Reexamination of Epidemic Asthma in New Orleans, Louisiana, in Relation to the Presence of Soy at the Harbor

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Epidemic asthma occurred in New Orleans, Louisiana, in the 1950s and 1960s, but its causes were never fully understood. Subsequently, similar outbreaks of epidemic asthma in Barcelona, Spain, were shown to be caused by the release of soy dust at the harbor. To investigate whether airborne soy dust may have contributed to epidemic asthma in New Orleans, the authors examined historical data on vessel cargo from the New Orleans harbor together with data on emergency department visits for asthma, for the period from 1957 through 1968. Days on which there were 64 or more visits for asthma were twice as likely to have occurred on days when a vessel carrying soy was at the harbor (odds ratio (OR) = 2.3, 95% confidence interval (CI) 1.5–3.3). The association was stronger when the maximum wind speed was less than 12 miles/hour (19.3 km/hour) (OR = 4.0, 95% CI 2.1–7.7) and strongest when wind speeds were low and the prevailing winds were from the south or southwest, the direction of two grain elevators from the hospital (OR = 6.7, 95% CI 1.5–46.7). Various temporal and climatic factors that had been associated with the occurrence of asthma outbreaks did not appear to be important confounding factors. The association was specific to soy cargo; no association was observed between asthma-epidemic days and the presence of either wheat or corn in vessels at the harbor. The results of this analysis provide further evidence that ambient soy dust is very asthmogenic and that asthma morbidity in a community can be influenced by exposures in the ambient atmosphere. Am J Epidemiol 1997; 145:432-8.

Beginning in 1953 and continuing for nearly 20 years, Charity Hospital in New Orleans, Louisiana, experienced outbreaks in which people, sometimes more than 200 in 1 day, sought treatment for asthma (1). At that time, Charity Hospital had the largest emergency department in New Orleans and served a predominantly indigent and black population (2). The causes of these outbreaks remain speculative.

In an extensive series of investigations conducted over several years, researchers identified several environmental factors that appeared to be associated with the occurrence of these outbreaks, including low wind speeds and winds from the south and southwest (3); autumn months, particularly October (1, 4); spring and fall months (5); low temperature and low humidity (6); and a cold front followed by a high pressure system accompanied by low wind speeds (7).

Follow-up investigations revealed that affected persons were more likely to be adults (2) and female (8) and to have higher skin reactivity to incinerator plume components (9) and positive skin tests to grain elevator extracts (10). There were no reports of these epidemics affecting children.

Two point sources were identified as potential contributors to these epidemics: city dumps where spontaneous underground combustion occurred (3, 8) and a public grain elevator (11). When the fires in the dumps were subsequently extinguished, no change was observed in the occurrence of asthma outbreaks (1, 9). Arguments against the grain elevator as a contributing factor focused on the observation that skin reactivity to grain elevator extracts did not differ substantially among persons with asthma who had and had not sought care at the hospital during the outbreaks (1, 9). Ambient levels of particulate pollution were not associated with asthma outbreaks (12).

An alternative to the point-source hypothesis was the suggestion that outbreaks of asthma were caused by naturally occurring aeroallergens whose concentra-
tions varied by season and by weather factors (13). By the late 1960s, the frequency and severity of asthma outbreaks at Charity Hospital had declined substantially, possibly because of improvements in medical care and housing for the poor and changes in treatment policies at Charity Hospital (14).

In the early 1980s, investigators in Barcelona, Spain, were faced with a similar occurrence of asthma outbreaks of unknown origin (15). The investigators observed a geographic clustering of cases near the harbor. Subsequent analyses demonstrated that asthma-epidemic days were associated with the unloading of soybeans at the harbor. The causal nature of this association was further demonstrated by a higher prevalence of serum immunoglobulin E antibodies to soybean antigens among persons with asthma who had been affected during the epidemics than among persons with asthma who had not been similarly affected (16), and by the fact that the installation of filters on silos prevented the occurrence of further outbreaks of asthma (17). A recent study from Cartagena, Spain, indicates that the unloading of soybeans at the harbor may have contributed to asthma epidemics in that community as well (18).

