

Health & Safety *Report*

Worker Health and Safety Branch

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Illnesses Related to Exposure to Metam-Sodium By-products in Earlimart, California in November, 1999

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Executive Summary

Background

The soil fumigant metam-sodium is used on a variety of crops as a pre-plant treatment for control of soil nematodes, weeds and fungi. On reaction with water, metam-sodium produces a complex mixture of irritant compounds, including methylisothiocyanate (MITC), methylisocyanate (MIC), carbon disulfide (CS₂), hydrogen sulfide (H₂S), and methylamine. MITC has commonly been employed as a indicator for the entire mixture in environmental monitoring studies and has been the subject of special toxicology studies to determine the threshold concentration associated with eye irritation. This report describes illnesses that occurred in the community of Earlimart, California following exposure to by-products of a sprinkler application of metam-sodium on November 13, 1999.

Methods

Community residents available for interview on November 19 were interviewed at the community church on Elm and Spruce Avenues. The interviews were conducted in an undirected fashion, similar to those conducted during clinical evaluations, after the community church contacted residents. Each interview focused on symptoms experienced on Saturday, November 13 and the resident's location at the time of the fumigant application. Children under 12 were not interviewed directly, but their reported problems were ascertained from whichever parent was available for interview.

Because a limited number of residents were interviewed on November 19, the interviews were supplemented by a review of complaints submitted to the Tulare County Department of Agriculture. Those reports included pesticide illness reports, emergency services and medical records collected during investigations by the county agricultural commissioner and the Department of Pesticide Regulation Pesticide Enforcement staffs.

Results

Between the on-site interviews, pesticide illness reports, and complaint forms, information was evaluated on a total of 171 community residents or visitors and 2 emergency response personnel (Table 4). These included 136 exposed in the area south of Armstrong Avenue (zone A). The vast majority of this group resided between Spruce and Armstrong avenues (0.45-0.60 miles from the north end of the treated field), although 3 individuals reported being exposed at or near the edge of the field on Avenue 44 (Figure 2). Eighteen were exposed in the area between Armstrong and School Avenue (zone B, 0.6-0.82 mile from the treated field), 10 in the area between East School Avenue and East Washington (zone C, 0.82-1.08 miles from the treated field), and 5 in the area north of East Washington (zone D). The location of 4 residents at the time of the incident could not be specifically determined. These included one with an unspecified address and 3 whose only listed address was a post office box. Based upon the distribution of residence addresses for all reported cases, these individuals were most likely to have been exposed in zone A.

Symptoms of eye or upper respiratory irritation (typically, burning of the eyes, nose, or throat) were present in most reported cases in all 4 zones. These included 81% of the 136 cases from zone A, 61% of the 18 cases from zone B, 50% of the 10 cases from zone C, and 60% of the 5

cases reported from zone D. Non-specific systemic symptoms (including complaints of headache, nausea, dizziness, shortness of breath, abdominal pain, vomiting, and weakness) were also present in 61.3% of the 173 individuals evaluated; 28 (16%) had respiratory complaints, including 5 (2.9%) with asthma or other lower airway problems.

Discussion and Conclusions

No air monitoring data were available from the day of the incident. Estimates of MITC concentrations generated using a standard dispersion model indicated levels of MITC were as high as 3 ppm at the edge of the treated field (where relatively few community members were exposed). At the southern edge of the populated area of town, concentrations ranged from 0.5 to 1 ppm, corresponding to levels of MITC recognized to cause eye irritation in humans.

Multiple factors were involved in causing the episode. These included a shift in the direction of prevailing wind (from northeast to southwest) at 5:00 p.m. on November 13th, a temperature inversion that occurred nearly simultaneously, and failure on the part of applicator to adequately monitor offsite movement of metam-sodium by-products.

Introduction

This report describes illnesses that occurred in the community of Earlimart, California, following exposure to by-products of a sprinkler application of metam-sodium on November 13, 1999. The community is located on California highway 99 about 75 miles south of Fresno. The 1990 population of the Earlimart designated census area was approximately 5,000, including 1,376 separate households.¹

Background

The soil fumigant metam-sodium is used on a variety of crops as a pre-plant treatment for control of soil nematodes, weeds and fungi. Upon reaction with water, metam-sodium produces a complex mixture of irritant compounds, including methylisothiocyanate (MITC), methylisocyanate (MIC), carbon disulfide (CS₂), hydrogen sulfide (H₂S), and methylamine (Figure 1).

Information on acute irritant effects of metam-sodium by-products

MITC has commonly been employed as a marker for the entire mixture in environmental monitoring studies and has been the subject of special toxicology studies to determine the threshold concentration associated with eye irritation. The other metam-sodium by-products, nevertheless, produce symptoms that clearly overlap with those caused by MITC.²

Acute eye irritation was identified as a critical acute toxicity endpoint in a 1996 experimental study of MITC, conducted with human volunteers. The no-observed-effect-level (NOEL) was 220 ppb for exposure to the isolated eye region using special goggles and the low-observed-effect-level (LOEL) was based on the observation of eye irritation at 800 ppb, cumulative over one hour. A NOEL for an absorbed dose was not calculated because the subjects did not inhale MITC. The observed odor threshold for MITC in this study ranged from 200 to 8,000 ppb with a geometric mean of 1,700 ppb.³ The irritating effect of MITC on ocular and respiratory tissues was also evident in animal studies, in humans exposed to MITC following the 1991 spill of metam-sodium into the Sacramento River, and in humans following its agricultural use (see below). Experimental human data were not available to determine threshold irritant concentrations for respiratory or dermal exposure to MITC, nor for determining the irritation thresholds of other metam-sodium by-products.

Occupational exposure standards, termed threshold limit values (TLVs), are available for carbon disulfide, hydrogen sulfide and methylamine. The TLVs are set just below the LOEL levels in the relevant study for each compound,⁴ rather than based upon a 10-fold margin-of-exposure below the NOEL, customary in the risk assessment process.⁵⁻⁸ The data supporting the 10 ppm TLV for hydrogen sulfide include case reports and observational studies, but not experimental data. The 10 ppm TLV for carbon disulfide is based largely on observational studies of neurotoxicity and cardiotoxicity. For methylamine, the 5 ppm TLV is based upon human eye irritation, as discussed in a review article on the aliphatic and alicyclic amines in a toxicology reference. For each of these compounds, its TLV greatly exceeds the reported odor thresholds. The mean odor threshold of hydrogen sulfide, for example, is variously reported as 0.5 ppb⁹ or 20 ppb,² concentrations equivalent to 0.005% - 0.2% of the 10 ppm TLV.

