Surveillance Investigation of the Cardiopulmonary Health Effects of the 2012 Wildfires in North Central Washington State

Washington State Department of Health

Chelan-Douglas Health District

Kittitas County Public Health Department

GCHD
Grant County Health District

Okanogan County Public Health

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Abbreviations

AQI	U.S. EPA's Air Quality Index
CI	95% confidence interval
COPD	Chronic obstructive pulmonary disease
CVD	Cardiovascular disease
Ecology	Washington State Department of Ecology
ED	Emergency department
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
$PM_{2.5}$	Particulate matter less than 2.5 micrometers in diameter
USFS	United States Forest Service
EPA	United States Environmental Protection Agency
WAQA	Washington State's Air Quality Advisory

Table of Contents

Tables

Figures

Technical Notes

Abstract

Background. Wildfires burned in north central Washington for 34 days in September and October 2012. The fires burned approximately 100,000 acres and caused very high levels of fine particulate matter ($PM_{2.5}$). Air monitors in Wenatchee recorded the highest levels of $PM_{2.5}$ with an average of 194 ug/m^3 (24-hour average measurement) from September 9-October 12. The Washington State Department of Health in collaboration with Chelan-Douglas Health District, Kittitas County Public Health, and Okanogan County Public Health conducted a surveillance investigation to understand the short-term cardiopulmonary effects of sustained exposures to high levels of wildfire smoke in north central Washington.

Methods. Three healthcare institutions serving Chelan, Douglas, Kittitas, Grant, and Okanogan counties provided patient information from emergency department (ED) and outpatient clinic visits for a 68-day period from several weeks before the 2012 wildfires to several weeks following the fires and for the corresponding time periods in 2010 and 2011. We calculated the average number of daily visits for cardiovascular (CVD) and respiratory diseases [International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes 390–519 and 786] before, during, and after the fires and for comparable time periods in 2010 and 2011. The primary analysis compared average daily visits before the fires in 2012 (baseline period) to average daily visits during and after the fires (comparison periods) in 2012. Secondary analyses included: 1) the same comparisons as the primary analysis using 2010–2011 data to see whether changes in average daily visits were unique for 2012 or represented normal seasonal variation and 2) comparing the three time periods in 2012 (comparison year) to comparable time periods in 2010 and 2011 combined (baseline years) to account for year to year variation independent of the fires. Comparisons included: 1) the number of average daily visits in the comparison periods minus the number in the baseline period for a measure of change in number of daily visits and 2) the ratio of average daily visits in the comparison period to visits in the baseline period for a measure of percent change.

Results. Overall in 2012 average daily patient visits for CVD and respiratory disease were 28 and 18 percent higher during and after the wildfires, respectively, compared to the two week period before the fires. These increases represented about 135 additional daily visits for the 34-day period during the fires and 87 additional daily visits for the 19 days following the fires. Overall in 2010–2011 average daily patient visits were 19 and 11 percent higher in the periods corresponding to during and after the wildfires, respectively, compared to before the fires. These increases represented about 87 and 52 additional daily visits for the periods corresponding to during and after the fires, respectively. The 2010–2011 increases suggest that some, but not all, of the 2012 increases represent seasonal patterns.

Increased daily patient visits were most pronounced for respiratory disease in children, with daily visits increasing by an average of 45 visits during the 2012 fires compared to the two weeks before the fires and 28 visits after the fires compared to before the fires. These increases are larger than the 22 and 14 excess daily visits in the corresponding periods in 2010-2011. Among subcategories of respiratory disease, children's visits for asthma, respiratory and chest symptoms, and acute respiratory infections were about double during the 2012 fires compared to the period before the fires. In comparison, for 2010-2011, children's visits for acute respiratory infections increased by approximately 50 percent during the corresponding time period of wildfires compared to before the fires. However, there were no increases in children's daily visits for asthma or respiratory and chest symptoms in 2010-2011 for the time period

corresponding to wildfires compared to before the fires. Visits for chronic obstructive pulmonary disease (COPD) excluding asthma for all age groups combined was about 60 percent higher during and after the fires compared to before the fires with no corresponding increases in 2010–2011. These findings suggest that some, but not all, of the increase in children's visits for acute respiratory infections in 2012 was seasonal, while all of the increases in visits for the other conditions could be related to the fires.

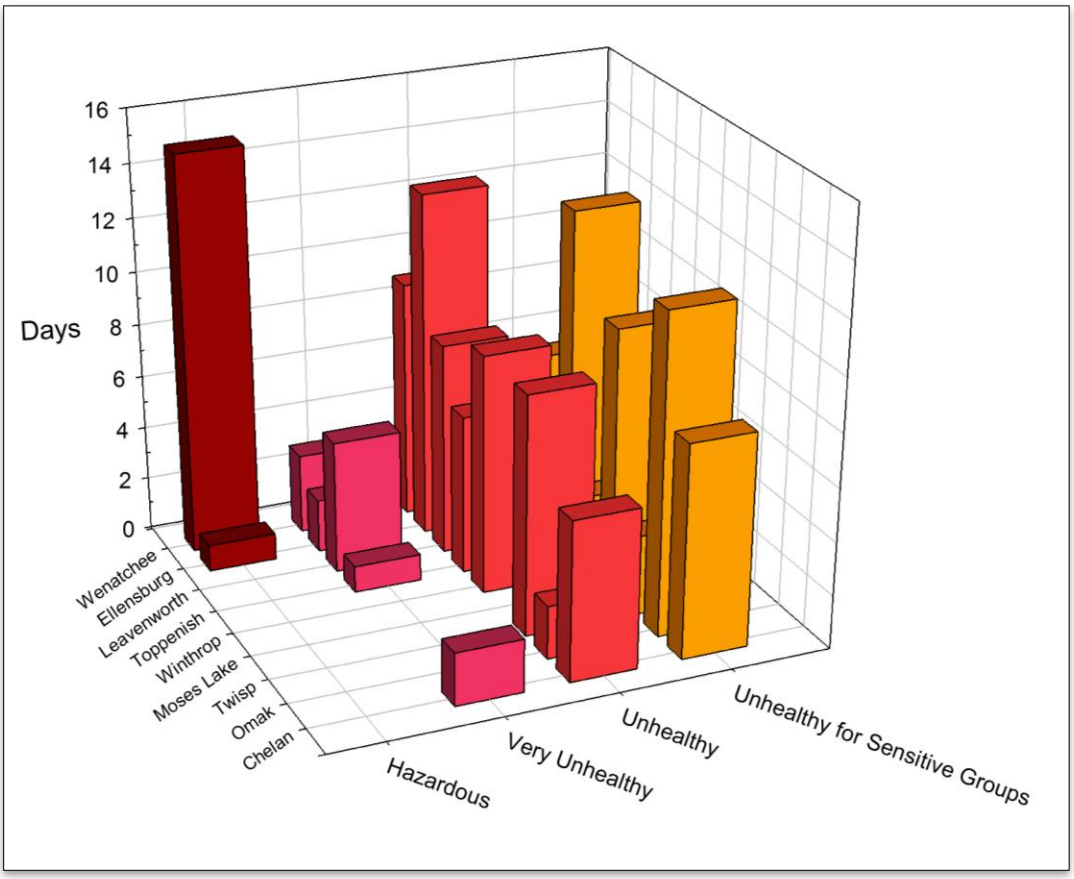
Conclusion. This surveillance study indicates that healthcare providers in north central Washington can expect an increase in ED and outpatient visits by people of all ages during wildfires. Providers are especially likely to experience an increase in visits for pediatric asthma and other childhood respiratory and chest symptoms, and an increase in visits for COPD across all age groups. These findings combined with findings from previously published studies suggest a need to minimize exposure to wildfire smoke. Health departments in north central Washington can use these results to tailor health messaging during wildfires. Healthcare system planning should modify available resources to meet the needs of at-risk populations during wildfire seasons. Children, especially those with asthma, and individuals with COPD may need to take extra precautions to avoid wildfire smoke. Additional studies on long-term effects of wildfire smoke are needed.

Introduction

Major wildfires burned in north central Washington in 2012. (See map in Technical Notes for wildfire locations.) A severe thunderstorm in early September ignited numerous small fires and produced two major fires, the Table Mountain Fire and the Wenatchee Complex Fire. These fires resulted in approximately 100,000 acres burned. The fires lasted more than a month through mid-October. People in north central Washington were exposed to smoke-filled air for most of this period. The Washington State Department of Health (the department) distributed over 50,000 N-95 respirator masks in affected counties. The governor declared a state of emergency. Multiple state and local agencies responded to the wildfires including the Washington State Department of Ecology (Ecology), United States Forest Service (USFS), Washington State Department of Natural Resources, local health departments, local clean air agencies, and tribes. The Chelan-Douglas Health District set up a smoke shelter, the first such shelter in the state, and advised people with lung and cardiovascular disease to leave the area if they were experiencing problems. The Chelan-Douglas Health District surveyed a number of local hospitals and clinics during the wildfires. These institutions reported an approximate 16 percent increase in overall visits.

Wildfire smoke is comprised of particulate matter and gases. Many of the gases are toxic, such as carbon monoxide, nitrogen dioxide, acrolein, formaldehyde, benzene, and other polyaromatic hydrocarbons. Small particulate matter with diameters of 2.5 micrometers or less ($PM_{2.5}$) is also harmful to human health. Ecology's Wenatchee air quality monitor recorded levels of $PM_{2.5}$ that were five times the federal 24-hour average standard of 35 ug/m^3 on 13 days during the fires. A USFS monitor—set up on a temporary basis in Wenatchee about a week after the start of the fire—recorded 12 days with $PM_{2.5}$ levels five times the standard. Higher than normal levels of $PM_{2.5}$ persisted for more than a month in this region. (Figure 1)

Figure 1. Number of days in Washington Air Quality Advisory (WAQA) categories of 'Unhealthy for Sensitive Groups' or worse by monitor location during the 2012 wildfire episode.[1]



The department's syndromic surveillance system (ESSENCE) receives reports of patients' admitting complaints from emergency departments across Washington State. During the 2012 wildfires, 15 emergency departments in eastern Washington—none of which were in Chelan, Douglas, Kittitas, Grant or Okanogan counties—participated in ESSENCE. The department used ESSENCE to estimate the impact of exposure to wildfire smoke on emergency department visits for respiratory complaints, including: difficulty breathing, wheezing, asthma, shortness of breath, and cough. The number of visits that occurred during the wildfires through two weeks after the wildfires compared to the same time period in 2011 showed an approximate 12 percent increase in complaints related to respiratory irritation.[2] The current surveillance study does not use data from ESSENCE.

