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Acute Effects of Nitrogen Dioxide after Accidental Release

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SYNOPSIS

Objectives. Following an accidental release of nitrogen dioxide from a railroad tank car containing nitrous tetroxide, the authors undertook a study of the health effects of the release, measuring the association between acute low level exposure and pulmonary symptoms.

Methods. The authors reviewed the records of three emergency departments, surveyed 80 emergency department patients, 552 community residents, 21 chemical plant workers, and 29 emergency workers, and conducted a case-control study. Pulmonary case status was defined as having an objective pulmonary finding noted on the emergency department record, reporting that the onset of symptoms was subsequent to the release, and being within the city limits at the time of the release. Self-reported case status was defined as reporting one or more symptoms consistent with exposure to nitrogen dioxide in the week after the release and having been within the city limits at the time of the release. Control subjects were survey respondents who reported no symptoms in the week after the release and had been within the city limits at the time of the release. Chemical exposure was characterized by proximity to, direction from, and being outdoors within one hour after the release. Duration of potential exposure was not measured. Logistic regression was used to estimate odds ratios and 95% confi-

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dence intervals for symptoms by exposure level, adjusted for age, sex, smoking, and preexisting pulmonary conditions.

Results. Local emergency department visits increased fivefold in the week after the release. The most common complaints recorded in a systematic sample of 528 visits in the first 30 hours after the release were headache (31%), burning eyes (30%), and sore throat (24%). Objective pulmonary findings were recorded for 41 (5%) patients in the week before and 165 (4%) in the week after the release. The odds of being a pulmonary case increased by 40% for each quarter-mile increment in proximity to the release (odds ratio [OR] 1.4; 95% confidence interval [CI] 1.1,1.7), while the odds of being a self-reported case increased by 20% for each quarter-mile increment in proximity (OR 1.2, 95% CI 1.1,1.4). People who met the pulmonary case definition were 2.5 times (CI 1.3,4.8) more likely than control subjects to have been outdoors and 6.4 times (CI 3.2,12.6) more likely to report a preexisting pulmonary condition. Self-reported cases were 2.6 times (95% CI 1.8,3,8) more likely than control subjects to have been outdoors and 1.9 times (95% CI 1.1,3.1) more likely to report a preexisting pulmonary condition.

Conclusions. Emergency department visits increased fivefold, but serious acute health effects were uncommon. People who met the pulmonary case definition were six times more likely to report pulmonary symptoms than those without preexisting conditions. This study was not designed to determine any potential long-term effects of exposure.

At 4:30 p.m. on October 23, 1995, a railroad tank car containing 100,000 pounds of nitrogen tetroxide (N_2O_4) ruptured at a chemical plant centrally located in a small city (population 14,280) in southeast Louisiana, releasing an orange-brown plume of an acrid-smelling gas, nitrogen dioxide (NO_2).

The Louisiana Office of Public Health investigated this event to determine the adverse health effects on people in the community, to assess the association between exposure to NO_2 and illness, and, if an association were found, to make recommendations for reducing morbidity in future incidents of this kind.

Liquid N_2O_4 is used in the manufacture of missile fuels and explosives and in the production of dimethyl sulfoxide, an anti-inflammatory drug, and dimethyl sulfate, an industrial chemical. When not kept under pressure, N_2O_4 spontaneously breaks down to nitrogen dioxide (NO_2), a gas. Nitrogen dioxide is a by-product of combustion and a constituent of air pollution, where it is thought to increase susceptibility to respiratory infections.[1]

Adverse health effects depend on the duration of exposure and the concentration of the chemical. Brief exposure to 10 parts per million (ppm) to 13 ppm of NO_2 is known to result in eye irritation, upper respiratory irritation and cough, and possibly bronchospasm, hypoxemia (subnormal oxygenation of arterial blood), and hemoptysis (coughing of blood from the lungs or bronchial tubes).[2] Exposure to concentrations higher than 100 ppm for 60 minutes or more may cause pulmonary edema and death.[2,3] The health effects of both acute and chronic exposures to NO_2 from missile fuels and explosives,[4–6] combustion engines,[7–9] unventilated gas stoves or heaters,[10,11] grain fermentation,[12,13] and outdoor air pollution[14] have been documented. However, acute outdoor community exposures to NO_2 and the associated health effects have not previously been described in the scientific literature.