In light of these more recent studies attributing epidemic asthma to the unloading of soybeans at the harbor in two different cities, we were interested in determining whether similar exposures may have contributed to epidemic asthma in New Orleans.

MATERIALS AND METHODS

Information on hospital emergency department visits

The data on daily visits for asthma at Charity Hospital, from 1953 through 1977, have been the subject of numerous studies and are described in detail elsewhere (5, 14). Asthma visits included "any diagnosis recorded as an asthmatic attack in the emergency room log book, regardless of type (excluding 'cardiac' asthma)" (14). No demographic information was available for the persons who made these visits, except that all were older than 13 years of age (19). Data were missing for the months of January through August for 1969, 1970, 1971, and 1972 and for January 1973 through July 1973. Because data for these years were incomplete, we restricted our analyses primarily to the period before 1969. This restriction also served to reduce the influence of long-term secular trends in asthma on the analysis.

Information on vessel cargo

The Marine Terminals Manager, Port of New Orleans, provided historical records with the following information for grain-carrying vessels at the New Orleans harbor: date of arrival, date of departure, departing cargo, and berth (grain elevator). Often, the records did not specify the type of grain, especially in the years before 1957. For example, for the years from 1954 through 1956, the type of grain was not specified for 92 percent of the vessels. Because of this lack of information on cargo type, we restricted analyses to the years 1957 through 1968.

From 1957 through 1968, 6,511 vessels carrying grain departed from the New Orleans harbor. Throughout this period, the type of grain carried was not specified for 52.5 percent of the vessels. When specified, the principal grains the vessels contained were corn, wheat, and soy. Thirty-one or fewer vessels contained barley, coffee, cotton, linseed, milo, oats, rice, rye, or sorghum. During this period, the proportion of vessels carrying soy declined, from 64.6 percent in 1957–1958 to 33.6 percent in 1967–1968. We assumed that most, if not all, of the vessels with unspecified cargo were carrying grains other than soy.

Vessels carrying soy remained at the harbor from less than 1 day to as long as 13 days, but three quarters departed within 2 days. Terminal records did not include information on the exact date the grain was loaded. For this analysis, we considered a vessel and its cargo present at the harbor from the date that the vessel arrived through the date that it departed. Thus, in this study, the community exposure to soybean dust, which usually occurs during loading and unloading, is defined in terms of the periods the vessel was at the harbor. This surrogate definition of soybean dust exposure results in varying degrees of exposure misclassification.

All of the ships carrying soy loaded at one of two berths: the public grain elevator or the private grain elevator in Westwego. Through 1959, all of the soy was loaded at the public grain elevator. The construction of a second, privately owned grain elevator was completed in 1961 in Westwego, Louisiana, just across the Mississippi River from the city of New Orleans. The physical proximity of the two grain elevators to Charity Hospital is illustrated in figure 1. By 1968, however, most of the soy grain was loaded at the Westwego wharf.

Information on weather

Several temporal and weather variables have been associated with the occurrence of emergency visits for asthma in this and other data sets (5, 7, 19–21). We obtained historical information on daily weather conditions from the National Climatic Data Center (Na-
The following variables were examined for this analysis: daily minimum temperature (10°F (12°C) intervals); daily maximum temperature (10°F intervals); and the occurrence of a thunderstorm on that day. Thunderstorms also have been associated with the occurrence of outbreaks of asthma (22-25; S. Corbett, New South Wales Health Department, unpublished manuscript). An examination of variations in temperature and the prevalence of thunderstorms by month suggested that seasonal variation might be best addressed by using six 2-month intervals.