Research studies consistently show associations between wildfire smoke and increased risk of respiratory disease.[3] Although findings are less consistent for the association between wildfire smoke and increased risk of cardiovascular disease (CVD) including heart disease and stroke, five of six studies cited in a 2014 systematic review consistently found associations between hospital admission for CVD and wildfire smoke in the United States.[3]

The Chelan-Douglas Health District, Kittitas County Public Health Department, Okanogan County Public Health and the department conducted a surveillance study to better understand the health impacts of the

2012 wildfires. Climate change models predict that wildfires will double to quadruple by 2080 in the Columbia Basin region.[4] This investigation was undertaken to:

- Understand the impacts of the 2012 wildfires on respiratory and cardiovascular health.
- Evaluate if certain age groups are at increased risk.
- Provide information to local health departments to aid in wildfire response and resource allocation to protect health.
- Inform emergency response efforts of other governmental agencies.
- Assist hospitals and clinics to plan for medical response and increased capacity, if needed, during wildfires.
- Target public health messaging for protective actions during wildfires.

Methods

Surveillance Area

This surveillance project includes data from air monitors, emergency departments, and outpatient clinics in five counties in north central Washington: Chelan and Douglas (a two-county health district), Grant, Kittitas, and Okanogan. (See map in Technical Notes.)

- Chelan and Douglas counties are on the eastern edge of the Cascade Mountains and are separated by the Columbia River. Chelan County has 2,920 square miles with 24 people per square mile. Douglas County is smaller with 1,819 square miles and 21 persons per square mile. The combined population in 2012 was 112,922. Chelan and Douglas counties topography includes mountains, lakes, and terraced land adjacent to the Columbia River. The two major industries are tourism and tree fruit agriculture.[5]

- Grant County is the fourth largest county in the state at 2,679 square miles with 33 residents per square mile. The 2012 population was 91,526. It is located toward the central-eastern edge of the state in the Columbia Basin. Grant County industry is heavily concentrated in ranching and agriculture.[6]

- Kittitas County is in the center of the state, 100 miles east of Seattle across the Cascade mountain range. Kittitas County has 2,297 square miles, which are sparsely populated with 17.8 persons per square mile. The 2012 population was 41,650. Over two-thirds of the county is hilly or mountainous making it valuable for recreation. Although agriculture is not a major employer, Kittitas also has significant agricultural lands.[7]

- Okanogan County is the largest county in the state at 5,268 square miles, but only 7.8 residents per square mile (fifth fewest in Washington). It borders Canada on the north, Columbia River Basin and Lake Roosevelt to the south and east, and the north Cascade Mountains on the west. It is an agricultural county with many outdoor recreation activities that attract tourists. [8]

In addition to permanent residents, north central Washington has a large number of second homes due to recreational opportunities, such as hiking, river rafting, and rock climbing. Tourists also come to the area to visit local breweries, wineries, and fruit stands. Harvests start with cherries in May, followed by peaches, apricots, nectarines, pears, and apples in late autumn.

Air Monitoring

Ecology and its air monitoring partners frequently use nephelometers to report near-real-time estimates of $PM_{2.5}$ pollution in the outdoor air in Washington State (see Technical Note #5 for information about nephelometers). Ecology and the USFS operate several of these nephelometers at long-term monitoring sites in central Washington. The data from several of these monitors was used for this study. Ecology operates nephelometers in Wenatchee, Ellensburg, Omak, and Moses Lake, while the USFS operates nephelometers in Leavenworth, Twisp, and Winthrop. (See Technical Note #1 for map of monitor locations.) The data from these monitors is telemetered to Ecology's central server in Lacey as part of the Washington State Ambient Air Monitoring network. Ecology flagged the data from their Wenatchee monitor from August 25–September 25, 2012 as invalid for failing to meet Ecology's quality control criteria as established in its standard operating procedures. In spite of such flagging, Ecology states that the data provide a rough estimate of $PM_{2.5}$ levels.[9] In addition to the long-term air monitoring sites operated by Ecology and the USFS, the USFS operated temporary monitors at six sites, including one in Wenatchee, to measure particulate matter during the wildfires (See Technical Note 4). We used data from the USFS temporary monitor in Wenatchee to gain perspective on the accuracy of the flagged data.

Based on findings from the air monitoring data, we defined three time periods for levels of $PM_{2.5}$: the two weeks before the wildfires (August 25—September 8, 2012), during the wildfires (September 9–October 12, 2012), and the two and a half weeks following the wildfires (October 13–October 31, 2012). For particulate matter, Ecology's Washington Air Quality Advisory (WAQA) index defines good air quality as $PM_{2.5}$ levels averaging below 13.5 ug/m^3 for a 24-hour period, midnight to midnight; the United States Environmental Protection Agency (EPA) has an Air Quality Index (AQI) that defines good air quality as a 24-hour average below 12 ug/m^3. (see Technical Note #2). A short duration wildfire in Kittitas County prohibited being able to include more days of good air quality before the fires. $PM_{2.5}$ air quality was also evaluated for the same time periods in the two preceding years (August 25–October 31, 2010 and August 25–October 31, 2011).

Participating Facilities, Requested Information and Data Analysis

Greater Wenatchee and Ellensburg serve as the two major medical hubs in the surveillance area. Greater Wenatchee serves Chelan, Douglas, Grant, and Okanogan counties. Ellensburg serves Kittitas County. Emergency department (ED) and outpatient clinics participating in this surveillance project included:

- **Central Washington Hospital** ED is located in Wenatchee. This ED is a Level III Adult and Pediatric Trauma Center staffed 24/7 by specialists in emergency and trauma medicine. Cardiac specialists have access to magnetic resonance imaging (MRI), cardiac catheterization labs and noninvasive labs, electrophysiology studies and angioplasty/stent, two digital cardiovascular laboratories, two open-heart surgery suites, and an intensive care/cardiac care unit. The hospital is accredited by the Intersocietal Accreditation Commission in echocardiography, nuclear medicine, and vascular ultrasound. The hospital offers the highest level of care available in north central Washington.[10] Visits to Central Washington Hospital accounted for about three percent of the visits in this surveillance study.
- **Wenatchee Valley Medical Center** provides outpatient primary care to area residents and patients throughout the region. The two clinics in Chelan County (Wenatchee and Cashmere) and the two in Douglas County (East Wenatchee and Waterville) have the largest volumes of visits. Patients are also seen in two Grant County clinics (Moses Lake and Royal City) as well as four clinics in Okanogan County (Brewster, Omak, Tonasket and Oroville). Visits to Wenatchee Valley Medical Center accounted for the vast majority of visits in this study: 86 percent. In July 2013, Wenatchee Valley Medical Center merged with Central Washington Hospital to create Confluence Health with 350 physicians and mid-level practitioners.
- **Kittitas Valley Healthcare** ED and clinics are located in Kittitas County. The ED is a Level IV trauma service with nine beds and is staffed 24/7 by an emergency physician. The hospital offers a comprehensive program of pulmonary and cardiac services. Seven clinics provide outpatient primary care, urgent care, internal medicine, orthopedics, surgery, and women's health services. Kittitas Valley Healthcare accounted for approximately 11 percent of visits in this study with about 10 percent from outpatient clinics and one percent from the ED and urgent care.

The local public health epidemiologist requested information on visits from the facilities described above for August 25–October 31, 2010, 2011 and 2012. (See Technical Note #1 for locations of participating facilities.) Requested information included medical record number and visit-related information including date of care, disposition, and up to six diagnoses with International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes 390–519 or 786. Demographic and other patient-specific information—age or date of birth, sex, race and ethnicity, and address—were also requested.

We received four sets of data—Central Washington Hospital, Wenatchee Valley Medical Center, Kittitas Valley Healthcare clinics and Kittitas Valley Healthcare ED and urgent care—as Microsoft Excel spreadsheets with each set having its unique layout and format. The most important of the differences was that the layout of the Kittitas Valley Healthcare clinics (10 percent of visits) allowed us to distinguish the primary diagnosis code from subsequent diagnosis codes while the layout of the data from the remaining facilities did not allow us to make that distinction.

The Kittitas Valley Healthcare clinic data listed each visit in one row with separate columns for diagnoses one, two, three, and four. They then dropped diagnosis codes that were not in the requested range. Thus,

some records had missing data for diagnosis one, which is considered the primary diagnosis. In subsequent cleaning, reformatting and merging of the four sets of spreadsheets for this report, the original data analyst retained only the primary diagnosis from Kittitas Valley Healthcare clinics. This resulted in missing diagnoses for 2,050 (19 percent spread evenly over the three years of data) visits from these clinics and exclusion of these visits from the analysis presented in this report. Overall, these records account for less than two percent of the ED and clinic visits used for this report.

The remaining facilities provided spreadsheets with separate rows for each diagnosis for a given patient on a given day. While only the first listed diagnosis code was retained in the dataset created for this report, the first diagnosis might or might not have been the primary diagnosis. No records were excluded from any of the remaining facilities because of missing data for primary diagnosis.

Diagnosis codes from two facilities did not cover the full range of diagnosis codes requested. Kittitas Valley Health Care ED had no records with a first diagnosis of ICD-9-CM 390–450. Since this range includes most heart disease, such as heart attack, heart failure, and stroke, it is not credible that there were no visits for these codes in the time periods covered by this study. Central Wenatchee Hospital ED had no records with a first diagnosis code of 786, respiratory and chest symptoms. This is a relatively common code making it likely that the hospital failed to provide these records. In both cases, diagnosis codes are missing for all time periods and all years and so the omissions do not introduce bias into the analysis.

Table 1. Characteristics of data by reporting facility.

Facility	Percent (number) of total reported visits 2010-2012	Indicated primary diagnosis	Reported full range of ICD-9-CM codes	Missing codes
Central Washington Hospital	3 (3697)	No	No	786 (Respiratory and chest symptoms)
Wenatchee Valley Medical Center	86 (94925)	No	Yes	
Kittitas Valley Healthcare clinics	10 (11053)	Yes	Yes	
Kittitas Valley ED and urgent care	1 (1151)	No	No	390-450 (Most cardio-vascular disease diagnoses)

The department combined visits from all facilities and calculated average daily visits (total number of visits during a time period divided by the number of days in the period) for three periods in 2012 and corresponding periods in 2010 and 2011: before (August 25–September 8), during (September 9–October 12), and after (October 13–October 31) the wildfires.

Analyses included measures of: 1) the excess number of average daily visits calculated as the difference between the number of average daily visits in the baseline and comparison periods as defined in Results section below and 2) the ratio of the number of average daily visits in the comparison period (observed) to the number of average daily visits in the baseline period (expected) or O/E. The O/E can be interpreted as a percent increase or decrease. An O/E of one means that the average number of daily visits in the baseline period is the same as the number in the comparison period. An O/E greater than one indicates an increase in visits during the comparison period; an O/E less than one represents a decrease. O/E ratios can easily be read as percentages. For example an O/E of 1.25 indicates a 25 percent increase, an O/E of 2.0 indicates a doubling or 100 percent increase, and an O/E of 0.75 indicates a 25 percent decrease.

We also calculated 95 percent confidence intervals (CI) around the O/E.[11] CIs help to understand the extent to which an O/E might be higher or lower than one due to random variation. If the CI includes one,

we conclude that the O/E is likely to be bigger or smaller than one due to chance. In this study, if the CI included one, we concluded that the average numbers of daily visits were similar in the baseline and comparison periods. Comparing O/Es must be done with caution because O/Es are more likely to be larger when there are few baseline events compared to O/Es with more baseline events. For example, an increase in average daily visits from one in the baseline period to two in the comparison period (that is, an increase of just one extra visit each day) gives an O/E of 2.0, but an increase from 100 average daily visits in the baseline to 150 in the comparison period (that is, an increase of 50 visits each day) gives an O/E of 1.5. Thus, in interpreting the findings, we considered the O/Es in light of the number of visits in the baseline periods and the number of excess visits. We compared O/Es only when the numbers of average daily visits were similar in baseline periods.