Environmental monitoring of metam-sodium by-products

Environmental monitoring data summarized in Table 1 demonstrate the variability of off-site movement of metam-sodium by-products, depending upon both the application method and ambient environmental conditions. Full details of the study conducted in Kern County in August, 1993 are given by Wofford et al.¹⁰ Metam-sodium by-products were monitored both upwind and downwind during and after application of metam-sodium with a fixed-set sprinkler system to a 20-acre fallow field. Off-site concentrations of MITC varied markedly according to wind direction. The maximum 6-hour concentrations occurred during the application itself. Slightly lower concentrations occurred during the 90-minute period afterwards when water was applied to the field. During the application MITC concentrations ranged from 2450 ppb at 5 meters from the field edge to 1320 ppb at 150 meters from the field edge, downwind of the site of application. Concentrations upwind measured less than 100 ppb at corresponding distances. The next highest levels of MITC occurred during the interval following the watering-in period. Hydrogen sulfide readings ranged up to 76 ppb at 75 meters from the field, but samples analyzed for carbon disulfide were all below the 4 ppb lower limit of detection.¹⁰

Modeling from metam-sodium monitoring data estimated that a buffer zone ranging from 200 to 6,000 feet, depending upon wind direction, was necessary to reach a target MITC concentration of 66 $\mu\text{g}/\text{m}^3$ (equivalent to 22 ppb).¹¹ This is equivalent to the concentration derived by the standard risk assessment practice of dividing the NOEL by a factor of 10 to account for the intra-species variation in susceptibility to a particular toxic endpoint. In this case, the 220 ppb air concentration of MITC air is the NOEL for acute eye irritation. Both the NOEL and its corresponding exposure limit are well below the mean MITC olfactory threshold, indicating that odor is not a sensitive means of monitoring off-site exposures to the compound. The cumulative effect period of MITC (see section on irritant effects above) suggests that a one-hour sample, rather than an eight-hour time-weighted-average sample is the most appropriate means of testing the environment for this contaminant.

Previously reported illnesses in California

Numerous medical problems were reported in surrounding communities in July 1991 following the accidental spill of 19,000 gallons of 32.7% metam-sodium from a railroad tank car into the Sacramento River at the Cantara Loop near the town of Dunsmuir. Exposure of the area population to airborne MITC evolving from the river resulted in numerous hospital visits, largely due to complaints of eye and respiratory irritation, nausea, headache, dizziness, vomiting and shortness of breath.¹² More persistent symptoms included a chemically induced asthma known as reactive airway disease or reactive airways dysfunction syndrome (RADS).¹³

Although the Dunsmuir spill was a unique event, the agricultural use of metam-sodium has also been associated with 301 illness reports between 1982 and 1997 (see Table 2), with 119 (39.5%) related to 11 cluster episodes (Table 3). In these episodes, 108 cases involved non-occupational exposures and 11 cases involved exposures to emergency response personnel from local fire or agriculture departments.

Group episodes related to shank injection applications included **87-2610** and 7 related cases (no priority number assigned), **5-SB-92** (25 feet from field to residence), **40-FRE-86** (0.12 mile from site of application), and **34-KER-97** (0.1-0.2 miles from site of application). One episode (**66-**

SJ-93) involved the Ro-To-Vate variant of the shank application method. The episodes related to sprinkler applications included **47-SJ-95** (estimated 0.13 miles from the site of application), **51-SJ-95** (0.51 miles from site of application), **52-SJ-95** (0.85 miles from site of application), and **25-SB-99** (0.8 miles from the site of application).

Use data

Department of Pesticide Regulation use data for the period 1991 to 1998 indicate that metam-sodium use in the state has increased markedly. Approximately 4,873,276 pounds were reported used in 1991 compared to 13,729,306 pounds used in 1998.^a It is principally used as a pre-plant soil fumigant, with applications prior to planting carrots, potatoes, and bush tomatoes accounting for approximately 70% of the total pounds used.^{14,15}

Current regulatory status of metam-sodium in California

The label for Sectagon[®] 42, the product involved in this outbreak, describes application by use of a proprietary Ro-To-Vate & Roll Applicator[®], by soil injection, sprinklers, flood (or check), or drip irrigation, disc application, a power roll seal method for beds or rows, and a soil covering method. California guidelines for applications emphasize methods for minimizing off-site movement as indicated by the presence of by-product odors. Attempts have been made to standardize the implementation of this practice by requiring that the odor monitoring be done by an employee with a "fresh nose".¹⁶

Sprinkler applications are allowed between 500 feet and ½ mile of occupied structures if the following conditions can be met:

- Application must occur during the coolest portion of the day during periods when air temperature exceeds 90 degrees Fahrenheit.
- During the application, the irrigation system shall be operated at the lowest possible pressure.
- Water shall be applied immediately after the application - equivalent to 1/4 inch of water
- Water is to be applied the day after the application to insure that the soil does not dry out.
- If strong odors occur, application of more water is required.

Otherwise, sprinkler applications are prohibited within ½ mile of an occupied structure.

Individual counties have authority to set wider buffer zones and other application requirements as local conditions for metam-sodium use require. To date additional permit conditions have been established in several counties. Kern County modified permit conditions in response to the 1997 episode in the Rosedale neighborhood of Bakersfield (see Table 3, priority episode 34-Ker-97).¹⁷ The Kern County conditions required a 1/2 mile buffer zone between the site of sprinkler applications and sensitive areas. (These were defined on the Sectagon[®] label as "residential areas, labor camps, businesses, day care centers, hospitals, in-patient clinics, nursing homes or any public areas such as schools, parks, playgrounds, or other public facilities not including public roads.") Similar restrictions were put in place at the same time in neighboring Kings

^a This coincided with a modest decrease in the use of methyl bromide, from 17,578,480 pounds in 1991 to 13,569,875 pounds in 1998.

