

Public Health

Acute Symptoms in Persons Residing Near a Field Treated With the Soil Fumigants Methyl Bromide and Chloropicrin

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Accidental chemical releases into the air from manufacturing plants, such as occurred in Bhopal, India, and in Institute, West Virginia, have made the public increasingly aware of the health hazards associated with toxic air contaminants. Similar hazards may arise from off-gassing of fumigants from agricultural applications. This has particularly been a problem in California, where urban and suburban areas have spread into prime agricultural lands, resulting in populated areas directly abutting agricultural fields. Physicians and public health staff in such areas should be aware of such potential exposures, symptoms and the appropriate treatment and response. In this report we describe one such episode that occurred in 1984.

Field fumigation with the volatile liquids methyl bromide and chloropicrin is an agricultural practice that can cause exposure to nearby residents. Fumigants are quite toxic to humans. The most common symptoms of methyl bromide and chloropicrin exposure are listed in Table 1.¹⁻⁷ Methyl bromide is an organic halogenated aliphatic hydrocarbon with the formula CH_3Br . It is a gas at normal ambient temperatures and is readily absorbed by inhaling. Most symptoms are due to neurotoxic effects, skin irritation or (at very high doses) lung irritation.⁴ Chloropicrin is an aliphatic nitro compound with the formula CCl_3NO_2 . It is a gas at ambient temperatures, and symptoms are due to direct irritant effects to the skin, eyes, mucous membranes and respiratory tract.⁴

These highly effective pesticides are injected 15 cm (6 in) or more into the soil before the planting of a number of crops to control nematodes, insects, weed seeds and fungi. A common method of application is to then cover the area with a plastic tarp for at least 48 hours, burying the edges of the tarp with at least 10 cm (4 in) of firmly packed soil. The compounds volatilize in the soil, react with organic compounds in the soil and presumably dissipate slowly through the tarp and rapidly when the tarp is removed.

Episodes of illnesses in nearby communities have been reported with agricultural applications of methyl bromide and chloropicrin. Table 2 shows the details of four such episodes that were reported and recently investigated.^{8,9} All four involved strawberry fields and occurred during times of little wind or of air inversion. In all episodes, the index cases were first seen in local emergency rooms. The fourth incident, which occurred in Stanislaus County in 1984, was investi-

gated in detail by the California Department of Health Services (CDHS) and the Stanislaus County Health Department (SCHD) and is the subject of the rest of this report.

During the day of October 23, 1984, a strawberry field in Ceres, California, was fumigated preplanting with methyl bromide and chloropicrin and the field was covered by a tarp. That evening was warm, about 30°C (86°F), with an air inversion and a variable wind of 2 mph. At about 9:30 PM, the Ceres Police Department received health complaints from residents living in widening areas around the field, and at 11 PM, the SCHD and the Ceres Fire Department began going door to door to evacuate about 75 homes in the area. Later that night, symptom reports came in from a disposable diaper manufacturing plant 0.8 km (½ mi) to the west of the field, and the night shift and workers at two other nearby plants were sent home. Several other businesses were told not to open the next day, October 24. No air samples were taken at the time of the incident. The California Department of Food and Agriculture took several air samples around the area on October 24th in the late morning and early afternoon. Samples were taken by drawing a known quantity of air through sorbent tubes; these were analyzed in a local laboratory and all were negative (< 1 part per billion detection level) for methyl bromide and chloropicrin, indicating that fumigants may have dispersed by late morning October 24. A sample, however, taken in the diaper plant at 11 PM on October 24 by the SCHD showed a methyl bromide level of 3 parts per million using a direct reading Drager tube method (3 ppm is the lower level of measurement for this method). Possibly there was less dispersion of the methyl bromide in the more closed environment of the plant.

Because many of the reported cases of possible exposure-related illnesses were unexpectedly distant from the site of fumigation, the CDHS and the SCHD undertook a community survey to determine the geographic extent of exposure and the nature of symptoms experienced by the community.