This report presents data for total visits and two broad diagnostic categories: 1) diseases of the circulatory system (referred to as cardiovascular disease or CVD; ICD-9-CM codes 390–459) and 2) diseases of the respiratory system combined with respiratory and chest symptoms (referred to as respiratory; ICD-9-CM codes 460–519 and 786). It also provides data for 20 subcategories of the two broad groupings following ICD-9-CM classifications. (See Tables 7 and 8 for classifications.) The report presents data for all ages combined; for two age groups (19–64 years and 65 years and older) for CVD and most CVD subcategories; and three age groups (0–18 years, 19–64 years, and 65 years and older) for respiratory disease and most subcategories of respiratory disease. Data by age are not presented for three subcategories in which the age groups had fewer than 30 visits during the 2012 wildfires, the primary period of interest. CVD and CVD subcategories do not include data for children due to the small number of visits (21 total) during the wildfires.

Results

Air Quality

In 2012, the average of 24-hour average $PM_{2.5}$ concentrations at seven permanent monitors were in the good air quality range as defined by both the WAQA and AQI both before and after the wildfires. Ecology's air monitors also consistently showed $PM_{2.5}$ air quality in the good range for all three periods in 2010 and 2011. (Table 2; See Technical Note #2 for WAQA and EPA AQI categories.)

Table 2. Fine particulate ($PM_{2.5}$) levels at monitors[1] in north central Washington during the surveillance time period (August 25–October 31).

Monitor Location	Year	Time Period		24-Hour Average $PM_{2.5}$	
County/City		Relative to Fires	Dates mm/dd	Average (ug/m^3)	Maximum (ug/m^3)
Chelan/Wenatchee	2010	All[2]	08/25–10/31	6.4	39.2
	2011	All[2]	08/25–10/31	7.7	34.9
	2012	Before	08/25–09/08	4.4[3]	7.6[3]
	2012	During	09/09–10/12	194.4[4]	1130.1[3]
	2012	After	10/13–10/31	6.9	13.9
Chelan/Leavenworth	2010	All[2]	08/25–10/31	3.0	8.1
	2011	All[2]	08/25–10/31	5.7	19.7
	2012	Before	08/25–09/08	3.6	5.8
	2012	During	09/09–10/12	39.4	121.2
	2012	After	10/13–10/31	6.2	11.5
Kittitas/Ellensburg	2010	All[2]	08/25–10/31	4.9	17.1
	2011	All[2]	08/25–10/31	5.4	18.8
	2012	Before	08/25–09/08	3.4	5.8
	2012	During	09/09–10/12	40.7	228.7
	2012	After	10/13–10/31	5.5	15.1
Grant/Moses Lake	2010	All[2]	08/25–10/31	5.5	19.9
	2011	All[2]	08/25–10/31	6.4	16.4
	2012	Before	08/25–09/08	5.5	8.0
	2012	During	09/09–10/12	17.2	32.9
	2012	After	10/13–10/31	6.2	12.8

Table 2 continued. Fine particulate ($PM_{2.5}$) levels at monitors[1] in north central Washington during the surveillance time period (August 25—October 31).

Monitor Location	Year	Time Period		24-Hour Average $PM_{2.5}$	
County/City		Relative to Fires	Dates mm/dd	Average (ug/m^3)	Maximum (ug/m^3)
Okanogan/Twisp	2010	All[2]	08/25–10/31	6.8	14.5
	2011	All[2]	08/25–10/31	6.9	17.9
	2012	Before	08/25–09/08	3.8	7.7
	2012	During	09/09–10/12	22.6	66.8
	2012	After	10/13–10/31	5.9	9.2
Okanogan/Winthrop	2010	All[2]	08/25–10/31	6.3	14.4
	2011	All[2]	08/25–10/31	6.9	17.2
	2012	Before	08/25–09/08	4.1	7.3
	2012	During	09/09–10/12	21.7	70.2
	2012	After	10/13–10/31	5.4	8.3
Okanogan /Omak[5]	2010	All	08/25—10/31	NA	NA
	2011	All	08/25—10/31	7.8	22.1
	2012	Before	08/25—09/08	3.6	8.4
	2012	During	09/09—10/12	17.7	57.9
	2012	After	10/13—10/31	5.2	9.0

[1] USFS maintains monitors in Winthrop and Twisp and reports results to the Washington State Department of Ecology (Ecology). Ecology maintains the remaining monitors.
[2] $PM_{2.5}$ air quality in 2010 and 2011 was mostly in the good range as defined by both Ecology and the U.S. EPA standards. Thus, levels are presented as averages over the entire surveillance period.
[3] Invalidated data (See Methods section.)
[4] Data invalidated for 17 days (See Methods and Results sections.)
[5] Omak monitoring site was established in October, 2010. Data for 2010 at this site are Not Available (NA)

Average 24-hour average $PM_{2.5}$ concentrations were higher during the wildfires than during other time periods. For September 9–October 12, Ecology's Wenatchee air monitor showed the highest concentrations of $PM_{2.5}$ with an average 24-hour average of 194 ug/m^3, a level defined as hazardous by Ecology's WAQA and very unhealthy by EPA's AQI.

Although data from Ecology's Wenatchee monitor were flagged as invalid from August 25–September 25, data from the temporary USFS monitor in Wenatchee that operated from September 14–October 4, 2012 support Ecology's conclusion that the flagged data provide a rough estimate of $PM_{2.5}$ levels. First, the average 24-hour averages at the Ecology and USFS monitors were 374 and 253 ug/m^3, respectively, from September 14–September 25, the 12-day period during which both monitors were running and

Ecology's data were flagged as invalid. While Ecology's monitor showed higher average levels of $PM_{2.5}$, the average levels measured by both monitors were in WAQA and AQI's hazardous range for the 12-day period. Second, over the 9-day period in which both monitors were operating and data from the Ecology monitor met all standard operating procedures, $PM_{2.5}$ levels measured at the Ecology monitor were again higher than levels measured at the USFS monitor with average 24-hour averages of 86 and 67 ug/m^3, respectively. This finding suggests that the higher $PM_{2.5}$ levels at the Ecology monitor during the period in which data were flagged as invalid might have been due to air quality being poorer at the Ecology monitor than at the USFS monitor rather than an indication of an error caused by failure to follow all standard operating procedures.

At average 24-hour averages of 41 ug/m^3 and 39 ug/m^3, air monitors in Ellensburg and Leavenworth, respectively, recorded concentrations in Ecology's unhealthy range. EPA classifies these levels as unhealthy for sensitive populations. Average 24-hour averages at the Twisp and Winthrop monitors measured levels in Ecology's unhealthy for sensitive groups range; EPA defines these levels as moderate. The average levels at Moses Lake and Omak were in the moderate range for both the WAQA and AQI.

Maximum 24-hour average $PM_{2.5}$ levels during the wildfires reached 1,130 at the Wenatchee monitor. (Table 2) The 24-hour average concentration was above 350 ug/m^3—and thus well into the hazardous ranges on both Ecology's WAQA and EPA's AQI—on seven of the 34 days. Maximum 24-hour averages at all air monitors except Moses Lake were in the unhealthy ranges or higher on both Ecology's WAQA and EPA's AQI. (Table 2; See Technical Note #2 for WAQA and AQI categories.)

Emergency Department and Outpatient Visits

Distribution by residence, year, sex and age group. We received information on 110,828 visits for the specified codes from August 25–October 31 for the three years combined. Approximately 36 percent of the visits came from people living in Wenatchee (Chelan County) and East Wenatchee (Douglas County). Together, Wenatchee and East Wenatchee make up the largest urban area in the five counties covered by this surveillance study, accounting for about 25 percent of the 2012 population in the five counties. About 16 percent of visits were from people residing in Moses Lake (Grant County) where about 12 percent of the population in the five counties resided. People from Ellensburg accounted for seven percent of the visits and made up seven percent of the population. The remaining visits were people living in other locations in the five counties, people visiting the region, and people with second homes who provided their primary address as their address.

Table 3. Visits for cardiovascular and respiratory conditions[1] by year, gender and age during the surveillance period (August 25–October 31).

	2010		2011		2012	
	Visits	Percent	Visits	Percent	Visits	Percent
Total Visits	34604		36366		39858	
Male	16654	48	17214	47	18714	47
Female	17949	52	19152	53	21144	53
Age: 0–18	4277	12	4245	12	5198	13
19–64	12291	36	12599	35	13805	35
≥ 65	18036	52	19522	54	20855	52

[1] International Classification of Diseases, 9th Revision, Clinical Modification codes 390–519 and 786

Approximately 31 percent of visits occurred in 2010, 33 percent in 2011, and 36 percent in 2012. With a population growth of less than one percent per year, if visits had been distributed in the same manner as the population, about one-third of visits would have occurred each year. A little over half of the annual visits were by women. The age distribution of patient visits was similar across the three years. (Table 3)

Average Daily Visits: Total, Cardiovascular and Respiratory

2012. The primary analysis compares the number of average daily visits before the wildfires to the number of average daily visits during and after the fires in 2012. In these comparisons, the number of average daily visits in the period before the wildfires represents the usual or baseline number. If conditions that result in ED and outpatient visits for CVD and respiratory disease were similar across the entire time period except for the deterioration in air quality (as measured by $PM_{2.5}$) during and after the fires, then any change in the number of visits during and after compared to before the fires might be related to the change in air quality caused by the fires.

Compared to before the wildfires, the total number of average daily visits for CVD and respiratory disease during the wildfires was about 28 percent higher resulting in an average increase of 135 visits each day for the 34-day period. Increases beyond what might be expected due to random variation ranged from about 16 percent for CVD to double (100 percent increase) for children's respiratory visits. These increases persisted, but were smaller during the 19 days immediately following the fires when total average daily visits for CVD and respiratory disease increased by 18 percent resulting in an average of 87 more visits daily. The largest increase (63 percent) continued to be for respiratory diseases in children. (Table 4)

2010 and 2011. The number of average daily visits in 2010 and 2011 help to interpret the 2012 findings. First and similar to the primary analysis, we compared the number of average daily visits in the period corresponding to before the wildfires to the number of average daily visits in the periods corresponding to during and after the fires using 2010 and 2011 data combined.

As in 2012, in 2010 and 2011 combined, the numbers of average daily visits were higher in the periods corresponding to during and after the fires than before. The same was true for 2012. Overall, there was an

average of 87 more visits (19 percent increase) in the period corresponding to during and 52 more visits (11 percent increase) in the period corresponding to after the fires than in the period corresponding to before the fires. These increases suggest that part of the overall increases during and after the 2012 fires were due to seasonal variation. ED and outpatient visits for CVD and respiratory disease might usually increase from summer into early fall due to changing air quality related to blowing dust, pollen, or temperature inversions, for example. Based on the 2010–2011 findings, about 87 of the 136 excess daily visits during the 2012 fires compared to before the fires might have been due to seasonal variation, while the remaining almost 50 daily extra visits could have been the result of poor air quality caused by the fires.