County. Santa Barbara¹⁸ established a 1 mile buffer zone for sprinkler applications following the 1999 incident Cuyama School (see Table 3, priority episode **25-SB-99**). In June 1999, a one-mile buffer zone for sprinkler applications was also established in San Luis Obispo County.¹⁹

Background on the application at Earlimart California and the reported incident

Avenue 44 forms the northern edge of the treated field, approximately 984 feet from Spruce Avenue, the southern edge of the populated area of town. The application consisted of a total of six sprinkler sets spread out over five days, November 9 through November 13, 1999.²⁰ During this period, the minimum air temperature varied from 42 – 45 ° F and the maximum air temperatures varied from 65 –72 ° F. Soil temperatures were relatively constant, varying from 58 ° F to 61 ° F. Minimum relative humidity varied from 57.2% to 63.5% and maximum relative humidity each day was 100%. Similar conditions were observed at other nearby weather stations in Lindcove (50 miles distant) and Visalia (36 miles distant).²¹

The final two sets were applied sequentially on November 13 between 7:30 a.m. and 7:30 p.m (Figure 3). Sunset occurred at 4:51 p.m. According to information from the Famoso weather station, about 20 miles south of Earlimart, the wind direction shifted from NNW (273 degrees) to SSE (150 degrees) between 5 and 6 p.m. In addition, both the air temperature and the wind speed dropped after sunset and an inversion condition developed. After 5:00 p.m. the atmospheric stability class was moderately to strongly stable.^{a 20}

About 5:00 p.m. on the evening of November 13, residents began to call emergency services to complain about an odor from a suspected natural gas leak. Investigation of the reported leak led to realization that the odor derived from the field being treated at the south end of town. Because many people were reporting symptoms, an evacuation was ordered for residents who lived south of Armstrong Avenue. A decontamination center was set up at Earlimart Middle School (599 Sutter Ave) in the northern portion of town and a number of residents were taken to area hospitals for evaluation. Because there is no hospital in Earlimart, residents visited emergency medical services and medical providers in Delano (12.3 miles), McFarland (20.2 miles), Porterville (32.5 miles), and Tulare (27.1 miles). Problems experienced by residents at the decontamination center and at the hospitals were discussed at a community meeting on November 18.²² DPR provided a fact sheet for the meeting describing common symptoms associated with metam-sodium by-products.

Methods

Interviews and records review

Interviews were conducted with available community residents on November 19 at the community church on Elm and Spruce Avenues (Figure 2). The interviews were conducted in an undirected fashion similar to a clinical interview after the community church contacted residents. Each interview focused on symptoms experienced on Saturday, November 13, and the resident's location at the time of the fumigant application. Children under 12 were not interviewed directly, but their reported problems were ascertained from whichever parent was available for interview.

^a Under stable atmospheric conditions vertical mixing of the atmosphere is damped out, resulting in little or no dilution of a plume of material in the vertical direction.

Because a limited number of residents were interviewed on November 19, the interviews were supplemented by a review of complaints submitted to the Tulare County Department of Agriculture. Those reports included pesticide illness reports, emergency services and medical records collected during investigations by the county agricultural commissioner and the Department of Pesticide Regulation Pesticide Enforcement staffs.

In the tables below, cases are identified by year and case number rather than by name. For example, a hypothetical case number 3521 for 1999 would be labeled as 1999-3521.

Distance estimates

Distances from the northern edge of the field at Avenue 44 to the site of exposure were estimated from the street address, a street map, and the map scale. North-South streets (Lane, Elm, Oak, Olive, Church, and State), with street addresses 900 South and higher corresponded to the northern portion of the area termed zone A (between Ave 44, also known as Dietz Avenue, and Armstrong Avenue, 0.0 - 0.60 miles from Avenue 44). Addresses on these streets less than 900 South corresponded to the area, termed zone B (between Armstrong and School Avenues, 0.6 - 0.82 miles). The area between School Avenue and Washington Street was designated as zone C (0.82 - 1.08 miles); the area of north of Washington Street was designated as zone D (greater than 1.08 miles from Avenue 44). The designated areas with relevant landmarks are illustrated in Figure 2.

Symptom classification

Symptoms reported on the complaint forms, in medical records, or recorded during interviews were classified according to expected effects of metam-sodium by-products, as indicated below:

- Odor only or no complaint: no symptoms recorded, or noted presence of odor without experiencing symptoms
- Irritation of the eyes or upper respiratory tract: burning or irritation of the eyes, nose or throat
- Respiratory: asthma or lower respiratory irritation (e.g. "burning of the lungs"), shortness of breath, chest pain or difficulty breathing, cough, presence of wheezing recorded on medical examination, reported use of inhaler following exposure.
- Non-specific systemic symptoms: headache, nausea, abdominal pain, diarrhea, and malaise
- Dermatitis: presence of skin rash
- Other: unrelated symptoms

Results

The residents interviewed, filing complaints, and seeking medical treatment did not describe the exposure in a completely uniform manner. Many noted the presence of a foul odor, described as similar to "cooking chiles", "cooking crank," "burning rubber," "Filipino food," "chemicals," "rotten eggs," or "propane gas." Several cases, identified below by illness registry case number, described a distinct, visible mist or fog, or noted the effect of changing weather conditions on the presence of odor:

1999-1252: "It was around 5 o'clock when I saw some kind of fog coming in but with a strong smell. Then less than a minute a cop came knocking on my door and told us to leave our homes because of a chemical going on."

1999-1234: At about 5:00 p.m. on Saturday, November 13, a 39-year-old, living near the corner of Dietz and Avenue 44, reported noticing an odor like burning rubber, and experienced eye irritation, and irritation of the nose and throat. The material coming from the fields resembled a cloud or a fog.

1999-1239: A resident of East Armstrong, at the northern edge of zone A, noticed a strong odor in the late afternoon on Saturday, November 13, corresponding with a change in wind direction - from south and east instead the usual direction, from north and west.

1999-1494: A resident of Spruce Avenue noted that there was an aroma "like garlic-my eyes started to burn. There was a cloud-like when it's foggy. My head started to ache around 6:00 p.m. The police came to my house and I was told to leave."

Summary of illness complaints by distance from the treated field

Between the onsite interviews, pesticide illness reports, and complaint forms, information was evaluated on 171 community residents or visitors and 2 emergency response personnel (Table 4). Of the 173 in the group, 136 (78.6%) were exposed in the area south of Armstrong Avenue (zone A). These included 3 individuals who reported being exposed at or near the edge of the field on Avenue 44, and 133 exposed between Spruce and Armstrong avenues (0.45-0.60 miles from the north end of the treated field).