Methods

The locale is semirural, on the outskirts of Modesto. The field was surrounded by three distinct areas: single-family homes to the east, an industrial area to the immediate north and west with homes further north and a few homes and large fields to the south.

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ABBREVIATIONS USED IN TEXT

CDHS = California Department of Health Services
SCHD = Stanislaus County Health Department

Surveys

The SCHD asked local emergency rooms to report the total number of acute illnesses that may have been attributable to the episode. The area around the fumigated field was surveyed by telephone. Homes within 3 km (2 mi) of the field and control homes further away in Ceres were selected for the survey. An attempt was made to include areas in all four directions and at distances varying from within 1 to 3 km (½ to 2 mi) from the site to assess direction and extent of symptoms, but not all areas contained homes. Cluster samples were taken of streets in the study areas, and attempts were made to contact all households on the selected streets by calling numbers listed in a reverse telephone directory. Employees of the SCHD and the CDHS were trained to administer a telephone questionnaire. All calls were made between one and three weeks after the epidemic. In all, 224 telephone numbers were called, of which there were 196 households eligible to participate. Of these, 20 (11%) were not reached and 42 (21%) refused to participate, giving a response rate among eligible households of 68%. The most common reasons given for refusing to participate were being "too busy" or, among those living further away, "we weren't involved in that." In all, 402 persons (280 adults and 122 children) from 134 households were interviewed.

A sample of residents was administered a telephone questionnaire asking about exposure and symptoms. Parents responded for their children. Questions were asked about age, race, sex, whether at home on October 23 and 24, whether absent from school or work October 23 or 24, location of schools or workplaces and the presence of possible predisposing factors for the development of symptoms, such as chronic lung disease, any other chronic illnesses and

smoking. If respondents had noticed any new illnesses since October 23, they were asked about the presence and timing of 33 new symptoms. Included were symptoms known to be associated with acute exposure to methyl bromide or chloropicrin (or both). Questions concerning symptoms not known to be related to exposure were asked to help eliminate viral illnesses and to detect overreporting of symptoms.

Before analyzing the survey results, exposure syndromes for acute exposure to methyl bromide and to chloropicrin were defined (Table 3). Only symptoms occurring between October 22 and 25 were included; symptoms appearing later were not included, although some persons might have experienced delayed or secondary illnesses. Symptoms occurring in conjunction with fever were considered to have been due to infectious disease and not to fumigant exposure and were excluded. Responses were tabulated by quadrant and distance from the fumigation site. Also, responding households were mapped, and maps of affected households produced. Tabulations were produced to identify the most common symptoms among the syndromes consistent with exposure.

Results

The emergency room survey showed that 32 persons from the affected area were seen between October 23 and 25, and 3 were seen between October 25 and October 29. They had incident-related symptoms such as eye irritation, sore throat, headache, shortness of breath and cough. One 6-year-old child was hallucinating. An employee of one of the local plants was admitted for observation because of tachycardia and shortness of breath. Several workers who were called to the scene to give emergency assistance became symptomatic and were treated at a local emergency room: four fire fighters, a sanitarian, a highway patrol officer and two police officers. Blood bromide concentrations measured in these eight symptomatic persons were subsequently normal.

In the survey population, 71 adults and 23 children reported illnesses with onset after October 22 ("new" ill-