The 2010–2011 data showed increases in visits for the separate categories of CVD and the different age groups that for the most part were similar to the increases seen in 2012. These findings suggest that many of the increases in 2012 were seasonal. The strongest potential for a non-seasonal increase related to the fires might be for respiratory disease in children. With almost the same numbers of average daily visits in the before periods, there were an average of 45 excess visits daily in 2012 compared to 22 extra visits in 2010–2011. (Tables 4 and 5).

Comparing results for 2010–2011 to results for 2012, it is difficult to determine whether the fires might have impacted adult visits for respiratory disease. The patterns of statistically significant increases (i.e. greater than expected by random variation) in visits by adults ages 19–64 and non-significant increases (i.e. not greater than expected by chance) in the older adults were similar in 2010–2011 and 2012. The similar findings suggest that the increased visits for adults after the fires were not fire-related.

The increases in adult visits for respiratory disease during, compared to before the fires, were greater than expected by chance in 2012, but not in 2010–2011. This might suggest that the visits among adults were fire-related, especially given the relative size of the increase in average daily visits in 2012 compared to 2010–2011. This interpretation is tempered, though, due to the O/E for older adults being only marginally different from that expected by chance in 2012 and the O/E for adults ages 19–64 being only marginally non-significant in 2010–2011. The findings for adult respiratory disease discussed below (Table 6) also temper the conclusion that visits for adult respiratory disease during the fires were fire-related.

Table 4. Outpatient visits for cardiovascular (CVD) and respiratory disease[1] before the 2012 wildfires in north central Washington compared to during and after the 2012 fires.

Diagnosis group	Age group	Before (15 days: 8/25–9/8)		During (34 days: 9/9–10/12)		Before to During Comparisons			After (19 days: 10/13–10/31)		Before to After Comparisons		
		Visits		Visits					Visits				
		Num-ber	Aver-age daily	Number	Aver-age daily	Excess[2]	O/E[3]	95% CI[4]	Num-ber	Aver-age daily	Excess[2]	O/E[3]	95% CI[4]
Total	All	7241	483	21014	618	135	**1.28**	1.18-1.39	10830	570	87	**1.18**	1.09-1.28
	0–18	686	46	3087	91	45	**1.99**	1.60-2.44	1409	74	28	**1.62**	1.27-2.04
	19–64	2591	173	7188	211	39	**1.22**	1.06-1.40	3766	198	25	1.15	0.99-1.32
	65+	3964	264	10739	316	52	**1.20**	1.07-1.33	5655	298	33	**1.13**	1.00-1.26
CVD	All	4682	312	12292	362	49	**1.16**	1.04-1.28	6410	337	25	1.08	0.97-1.20
	19–64	1387	92	3554	105	12	1.13	0.92-1.37	1845	97	5	1.05	0.85-1.28
	65+	3284	219	8717	256	37	**1.17**	1.03-1.32	4548	239	20	1.09	0.96-1.24
Respiratory	All	2559	171	8722	257	86	**1.50**	1.33-1.70	4420	233	62	**1.36**	1.19-1.55
	0–18	675	45	3066	90	45	**2.00**	1.61-2.46	1392	73	28	**1.63**	1.28-2.05
	19–64	1204	80	3634	107	27	**1.33**	1.09-1.61	1921	101	21	**1.26**	1.03-1.53
	65+	680	45	2022	59	14	**1.31**	1.00-1.68	1107	58	13	1.29	0.98-1.66

[1] Cardiovascular (ICD-9-CM 390-459) or respiratory (ICD-9-CM 460-519 and 786) disease listed as first diagnosis. About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms. Numbers might not add or subtract due to rounding and omission of children in CVD category due to small numbers (11 before, 21 during and 17 after the fires).

[2] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period.

[3] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolded O/Es are statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[4] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 5. Outpatient visits for cardiovascular (CVD) and respiratory disease[1] in 2010 and 2011 combined for periods corresponding to before, during, and after the 2012 wildfires.

Diagnosis group	Age group	Before (30 days: 8/25–9/8)		During (68 days: 9/9–10/12)		Before to During Comparisons			After (38 days: 10/13–10/31)		Before to After Comparisons		
		Visits		Visits					Visits				
		Num-ber	Average daily	Num-ber	Averag e daily	Excess[2]	O/E[3]	95% CI[4]	Num-ber	Average daily	Excess[2]	O/E[3]	95% CI[4]
Total	All	13632	454	36812	541	87	**1.19**	1.09-1.30	19247	507	52	**1.11**	1.02-1.22
	0–18	1436	48	4738	70	22	**1.46**	1.13-1.84	2321	61	13	1.28	0.98-1.64
	19–64	4828	161	12645	186	25	1.16	1.00-1.33	6995	184	23	1.14	0.98-1.32
	65+	7368	246	19429	286	40	**1.16**	1.03-1.31	9931	261	16	1.06	0.94-1.20
CVD	All	8698	290	22382	329	39	**1.14**	1.02-1.26	11347	299	9	1.03	0.92-1.15
	19–64	2665	89	6551	96	8	1.08	0.88-1.32	3387	89	0	1.00	0.81-1.23
	65+	5997	200	15763	232	32	**1.16**	1.02-1.32	7929	209	9	1.04	0.91-1.20
Respiratory	All	4934	164	14430	212	48	**1.29**	1.12-1.48	7900	208	43	**1.26**	1.10-1.45
	0–18	1400	47	4670	69	22	**1.47**	1.14-1.86	2290	60	14	1.29	0.99-1.66
	19–64	2163	72	6094	90	18	1.24	1.00-1.53	3608	95	23	**1.32**	1.06-1.61
	65+	1371	46	3666	54	8	1.18	0.89-1.54	2002	53	7	1.15	0.86-1.51

[1] Cardiovascular (ICD-9-CM 390-459) or respiratory (ICD-9-CM 460-519 and 786) disease listed as first diagnosis. About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms. Numbers might not add or subtract due to rounding and omission of children in CVD category due to small numbers.

[2] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period corresponding to before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[3] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[4] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

The second analysis with the 2010 and 2011 data uses these data as the baseline and compares average daily visits in 2010–2011 to average daily visits in 2012 for each of the three periods. If the wildfires caused the increase in average daily visits for CVD and respiratory disease seen during and after the wildfires, one would expect excess visits in 2012 compared to corresponding periods in 2010–2011 during and after the fires, but similar numbers of average daily visits in the period before the fires.

Table 6. Outpatient visits for cardiovascular (CVD) and respiratory disease[1] before, during, and after the 2012 wildfires compared to the same periods in 2010 and 2011 combined.

6a. Before: August 25–September 8

Diagnosis group[1]	Age group	2010 and 2011 combined (30 days)		2012 (15 days)	Comparisons: 2012 to 2011 and 2010 combined		
		Visits					
		Number	Average daily	Average daily	Excess[2]	O/E[3]	95% CI[4]
Total	All	13632	454	483	28	1.06	0.97-1.16
	0–18	1436	48	46	-2	0.96	0.70-1.27
	19–64	4828	161	173	12	1.07	0.92-1.25
	65+	7368	246	264	19	1.08	0.95-1.21
CVD	All	8698	290	312	22	1.08	0.96-1.20
	19–64	2665	89	92	4	1.04	0.84-1.28
	65+	5997	200	219	19	1.10	0.95-1.25
Respiratory	All	4934	164	171	6	1.04	0.89-1.21
	0–18	1400	47	45	-2	0.96	0.70-1.29
	19–64	2163	72	80	8	1.11	0.88-1.39
	65+	1371	46	45	-0	0.99	0.72-1.33

[1] Cardiovascular (ICD-9-CM 390-459) or respiratory (ICD-9-CM 460-519 and 786) disease listed as first diagnosis. About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms. Numbers might not add or subtract due to rounding and omission of children in CVD category due to small numbers.
[2] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in 2010-2011 from the average number of daily visits in 2012.
[3] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).
[4] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding, a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

6b. During: September 9–October 12

Diagnosis group[1]	Age group	2010 and 2011 combined (68 days)		2012 (34 days)	Comparisons of 2012 to 2011 and 2010 combined		
		Visits					
		Number	Average daily	Average daily	Excess[2]	O/E[3]	95% CI[4]
Total	All	36812	541	618	77	**1.14**	1.05-1.24
	0–18	4738	70	91	21	**1.30**	1.05-1.60
	19–64	12645	186	211	25	1.14	0.99-1.30
	65+	19429	286	316	30	1.11	0.99-1.23
CVD	All	22382	329	362	32	1.10	0.99-1.22
	19–64	6551	96	105	8	1.09	0.89-1.31
	65+	15763	232	256	25	1.11	0.97-1.25
Respiratory	All	14430	212	257	44	**1.21**	1.07-1.37
	0–18	4670	69	90	22	**1.31**	1.06-1.61
	19–64	6094	90	107	17	1.19	0.98-1.44
	65+	3666	54	59	6	1.10	0.82-1.42

[1] Cardiovascular (ICD-9-CM 390-459) or respiratory (ICD-9-CM 460-519 and 786) disease listed as first diagnosis. About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms. Numbers might not add or subtract due to rounding and omission of children in CVD category due to small numbers.
[2] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in 2010-2011 from the average number of daily visits in 2012.
[3] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).
[4] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

6c. After: October 13–October 31

Diagnosis group[1]	Age group	2010 and 2011 combined (38 days)		2012 (19 days)	Comparisons: 2012 to 2011 and 2010 combined		
		Visits					
		Number	Average daily	Average daily	Excess[2]	O/E[3]	95% CI[4]
Total	All	19247	507	570	64	**1.13**	1.03-1.22
	0–18	2321	61	74	13	1.21	0.95-1.52
	19–64	6995	184	198	14	1.08	0.93-1.24
	65+	9931	261	298	36	**1.14**	1.01-1.28
CVD	All	11347	299	337	39	**1.13**	1.01-1.26
	19–64	3387	89	97	8	1.09	0.88-1.33
	65+	7929	209	239	31	**1.15**	1.01-1.30
Respiratory	All	7900	208	233	25	1.12	0.98-1.27
	0–18	2290	60	73	13	1.22	0.95-1.53
	19–64	3608	95	101	6	1.06	0.87-1.29
	65+	2002	53	58	6	1.11	0.84-1.43

[1] Cardiovascular (ICD-9-CM 390-459) or respiratory (ICD-9-CM 460-519 and 786) disease listed as first diagnosis. About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms. Numbers might not add or subtract due to rounding and omission of children in CVD category due to small numbers.
[2] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in 2010-2011 from the average number of daily visits in 2012.
[3] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).
[4] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 6a shows a six percent increase in average daily visits for all diagnoses combined in the before period, but this increase was not larger than might be expected due to normal random variation or chance. In contrast, the increases in the during (14 percent) and after (13 percent) periods were larger than expected from random variation. (Tables 6b and 6c, respectively)

While average daily visits for respiratory disease in children were similar in the before and after periods, this group experienced larger than expected increases during the fires that could not be explained by chance when compared to the corresponding period in 2010–2011. These findings support the conclusion that the increase in visits for respiratory disease in children could have been caused by the fires. The overall increase in respiratory visits for all age groups combined was primarily due to the increases among children. Increases in respiratory visits for adults were not larger than expected by chance during the 2012 fires compared to the corresponding period in 2010–2011.