Eighteen (10.4%) were exposed in the area between Armstrong and School Avenue (zone B, 0.6-0.82 mile from the treated field). Ten (5.8%) in the area between East School avenue and East Washington (zone C, 0.82-1.08 miles from the treated field), and 5 (2.9%) in the area north of East Washington (zone D). The location of 4 residents at the time of the incident could not be specifically determined. These included one without any specified address and 3 listing only a post office box. Based upon the distribution of residence addresses for all reported cases, these individuals were most likely to have been exposed in zone A (Figure 2).

Symptoms of eye or upper respiratory irritation (typically, burning of the eyes, nose, or throat) were present in the majority of reported cases in all 4 zones. These included 81% of the 136 cases from zone A, 61% of the 18 cases from zone B, 50% of the 10 cases from zone C, and 60% of the 5 cases reported from zone D. Non-specific systemic symptoms (including complaints of headache, nausea, dizziness, shortness of breath, abdominal pain, vomiting, and weakness) were also present in 61.3% of the 173 individuals evaluated. Twenty-eight (16%) had respiratory complaints, including 5 (2.9%) with asthma or other lower airway problems, discussed more extensively below.

Effects on pre-existing medical problems

Five cases of asthma with other lower respiratory tract problems were reported in community residents in conjunction with the November 13 exposure (Table 5). There were 23 additional cases of possible lower respiratory symptoms. These included 16 cases with dyspnea or chest pain and no other lower respiratory complaints, 6 cases with cough, and 1 case with both cough and dyspnea. Because some residents (e.g., **1999-1539**) could not afford medical care, it is possible that some additional cases may have occurred, but went undocumented.

Non-respiratory problems possibly aggravated by the exposure to metam-sodium by-products are shown in Table 6. These included a man with a peptic ulcer treated for vomiting and "coughing blood" and a case of chronic, incompletely treated hypertension possibly aggravated by anxiety related to the incident. A similar case involved a 62-year-old man with a prior history of stroke and diabetes who required observation to rule out a myocardial infarction after the incident. A 27-year-old farm worker with bilateral pterygia (conjunctival overgrowth) experienced eye irritation, but the symptoms were not more prolonged than those reported by other community residents.

Skin complaints

There were 8 cases of rash reported by community residents (Table 7). One case (**1911-1311**) was a possible case of varicella (chickenpox). The other cases had variable or unreported distribution of skin lesions. In one case the reported rash was limited to the face (**1999-1572**), and in another the rash was reported to be generalized (**1999-1619**). In the 4 remaining cases, the distribution of the reported rash was not specified.

Discussion

Air concentrations of MITC were not measured during the November 13 incident in Earlimart. However, Barry estimated MITC levels,²³ using the EPA's ISC air dispersion model, data from prior DPR monitoring studies,¹⁰ and data from the Famoso weather station (approximately 20 miles south of Earlimart). Observations made by community residents confirmed that conditions in Earlimart did resemble those in Famoso, especially in regard to the critical early evening change in the wind direction from northwest to southeast.

Assumptions and limitations of the modeling included:

1. Metam-sodium applied November 9, 10, and 11 (sprinkler sets 1, 2, and 3) had dissipated by November 13. Prior monitoring studies showing an approximately 7-hour dissipation half-life for metam-sodium supports this assumption.¹¹
2. The effect of diminished water applied (approximately 2/3 of the amount required) on flux from sprinkler sets 4 and 5 can not be estimated with available information. However, the depth of the water penetration may be more crucial during summer applications when the San Joaquin Valley soil temperature may exceed 80 ° F (Table 1). Data from the Famoso weather station show soil temperature between November 9 – November 13, 1999 ranged from 58 ° F to 60 ° F. If the flux from those sprinkler sets 4 and 5 was increased, the contribution of sprinkler set 6 (66.2%) to total exposure may have been somewhat less than that shown in the caption table shown in Figure 3.

3. There was a relatively homogeneous spatial distribution of metam-sodium by-products exposure downwind of the treated field. This assumption was contradicted by the observations of some community residents who described contact with a localized fumigant aerosol or mist coming from the treated field. Exposures to these residents may have been higher than those estimated by the model.
4. The model estimated average exposure for the period between 5 p.m. and 7 p.m. on November 13, 1999, in 1-hour intervals. Short-term excursions above the average air concentrations were not estimated.
5. Concentrations of other metam-sodium by-products were not calculated.

According to the model, immediately adjacent to the treated field, the estimated MITC concentrations were as high as 3 ppm. Along the south edge of the populated areas of zone A (Spruce Avenue between Oak Road and Church Road), the estimated 1 hour concentrations averaged 1 ppm. Peak concentrations (based upon estimated 3 minute time-weighted-average concentrations) along the 1 ppm contour line shown in Figure 2 may have been as high as 4 ppm.²⁴ The estimated MITC concentrations for zone A thus exceeded the average 220 ppb 1 hour NOEL for acute eye irritation reported in the study by Russel and Rush.³ Estimated MITC concentrations well to the north of Avenue 48 (the southern edge of zone B) ranged from 0.5 – 1 ppm (Figure 2).

The large number of cases reported substantiated the presence of MITC in zone A in the range of the LOEL. Those were compatible with the recognized effects of MITC and other metam-sodium by-products. These included eye and upper respiratory irritation, non-specific systemic symptoms, and exacerbation of pre-existing cases of lower respiratory disease (Tables 4 and 5). Some anxiety-related conditions probably occurred as well (Table 6), perhaps related to the disruption caused by the hazardous materials response and evacuation.²² It appeared that inadequate access to routine medical care, unrelated to the metam-sodium exposure *per se*, was factor in some cases (e.g., **1999-1250**, involving untreated hypertension). These unrelated conditions may have been aggravated by the exposure to metam-sodium by-products. Prior literature has suggested that, in some individuals, exposure to odor by itself may trigger catecholamines and other potential mediators of hypertension.²⁵

Although dermatitis is a fairly typical response to direct dermal contact with metam-sodium,²⁶⁻²⁸ it has not been a prominent part of the syndrome produced by airborne exposure to metam-sodium by-products (Table 3). It is possible that the air concentration of metam-sodium by-products was high enough to produce skin reactions in some instances. There was no recorded evidence of direct exposure to a concentrated mist or fog coming off the treated field, but most of the dermatitis cases did have eye irritation, and non-specific systemic symptoms compatible with exposure metam-sodium by-products. However, some individual cases (e.g., **1999-1311**) may have been unrelated conditions such as varicella (chicken pox), or exanthems produced by other viral infections. Medical histories were incomplete, but none of those reporting dermatitis had any recorded history of atopic eczema or other pre-existing skin problems, comparable to the history of prior asthma and emphysema reported by residents experiencing lower respiratory irritation (Table 5).

