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Surveillance for Dust Storms and Respiratory Diseases in Washington State, 1991

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ABSTRACT. Southeast Washington State, which has a long history of seasonal dust storms, experienced 2 d of dust storms in October 1991, during which PM_{10} levels exceeded 1 000 $\mu g/m^3$ (i.e., six times greater than the Environmental Protection Agency's 24-h PM_{10} standard). Three community hospitals in southeast Washington were visited for the purpose of assessing the possible effects of dust storms on respiratory health. During these visits, the number of emergency room visits for respiratory disorders for each day of 1991 were abstracted. These numbers were compared with daily PM_{10} levels for 1991. Also determined were the observed/expected ratios for the number of emergency room visits for each respiratory disorder category during October 1991. The maximum observed/expected ratio for the respiratory disorders was 1. 2. For 1991, we found a 3.5% increase in the number of daily emergency room visits for bronchitis for each 100 $\mu g/m^3$ increase in PM_{10}. In addition, 2 d subsequent to those days on which the PM_{10} levels exceeded 150 $\mu g/m^3$, there was a 4.5% increase in the number of emergency room visits for sinusitis for each 100 $\mu g/m^3$ increase in PM_{10}. Our results indicate that the naturally occurring PM_{10} in this setting has a small effect on the respiratory health of the population in general.

SOUTHEAST WASHINGTON STATE has a long history of seasonal dust storms. Reportedly, the dust-storm phenomenon takes place a number of times each spring and fall and occurs when high-velocity gales from the Columbia River basin reach the arid plains of eastern Washington, during which particulate matter is dispersed into the atmosphere. Notations in the Lewis and Clark diaries of October 1805 concerning the Columbia River basin in southwest Washington and Oregon record the high wind velocities the explorers encountered in the area. Later, a historian described "a miserable country" in which "westerly winds came inland from the sea to send stinging clouds of dust and sand whirling in every direction."[1]

Modern cultivation of the region, which denudes some of the land, and a regional 5-y drought have been accused of making the dust storms more severe. The purpose of this investigation was to determine what effects these dust storms, particularly thoracic particulate matter less than 10 μ in diameter (PM_{10}), may have had on respiratory health in 1991. We were specifically interested in examining the effect that very high PM_{10} levels ($> 1\ 000\ \mu g/m^3$) during October 1991 (October 16 and

21) had on the number of visits to emergency rooms for respiratory disorders. The Environmental Protection Agency (EPA) has set National Ambient Air Quality Standards for PM_{10} that include a maximum level of 150 μg/m³ over a 24-h period and a maximum average level of 50 μg/m³ over a 1-y period.[2]

Materials and methods

In an effort to investigate the possible effects of dust storms on respiratory health, in April 1991 we visited three community hospitals in Richland, Pasco, and Kennewick, the three cities that constitute the Tri-Cities area of Washington State. Data collection involved the review of emergency room logs at each of the hospitals to abstract the total number of emergency room visits and the number of emergency room visits for respiratory disorders. The respiratory disorders categorized were otitis media, bronchitis, upper respiratory tract infections (including rhinitis and viral syndromes), pharyngitis (also included tonsillitis and laryngitis), sinusitis, croup, pneumonia (all types), asthma, influenza, bronchiolitis, and chronic obstructive pulmonary disease (COPD). The total number of emergency room visits and the number of emergency room visits for each of the disorders were determined for each day during October 1990 and for all months of 1991. Information from October 1990 was collected and compared with data from October 1991.

A dust storm day was defined as a day with blowing dust that resulted in visibility of 5/8 of a mile or less (which is the definition of a dust storm day used by Batelle, Pacific Northwest Laboratories) or as a day with blowing dust and a peak windspeed of 20 miles per hour (mph) or greater.

Daily PM_{10} data for the Tri-Cities area was obtained from the Washington Department of Ecology. The PM_{10} samples were collected on top of a building in Kennewick, Washington, on microquartz fiber filters with a high-volume PM_{10} sampler for 24 h; gravimetric analysis was performed on all samples after collection.[3] Other environmental pollutants are not measured in the Tri-Cities area. Meteorological data were obtained for the area (daily mean temperature, humidity, windspeed, and visibility) from Batelle, Pacific Northwest Laboratories, Richland, Washington.