Compared to the corresponding period in 2010–2011, CVD visits among adults ages 65 and older were similar in the before and during periods, but larger than expected by chance after the fires. (Tables 6a, 6b and 6c). This might suggest a late effect of the fires on CVD in older adults; however, this interpretation of the findings is not supported by the findings for 2012, which did not show an increase greater than expected by chance for older adults after the fires compared to before the fires. (Table 4) Additionally, while the 15 percent increase after the fires—which is only marginally different from that expected by chance— is 50 percent higher than the 10 percent increase in the period before the fires, in absolute terms, the 10 and 15 percent can be viewed as similar.

Average Daily Visits: Subcategories of Cardiovascular Disease

When analyzing CVD by individual subcategories, the percent increase in visits in each subcategory during and after compared to before the 2012 fires were within what would be expected by chance (Tables 7a and 7b). Visits for hypertension and irregular heart rhythm (dysrhythmia) had the largest increase in numbers of average daily visits during compared to before the fires, but similar increases are apparent during the corresponding baseline period in 2010–2011. This makes interpretation of the observed increases for CVD subcategories difficult, but indicates that no one individual CVD subcategory stood out as more impacted during or after the fires.

Average Daily Visits: Subcategories of Respiratory Disease

Acute Respiratory Infections. For all ages combined, acute respiratory infection diagnosis had the largest increase in average daily visits accounting for 36 of the 135 total daily excess visits during the 2012 wildfires compared to before. The largest increase was observed among children ages 0-18. Acute respiratory infections also accounted for 32 of the 87 excess total daily visits in the 19 days after the fires. However, similar increases in 2010–2011 make it less likely that the increases in 2012 were solely related to the fires. In contrast, the increases in children's visits measured by both excess daily visits and O/Es during and after the 2012 fires are larger than those seen in corresponding periods in 2010–2011, suggesting that some of these increases might have been fire-related. (Tables 8a and 8b)

Asthma. Visits for asthma for all age groups combined were about 88 percent higher during the 2012 fires compared to before the 2012 fires, with visits among children more than doubling. Unlike the comparable analysis using the 2010–2011 data, these increases were higher than expected by chance suggesting that they might have been fire-related. Visits for asthma were not higher after the fires compared to before. (Tables 8a and 8b).

Respiratory and chest symptoms. Visits for respiratory and chest symptoms were about 37 percent higher during compared to before the 2012 fires with visits among children more than doubling. These increases were higher than expected by chance. Visits in the corresponding periods in 2010–2011 did not differ from what might have been expected by chance suggesting that excess visits for respiratory and chest symptoms during the 2012 fires might have been fire-related. Visits for respiratory and chest symptoms were not higher after the files compared to before. (Tables 8a and 8b)

Chronic obstructive pulmonary disease (COPD) excluding asthma. This subcategory includes a variety of airway disease. Combining all years and periods, the vast majority of diagnoses in this category (about 60 percent) were chronic airway obstruction not elsewhere classified; about 20 percent were bronchitis not specified as acute or chronic and 12 percent were chronic bronchitis. In 2012, visits for COPD for all age groups combined were about 60 percent higher during and after the fires compared to

before. These increases were larger than expected by chance. COPD visits were also higher after the fires compared to before for all age groups combined. Visits in the corresponding periods in 2010–2011 were not higher than expected suggesting that the increase in 2012 visits for COPD might have been fire-related. (Tables 8a and 8b)

Table 7a. Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis) before the 2012 wildfires in north central Washington (15 days: 8/25–9/8) compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Acute rheumatic fever and chronic rheumatic heart disease (ICD-9-CM 390-398)												
All	7	0	23	1	0	1.45	0.04-10.28	7	0	-0	0.79	0.02-8.63
Hypertensive disease (ICD-9-CM 401-405)												
All	1794	120	4782	141	21	1.18	0.99-1.39	2504	132	12	1.10	0.92-1.31
19–64	642	43	1733	51	8	1.19	0.89-1.57	870	46	3	1.07	0.78-1.43
65+	1148	77	3045	90	13	1.17	0.94-1.44	1629	86	9	1.12	0.90-1.38
Heart attack (myocardial infarction, ICD-9-CM 410)												
All	27	2	89	3	1	1.45	0.26-4.53	39	2	0	1.14	0.16-4.10
19–64	8	1	28	1	0	1.54	0.04-9.48	12	1	0	1.18	0.03-8.51
65+	19	1	61	2	1	1.42	0.16-5.44	27	1	0	1.12	0.09-4.92
Ischemic heart disease excluding heart attack (ICD-9-CM 411-414)												
All	265	18	717	21	3	1.19	0.74-1.82	365	19	2	1.09	0.63-1.66
19–64	69	5	168	5	0	1.07	0.34-2.51	90	5	0	1.03	0.32-2.44
65+	196	13	548	16	3	1.23	0.71-2.00	266	14	1	1.07	0.59-1.80

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 7a (continued). Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis) before the 2012 wildfires in north central Washington (15 days: 8/25–9/8) compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Diseases of the pulmonary circulation (ICD-9-CM 415-417)												
All	144	10	404	12	2	1.24	0.64-2.17	268	14	5	1.47	0.81-2.46
19–64	56	4	151	4	1	1.19	0.35-2.90	106	6	2	1.49	0.53-3.35
65+	88	6	253	7	2	1.27	0.52-2.55	162	9	3	1.45	0.65-2.80
Other forms of heart disease excluding conduction disorders, dysrhythmia and heart failure (ICD-9-CM 420-425, 429)												
All	199	13	538	16	3	1.19	0.68-1.94	256	13	0	1.02	0.55-1.72
19–64	60	4	166	5	1	1.22	0.39-2.88	84	4	0	1.11	0.33-2.70
65+	136	9	370	11	2	1.20	0.60-2.16	171	9	-0	0.99	0.45-1.88
Conduction disorders (ICD-9-CM 426)												
All	16	1	35	1	-0	0.97	0.02-5.22	28	1	0	1.38	0.13-6.00
Irregular heart rhythms (cardiac dysrhythmias, ICD-9-CM 427)												
All	1334	89	3496	103	14	1.16	0.94-1.40	1871	98	10	1.11	0.90-1.35
19–64	189	13	484	14	2	1.13	0.62-1.88	284	15	2	1.19	0.66-1.95
65+	1143	76	3009	89	12	1.16	0.93-1.43	1585	83	7	1.09	0.87-1.36

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 7a (continued). Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis) before the 2012 wildfires in north central Washington (15 days: 8/25–9/8) compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Heart failure (ICD-9-CM 428)												
All	79	5	221	7	1	1.23	0.48-2.61	140	7	2	1.40	0.58-2.84
19–64	16	1	34	1	-0	0.94	0.02-5.22	20	1	-0	0.99	0.04-5.38
65+	63	4	187	6	1	1.31	0.46-2.94	120	6	2	1.50	0.57-3.21
Stroke (cerebrovascular disease, ICD-9-CM 430-438)												
All	156	10	347	10	-0	0.98	0.47-1.79	200	11	0	1.01	0.49-1.83
19–64	55	4	104	3	-1	0.83	0.18-2.43	66	3	-0	0.95	0.23-2.59
65+	101	7	242	7	0	1.06	0.43-2.16	134	7	0	1.05	0.43-2.16
Diseases of arteries, arterioles and capillaries (ICD-9-CM 440-449)												
All	197	13	507	15	2	1.14	0.63-1.87	201	11	-3	0.81	0.40-1.46
19–64	62	4	150	4	0	1.07	0.32-2.62	59	3	-1	0.75	0.16-2.16
65+	135	9	352	10	1	1.15	0.56-2.10	141	7	-2	0.82	0.34-1.66
Diseases of veins and lymphatics and other diseases of the circulatory system (ICD-9-CM 451-459)												
All	464	31	1133	33	3	1.08	0.74-1.51	540	28	-3	0.92	0.61-1.32
19–64	219	15	516	15	1	1.04	0.59-1.71	236	12	-2	0.85	0.44-1.47
65+	243	16	612	18	2	1.11	0.66-1.76	297	16	-1	0.96	0.55-1.57

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 7b. Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days: 8/25 – 9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13-10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Acute rheumatic fever and chronic rheumatic heart disease (ICD-9-CM 390-398)												
All	12	0	23	0	-0	0.85		7	0	-0	0.46	
Hypertensive disease (ICD-9-CM 401-405)												
All	3090	103	8448	124	21	**1.21**	1.00-1.44	4379	115	12	1.12	0.92-1.34
19–64	1261	42	3180	47	5	1.11		1688	44	2	1.06	
65+	1820	61	5251	77	17	**1.27**	1.00-1.59	2687	71	10	1.17	0.91-1.47
Heart attack (myocardial infarction, ICD-9-CM 410)												
All	25	1	57	1	0	1.01		31	1	-0	0.98	
19–64	16	1	30	0	-0	0.83		11	0	-0	0.54	
65+	9	0	27	0	0	1.32		20	1	0	1.75	
Ischemic heart disease excluding heart attack (ICD-9-CM 411-414)												
All	544	18	1597	23	5	1.30		727	19	1	1.06	
19–64	138	5	395	6	1	1.26		201	5	1	1.15	
65+	405	14	1202	18	4	1.31		526	14	0	1.03	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period corresponding to before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

Table 7b (continued). Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days: 8/25 – 9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13-10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Diseases of the pulmonary circulation (ICD-9-CM 415-417)												
All	300	10	761	11	1	1.12		385	10	0	1.01	
19–64	125	4	294	4	0	1.04		164	4	0	1.04	
65+	175	6	467	7	1	1.18		221	6	-0	1.00	
Other forms of heart disease excluding conduction disorders, dysrhythmia and heart failure (ICD-9-CM 420-425, 429)												
All	572	19	1362	20	1	1.05		668	18	-1	0.92	
19–64	165	6	424	6	1	1.13		206	5	-0	0.99	
65+	406	14	932	14	0	1.01		460	12	-1	0.89	
Conduction disorders (ICD-9-CM 426)												
All	21	1	70	1	0	1.47		35	1	0	1.32	
Irregular heart rhythms (cardiac dysrhythmias, ICD-9-CM 427)												
All	2451	82	6108	90	8	1.10		3115	82	0	1.00	
19–64	318	11	858	13	2	1.19		408	11	0	1.01	
65+	2128	71	5243	77	6	1.09		2705	71	0	1.00	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period corresponding to before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