The occurrence of both respiratory and ocular irritation in this episode raises the question of the relationship between the eye irritation and respiratory irritation thresholds. Although a good experimental study³ is available to estimate the average ocular irritation threshold for MITC, the corresponding average thresholds for upper and lower respiratory irritation are not known. It is also uncertain to what degree the irritation threshold is lowered in patients with asthma and other lower respiratory conditions, or to what degree the presence of pterygia (e.g., case number **1999-1573** in Table 6), allergic conjunctivitis, or other ocular conditions increase susceptibility to ocular irritation from MITC. A final element of uncertainty is introduced by presence of unknown quantities of other metam-sodium by-products (Figure 1), such as methylamine, carbon disulfide, MIC, and hydrogen sulfide, whose effect can not readily be quantified. Although occupational exposure standards exist for each of these compounds, they are based on much less precise information (see discussion in the introduction, above) than the MITC study conducted by Russell and Rush.³

Study limitations

This study involved cases reported through the existing surveillance program, but did not include a complete survey or systematic sample of community residents. Information was consequently derived from heterogeneous sources. It is not possible to estimate from the available data the specific number or the incidence of exposure related cases.

Systematic follow-up examinations of affected community residents have not yet been conducted. Although some clearly had only transient symptoms, it is uncertain whether persistent cases of reactive airway disease occurred, similar to those reported following the Dunsmuir accident.¹³ It might be possible to judge the likelihood of such outcomes if air sampling data were available from both incidents. Sampling was not done near Dunsmuir until 3 days after the 1991 spill and only modeling data were available from Earlimart.

Prevention of future outbreaks

On-site monitoring of metam-sodium applications has in the past frequently relied on use of odor monitoring. The mean odor threshold of the metam-sodium's principal byproduct, MITC, is well above its irritation threshold.³ The extent to which odor of other metam-sodium by-products can be relied upon as a means of preventing irritation-related adverse health outcomes has not been systematically studied.^{16,29} However, in the Earlimart episode, odor was noted by multiple residents. Had required monitoring been conducted during the sixth sprinkler set, it would have been possible to terminate the application when weather conditions changed at nightfall on November 13, 1999. It cannot be determined from the available information how many illnesses might have been prevented by this action *per se*.

Although high fines were levied following this incident, the numerous violations (Table 8) suggest that tighter enforcement of existing regulations may be helpful in preventing future outbreaks, additional regulatory measures may also improve the margin-of-safety when metam-sodium is used. Measures adopted by individual counties to date have included 1-mile buffer zones for sprinkler applications^{18,19} and prohibition of nighttime applications (adopted by Tulare County following the incident reported here).³⁰

Conclusions

The major cause of off-site movement of metam-sodium by-products affecting the populated area of Earlimart, was a shift in the wind direction that occurred during the middle of the second November 13 application, a condition that was aggravated by the occurrence of a temperature inversion after sunset. Community residents who lived downwind from the site of application had symptoms related to both the odor and irritant effects of MITC and other metam-sodium by-products. Follow-up studies may be necessary to determine whether any community residents suffered reactive airway disease or other persistent health effects.

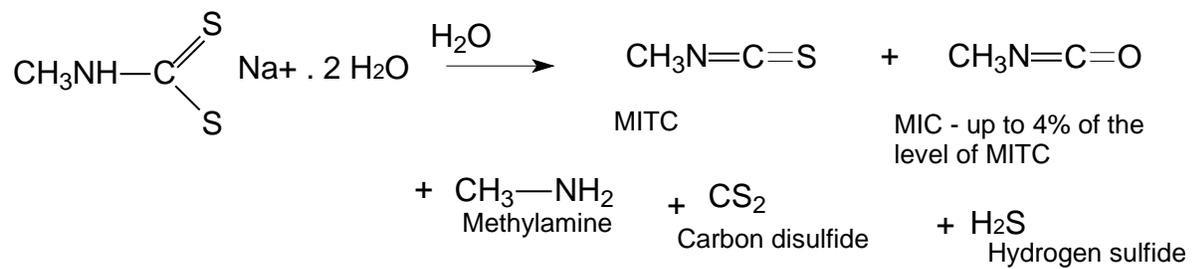


Figure 1- Generation of metam-sodium by-products by reaction with water.
MITC = Methylisothiocyanate; MIC = methylisocyanate.

Table 1 – 24-hour time-weighted-average (TWA) monitoring of off-site movement of methylisothiocyanate (MITC) from sites of injection and sprinkler applications of metam-sodium*

Site and field conditions	Application method	Monitoring distance miles	Estimated or measured MITC concentration, ppb			Number of measured samples
			1-hour estimate	8-hour estimate	24-hour measurement (range)	
Contra Costa County, March 1993 – cool air / soil (53-55°F)	Injection	0.009	646	646	618 (597-646)	2
Kern County, Summer 1993 – warm air (61-92°F) / warm soil (79-88°F)	Injection	0.011 – 0.023	827	827	472 (70-827)	3
Bakersfield, August 1995 – warm air (59.7-98.8°F) / warm soil (78-86°F).	Injection	0.007 – 0.012	236	236	236	1
Kern County, August 1993 – warm air / soil (80-86°F)	Sprinkler	0.003	2853	2321	1102 (61.3-2853)	5
		0.047	2813	2348	878 (2.67-2813)	5
		0.093	1760	1534	468 (2.67-1760)	5
Madera County, May 1992 – warm soil (58-88°F) / warm air 53-94°F)	Sprinkler	0.003 (5 M)	1255	811	186 (17.0-419)	6
		0.016 (25 M)	1043	701	171 (12.8-348)	6
		0.078 (125 M)	762	513	118 (20.2-273)	6
		0.311 (500 M)	163	106	22.8 (2.93-54.4)	6
Kern County, June 1999 – air temperature < 90°F	Sprinkler	0.093206	281	195	101 (30-101)	5
		0.186411	200	133	52 (8-52)	5
		0.301986	99	90	31 (3.6-31)	5
		0.520088	41	32	12.7 (0.08-12.7)	5
Kern County, June 1999 – soil temperature < 90°F	Shank	0.093206	281	244	175 (5.3 –175)	6
		0.186411	216	151	106 (5.4-106)	6
		0.43496	199	123	84 (6-84)	6
		0.60273	242	149	106 (4-106)	6

*Source: Risk characterization of MITC as a toxic air contaminant³¹

Table 2 – 1982-1997 Metam-sodium cases*, excluding cases associated with the 1991 Dunsmuir spill**

Symptom complex	Handler	Residue exposure	Drift	Emergency response	Other	Total
Irritant only	76	25	27	8	16	152
Systemic/respiratory	22	22	81	3	21	149
Total	98	47	108	11	37	301

*Source of Data: California Pesticide Illness Surveillance Database

** 1991 Dunsmuir Spill: Six railroad cars and a locomotive derailed at the Cantara loop near Dunsmuir. One tanker car fell into the Sacramento River and leaked 19,000 gallons of metam-sodium into the river. Several hundred people in and around Dunsmuir developed symptoms and sought medical attention.

