daily PM_{10} concentrations during the 1999 fires were predictive of patients seeking care at the clinic for asthma, CAD and for headaches. Stratified multivariate analysis suggests that daily PM_{10} concentrations were predictive of clinic visits for respiratory conditions among Hoopa residents and residents of nearby communities. These findings suggest that individuals with the conditions in this investigation are a high risk group that could benefit from targeted interventions, such as evacuation or HEPA cleaners to reduce their exposure to wildfire particulate.

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