Wind speed was considered to be of interest because higher wind speed velocity could result in lowered exposures to airborne particles. Using definitions from the U.S. Department of Commerce’s Weather Bureau, we classified days as having light and gentle winds if the daily maximum 1-minute wind speed was less than or equal to 12 miles/hour (19.3 km/hour). Wind direction was of interest because earlier reports had linked outbreaks of asthma with winds from the south and southwest (3) and because the two grain elevators were located south and southwest of Charity Hospital (figure 1). The public grain elevator was southwest of the area in which the majority of the population utilizing Charity Hospital resided (11). Winds from the south or southwest were fairly common. Until 1965, the Weather Bureau reported the direction of the prevailing wind on each day. Beginning in 1965, the resultant wind direction (the vector sum of wind directions and speeds divided by the number of observations) rather than the prevailing wind direction was reported. The resultant wind direction and the prevailing wind direction are not equivalent. Therefore, we restricted analyses that included wind direction to the period 1957 through 1964. We classified days as having winds from the south or southwest if the prevailing wind was from the south, south-southwest, or southwest (170–230°).

Statistical methods

Definition of epidemic days. For the period from 1957 through 1968, the median daily number of visits to Charity Hospital for the treatment of asthma was 21, and the range was 1–218. An earlier report of epidemic asthma had used values to define epidemic days of 35, 40, and 50, depending on the month (6). The use of a 15-day moving average, centered on the index day, has been proposed as a preferred method to identify epidemic days because it adjusts for seasonal trends (26). A day is designated as an epidemic day if the observed number of emergency visits for the treatment of asthma exceeds the 15-day moving average by some predetermined probability. This method was used successfully in the investigation of epidemic asthma in Barcelona over a shorter period (15) and also has been used previously on this data set (7).

When we calculated a 15-day moving average on these data, however, we found that this method was relatively sensitive for identifying days with higher numbers of visits for the treatment of asthma but not highly specific for identifying days with the highest number of visits. For instance, on the basis of a 15-day moving average and a Poisson probability of less than 0.01 that the number of visits exceeds this average, we identified 400 days as epidemic during the period from 1957 through 1968; the median number of visits for asthma on those days was 47, and the range was 18–218. Approximately one quarter of the days classified as epidemic (102 days) had 37 or fewer visits. On the days not identified as epidemic, the median number of visits for asthma was 20, the range was 1–91, and 106 nonepidemic days had 50 or more visits.

The use of the 15-day moving average to identify epidemic days would classify many days with widely varying numbers of visits for asthma as epidemic and would classify a few days that had high numbers of visits for asthma as not epidemic. On the basis of the results of a study relating soy dust exposure to large elevations in emergency visits for asthma (15), we decided that it would be preferable to focus on the days that had the highest number of emergency department visits for asthma and then to control for
confounding by seasonality and year in the analysis. We applied a log-transformation to the data to improve normality and then classified a day as an epidemic day if the number of visits exceeded the average number over the study period (1957-1968) with one-tailed probability of 0.025 (on the transformed data). Using this approach, there were 122 epidemic days that had from 64 to 218 visits for asthma (median = 75.5 visits).

**Multivariate analyses.** We treated the occurrence of epidemic days as dichotomous. To evaluate potential effect modification, we stratified by each of the variables described above (year, season, weekday, minimum temperature, maximum temperature, thunderstorms, prevailing wind, and maximum wind speed) and examined patterns in the measure of association across strata. We also used the Breslow-Day test for homogeneity of the odds ratio to test the hypothesis that the odds ratio was constant across the strata (27). When the stratum-specific odds ratios across an ordinal variable suggested a possible trend, we also tested for trend (27). When the sample size was small within a stratum, Zelen's exact test for homogeneity of the odds ratio was calculated (28). If the measure of association appeared relatively consistent across strata and no test for homogeneity was significant at \( p = 0.05 \), we then calculated the Mantel-Haenszel estimator of a uniform odds ratio and the test-based 95 percent confidence interval.

We also addressed the potential for confounding by seasonal and weather variables that had previously been identified as potential risk factors for asthma epidemics. We considered the difference between the crude and adjusted odds ratios for the association between asthma-epidemic days and the presence of soy at the harbor as a useful indicator of possible confounding.