Table 3 – Priority illness episodes in California involving off-site movement of metam-sodium by-products*

Case number or priority number**	Number of cases	Application Method	Estimated Distance (miles) from area of application to location of person injured	Comment
1987-2610	8	Sprinkler	1.9	Members of 2 families complained of a strong odor eye and nasal irritation possibly from a pre-plant metam-sodium application to a parsley field down the road, but did not seek medical treatment.
90-FRE-88	15	Shank	0.006	Residents across the street from a metam-sodium treated field sought treatment for eye irritation following the application
5-SB-92	6	Shank	0.005	Residents/visitors at a house on Northwest corner of parsley field treated with metam-sodium. They developed mostly eye irritation and throat irritation.
13-RIV-93	6	Sprinkler	0.008	Sprinkler application across the street from a field treated with metam-sodium complained of a foul odor, like propane gas, and experienced eye irritation, itching, sore throat, nausea, and headache.
66-SJ-93	5	Rotovator	2	Residents approximately 2 miles from the site of application complained of eye irritation, itching, sore throat, nausea, and headache.
47-SJ-95	14	Sprinkler	0.13	Fourteen employees of a small manufacturing company developed irritation of the eyes and respiratory tract after a sprinkler application across the highway from their plant east of Stockton. An inversion layer apparently trapped the metam-sodium by-products near the ground
51-SJ-95	19	Sprinkler	0.51	Eight employees and 11 wards at a California Youth Authority facility developed symptoms after smelling an odor that resembled sulfur. It came from a sprinkler application of metam-sodium to a field about a half-mile away. Symptoms included headache, irritated eyes and skin, sore throat, dizziness, and respiratory irritation.
52-SJ-95	6	Sprinkler	0.85	Six employees at a manufacturing plant were examined and released after they smelled an odor from a metam-sodium sprinkler application to a field nearby. This was a re-exposure of workers involved in 47-SJ-95. The re-exposure occurred 42 days after the last episode. Symptoms included eye irritation, irritated nose & throat.
36-SJ-96	11	Sprinkler	0.8	Workers at California Youth Authority noticed an odor from a metam-sodium application nearby and complained of eye irritation.
40-FRE-96	29	Shank	0.13	Waiting for a bus, 28 students and 1 adult woman were exposed to metam-sodium application 1/8 mile away. Symptoms involved were mostly eye irritation.
34-KER-97	38	Shank	<0.1- 0.2	Off-site movement of metam-sodium by-products affected a mixed agricultural, residential and commercial business neighborhood in Bakersfield. Telephone or in-person interviews were conducted with 28 residents or visitors to the neighborhood and with 10 emergency responders. Symptoms included eye and upper respiratory irritation, aggravation of pre-existing asthma, and non-specific systemic symptoms.
25-SB-99	22	Sprinkler	0.8	The odor from various metam-sodium applications affected 2 business owners and their children while at the shop. Two days later, similar odors affected children and staff at a nearby elementary school. Symptoms included nausea, eye irritation and sore throats

* Data Source: California Pesticide Illness Surveillance Program (PISP) Database

** Case Number is the number assigned for the PISP database. Priority Number is a number assigned to select group of episodes based upon an agreement between DPR, the U.S. EPA and the agricultural commissioners.