The prevailing winds carried the October 1995 plume of NO_2 north. Community members were initially advised by emergency personnel to remain or return indoors. Over the next 48 hours, emergency personnel issued three evacuation orders. The first evacuation (voluntary in the sense that people provided their own transportation and shelter) was ordered one hour after the release for residents within one mile north or northwest of the chemical plant. In response to a wind shift that occurred nine hours after the release, a second voluntary evacuation was ordered 14 hours after the release for residents within one mile southeast of the plant. A manda-

"Thirty percent of the community's population was seen in emergency departments in the seven days following the release."

tory evacuation was ordered 25 hours after the release for the area southeast of the plant as a precaution against possible exposure due to potential further release of N_2O_4 during efforts to remove the remaining chemical from the damaged tank car. The mandatory evacuation was lifted at 6:00 a.m. on October 25. In all, between 3000 and 4000 people were evacuated for up to two nights.

METHODS

Epidemiologic investigation. Our investigation included *(a)* a review of emergency department (ED) records to document symptoms reported following the release; *(b)* identification of ED patients with objective pulmonary findings (*cases*) and interviews with 80 of the 165 people who met the case definition; *(c)* surveys of community members and plant and emergency workers; *(d)* identification of people who were within the city limits at the time of the release but did not become ill (*controls*); and *(e)* a case-control comparison to assess the association between opportunity for exposure to NO_2 and illness.

Review of ED records and identification of pulmonary cases. In the first 30 hours after the release, 1601 ED visits occurred. We recorded reported symptoms for every third visit (N=528). In addition, we reviewed all records for seven 24-hour periods beginning with 4:30 p.m. on the day of the release (N=4320) and identified all patients with objective pulmonary findings noted on the ED record (N=165). Some people visited the ED more than once during the week after the release or visited more than one hospital; the total number of visits includes multiple visits by the same person. However, the list of patients with objective pulmonary findings noted on ED records represents 165 unique individuals.

Objective pulmonary findings were defined as *(a)* an abnormal lung examination characterized by wheezes, rales, or rhonchi on auscultation; *(b)* an abnormal chest X-ray showing new interstitial markings or infiltrates; or *(c)* an oxygen saturation by pulse oximeter of less than 90% or an arterial blood oxygen (PaO_2) by arterial blood gas of less than 90 millimeters of mercury (mm Hg).[15] Using either mailed questionnaires or telephone interviews, we attempted to survey all of the people identified as having objective pulmonary findings on their ED records.

We also examined records for seven 24-hour periods before the release, ending at 4:30 p.m. on October 23. Fewer than 10 people visited the EDs on the morning of October 23 and were grouped with the preceding seven 24-hour periods.

Community survey. Within two weeks of the release, survey packets were mailed to a systematic sample of 1398 residential postal addresses (every seventh) in the city, using a listing obtained from the U.S. Postal Service. Each packet contained two questionnaires: one for the head of household and one for a second adult in the household. Anonymous surveys were completed and returned by 305 heads of households and 184 other adults. Two hundred and thirty-three were returned undelivered by the Postal Service.

Postal Service mail routes with low response rates to the mailed survey after four weeks (fewer than 25%) were targeted for in-person interviews with one adult per household. Of 860 households that did not return surveys, 234 were chosen for home interviews. Sixty-three in-person interviews were completed by students from the Tulane University School of Public Health and Louisiana health department staff. All community surveys were completed within six weeks of the release. Questionnaires were also mailed to all 25 of the workers employed by the chemical plant and to 67 emergency workers identified as having been on duty or called into service during the release.

Data collected. The following information was collected by mail or through telephone interviews from people seen in the ED with objective pulmonary findings; by mail or in-person interviews from community members; and by mail from plant employees and emergency workers: the

person's location at the time of the release; the type, severity, time of onset, and duration of symptoms experienced after the release; the type and duration of any therapies given; and history of smoking, asthma, bronchitis, and emphysema, health insurance status, age, and sex.

Case-control study. We conducted a case-control study to measure the association of acute exposure to NO_2 with objective pulmonary findings documented in the records of three local EDs and with self-reported symptoms. *Pulmonary cases* were all people identified through the ED record review of 4230 ED visits on the day of and in the seven days after the release who: *(a)* had an objective pulmonary finding documented in the ED record *(b)* in which the onset of symptoms was reported as having occurred following the release *(c)* and who were within the city limits at the time of the release. *Self-reported cases* were survey respondents who reported *(a)* having symptoms in the week after the release, *(b)* onset of symptoms after the release, and *(c)* being within the city limits at the time of the release. Control subjects were surveyed community members or plant or emergency workers who were within the city limits at the time of the release and denied having had any symptoms in the week after the release.