The SAS statistical package was used, and the daily respiratory disorders, PM_{10} levels, and meteorological data were entered and analyzed. The annual, monthly, and daily totals for each respiratory disorder were calculated and correlations were made between the respiratory disorders, PM_{10} levels, and meteorological data. We calculated the observed/expected ratios for each respiratory disorder in October 1991, using the first 15 d as a reference period and the next 15 d as the period of exposure.[4]

We performed multivariable analysis using generalized estimating equations to predict the number of daily emergency room visits for each disorder (dependent variable). A log link function was used, and daily visits were assumed to have a poisson distribution. Each month of 1991 was treated independently, allowing for correlation from day to day. An exchangeable correlation structure was used. The predictors (independent variables) in the logistic models included daily PM_{10} values (all values, values > 150 μg/m³ only, and values with a 1- and 2-d lag period, each analyzed separately); seasons of the year; relative humidity; and the previous day's emergency room visit total for each disorder. With respect to the independent variables, Robust z values were obtained and 95% confidence intervals (CIs) were calculated. As to the log linear function, each incremental change of 100 in an independent variable results in a multiplicative change ($e^{100\hat{\beta}}$) in the dependent variable.[5]

Results

In 1990, the population of the Tri-Cities area of Washington State was 101 623 persons (Pasco, 27 153; Richland, 32 315; Kennewick, 42 155).[6] In 1991, the total number of emergency room visits for the three hospitals of the Tri-Cities area was 73 749 (Pasco, 20 231; Richland, 22 150; Kennewick, 31 368). The total number of emergency room visits for all respiratory disorders was 23 349. Total emergency room visits for each respiratory disorder and daily averages are given in Table 1.

The percentages of total monthly emergency room visits that were the result of respiratory disorders for each month of 1991 are as follows: January, 34%; February, 43%; March, 40%; April, 34%; May, 30%; June, 26%; July, 22%; August, 24%; September, 26%; October, 34%; November, 33%; December, 35%.

The total number of emergency room visits for all respiratory disorders was significantly higher for October 1991 (2 001 visits) than for October 1990 (1 656 visits) ($p < .001$). During each month, from February through May 1991, however, there were higher emergency room visit totals for respiratory disorders than for October 1991 (Fig. 1).

The days on which there were the highest emergency room visit totals for most of the respiratory disorders occurred during the winter months of 1991. None of the highest daily emergency room visit totals for respiratory disorders occurred during October 1991.

A greater number of emergency room visits for pneumonia, influenza, otitis media, pharyngitis, upper respi-

Table 1.—Annual Total of Emergency Room Visits to Three Tri-City Hospitals and Daily Averages for Each Respiratory Disorder, 1991

Respiratory disorder	Total ER visits	Daily average visits
Otitis media	5 775	15.8
Bronchitis	4 992	13.7
URI	4 586	12.6
Pharyngitis	4 253	11.6
Sinusitis	1 111	3.0
Asthma	850	2.3
Pneumonia	767	2.1
Influenza	397	1.1
COPD	303	< 1.0
Croup	248	< 1.0
Bronchiolitis	42	< 1.0
Respiratory allergy	25	< 1.0