For comparison, we performed the same stratified analyses to examine the relation between asthma-epidemic days and the presence of wheat or corn at the harbor. The number of vessels carrying other grains was too few to support similar analyses for other grains.

We used logistic regression to examine the association between the occurrence of epidemic days and the presence of soy at the harbor, adjusted for any potential confounding or effect-modifying variables. Because the occurrence of asthma epidemics on sequential days may not be independent, we applied a regressive logistic model (29) to these data by including a term that indicated whether the previous day had been an epidemic day. To address possible autocorrelation in the error terms of the logistic regression model, we calculated the Durbin-Watson \( D \) test (30) on the deviance residuals (31).

### RESULTS

**Temporal variation in the occurrence of asthma-epidemic days**

Asthma-epidemic days were more likely to occur in 1957 than in later years, but the severity of these epidemics, as measured by either the mean or the median number of visits that occurred on epidemic days, was not greater in the earlier years compared with later years (table 1). Vessels carrying soy were present throughout the year, while 44 percent of epidemic days occurred in September and October. Asthma-epidemic days were most likely to occur on Wednesday or Thursday; 42 percent of asthma-epidemic days occurred on these 2 days. Vessels carrying soy were present throughout the week but arrived slightly more often (18.1 percent) on Wednesday than on other days.

**Cargo contents and epidemic days**

Throughout the time period examined, days with soy exposure were more likely to be identified as epidemic than were days without soy exposure (table 2). Overall, 75 of the 122 epidemic days (61.5 percent) occurred on days when soy was present at the harbor. No variable examined appeared to be an important effect modifier, with the exception of maximum wind speed (table 3). On days when the maximum wind speed was calm or gentle (less than or equal to 12 miles/hour), the odds ratio for asthma-epidemic days and the presence of soy was nearly double that obtained from the crude analysis and nearly three times the odds ratio for days with wind speeds greater than 12 miles/hour. The odds ratio for asthma-epidemic days and the presence of soy increased when the analysis was stratified by year, a finding that suggests confounding by year. This odds ratio changed very little when the analysis was stratified by other temporal or weather variables, including season (2-month), weekday, minimum temperature, maximum temperature, thunderstorms, prevailing wind, and maximum wind speed.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of asthma-epidemic days</th>
<th>Mean no. of visits on asthma-epidemic days</th>
<th>Median no. of visits on asthma-epidemic days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957–1958</td>
<td>63</td>
<td>82.5</td>
<td>75</td>
</tr>
<tr>
<td>1959–1960</td>
<td>11</td>
<td>95.0</td>
<td>78</td>
</tr>
<tr>
<td>1961–1962</td>
<td>14</td>
<td>85.2</td>
<td>75.5</td>
</tr>
<tr>
<td>1963–1964</td>
<td>10</td>
<td>95.0</td>
<td>84</td>
</tr>
<tr>
<td>1965–1966</td>
<td>10</td>
<td>108.4</td>
<td>91</td>
</tr>
<tr>
<td>1967–1968</td>
<td>8</td>
<td>75.0</td>
<td>71</td>
</tr>
</tbody>
</table>

* Asthma-epidemic day = 64 or more visits for asthma during 1 day

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TABLE 2. Proportion of days with soy-carrying vessels and days without soy-carrying vessels identified as epidemic days,* by year, New Orleans, Louisiana, 1957–1968

| Year | Total | Days with soy | | Total | Days without soy | |
|------|-------|--------------|---|-------------|--------------|
|      |       | No of epidemic days | % | |              | |
| 1957 | 137   | 25            | 18.3 | 228 | 25            | 11.0 |
| 1958 | 123   | 5             | 4.1  | 242 | 8             | 3.3  |
| 1959 | 108   | 2             | 1.9  | 257 | 0             | 0.0  |
| 1960 | 153   | 5             | 3.3  | 213 | 4             | 1.8  |
| 1961 | 156   | 5             | 3.2  | 209 | 3             | 1.4  |
| 1962 | 136   | 5             | 3.7  | 229 | 1             | 0.4  |
| 1963 | 155   | 5             | 3.2  | 210 | 2             | 1.0  |
| 1964 | 191   | 8             | 4.2  | 175 | 1             | 0.6  |
| 1965 | 190   | 6             | 3.2  | 175 | 2             | 1.1  |
| 1966 | 181   | 2             | 1.1  | 184 | 0             | 0.0  |
| 1967 | 182   | 5             | 2.8  | 183 | 0             | 0.0  |
| 1968 | 123   | 2             | 1.6  | 243 | 1             | 0.4  |
|      | Total | 1,835         | 75  | 2,548 | 47            | 1.8  |