Table 7b (continued). Outpatient visits for subcategories of cardiovascular disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days: 8/25 – 9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13-10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Heart failure (ICD-9-CM 428)												
All	175	6	479	7	1	1.21		232	6	0	1.05	
19–64	23	1	65	1	0	1.25		39	1	0	1.34	
65+	152	5	414	6	1	1.20		193	5	0	1.00	
Stroke (cerebrovascular disease, ICD-9-CM 430-438)												
All	302	10	724	11	1	1.06		363	10	-1	0.95	
19–64	87	3	185	3	-0	0.94		89	2	-1	0.81	
65+	214	7	537	8	1	1.11		273	7	0	1.01	
Diseases of arteries, arterioles and capillaries (ICD-9-CM 440-449)												
All	340	11	781	11	0	1.01		391	10	-1	0.91	
19–64	121	4	258	4	-0	0.94		125	3	-1	0.82	
65+	213	7	509	7	0	1.05		255	7	-0	0.95	
Diseases of veins and lymphatics and other diseases of the circulatory system (ICD-9-CM 451-459)												
All	866	29	1972	29	0	1.00		1014	27	-2	0.92	
19–64	402	13	837	12	-1	0.92		443	12	-2	0.87	
65+	452	15	1116	16	1	1.09		561	15	-0	0.98	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period corresponding to before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

Table 8a. Outpatient visits for subcategories of respiratory disease (listed as first diagnosis) before (15 days: 8/25–9/8) the 2012 wildfires in north central Washington compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Acute respiratory infections (ICD-9-CM 460-466)												
All	795	53	3011	89	36	**1.67**	1.34-2.06	1619	85	32	**1.61**	1.28-1.99
0–18	378	25	1687	50	24	**1.97**	1.46-2.60	811	43	17	**1.69**	1.22-2.28
19–64	342	23	1108	33	10	1.43	0.98-2.01	627	33	10	1.45	1.00-2.03
65+	75	5	216	6	1	1.27	0.49-2.72	181	10	5	1.91	0.89-3.55
Other diseases of the upper respiratory tract (ICD-9-CM 470-478)												
All	471	31	1347	40	8	1.26	0.90-1.72	646	34	3	1.08	0.75-1.51
0–18	89	6	355	10	5	1.76	0.86-3.19	140	7	1	1.24	0.52-2.52
19–64	279	19	722	21	3	1.14	0.71-1.74	385	20	2	1.09	0.67-1.68
65+	103	7	270	8	1	1.16	0.49-2.28	121	6	-0	0.93	0.36-1.98
Pneumonia and influenza (ICD-9-CM 480-488)												
All	83	6	213	6	1	1.13	0.43-2.43	108	6	0	1.03	0.37-2.28
0–18	17	1	71	2	1	1.84	0.25-6.51	30	2	0	1.39	0.14-5.79
19–64	38	3	82	2	-0	0.95	0.16-3.10	33	2	-1	0.69	0.07-2.66
65+	28	2	60	2	-0	0.95	0.11-3.69	45	2	1	1.27	0.21-4.20

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 8a (continued). Outpatient visits for subcategories of respiratory disease (listed as first diagnosis) before (15 days: 8/25–9/8) the 2012 wildfires in north central Washington compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Chronic obstructive pulmonary disease and allied conditions excluding asthma (ICD-9-CM 490-492, 494-496)												
All	252	17	912	27	10	**1.60**	1.05-2.32	501	26	10	**1.57**	1.03-2.30
0–18	10	1	63	2	1	2.78	0.33-10.59	44	2	2	3.47	0.53-11.53
19—64	81	5	314	9	4	1.71	0.79-3.21	193	10	5	1.88	0.91-3.45
65+	161	11	535	16	5	1.47	0.83-2.39	264	14	3	1.29	0.71-2.18
Asthma (ICD-9-CM 493)												
All	256	17	1090	32	15	**1.88**	1.29-2.65	430	23	6	1.33	0.84-1.99
0–18	94	6	450	13	7	**2.11**	1.13-3.59	161	8	2	1.35	0.60-2.62
19–64	127	8	501	15	6	1.74	0.97-2.88	206	11	2	1.28	0.63-2.29
65+	35	2	139	4	2	1.75	0.49-4.45	63	3	1	1.42	0.33-3.95
Pneumoconiosis and other lung diseases due to external agents (ICD-9-CM 500-508)												
All	16	1	49	1	0	1.35	0.11-5.84	14	1	-0	0.69	0.02-4.50

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

Table 8a (continued). Outpatient visits for subcategories of respiratory disease (listed as first diagnosis) before (15 days: 8/25–9/8) the 2012 wildfires in north central Washington compared to during (34 days: 9/9–10/12) and after (19 days: 10/13–10/31).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Other diseases of the respiratory system (ICD-9-CM 510-519)												
All	77	5	203	6	1	1.16	0.43-2.54	101	5	0	1.04	0.35-2.35
0–18	4	0	16	0	0	1.76	0.05-16.06	16	1	1	3.16	0.08-18.96
19–64	25	2	68	2	0	1.20	0.15-4.33	40	2	0	1.26	0.17-4.43
65+	48	3	119	4	0	1.09	0.27-2.97	45	2	-1	0.74	0.12-2.45
Symptoms involving the respiratory system and other chest symptoms (ICD-9-CM 786)[4]												
All	609	41	1897	56	15	**1.37**	1.04-1.79	1001	53	12	1.30	0.97-1.70
0–18	83	6	421	12	7	**2.24**	1.17-3.88	190	10	4	1.81	0.87-3.32
19–64	306	20	814	24	4	1.17	0.75-1.74	435	23	2	1.12	0.71-1.69
65+	220	15	662	19	5	1.33	0.81-2.06	376	20	5	1.35	0.82-2.09

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998.

[4] About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms.

Table 8b. Outpatient visits for subcategories of respiratory disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days; 8/25-9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13 -10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Acute respiratory infections (ICD-9-CM 460-466)												
All	1754	58	5932	87	29	**1.49**	1.19-1.84	3413	90	31	**1.54**	1.23-1.89
0–18	851	28	2940	43	15	**1.52**	1.10-2.05	1470	39	10	1.36	0.97-1.87
19–64	716	24	2426	36	12	**1.49**	1.05-2.07	1551	41	17	**1.71**	1.23-2.32
65+	187	6	566	8	2	1.34	0.59-2.59	392	10	4	1.65	0.8-3.01
Other diseases of the upper respiratory tract (ICD-9-CM 470-478)												
All	909	30	2317	34	4	1.12		1163	31	0	1.01	
0–18	251	8	732	11	2	1.29		327	9	0	1.03	
19–64	492	16	1179	17	1	1.06		621	16	-0	1.00	
65+	166	6	406	6	0	1.08		215	6	0	1.02	
Pneumonia and influenza (ICD-9-CM 480-488)												
All	133	4	393	6	1	1.30		220	6	1	1.31	
0–18	30	1	101	1	0	1.49		46	1	0	1.21	
19–64	52	2	126	2	0	1.07		90	2	1	1.37	
65+	51	2	166	2	1	1.44		84	2	1	1.30	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

Table 8b (continued). Outpatient visits for subcategories of respiratory disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days; 8/25-9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13 -10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Chronic obstructive pulmonary disease and allied conditions excluding asthma (ICD-9-CM 490-492, 494-496)												
All	462	15	1314	19	4	1.25	0.76-1.95	758	20	5	1.30	0.79-2.00
0–18	10	0	49	1	0	2.16		24	1	0	1.89	
19–64	149	5	405	6	1	1.20		259	7	2	1.37	
65+	303	10	860	13	3	1.25		475	13	2	1.24	
Asthma (ICD-9-CM 493)												
All	442	15	1339	20	5	1.34	0.81-2.07	698	18	4	1.25	0.75-1.96
0–18	165	6	529	8	2	1.41	0.60-2.82	263	7	1	1.26	0.5-2.60
19–64	204	7	579	9	2	1.25		320	8	2	1.24	
65+	73	2	231	3	1	1.40		115	3	1	1.24	
Pneumoconiosis and other lung diseases due to external agents (ICD-9-CM 500-508)												
All	4	0	26	0	0	2.87		11	0	0	2.17	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

Table 8b (continued). Outpatient visits for subcategories of respiratory disease (listed as first diagnosis), 2010-2011 period corresponding to before the wildfires (30 days; 8/25-9/8, 2010 & 2011) in north central Washington compared to periods corresponding to during (68 days: 9/9-10/12, 2010 & 2011) and after (38 days: 10/13 -10/31, 2010 & 2011).

Age group	Visits Before		Visits During		Before to During Comparisons			Visits After		Before to After Comparisons		
	Number	Average daily	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]	Number	Average daily	Excess[1]	O/E[2]	95% CI[3]
Other diseases of the respiratory system (ICD-9-CM 510-519)												
All	132	4	320	5	0	1.07		155	4	-0	0.93	
0–18	14	0	19	0	-0	0.60		17	0	-0	0.96	
19–64	38	1	107	2	0	1.24		55	1	0	1.14	
65+	80	3	194	3	0	1.07		83	2	-0	0.82	
Symptoms involving the respiratory system and other chest symptoms (ICD-9-CM 786)												
All	1098	37	2789	41	4	1.12	0.80-1.52	1482	39	2	1.07	0.76-1.46
0–18	79	3	299	4	2	1.67	0.49-4.11	143	4	1	1.43	0.38-3.78
19–64	510	17	1261	19	2	1.09		711	19	2	1.10	
65+	509	17	1229	18	1	1.07		628	17	-0	0.97	

[1] Excess represents the excess number of average daily visits calculated by subtracting the average number of daily visits in the period before the wildfires from the average number of daily visits during the specified period; subtraction might not look accurate due to rounding.

[2] O/E: ratio of observed number of average daily visits to the expected number based on average daily visits in the period corresponding to before the wildfires; bolding indicates the O/E is statistically significant at $p<0.05$ (i.e. the O/E is outside the range we might expect through random variation or chance).

[3] 95% CI: 95% confidence interval around O/E. If the CI includes one, the O/E is not outside the range we expect by chance alone. Due to rounding a CI of 1.00 might be either greater or less than one, e.g., 1.004 or 0.9998. CI calculated only for subcategories with statistically significant O/Es in Table 7a.

[4] About half of ICD-9-CM 786 (included here with respiratory disease) is CVD symptoms.

Average Daily Visits: Summary

This surveillance study found increased visits for both CVD and respiratory disease during and after the 2012 wildfires in north central Washington compared to before the fires. However, consideration of the 2010–2011 findings suggests that some of the increase was seasonal and, thus, not related to the fires. For example, about 87 of the 135 excess daily visits during the 2012 fires compared to before the fires might have been due to seasonal variation, while the remaining almost 50 daily extra visits could have resulted from poor air quality caused by the fires. Similarly, about half of the increase in visits for respiratory disease among children during the fires might have been due to seasonal variation unrelated to the fires.

Among subcategories of CVD and respiratory disease, some of the increases in ED and outpatient visits for asthma, respiratory and chest symptoms, and acute respiratory infections during the fires might have been fire-related. For all three of these conditions, increases in children accounted for large portions—if not all—of the overall increase. A portion of the increased visits for COPD excluding asthma both during and after the fires might also have been related to the fires.