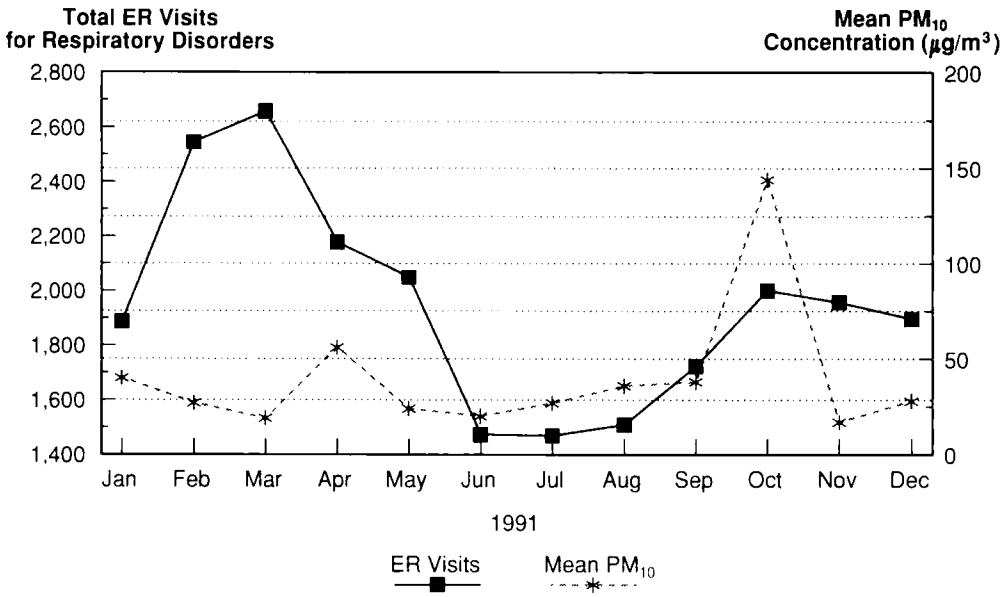

Fig. 1. Total emergency room visits for respiratory disorders and mean PM_{10} levels, by month (1991).

ratory tract infections, and bronchitis were made during the second half of October 1991 than during the first half; however, even during this month the observed/expected ratios for these disorders did not exceed 1.2 (Table 2).

A total of 278 daily PM_{10} samples was obtained for 1991; most of the samples were obtained on Tuesday through Saturday for each week of the year. Daily levels of PM_{10} correlated with daily 1:00 P.M. windspeed (Pearson $r = 0.4$; $p < .001$). The annual mean PM_{10} value was 40 $\mu g/m^3$, with a daily range of 3–1 689 $\mu g/m^3$. As shown in Figure 1, October had the highest mean PM_{10} value (144 $\mu g/m^3$) and November had the lowest (17 $\mu g/m^3$). During October 1990, the mean PM_{10} value was 32 $\mu g/m^3$. There were 7 d in 1991 when PM_{10} values exceeded 150 $\mu g/m^3$ (the EPA standard for a 24-h period), including October 16 and 21 when PM_{10} values reached 1 689 and 1 035 $\mu g/m^3$, respectively. In accordance with our definition, we identified these two dates as the only 2 d in 1991 during which dust storms occurred. In Figure 2 is shown the comparison of daily total emergency room visits for respiratory disorders with daily PM_{10} levels for October 1991.

Daily PM_{10} levels and emergency room visit totals for each day of 1991 showed a statistically significant correlation for bronchitis only (Pearson $r = 0.13$; $p = .03$). Correlations between daily PM_{10} levels, restricted to days on which levels exceeded 150 $\mu g/m^3$, and the number of emergency room visits were statistically significant for sinusitis (Pearson $r = 0.80$; $p = .03$). Correlations between daily PM_{10} levels greater than 150 $\mu g/m^3$ and the number of emergency room visits 2 d later were statistically significant for sinusitis (Pearson $r = 0.94$; $p = .002$) and upper respiratory tract infections (Pearson $r = 0.74$; $p = .05$).

The daily emergency room totals for each disorder, except respiratory allergy, had statistically significant inverse correlations with mean daily temperature. Statistically significant correlations were found between daily relative humidity and bronchitis, COPD, croup, pneumonia, and upper respiratory tract infections (Table 3). On a given day, for each disorder, the number of emergency room visits was significantly related to the number of daily emergency room visits on the preceding day ($p < .01$), except in the cases of bronchiolitis and pneumonia.

In our final logistic models, the variables associated significantly with the number of daily emergency room visits for bronchitis were daily PM_{10} values (z-Robust = 8.4, $\hat{\beta} = 0.000353$, CI = 0.00027, 0.00043); and seasons of the year (z-Robust = 4.1, $\hat{\beta} = 0.1855789$, CI = 0.09607, 0.27509). The variables associated significantly with the number of daily emergency room visits

Table 2.—Observed and Expected Numbers of Emergency Room Visits for Respiratory Disorders in Three Tri-City Hospitals, October 1–30, 1991

Respiratory disorder*	Observed visits (Oct. 16–30)	Expected visits (Oct. 1–15)	Observed/expected	p
Otitis media	246	210	1.2	.1
Bronchitis	235	210	1.1	.2
URI	222	184	1.2	.06
Pharyngitis	176	163	1.1	.5
Sinusitis	44	56	0.8	.2
Asthma	28	36	0.8	.3
Pneumonia	33	32	1.0	.9
Influenza	18	16	1.1	.7
COPD	8	11	0.7	.5
Croup	17	25	0.7	.2
Bronchiolitis	2	2	1.0	1.0

*We observed no respiratory allergy diagnoses for October 1991.