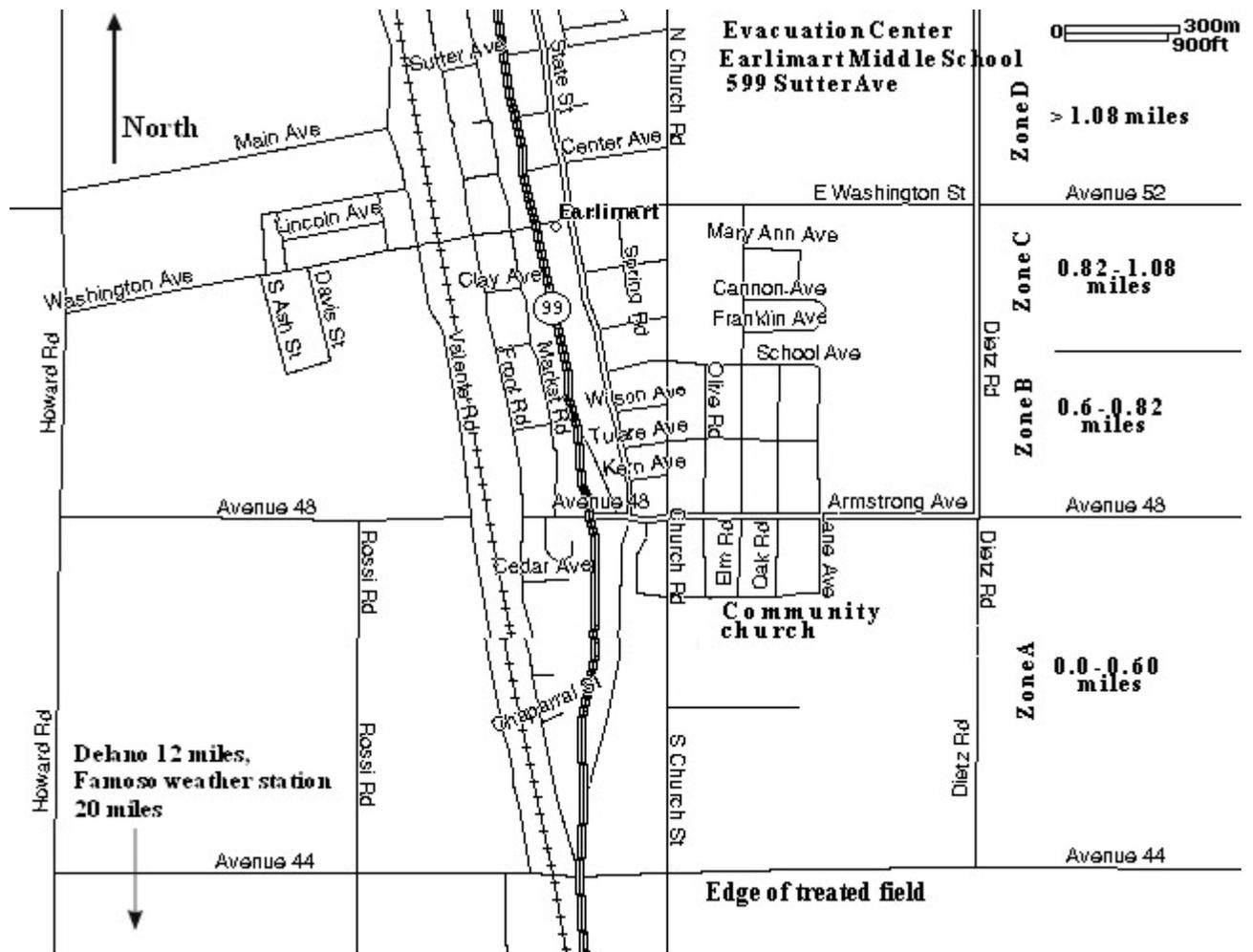


Figure 2 – Map of Earlimart with relevant landmarks indicated

Table 4 – Total number of cases by the type of symptoms and their distance from the metam-sodium treated field on November 13, 1999

Symptom complex	Zone A	Zone B	Zone C	Zone D	PO box only	Total
	≤0.6 miles	0.61- 0.82 miles	0.83-1.08 miles	>1.08 miles		
Odor only or no complaint*	4	0	0	1	0	5
Irritant** symptoms	49	4	0	0	0	53
Non-specific Systemic ***symptoms	22	7	5	0	0	34
Irritant/systemic	45	6	2	0	0	53
Respiratory ****	0	0	0	0	1	1
Respiratory/irritant	6	0	0	1	1	8
Respiratory/ non-specific systemic	0	0	0	2	0	2
Respiratory/irritant/ non-specific systemic	10	1	3	1	2	17
Total	136	18	10	5	4	173

* Odor only or no complaint - no symptoms recorded, or noted presence of odor without experiencing symptoms

** Irritation of the eyes or upper respiratory tract: burning or irritation of the eyes, nose or throat

*** Non-specific systemic symptoms - headache, nausea, abdominal pain, diarrhea, malaise

**** Respiratory: asthma or lower respiratory irritation (e.g. burning of the lungs, shortness of breath, chest pain or difficulty breathing, cough, presence of wheezing recorded on medical examination, reported use of inhaler following exposure.

Table 5 – Cases of lower respiratory irritation following exposure to metam-sodium by-products on November 13, 1999

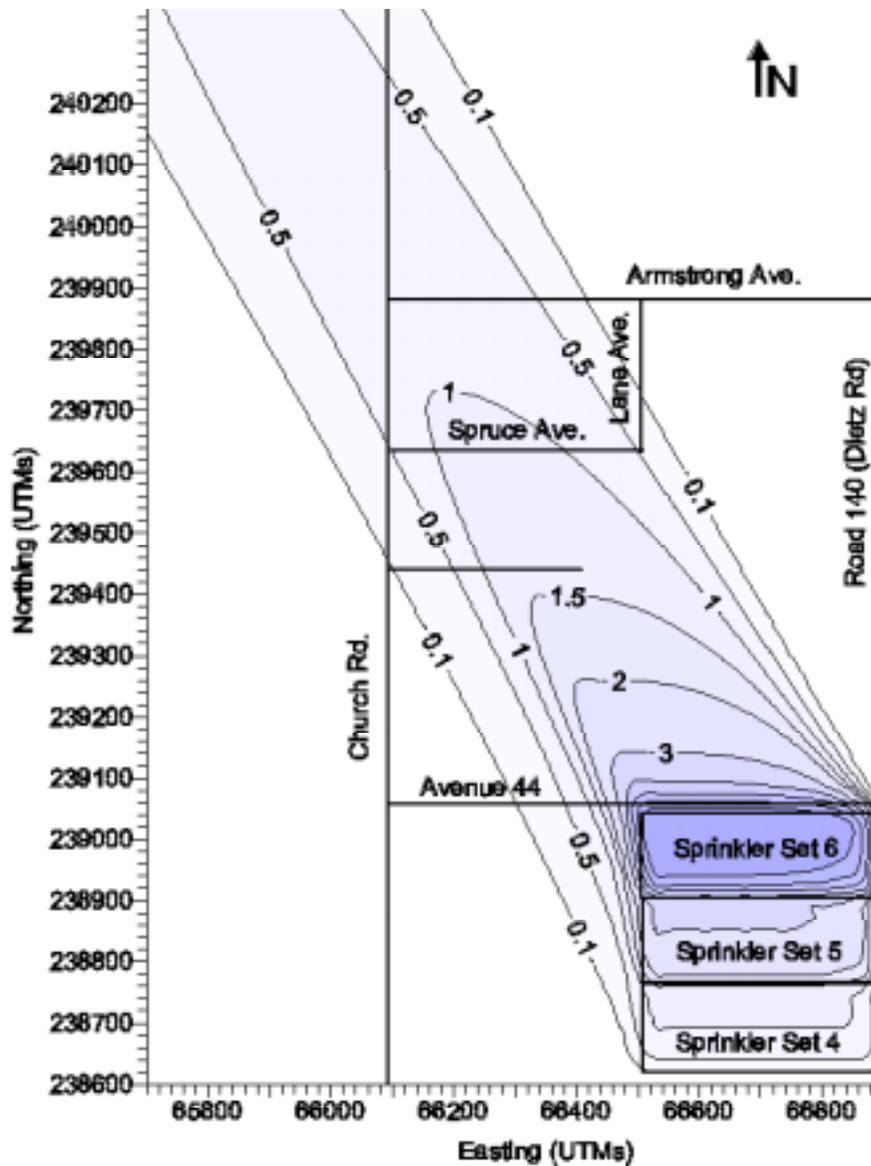
Case number	Description
<i>Cases of probable lower respiratory irritation with medical history of asthma.</i>	
<i>Zone A (≤ 0.6 miles from the treated field)</i>	
1999-1239	This 71-year-old resident had a history of chronic emphysema, asthma and bronchitis. He normally was unable to walk any distance because of his lung disease and regularly used oxygen at home. At the time he was evacuated at 8 p.m. November 13, the odor was bothering him and causing him some mild increased difficulty breathing, shortness of breath and some eye irritation. Medical records from the Delano Regional Medical Center indicate that he had a respiratory rate of 22 when seen in the emergency department, but had normal oxygen saturation (98%) with use of supplemental oxygen. He did not require treatment with albuterol.
1999-1252	This 47-year-old resident, with a past history of hypertension and asthma, reported inhaling a foul odor after seeing a kind of fog come into her neighbor hood. She vomited and developed transient shortness of breath. On evaluation at the decontamination center, she was noted to be in moderate respiratory distress, but improved when seen at the Tulare District Hospital. She did not require treatment beyond removal from exposure. On follow-up with her own physician, in McFarland, she was noted to have a persistent cough over the next few days and required extra medication for treatment of her blood pressure.
1999-1503	This resident had a history of asthma. At approximately 5 p.m., she had watery eyes and had to use her inhaler because she found it hard to breathe. She went to her doctor, but details of the medical findings and treatment are not available.
<i>Zone D (>1.08 miles from the treated field)</i>	
1999-1249	A 60-year-old woman worked as a security officer at Earlimart Middle School, site of the Hazmat decontamination and evacuation center. She had a history of asthma, diabetes, and hypertension. She had nausea, shortness of breath and chest pain while working at the school Saturday evening, November 13. On examination at the Delano Regional Medical Center, she had elevated blood pressure and scattered wheezing on examination that responded to treatment with nebulized albuterol. Because of the chest pain, she had a cardiogram, and a serum troponin (cardiac muscle protein) measurement, which both proved normal.
<i>Undetermined address</i>	
1999-1242	An 18-year-old, whose address was not specified in the available information, was treated at Delano Regional Medical Center for throat irritation and exacerbation of her pre-existing asthma. A few scattered wheezes were recorded on initial physical examination, but cleared after treatment with nebulized albuterol. Oxygen saturation on room air was 98%. She was improved on discharge from the emergency department.
<i>Other cases of possible lower respiratory irritation with zones of residence as designated</i>	
1999-1241	An 8-year-old girl, a resident of zone A, with a history of asthma was evaluated for eye irritation, nausea and shortness of breath. Her symptoms subsided in the emergency room and she did not require treatment with a bronchodilator.
1999-1539	An adult male, a resident of zone A, complained of problems breathing, but did not go to the doctor, because he didn't have any money or health insurance.
1999-1559	A 35-year-old woman, a resident of zone D, returned to Earlimart at approximately 9 p.m. on Saturday after spending the evening in Delano. Although she lives on the north end of town, she started feeling slight chest tightness, a headache, and a rash; symptoms resolved over the next 1-2 days.
1999-1237	This 18-year-old resident, whose only address was a post office box, experienced chest pain, shortness of breath and vomiting. She was evaluated at the Delano Regional Medical Center, but did not have any wheezing on auscultation and did not require any treatment beyond avoiding re-exposure.