Potential exposure was defined in terms of a person's self-reported location during the first hour after the release. Three measures were used: proximity to the release in quarter-mile increments during the first hour; direction from the release (northwest, northeast, southwest, or southeast quadrants) during the first hour, and whether the person was outdoors or indoors during the first hour.

Bivariate and multivariate analyses were performed using the Statistical Analysis System (SAS).[16] Multivariate logistic regression was used to estimate odds ratios for exposure after the data were adjusted for confounding variables. Variables associated with both exposure and case status with a *P*-value of less than 0.1 were included in the logistic regression model as potential confounding variables. All other variables associated with case status in the bivariate analysis were entered simultaneously into the regression model. Those that improved neither the fit nor the predictive capability of the model were eliminated in a backward fashion. Variables considered were history of pulmonary problems, evacuation status, smoking status, health insurance status, age, sex, and whether the respondent was a plant or emergency worker.

Environmental investigation. The environmental investigation included *(a)* estimates of the movement and dispersion of NO_2 across the community and *(b)* monitoring of the air for oxides of nitrogen, including NO_2.

One of the authors (AN), of the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), used three widely available computer models to estimate the movement and dispersion of NO_2 in the air after the release. He judged the most appropriate model to be the one developed with the Areal Locations of Hazardous Atmospheres (ALOHA) system.[17] ALOHA can take into account the physical properties of the chemical and container as well as atmospheric conditions and the engineering failure that resulted in the release, all of which affect the estimates of chemical concentrations and the area and duration over which those concentrations are likely to have occurred. Air monitoring for oxides of nitrogen, including NO_2, was conducted by the Louisiana Department of Environmental Quality (LDEQ), which began intermittent field air sampling at 7:45 p.m. on October 23, three hours after the release; continuous air monitoring began on October 24. LDEQ monitoring continued for 40 hours, ending at 11:30 a.m. on October 25. Air monitoring was concentrated in areas downwind of the chemical plant but included areas near the plant in other directions as well.

RESULTS

Epidemiologic investigation.

ED visits. In the seven days following the N_2O_4 release, visits to the three local EDs increased fivefold, to 4230, in comparison with the 841 ED visits made in the previous seven days. Objective pulmonary findings were recorded in 165 (4%) of the 4230 ED visits, compared with 41 (5%) visits in the seven days preceding the release, a fourfold increase in absolute numbers but a 20% decrease in the proportion of patients exhibiting objective pulmonary findings.

Pulmonary cases. Of the 165 patients for whom objective pulmonary findings were documented in the ED record (pulmonary cases), 150 (91%) of the patients had abnormal lung examinations, 46 (28%) had oxygen saturations lower than 90% or PaO_2 lower than 90 mm Hg, and 36 (22%) had abnormal chest X-rays; 81 (53%) patients were hospitalized.

We completed interviews with 80 (48%) of the 165 patients who had pulmonary findings. Of these 80, 13 were excluded from the case-control study because they reported being out of town at the time of the release and

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therefore did not meet the case definition. Seventeen of the 165 (10%) refused to participate, and 68 (41%) did not complete a mail survey and could not be reached by telephone. A total of 67 people completed interviews and met the pulmonary case definition. Those who completed an interview did not differ significantly from those who did not with respect to age, sex, smoking status, having a preexisting pulmonary condition, being hospitalized, receiving steroid treatment, having any of the four pulmonary findings, or visiting a public versus private hospital.

Self-reported cases and controls. Survey packets were mailed to 1398 residential addresses, and surveys were mailed to 25 chemical plant workers and 67 emergency workers. Surveys were completed and returned by 489 community residents from 305 households, by 21 of 25 plant workers, and by 29 of 67 emergency workers. In-person interviews were completed with an adult in each of an additional 63 sampled households. Thus 602 surveys were completed. Survey response rates were 32% for the community heads of households (after subtracting 250 vacant addresses), 43% for emergency workers, and 84% for plant workers. There were no differences between the ethnic, sex, and age distributions of community members who completed a questionnaire and those of the community as a whole, based on 1990 Census data.