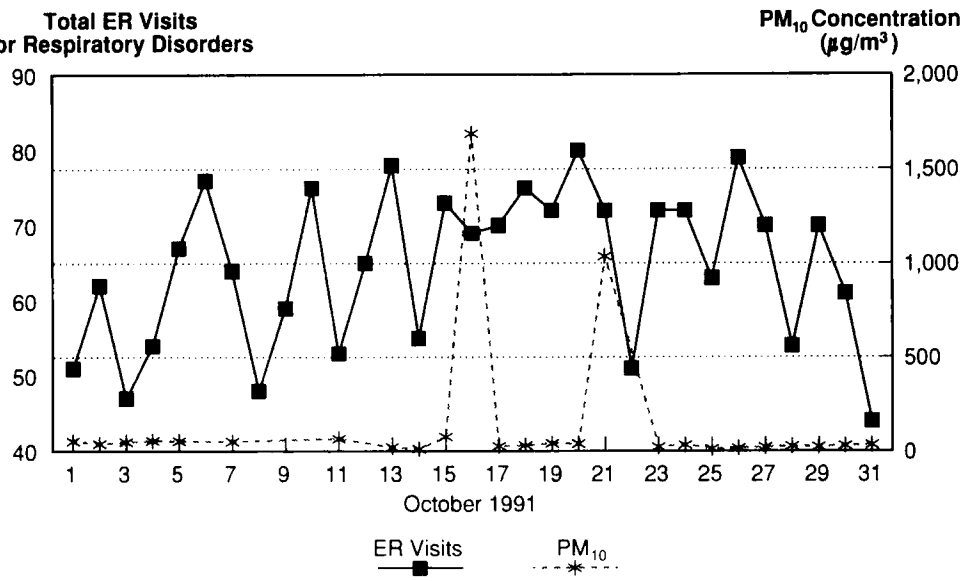

Fig. 2. Daily total emergency room visits for respiratory disorders and daily PM_{10} levels for October, 1991.

for sinusitis were daily PM_{10} values greater than 150 µg/m³ accompanied by a 2-d lag period (z-Robust = 7.6, $\hat{\beta}$ = 0.0004525, CI = 0.00033, 0.00057); and seasons of the year (z-Robust = 3.0, $\hat{\beta}$ = 0.10474, CI = 0.03619, 0.17329). The only variable associated significantly with the number of daily emergency room visits for upper respiratory tract infections was seasons of the year (z-Robust = 3.8, $\hat{\beta}$ = 0.1848814, CI = 0.08966, 0.28010).

Table 3.—Correlation of Each Respiratory Disorder with Mean Daily Temperature and Daily Relative Humidity in the Tri-City Area, 1991

Respiratory disorder	Mean daily temp.		Daily rel. humidity	
	Pearson r	p value	Pearson r	p value
Otitis media	−0.2	.0001	0.05	.3
Bronchitis	−0.4	.0001	0.19	.0003
URI	−0.3	.0001	0.12	.03
Pharyngitis	−0.2	.006	0.01	.9
Sinusitis	−0.1	.01	0.07	.2
Asthma	−0.1	.04	0.04	.4
Pneumonia	−0.2	.001	0.12	.02
Influenza	−0.1	.02	0.04	.4
COPD	−0.1	.04	0.13	.01
Croup	−0.2	.0001	0.16	.002
Bronchiolitis	−0.2	.0001	0.10	.06
Respiratory allergy	0.2	.001	0.08	.3

Discussion

In this investigation, a relationship was found between PM_{10} levels and the number of emergency room visits during 1991 for bronchitis and sinusitis. These disorders had statistically significant correlations with what we believe is PM_{10} from mostly natural sources. Other air pollutants are not measured in the Tri-Cities area because the region is relatively free of industrial development.