* Asthma-epidemic day = 64 or more visits for asthma during 1 day

TABLE 3. Odds ratios for asthma-epidemic days* and the presence of vessels carrying soy, wheat, and corn at the harbor, adjusted for temporal and weather variables, New Orleans, Louisiana, 1957–1968

<table>
<thead>
<tr>
<th></th>
<th>Soy</th>
<th>Wheat</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR†</td>
<td>95% CI</td>
<td>OR</td>
</tr>
<tr>
<td>Crude analysis</td>
<td>2.3</td>
<td>1.5–3.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Stratified by</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum wind speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤12 miles/hour†</td>
<td>4.0</td>
<td>2.1–7.7</td>
<td>0.6</td>
</tr>
<tr>
<td>&gt;12 miles/hour</td>
<td>1.5</td>
<td>0.9–2.4</td>
<td>0.8</td>
</tr>
</tbody>
</table>

* Asthma-epidemic day = 64 or more visits for asthma during 1 day.
† OR, odds ratio; CI, confidence interval.
‡ Metric equivalent: 19.3 km/hour.

The prevailing wind direction (south to southwest) was associated with the occurrence of asthma-epidemic days (odds ratio (OR) = 3.15, 95 percent confidence interval (CI) 1.56–5.90), but it did not appear to be either an effect modifier or a confounder for the association between asthma-epidemic days and the presence of soy at the harbor. However, on the 113 days that had both calm or gentle winds and prevailing winds from the south to southwest, the association between soy at the harbor and asthma-epidemic days was stronger (OR = 6.70, 95 percent CI 1.48–46.74) than it was on other days (OR = 1.90, 95 percent CI 1.23–2.94).

Asthma-epidemic days were not associated with the presence of either wheat or corn at the harbor (table 3).

In the logistic regression model that included five indicator terms for year (2-year intervals), an indicator term for maximum wind speed of less than or equal to 12 miles/hour, and an interaction term for wind speed and the presence of soy at the harbor, asthma-epidemic days were associated with the presence of soy at the harbor, and this association was strongest when the maximum wind speed was low. The addition of a term to this model that indicated whether the previous day had been an epidemic day appeared to satisfactorily reduce the autocorrelation in the error terms (the Durbin-Watson D statistic increased from 1.39 to 1.84). The measures of association between the presence of soy at the harbor and the occurrence of asthma-epidemic days from the regressive logistic model were consistent but somewhat smaller than those obtained from the logistic model that did not account for autocorrelation (table 4).

DISCUSSION

Exposure to soy dust occurs throughout the world, and this study demonstrates another situation in which...
Reexamination of Epidemic Asthma in New Orleans

TABLE 4. Odds ratios for asthma-epidemic days* and the presence of vessels carrying soy at the harbor, adjusted for year and maximum wind speed, New Orleans, Louisiana, 1957-1968

<table>
<thead>
<tr>
<th>Maximum wind speed</th>
<th>No of days</th>
<th>% of days epidemic</th>
<th>OR†</th>
<th>95% Cl†</th>
<th>Adjusted for epidemic on the previous day</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤12 miles/hour‡</td>
<td>992</td>
<td>5.7</td>
<td>4.4</td>
<td>2.4-8.4</td>
<td>3.5</td>
</tr>
<tr>
<td>&gt;12 miles/hour</td>
<td>3,390</td>
<td>2.0</td>
<td>1.7</td>
<td>1.1-2.9</td>
<td>1.6</td>
</tr>
<tr>
<td>No soy</td>
<td>2,548</td>
<td>1.8</td>
<td></td>
<td></td>
<td>1.0-2.8</td>
</tr>
</tbody>
</table>

* Asthma-epidemic day = 64 or more visits for asthma during 1 day.
† OR, odds ratio; Cl, confidence interval.
‡ Metric equivalent: 19.3 km/hour.

soy dust in the ambient air was likely very asthmogenic. This study also illustrates the potential value of more carefully evaluating the role of airborne exposures in the general environment as asthma sensitizers and triggers of acute asthma exacerbations.