TABLE 1.—Comparison of Use and Toxicity of Methyl Bromide and Chloropicrin

| <i>Characteristics and Use</i> | <i>Methyl Bromide</i> | <i>Chloropicrin</i> | <i>References</i> |
|---|---|---|-------------------|
| Threshold limit value, ppm | 5 | 0.1 | 1 |
| Odor threshold, ppm | Practically no odor | 1.1 | 2,3 |
| Reported use by California agriculture, 1984, kg (lb) | 3.175 million (7 million) | 680,400 (1.5 million) | 4 |
| Acute toxicity | | | |
| Rat survival | 6 h at 514 ppm | 1 min at 340 ppm 20 min at 110 ppm | 1 |
| Human survival | No information found | 10 min at 298 ppm 30 min at 119 ppm | 5 |
| Symptoms | | | |
| Acute, mild | Headache Nausea Vomiting Malaise Weakness Dyspnea Skin irritation | Odor Lacrimation Nose irritation Throat irritation Cough Nausea Vomiting Skin irritation | 1,2,3,6,7 |
| Acute, severe | Convulsions Pulmonary edema Death | Orthostatic hypotension Pulmonary edema Death | |
| Chronic effects | ?Neurotoxicity ?Carcinogenicity ?Teratogenicity | Unknown | |

ppm=parts per million

TABLE 2.—California Episodes of Community Exposures From Methyl Bromide and Chloropicrin Soil Fumigation

| Place | Year | Weather Conditions | Index Cases, number | Comments |
|---------------------|------|------------------------|---------------------|---|
| Los Angeles County* | 1973 | No wind; air inversion | 3 | Attack rate 53% in residents on nearest street |
| Ventura County† | 1980 | No wind | 16 | Fumigation stopped by the county because of illnesses |
| Kern County‡ | 1984 | Air inversion | 3 families | All three homes evacuated |
| Stanislaus County | 1984 | No wind; air inversion | 32 | Nearby plant and homes evacuated |

*From Murray et al.⁸ †From the California Department of Health Services.⁹ ‡From the *Shafter (California) Press*, July 4, 11 and 18, 1984.

nesses). Of these, 32 adults and 4 children in 26 households reported symptoms consistent with exposure to fumigants during October 22 through 25. For 7 adults, symptoms were possibly attributable to methyl bromide exposure and for 31 adults and 5 children, symptoms may have been attributable to chloropicrin exposure.

Symptoms were experienced in areas outside the evacuated area, which was the area within about 0.8 km (½ mi) of the field. Among adults, 30% of those surveyed who lived within 0.8 km of the field reported chloropicrin symptoms compared with 14% at 0.8 to 1.6 km (½ to 1 mi), 7.9% at 1.6 to 2.4 km (1 to 1½ mi) and 4.5% at greater than 3.2 km (2 mi) (Table 4). All 4 children with chloropicrin symptoms were in the evacuated area but, for adults, only 15 of 32 with these symptoms were in the evacuated area.

Three of the four children who had symptoms consistent with exposure lived within 0.8 km of the fumigated field, and three lived to the southeast of the field. In all four cases parents reported that children had been absent from school during their illnesses. All attended schools farther from the field than their homes were. None were reported to have chronic lung disease. There were no children living in the households interviewed in the southwest quadrant.

For adults, the greatest percentage of people with chloropicrin symptoms was in the area to the southeast of the field (Table 4). Although most symptomatic persons lived within 1 km of the site, there were also a number of them who lived up to 2.4 km (1½ mi) away from the site. Adults with possible methyl bromide symptoms were widely scattered throughout the area. Possible confounding variables such as location of work, preexisting chronic lung disease and smoking were also examined. One person, who lived 3.2 km (2 mi) to the southeast of the site and had symptoms of both methyl bromide and chloropicrin exposure, worked in a plant that was evacuated October 23. Two others, who had chloropicrin exposure symptoms only, both lived and worked in the evacuated area. People with preexisting chronic lung disease who were cigarette smokers were no more likely than others to report these symptoms.

To see which symptoms were most strongly associated with these syndromes, the symptom list was reviewed for adults with new illnesses (illnesses occurring after October 22) and with symptoms consistent with methyl bromide or chloropicrin exposure (Table 5). For those with chloropicrin syndromes, the following frequencies of reporting of symptoms were noted: eye irritation (65%), headache (48%), throat irritation (45%) and unusual odors (39%). For those with methyl bromide syndromes, the following frequencies of reporting of symptoms were noted: headache (100%), eye irritation (71%), weakness (57%), dizziness (57%), throat irritation (57%), nausea (57%), lightheadedness (43%) and cough (43%). There was considerable overlap between these

groups; six of seven of those with methyl bromide symptoms also had chloropicrin symptoms. Of note is one person with both types of symptoms who also reported dysuria, a symptom not expected to be caused by either exposure.