Previous investigations have shown that PM_{10} contributes to respiratory disorders, especially to asthma and acute bronchitis, but in those investigations the source of the particulate matter was primarily industrial.[7-9] Particulates from an industrial source are a complex mixture of smoke, sulfates, nitrates, and gases, such as oxides of sulfur and nitrogen.[7] These differ from the particulates of rural eastern Washington, which are volcanic in origin, are mostly PM_{10}, and belong to the plagioclase (glass) mineral class of aluminum silicates and other oxides.[10] The source of particulates may be important because some investigators report that an increase in respiratory disorders, especially asthma, is usually associated with increased levels of particulate matter and a concurrent increase in other pollutants, such as sulfur dioxide.[11,12]

Furthermore, some studies indicate that the greatest impact of PM_{10} is on certain population subgroups, specifically people with pre-existing pulmonary disease, the very young, and the elderly.[7,13,14] This conclusion is supported by the results of the investigations of people's exposure to naturally occurring particulates following the eruption of Washington State's Mount St. Helens in 1980.[10] Several studies concluded that no new ash-related asthma was observed but that there were increases in adverse respiratory effects among those with pre-existing asthma and chronic bronchitis. They also considered it unlikely that the adult general population exposed to volcanic ash would be at risk, as a result of that exposure, for developing respiratory disease.[10]

An investigation of the effect of smoke from California forest fires on respiratory health revealed a relatively modest overall health impact. Investigators found a significant increase in emergency room admissions for asthma and COPD (observed/expected ratios 1.4 and 1.3, respectively), and they concluded that people with pre-existing respiratory disease should be targeted for in-

tervention if potential exposure to smoke from forest fires occurs.[4]

The health effects induced by particulates result from an inflammatory response caused by the penetration and deposition of particles into the respiratory tract. This response affects pulmonary function, mucociliary clearance, and other host defense mechanisms and is a plausible explanation for the respiratory disorders we found to be associated significantly with PM_{10} (bronchitis and sinusitis).[7] However, it is surprising that we not only found no significant association between PM_{10} and asthma, but we found relatively few emergency room admissions for asthma in a community that would be expected to have 4 800 persons with asthma (asthma prevalence, 47.7/1 000 persons × Tri-Cities' population).[15]

There are at least four reasons for the fewer than expected emergency room admissions for asthma. People with asthma may premedicate themselves if they anticipate exposure to an asthma-inducing event or they may visit a private physician for an asthma attack, thereby reducing the number of people seeking treatment at emergency rooms. Another possibility is that emergency room cases of asthma may have been misclassified as bronchitis. Bronchitis appeared to be a generic diagnosis (sometimes labeled as tracheobronchitis, laryngotracheobronchitis, or sinobronchitis). Finally, we must consider the possibility that thoracic particulates from a natural source do not exacerbate asthma.

The relatively high numbers of emergency room visits for respiratory disorders in most of the winter and spring months of 1991 (Fig. 1) were probably the result of expected seasonal effects, such as prevalent viral infections. In addition, given the statistically insignificant relationship between the number of emergency room visits for most of the respiratory disorders and PM_{10} levels, the higher number of visits for October 1991, compared with October 1990, was unlikely to be due solely to the higher mean PM_{10} level for October 1991. An outbreak of viral illness may have occurred in October 1991, which could explain the difference in the number of emergency room visits.

We determined that the maximum observed/expected ratio for respiratory disorders resulting from the dust storms on October 16 and 21 (which produced the highest PM_{10} levels of 1991) was 1.2. This relatively low ratio indicates that the high PM_{10} levels probably had a minimal public health impact. We demonstrated a statistically significant relationship between a year of daily PM_{10} levels and two respiratory disorders (bronchitis and sinusitis), although $\hat{\beta}$ values from our longitudinal regression analysis indicate a small effect, i. e., an increase of 100 $\mu g/m^3$ of PM_{10} results in a 3.5% increase in number of emergency room visits for bronchitis. Further investigation is necessary to determine if the increase in the number of emergency room visits for these disorders represents sensitive groups, so that appropriate steps for intervention can be taken when PM_{10} levels are high.

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