Discussion

The 2012 wildfires resulted in sustained smoky conditions with high levels of $PM_{2.5}$ over a large portion of north central Washington. The average of the 24-hour average $PM_{2.5}$ levels during the wildfires ranged from Ecology's unhealthy for sensitive groups category to hazardous at all air monitors except for the monitor at Moses Lake where average air quality was in the moderate category. Peak levels at all air monitors except Moses Lake were in the unhealthy ranges or higher on both Ecology's WAQA and EPA's AQI.

A complete review of the literature to assess consistency of findings with similar studies is beyond the scope of this project. Based on a recent systematic review[3], the findings from this study are consistent with findings from other studies showing an association between wildfire smoke and increased morbidity from respiratory disease. The review cites one study that found increases in asthma visits on fire days, but no increases on non-fire days. This finding is also consistent with the findings from this study showing elevated asthma visits during the fires. In addition to asthma, the review cites associations between wildfire smoke and morbidity from cough, wheeze and eye irritation, but does not provide detail on subcategories of respiratory disease to allow comparisons to our study.

Compared to studies looking at respiratory disease, the review found fewer studies of the association between wildfire smoke and CVD. Five of six studies conducted in the United States showed an association between wildfire smoke and CVD hospitalizations or ED visits. Of seven studies conducted in Australia or Canada, none showed a significant association of wildfire smoke and CVD morbidity.

This surveillance study has several limitations some of which could be addressed by a more rigorous research study that includes additional years of data. Some of the limitations could be addressed by reanalysis of the current data. Most importantly, the current study did not distinguish visits that might have been related to smoke exposure from those that were not. Aspects of this general limitation include:

1. The focus on the five-county area might dilute an effect that would be evident if we had focused on visits from people living in the areas most impacted by the fires. Including visits in highly impacted counties along with visits in counties that were less impacted by smoke might have resulted in a failure to find impacts or an underestimation of impacts.

2. An advantage of this study was the extensive number of air monitors collecting $PM_{2.5}$ levels during the wildfires that likely provided a fairly good estimate of smoke exposures to people in the area. However, even within a county, exposures can vary depending on one's location and short exposures to high levels of $PM_{2.5}$ can trigger some health events. There were likely areas within the counties that had air with lower levels of $PM_{2.5}$ measured by monitors and there might have been some areas with higher levels that were not monitored. Models could, perhaps, estimate $PM_{2.5}$ levels more accurately for smaller areas across the five counties and help provide better information about people's exposures to smoke.

3. We did not try to account for day-to-day fluctuations in air quality. We might have found stronger relationships between air quality and visits if we had looked at visits (and lagged visits) in relation to daily $PM_{2.5}$ levels rather than combining visits across all days of a period.

4. We did not collect information about localized or regional conditions in 2010–2011 that might have affected visits. For example, were pollen or heat particularly high in 2010 or 2011 in the periods corresponding to during or after the fires? Pollen and heat can also affect CVD and respiratory conditions

As discussed in Methods, the data and original analysis included a number of limitations.

1. The format in which most of the data were arranged prevented distinguishing the primary diagnosis from subsequent diagnoses. For example, someone with a clinic visit for diabetes who also happened to have a cough would have, for the most part, been included with a first diagnosis of cough. The one facility that allowed us to distinguish primary from subsequent reasons for visits showed almost 20 percent of visits with a primary diagnosis other than CVD or respiratory disease. It is unclear the extent to which the inability to distinguish primary from subsequent diagnosis might have biased the findings.

2. Several facilities failed to send the full range of requested ICD-9-CM codes. Since some of the codes were missing for all years during all periods, these omissions reduce the study's power because the smaller the number of visits, the larger the differences need to be to achieve statistically significant results. If all of the data had been sent, there would have been more visits and some of the marginal findings might have become statistically significant.

3. Respiratory and chest symptoms were combined with respiratory disease. Some of these visits could have been for CVD-related symptoms. For example, it is difficult to know the extent of misclassification in the over 4,000 visits for chest pain (ICD-9-CM 786.5). Additional analysis would be needed to determine how assigning these visits to CVD would change the findings. This misclassification does not affect the subcategory analyses.

4. The original analysis combined all children into one category. Because older children are more similar to adults than to younger children in terms of breathing rates, lung development, and physical size, combining everyone through age 18 into one group might have obscured findings for younger children. If there are sufficient numbers of visits, future analyses could separate children into two or more age groups.

5. Because of the surveillance methodology used in this study, we did not distinguish between people with preexisting disease and those with no preexisting disease, which would be important for

targeting public health messages. Additional patient information would have had to be collected in order to identify preexisting disease.

6. Patients included in this analysis may not be representative of the regional population impacted by wildfire smoke. A number of area medical facilities, including hospitals and community clinics, were not included in this analysis. Our results might have been different if we had included groups who use other medical facilities. For example, patients assigned to federally qualified health centers tend to represent a larger proportion of migrant farm workers, who may have been under-represented in our study.
7. Because comparing O/Es is difficult (see Methods section), some findings in this surveillance study are not easy to interpret. If this study is repeated, developing rates of outpatient visits might offer an approach that would make the study more robust and interpretation of findings more straightforward. However, an analysis that included rates would need to account for seasonal variation in population in the study area as many people have second homes or vacation in these counties during the summer.
8. Finally, there might be some bias in the results based on different ratios of weekday and weekend days in the different periods. Day of the week can affect visits for a number of reasons. For example, people might delay visits to an ED over the weekend preferring to wait if at all possible until clinics open on Monday. The number of days that occurred during the weekday and weekend was fairly similar in the three periods over the three years, suggesting that this is not a major limitation.

Conclusion

This surveillance study indicates that healthcare providers in north central Washington can expect increases in ED and outpatient visits during wildfires. Overall in 2012 average daily patient visits for CVD and respiratory disease were 28 and 18 percent higher during and after the wildfires, respectively, compared to before the fires. Increased daily patient visits were most pronounced for respiratory disease in children, with daily visits increasing by an average of 45 visits during the 2012 fires compared to the two weeks before the fires; and 28 visits after compared to before the fires. These increases are larger than the 22 and 14 excess daily visits in the corresponding periods in 2010–2011.

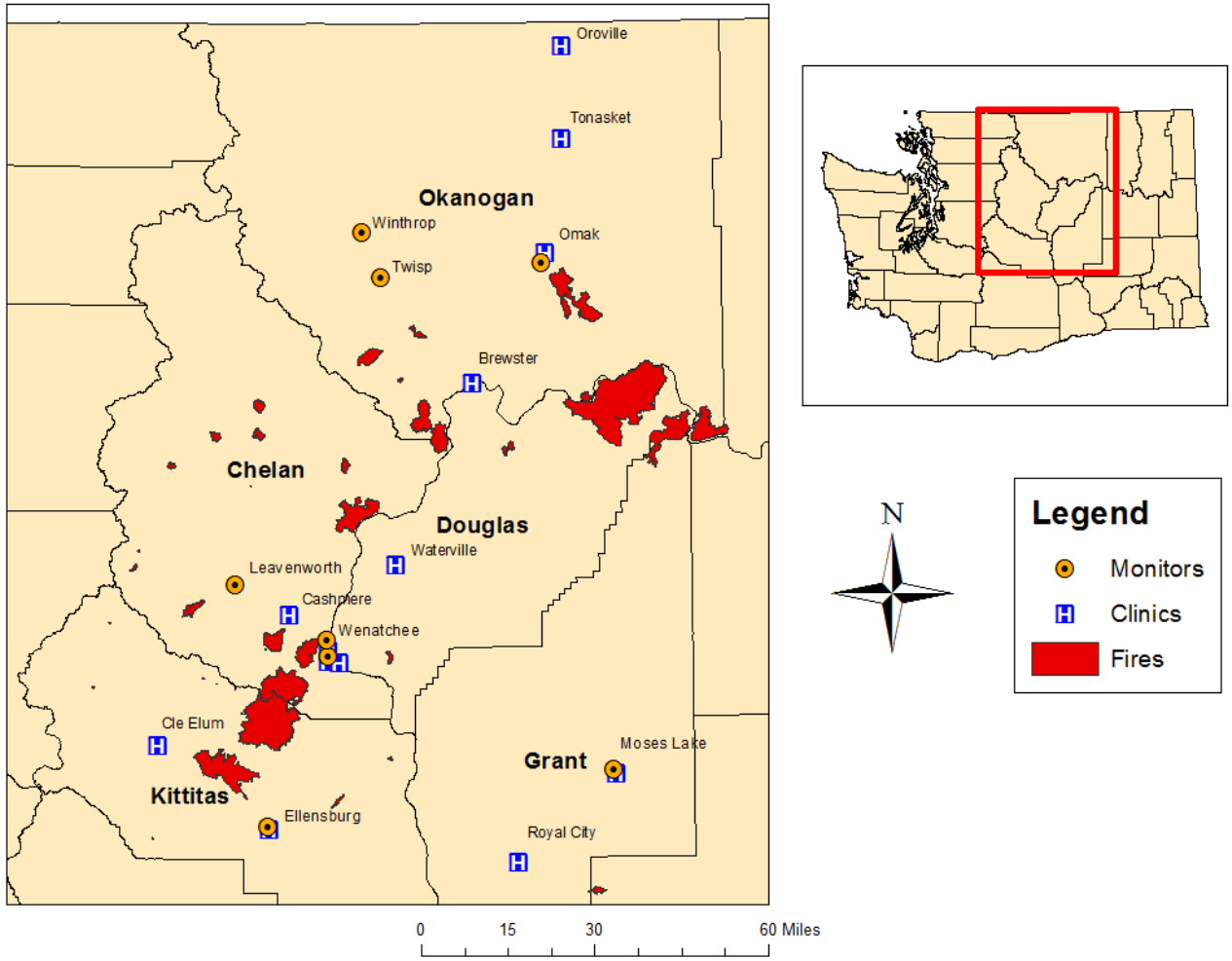
Increases in children's daily visits for asthma, respiratory and chest symptoms, and acute respiratory infection were about double for the time period during the fires compared to before the fires. Considering patterns in 2010–2011, some of the increase in children's visits for acute respiratory infection was likely seasonal, but a portion of the increase might have been fire-related. Increases in children's visits for asthma and respiratory and chest symptoms were likely to have been mostly fire-related. Visits for COPD excluding asthma for all ages combined were about 60 percent higher both during and following the fires compared to before. Comparable increases in COPD visits were not seen in 2010–2011, suggesting that the 2012 increase in visits might have been related to the fires.

These findings, combined with previously published studies, underscore a continued need for effective interventions to minimize harmful effects of smoke from wildfires. Healthcare system planning should reflect the seasonally increased need for adequate staffing, sufficient resources, and personnel training to meet the needs of those at risk during wildfire seasons. Children, especially those with asthma, seem predisposed to harmful effects of wildfire smoke and should be targeted with additional efforts to reduce illness and disease exacerbations.

Health departments in north central Washington can use these results to tailor health messages during wildfires. General advice to minimize exposure to wildfire fire smoke seems important, given the overall increase in respiratory disease visits, our inability to distinguish people with preexisting disease from those with no history of disease, and what we know from other studies. The overall increase in children's visits for respiratory disease suggests a need for special attention to children. Additional studies on long-term effects of wildfire smoke are needed, as are studies designed to eliminate confounding effects of weather and other environmental factors are needed.