Of the 602 survey respondents, 14 with missing data on location and 81 who reported being out of town at the time of the release were excluded from the study sample. Of the remaining 507, 268 self-reported experiencing symptoms within the week following the release. Five plant and emergency workers had been identified as pul-

Table 1. Most common symptoms reported in a sample of 528 emergency department (ED) visits within first 30 hours after release of nitrogen dioxide, people meeting the pulmonary case definition and people meeting the self-reported case definition, Louisiana, 1995

Symptom reported in medical records	*Sample (n = 528)*		*Pulmonary cases[a] (n = 67)*		*Self-reported cases[b] (n = 268)*	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Headache	162	31	56	84	205	76
Burning eyes	161	30	44	66	151	56
Sore throat	128	24	48	72	161	60
Nausea	116	22	39	58	100	37
Dyspnea	95	18	61	91	142	53
Cough	43	8	60	90	187	70
Left before seen	29	6	—	—	—	—
No symptoms	28	5	—	—	—	—

[a]People who met the definition of a pulmonary case were those in this sample who (*a*) had an objective pulmonary finding documented in the ED record (*b*) in which the onset of symptoms was reported as having occurred following the release (*c*) and were within the city limits at the time of the release. Objective pulmonary findings were defined as (*a*) an abnormal lung exam characterized by wheezes, rales or ronchi on auscultation, (*b*) an abnormal chest X-ray showing new interstitial markings or infiltrates, or (*c*) an oxygen saturation by pulse oximeter of less than 90% or a PaO_2 by arterial blood gas of less than 90 mm HG.

[b]Self-reported case status was defined as reporting one or more symptoms consistent with exposure to nitrogen dioxide in the week after the release and having been within the city limits at the time of the release.

Table 2. Comparison of people meeting the pulmonary case definition or self-reported case definition and control subjects in attributes and in locations within one hour after the nitrogen dioxide release, Louisiana, 1995

Attribute	Pulmonary cases (n = 67)			Self-reported cases (n = 268)			Controls (n = 234)	
	Number	Percent	P-value[a]	Number	Percent	P-value[b]	Number	Percent
Distance from release								
Onsite[c]	4	6	—	11	4	—	7	3
Less than 0.5 miles	28	42	0.02	94	35	0.05	63	27
0.5–1 miles	26	39	—	91	34	—	66	29
More than 1 mile	9	13	<0.0005	72	27	<0.0005	98	41
Direction from release								
Onsite	4	6	—	11	4	—	7	3
Northwest	20	30	—	77	29	0.03	48	21
Northeast	13	19	—	64	24	—	68	29
Southeast	23	34	0.02	67	25	—	47	20
Southwest	7	10	<0.0005	49	18	0.02	64	27
Outdoors	49	73	<0.0005	182	68	<0.0005	102	44
History of:								
Asthma	20	31	<0.0005	32	12	0.02	15	7
Bronchitis	21	32	<0.0005	33	12	0.05	13	6
Emphysema	7	11	0.03	8	13	—	8	4
Any of these pulmonary conditions	34	51	<0.0005	54	20	0.04	31	13
Evacuated	34	51	0.04	162	60	0.001	86	37
Medicaid or no health insurance	34	51	<0.0005	107	40	<0.0005	42	18
Age younger than 50	41	61	0.03	154	58	0.007	107	46
Female	38	57	—	164	61	—	131	57
Plant or emergency worker	5	8	—	16	6	—	20	9
Current smoker	22	33	—	91	34	0.01	46	20

[a]Chi square comparison between pulmonary cases and controls
[b]Chi square comparison between self-reported cases and controls
[c]Onsite was defined as being on chemical plant property.

monary cases in the ED record review. (Because the household survey was anonymous we could not determine if any of the household respondents were also ED cases.) Thus, a total of 268 survey respondents met the self-reported case definition and 234 survey respondents met the control definition and were included in the case-control study.

Symptoms recorded for ED visits within 30 hours of release. In the sample of 528 ED visits, nonpulmonary complaints were recorded more commonly than pulmonary complaints (Table 1). The most common symptoms reported on the sample of ED visit records were headache (162, 31%) and sore throat (128, 24%). Five percent of visits reported "no complaint" on presentation in the ED but wanted to be "checked out."