Discussion

Methyl bromide-chloropicrin fumigation can be a hazard to surrounding communities. In the case of the Ceres incident, it is probable that unusual weather conditions or human error,

TABLE 3.—Definition of Methyl Bromide and Chloropicrin Acute Exposure Syndromes

| Methyl Bromide Syndrome | Chloropicrin Syndrome |
|-------------------------------|-------------------------------|
| No fever, no diarrhea | No fever |
| At least two | At least one |
| Weakness | Eye irritation |
| Headache | Nose irritation |
| Dizziness | Noticed unusual odor |
| Unconsciousness | Throat irritation |
| Nausea | |
| Tremor | |
| Also consistent with exposure | Also consistent with exposure |
| Loss of appetite | Headache |
| Shortness of breath | Anxiety |
| Chest pain | Eye redness |
| Vomiting | Runny nose |
| | Unusual taste |
| | Cough |
| | Cough produces mucus |
| | Shortness of breath |
| | Chest pain |
| | Nausea |
| | Vomiting |

TABLE 4.—Percent of Adults With Chloropicrin Symptoms by Quadrant and Distance From the Fumigated Field

| Distance, km (mi) | Quadrant | | | | Total |
|-------------------------|-----------|-----------|-----------|-----------|-------|
| | Northeast | Southeast | Southwest | Northwest | |
| 0 to 0.8 (0.0 to 0.5) | | | | | |
| n | 28 | 12 | 0 | 0 | 40 |
| (%) | (25) | (42) | ... | ... | (30) |
| 0.8 to 1.6 (0.5 to 1.0) | | | | | |
| n | 15 | 24 | 0 | 11 | 50 |
| (%) | (0) | (21) | ... | (18) | (14) |
| 1.6 to 2.4 (1.0 to 1.5) | | | | | |
| n | 29 | 27 | 8 | 27 | 101 |
| (%) | (0) | (15) | (13) | (8) | (8) |
| >2.4 (1.5) | | | | | |
| n | 22 | 15* | 3 | 49 | 89 |
| (%) | (5) | (7) | (33) | (2) | (5) |
| Total | 94 | 78 | 11 | 97 | 280 |
| % | (9) | (19) | (18) | (6) | (11) |

*One person worked in an evacuated plant.

or both, contributed to the community exposure because past fumigations there have not caused similar episodes. Nevertheless, regulations governing fumigant application should take these possibilities into account.

In the incident investigated here, we were able to show symptoms of chloropicrin and methyl bromide exposure in neighborhoods in quadrants northeast and southeast of the fumigated field. This is consistent with the direction of the prevailing winds in the area (from the northwest). There were, however, only a few homes close to the field in the northwest and southwest so that there are not enough data to reliably estimate the rates of illnesses in these areas. Also, a plant northwest of the field and within 1 km of it was evacuated because workers experienced symptoms, indicating possible exposures in this area. Distance from the field was an important factor in the development of symptoms; nonetheless, evacuation did not succeed in moving out many of the nearby symptomatic residents.

The symptoms most commonly experienced by the exposed group were headache and eye and throat irritation. Though many of the symptoms reported were minor and non-specific, the emergency room survey detected several more serious illnesses occurring during the same time period, including several cases with shortness of breath and a child who

was hallucinating. Although chloropicrin is often added to fumigants because of ability to detect the odor, the rates for other symptoms exceeded those for the observation of unusual odor. (In this case, the chloropicrin was used as a fumigant.) No one symptom could be relied on as an index of chloropicrin exposure. For those with symptoms of possible methyl bromide exposure, headache was universal and 70% had eye irritation. It should be noted, however, that among a different group of persons (mostly symptomatic fire fighters involved with the evacuation) who were tested for methyl bromide levels, none were positive, indicating that their symptoms may have been due to chloropicrin exposure. None of the persons found in this study to have methyl bromide symptoms were tested for serum bromide concentrations as the study was done several days after the incident.