The association between the occurrence of asthma outbreaks and the presence of soy cargo at the harbor in this study is consistent with reports from Barcelona and Cartagena, Spain, that linked community outbreaks of asthma with the unloading of soybeans at the harbor (15, 18). As in Barcelona, there were no reports to our knowledge of asthma epidemics affecting children in New Orleans. The association is also biologically plausible, since asthma patients involved in asthma outbreaks in these other cities were found to have higher levels of serum immunoglobulin E antibodies to soybean antigens than were asthma patients not involved in asthma outbreaks (16, 18).

It is possible that the association between asthma outbreaks and the presence of soy cargo at the harbor may have been due to confounding by another factor not yet identified. Adjustment for temporal and weather factors, however, made little or no difference in the odds ratio for asthma-epidemic days and the presence of soy. After extensive research on this phenomenon as described earlier, no other likely confounding variables have been identified.

More than half of the 122 days identified as epidemic occurred between 1957 and 1959, when soy was loaded at only the public grain elevator. By the late 1960s, most of the soy was loaded at the Westwego wharf, and the number of epidemic days diminished. Modernization work was done at this elevator in 1968-1970, the modernization including the addition of dust control equipment (M. Brown, Continental Grain Corporation, personal communication, 1991). In 1977, 90 percent of the ships carrying soy loaded at the Westwego grain elevator. In December of that year, an explosion at the Westwego grain elevator killed 36 people and injured nine others (32). This event led to enhanced efforts to reduce and remove dust at this grain elevator. These improvements in dust control coincided with a reduced incidence of asthma outbreaks over this same period.

Because of the retrospective nature of this analysis, the available data had several limitations. It was not possible, for instance, to determine the location of the patients’ residences or the time of their arrival at Charity Hospital. Such information could have been used to better characterize epidemic events. We used a very restrictive definition for an asthma-epidemic day; it is possible that soy dust might have contributed to elevations in the number of emergency department visits for asthma on days that did not meet our definition of epidemic.

Cargo records were often incomplete and did not indicate the actual date and time that cargo was loaded. The percentage of ships with unknown cargo progressively diminished over time. If our assumption was wrong that the unidentified cargo was not soy, then one might have expected that the association between soy and asthma epidemics would have been smaller in the earlier years, when presumably more soy exposure days would have been misclassified. This was not the case. Alternatively, if the error introduced by the unknown cargo had led to a spurious association between soy and asthma epidemics, then the association between soy and asthma epidemics should have been reduced after adjustment was made for year, since year was associated with the degree of unknown cargo. In fact, the association between soy and asthma epidemics increased after the analysis was adjusted by year.

Given the limited nature of the available data and the high likelihood of misclassification of both soy exposure and asthma epidemic days, one might have expected that it would be difficult to detect an association, if one existed, between events at the harbor and outbreaks of asthma at Charity Hospital, or that measures of association would have led to an underestimate of effect. The quality of the available data also limited our ability to estimate the percentage of asthma-epidemic days that could be attributed to soy-
Acknowledgments

The authors thank Clifford H. Cox, Marine Terminals Manager, Port of New Orleans, for his generous assistance in providing information on vessel cargo; Mary H. Boyd, Tami Laplante, Dr. David Mannino, and Norman W. Staehling for technical assistance; and Drs. Josep Maria Antó, Edwin M. Kilbourne, Henry Falk, and Dana Flanders for constructive comments on earlier drafts.

References