Symptoms in pulmonary cases and self-reported cases. Among people meeting the pulmonary case definition, the most common reported symptoms were dyspnea (61, 91%) and cough (60, 90%), while those meeting the self-reported case definition most commonly reported headache (205, 76%) and cough (187, 70%) (Table 1). Most (151, 56%) of the people who self-reported symptoms sought medical care for their symptoms: 75 in EDs, 56 at physicians' offices, 15 at both, and 5 elsewhere. For pulmonary case

Table 3. Logistic regression analysis of risk factors for pulmonary case and self-reported case status following release of nitrogen dioxide, Louisiana, 1995

Risk factor	Pulmonary cases (n = 67) and controls (n = 234)		Self-reported cases (n = 268) and controls (n = 234)	
	Odds ratio	95% confidence limits	Odds ratio	95% confidence limits
Proximity[a]	1.4	1.1, 1.7	1.2	1.1, 1.4
Outdoors[b]	2.5	1.3, 4.8	2.6	1.8, 3.8
Direction				
Onsite	2.1	0.4, 11.6	0.9	0.3, 2.8
Southeast	3.1	1.1, 8.6	1.8	1.1, 3.2
Northwest	2.2	0.8, 6.1	1.8	1.1, 3.1
Northeast	1.5	0.5, 4.4	1.1	0.7, 2.0
Southwest	1.0	—	1.0	—
Preexisting pulmonary condition	6.4	3.2, 12.6	1.9	1.1, 3.1

[a]Proximity in quarter-mile increments.
[b]Outdoors refers to being outdoors less than one hour after the release occurred.

patients, the mean and median day of arrival in the ED was October 25, two days after the release. Thirty (45%) of the 67 people who met the pulmonary case definition were admitted to the hospital. The mean duration of their hospital stay was 3.4 nights, with a median of two nights and a range of one to eight nights.

Case-control comparison. The bivariate analyses showed that people who met either the pulmonary or self-reported case definition were significantly more likely than control subjects to have been within a half-mile of the release, to have been outdoors within one hour after the release, to have been evacuated in any of the three evacuations, to have a history of pulmonary problems including asthma, to lack health insurance or to be a Medicaid recipient, and to be younger than age 50 (Table 2). Control subjects were significantly more likely than people who met the case definition to have been located more than a mile from the release and to have been to the southwest of the release. People who met the definition of self-reported cases were more likely than control subjects to be current smokers.

In multivariate modeling (Table 3), people who met the pulmonary or self-reported case definitions were found to be more likely than control subjects to have been closer to the release; the odds of being a pulmonary case increased by 40% (odds ratio [OR] 1.4, 95% confidence interval [CI] 1.1,1.7) and the odds of being a self-reported case increased by 20% (OR 1.2, 95% CI 1.1,1.4) for each quarter-mile increment in proximity to the release. People who met the pulmonary case-definition were 2.5 more likely than control subjects (OR 2.5, 95% CI 1.3,4.8) and people who met the self-reported case definition were 2.6 times more likely than control subjects (OR 1.2, 95% CI 1.8, 3.8, respectively) to have been outdoors at the time of the release In addition, people who met the pulmonary case definition were 3.1 times more likely to have been southeast of the release than in the low risk southwesterly direction. Because those who were onsite (on chemical plant property) were closest to the release, the proximity and direction variables were combined for these five plant and emergency workers identified as pulmonary cases. Those who were onsite were more likely (OR 13.6, 95% CI 2.4,78.8) to meet the pulmonary case definition than those who were more than a mile southwest of the site. People who met the pulmonary case definition were 6.4 times more likely than control subjects to have a preexisting pulmonary condition (OR 95% CI 3.2,12.6) (Table 3). Inclusion in the model of age, sex, smoking, health insurance, or whether someone had been evacuated from his or her residence did not substantially alter these odds ratios.

Environmental investigation. One of the authors (RN), of ATSDR, estimated that the maximum concen-

tration of oxides of nitrogen may have exceeded 100 ppm outdoors and approached 15 ppm indoors in some areas within a quarter mile downwind of the site for a brief period during the first hour after the release. There are no residential areas within a quarter mile north of the release site. ATSDR-estimated concentrations of NO_2 during the early hours after the release were 10 ppm to 13 ppm outdoors, extending 1500 yards by 400 yards to the north and 1 ppm to 3 ppm extending up to 1.5 miles by 0.3 miles north.

LDEQ collected 22 air samples from 7:45 p.m. through 11:30 p.m. on October 23 within 0.25 mile to the north and west of the site. Of these, 21 showed concentrations of oxides of nitrogen (including NO_2) of 0 ppm; one, collected onsite at 11:30 p.m., showed a concentration of 1.4 ppm. A total of 253 readings were taken over 40 hours, primarily downwind (which varied over time), of which 64 (25%) showed concentrations of NO_2 of 0.1 ppm to 2.9 ppm. The five readings showing concentrations of more than 1.1 ppm occurred in a residential area southeast of the release after the mandatory evacuation of that area and coincided with onsite efforts to remove the remaining chemical from the damaged railroad car. These levels are below the symptom threshold of 10 ppm to 13 ppm for healthy adults but in the range shown to potentiate bronchospasm in asthmatics.[18]

DISCUSSION

Following this acute release of N_2O_4, local ED visits increased fivefold. Many were for mild or no symptoms. Although visits for serious pulmonary conditions increased fourfold, they represented only 4% of total ED visits (similar to the 5% observed in the week before the release). Serious acute health effects of this release were uncommon. Objective pulmonary findings documented in the ED in the week after the release, however, were associated with an increased likelihood of exposure to NO_2, as characterized by proximity to the release and being outdoors within an hour after the release.