Technical Notes

1. Locations of wildfires, Ecology $PM_{2.5}$ air monitors and participating healthcare facilities, September – October, 2012.



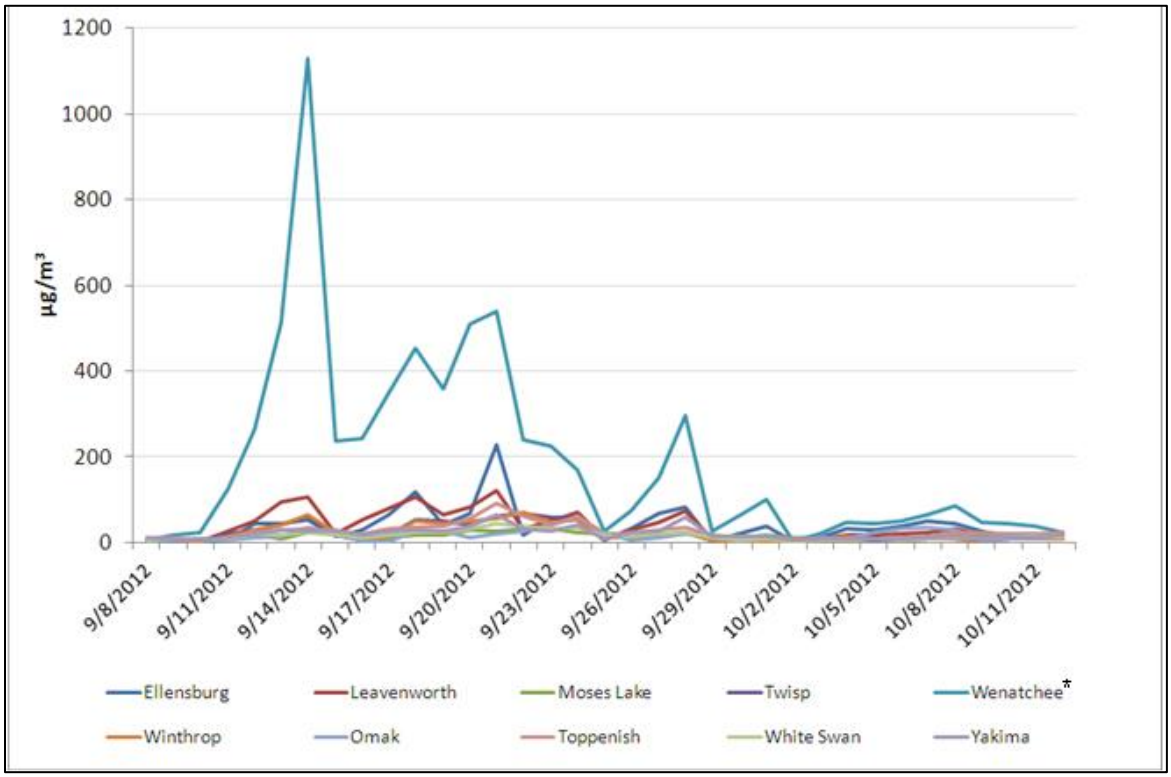
Additional maps of 2012 wildfires are available at: http://www.nasa.gov/mission_pages/fires/main/usa/20120920-wash.html, http://inciweb.nwcg.gov/incident/maps/3269/1/ and http://inciweb.nwcg.gov/incident/3258/.

2. Category ranges for Ecology's Washington Air Quality Advisory (WAQA) and EPA's Air Quality Index (AQI) for $PM_{2.5}$ 24-hour average concentrations (ug/ m^3)

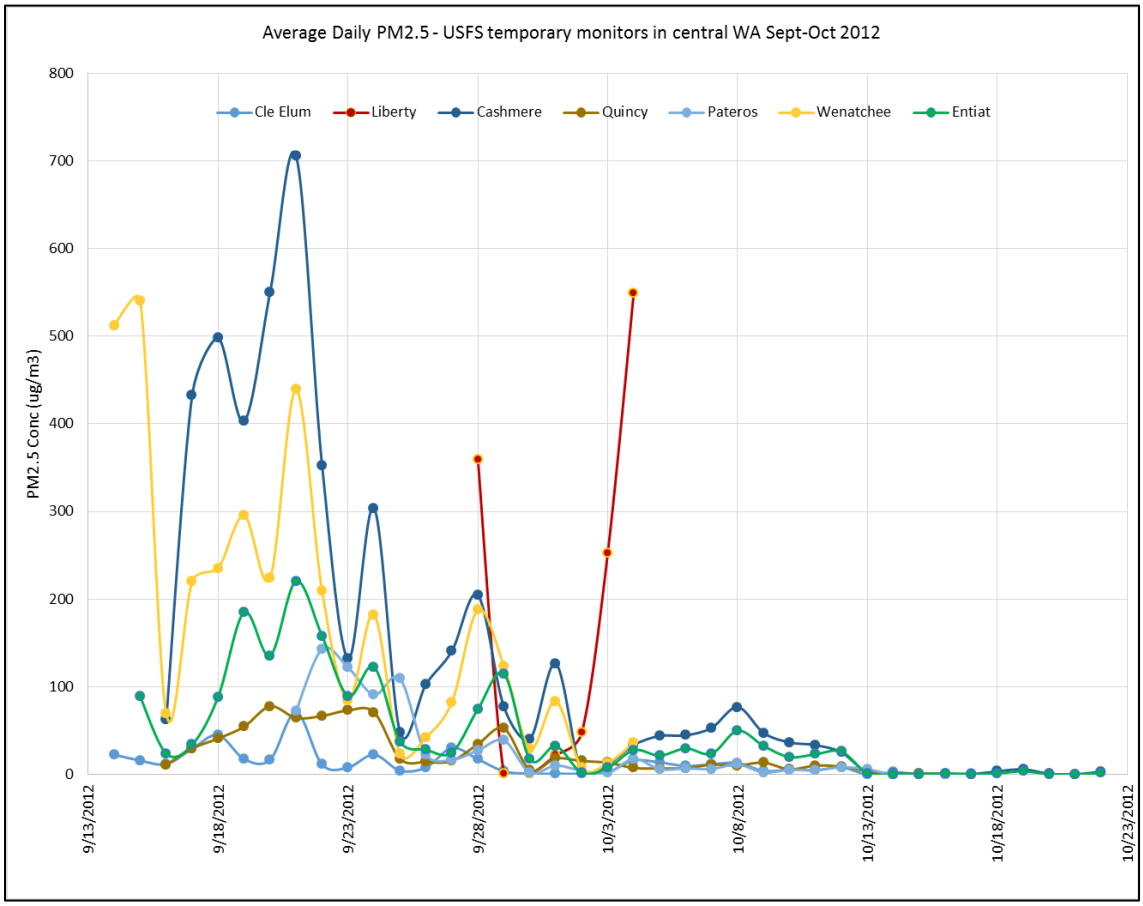
Category	WAQA [a]	AQI[b]
Good	0–<13.4	0–12.0
Moderate	13.4–<20.4	12.1–35.4
Unhealthy for sensitive groups	20.4–<35.4	35.5–55.4
Unhealthy	35.4–<80.4	55.5–150.4
Very unhealthy	80.4–<135.4	150.5–250.4
Hazardous	≥135.4	250.5–350.4
Hazardous		350.5–500

[a] Ranges provided by Matt Kadlec, Washington State Department of Ecology. October 2015. WAQA Table available at: https://fortress.wa.gov/ecy/publications/documents/0802022.pdf (accessed November 2015)
[b] U.S. Environmental Protection Agency. The National Ambient Air Quality Standards for Particle Pollution: Revised Air Quality Standards for Particle Pollution and Updates to the Air Quality Index (AQI). http://www3.epa.gov/pm/2012/decfsstandards.pdf (accessed September 2015).

3. 24-hour $PM_{2.5}$ concentrations (ug/m^3) monitored by Ecology at different locations in central Washington, September 8-October 11, 2012 (* invalidated data) (Figure courtesy of Dept. Of Ecology)



4. 24-hour $PM_{2.5}$ concentrations (ug/m^3) monitored at USFS temporary monitors in central Washington, September – October, 2012. (Figure courtesy of Gary Palcisko, Department of Ecology)



5. Information about nephelometers used for monitoring $PM_{2.5}$ air concentrations.

   Nephelometers measure back scattering of light (bscat) from tiny particles suspended in ambient air. The U.S. EPA does not recognize nephelometers as a Federal Reference or Equivalent Method (FRM/FEM) for the monitoring of $PM_{2.5}$ so the data produced from them cannot be used to determine compliance with National Ambient Air Quality Standards. However, Ecology and its air quality partners in the Washington Network implement U.S. EPA guidance for mathematically relating (correlating) bscat to $PM_{2.5}$ concentrations from a FRM/FEM $PM_{2.5}$ instrument. Ecology requires each nephelometer to FRM/FEM relationship to have a coefficient of determination (r2) of 0.85 or above. When the 0.85 criteria is met, the resulting slope and intercept equation is applied to the nephelometer bscat data via a calculated channel on the data logger to produce FRM-like $PM_{2.5}$ concentrations in near-real-time. (Personal communication. Sean Lundblad, Department of Ecology, January 06, 2015)

References

[1] Chart developed by Matt Kadlec, Washington State Department of Ecology, September 2015. For information on WAQA see "What is WAQA?" available at http://www.ecy.wa.gov/programs/air/pdfs/WAQA.pdf .

[2] Washington State Department of Health, 2012. Unpublished data.

[3] Liu JC, Pereira G, Uhl SA, Bravo A, Beli ML, 2014. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environmental Research 136, 120-132.

[4] Climate Impacts Group. *The Washington climate change impacts assessment: evaluating Washington's future in a changing climate*. Seattle, WA: University of Washington; 2009. http://cses.washington.edu/db/pdf/wacciaexecsummary638.pdf. Accessed May 18, 2015.

[5] Washington State Employment Security Department, Chelan and Douglas Counties Profile, 2015 update. Available at: https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/county-profiles/chelan-and-douglas-counties-profile.

[6] Washington State Employment Security Department, Grant County Profile, 2014 update. Available at: https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/county-profiles/grant-county-profile.

[7] Washington State Employment Security Department, Kittitas County Profile, 2014 update. Available at: https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/county-profiles/grant-county-profile.

[8] Washington State Employment Security Department, Okanogan County Profile, 2015 update. Available at: https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/county-profiles/okanogan-county-profile

[9] Personal communication. Sean Lundblad, Washington State Department of Ecology Air Program, October 21, 2015.

[10] Confluence Health, Central Washington Hospital and Clinics, Trauma and Emergency Room information. Available at: http://www.cwhs.com/services/emergency.aspx .

[11] Washington State Department of Health, 2012. Guidelines for Using Confidence Intervals for Public Health Assessment. Available at www.doh.wa.gov/DataandStatisticalReports/DataGuidelines.aspx; (accessed July 2015).