A much lower percentage of children than adults were reported to have been symptomatic. This could be due to reporting or recall bias of parents for their children's symptoms compared with their own symptoms, or to a higher symptom threshold to these chemicals among children. It should be noted, however, that few children were surveyed in the areas where highest levels of symptoms among adults were found, so that estimates for children in these areas may not be reliable.

In conclusion, a community exposed to a methyl bromide and chloropicrin-fumigated field experienced high rates of airborne-irritant symptoms in the 24 hours following fumigant application. Reporting of fumigant-related symptoms dropped off sharply with distance, 30% within 1 km compared with 4.5% greater than 2 km from the field. Most symptoms were probably related to chloropicrin exposure. The fumigants were apparently applied properly and according to regulations, but atmospheric conditions (air inversion and very little wind) and high temperatures (32°C [90°F]) probably resulted in higher ambient air concentrations than usual. These atmospheric conditions frequently occur in the California Central Valley.

Practitioners, particularly those working in emergency rooms, should be aware of the possibility of further such outbreaks occurring and the need for rapid diagnosis and calling in of county and state public health and agricultural officials. The incident highlights the need for larger buffer zones between areas where highly toxic airborne agents are being applied and residential areas. Notification of local health and emergency response agencies and the local community is imperative. There may be a need for soil pesticide scientists to develop agents that degrade more readily on site and are less likely to volatilize into the local environment.

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TABLE 5.—Adults With New Symptoms Between October 22 and 25 by Presence of New Illness, Methyl Bromide Symptom Cluster and Chloropicrin Symptom Cluster, %

| Symptom | New Illness, n=71 | Methyl Bromide Oct 22 to Oct 25, n=7 | Chloropicrin Oct 22 to Oct 25, n=31 |
|--------------------------------|----------------------|--|---|
| Fever | 7 | 0 | 0 |
| Weakness | 14 | 57 | 19 |
| Sweating | 14 | 27 | 19 |
| Loss of appetite | 11 | 14 | 13 |
| Headache | 37 | 100 | 48 |
| Lightheadedness | 14 | 43 | 16 |
| Dizziness | 14 | 57 | 19 |
| Anxiety | 4 | 0 | 6 |
| Confusion | 4 | 14 | 6 |
| Irritability | 4 | 14 | 6 |
| Unconsciousness | 1 | 0 | 0 |
| Eye irritation | 28 | 71 | 65 |
| Eye redness | 6 | 14 | 10 |
| Nose bleed | 4 | 14 | 6 |
| Runny nose | 14 | 29 | 19 |
| Nose irritation | 11 | 29 | 23 |
| Unusual odor | 20 | 14 | 39 |
| Throat irritation | 23 | 57 | 45 |
| Unusual taste | 7 | 14 | 10 |
| Cough | 21 | 43 | 29 |
| Cough produces mucus | 8 | 29 | 10 |
| Cough produces blood | 1 | 0 | 3 |
| Short of breath | 14 | 29 | 19 |
| Chest pain | 11 | 29 | 19 |
| Nausea | 13 | 57 | 19 |
| Vomiting | 7 | 14 | 10 |
| Diarrhea | 8 | 0 | 13 |
| Abdominal pain | 6 | 0 | 10 |
| Pain with urination | 1 | 14 | 3 |
| Skin irritation | 8 | 14 | 10 |
| Skin rash | 0 | 0 | 0 |
| Tingling | 3 | 0 | 3 |
| Tremor | 1 | 0 | 0 |