In the case-control study, people with objective pulmonary findings documented in their ED records were found to be 6.4 times more likely than control subjects to report preexisting pulmonary conditions such as asthma and bronchitis. Several studies have shown that people with asthma are more susceptible to the effects of NO_2 at very low levels (lower than 1.0 ppm),[18–20] and data from this investigation are consistent with those reports.

Three measures of potential exposure were evaluated—proximity to the release, being outdoors at the time of the release, and direction from the release. The association between case status and proximity was graded and strong. The odds of meeting the case definition increased with greater proximity to the site of the release and were highest for those at the site of the release. Control subjects were 4.6 times more likely than people who met the pulmonary case definition to have been more than one mile from the release. People who met either case definition were 2.5 times more likely to have been outdoors within one hour after the release. People who met the pulmonary case definition were three times as likely as control subjects to have been southeast of the site during the hour following the release.

This finding was unexpected because the prevailing wind direction in the first eight hours after the release was reported to be north. However, local wind directions in a small vicinity can vary substantially from winds across a larger area and recorded at weather stations. Thus, exposure to NO_2 among people to the southeast in the first three hours after the release cannot be ruled out. People who reported being to the southeast within one hour after the release did not differ significantly from those in the other directions with regard to self-reported smoking status, history of pulmonary disease, proximity to the site, or likelihood of being outside in the hour after the release.

Anecdotal evidence suggests that in this incident many people put themselves at greater risk of exposure in the process of evacuating as they approached the site of the release (in the center of town) to collect family members or identify an exit route. In multivariate modeling, evacuation was not associated with pulmonary case status (OR 1.7; 95% CI 0.9,3.2), although the direction of the odds ratio suggests an increased risk associated with evacuation. Given the complexity of the evacuation, the odds ratio is difficult to interpret: three separate evacuations occurred over two days, some people not in danger evacuated themselves, others within an evacuation zone refused to leave, the mandatory evacuation occurred after the greatest risk of exposure had subsided, evacuation was based on where someone lived, while exposure was based on where someone was, and only persons thought to be at risk of exposure were advised to evacuate. Because the addition of any evacuation variables to the multivariate model did not substantially change the estimates of the other variables, none was included in the final model.

In the seven days after the release, thousands of people visited the ED for minor complaints, some of which

may have been related to anxiety. Apprehension in the community might have been exacerbated by sensationalized reports in the media about suddenly "dropping dead" or "coughing up pieces of lung" despite feeling fine. These reports may have motivated people to visit the ED, where 30% of the community's population was evaluated within the seven days following the release. Such mass screening may have identified previously unrecognized disease and been partly responsible for the increase in absolute numbers of people identified with objective pulmonary findings during that time.

The most serious limitations of this investigation are the low response rates to the pulmonary case, community, and emergency worker surveys. We noted no differences, however, in a variety of attributes, between those with pulmonary symptoms who completed a survey and those who did not. In the community survey, the sex and age distributions of those who completed a survey were similar to those in the community as a whole. However, we cannot determine whether non-respondents differed from respondents with respect to exposure and symptoms.

Two steps can be taken to reduce morbidity and ED visits following similar events. First, communities and chemical companies should develop and implement plans for handling emergencies, as required by Title III of the Superfund Amendment and Reauthorization Act of 1977. In this case, a community-wide instant notification system might have alerted a properly trained community to remain or return indoors, thereby limiting initial exposure. Without proper preparation, however, good compliance and proper sheltering are difficult to achieve.

Second, essential information on the nature and effects of the chemical involved should be promptly provided by the company and the health department to the community, physicians, and media in an understandable and accessible format. To accomplish this, health departments should be included in the core emergency response team for selected emergencies, especially those in close proximity to populations and involving chemicals known to cause adverse health effects. Health departments should have a plan for the rapid distribution of health information to the medical community, local residents, and media as resources allow. Such information may reduce anxiety in the community, thereby reducing both morbidity and numbers of ED visits.

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