Table 6 – Non-respiratory conditions possibly aggravated by exposure to metam-sodium by-products on November 13, 1999

Case number	Description
1999-1247	A 33-year-old security guard, with a prior history of peptic ulcer disease, worked 8 hours on Saturday evening, November 13 at a business on East Washington (zone C). He sought treatment at the Delano Regional Medical Center on November 14, complaining of vomiting and coughing up blood, chest pain, eye irritation, and a slightly pruritic rash on his trunk and extremities. His physical examination was unremarkable apart from some excoriations on the skin. He had a normal CBC and chemistry panel and responded to treatment with Benadryl® and intravenous fluid.
1999-1250	A 53-year-old woman, whose address was listed only as a post office box, was treated for chest pain, nausea and vomiting, weakness, dizziness and headache. Hospital records indicated that her blood pressure was 212/114; it could not be determined whether her condition was related to anxiety or to having run out of her blood pressure medicine 2 weeks earlier. She was observed at the hospital to rule out myocardial infarction
1999-1253	A 62-year-old man, whose address was listed only as a post office box, was treated at Delano Regional Medical Center for hypertension, shortness of breath and chest pain. The treating physician reported that his condition was aggravated by anxiety related to the metam-sodium exposure.
1999-1573	A 27-year-old farm laborer, a resident of zone B, with bilateral pterygia (conjunctival overgrowth encroaching on the cornea) reported experiencing transient eye irritation. On interview he indicated that he had the pterygia for several years previously.

Table 7 - Skin conditions reported following exposure to metam-sodium by-products on November 13, 1999

Case number	Description
<i>Zone A (≤ 0.6 miles from the treated field)</i>	
1999-1617	A 40-year-old resident of South Elm Street reported noticing a strong odor as well as experiencing a facial dermatitis, eye irritation, nausea, and dizziness. She also had a child ill with chicken pox.
1999-1537	A resident of South Elm noted that her daughter had a rash, possibly due to the pesticide exposure, because the windows of their home were open on November 13, 1999. When she took her daughter to the doctor, she was told that the rash was unrelated to the metam-sodium episode, but no medical records were available for review.
1999-1244	A 10-year-old resident of South Elm experienced headache, nausea and eye irritation, noted on evaluation at the Tulare District Hospital. He reported breaking out in a rash on 11/16/99.
1999-1572	A 5-year-old resident of South State was noted by her father to have eye irritation, a facial rash, and vomiting on Saturday 11/13/99. On medical examination 11/19/99, she had a slight residual eruption, consisting of fine papules across the forehead.
1999-1587	A child residing on South Lane was noted by his mother to have experienced irritated eyes, a severe rash, and a bad cough.
1999-1619	A child residing in the 800 block of South Olive was noted by her mother to have pain in her legs and rashes all over her body.
<i>Zone B (0.61 – 0.82 miles from the treated field)</i>	
1999-1235	A 56-year-old resident of East School noted a strong odor and itching of the throat. She reported to the agricultural commissioner’s office in an interview that she also had a headache and a rash, but a rash was not noted when she was examined at the Tulare District Hospital.
<i>Zone C (0.83 – 1.08 miles from the treated field)</i>	
1999-1311	A woman residing on East Washington experienced trouble breathing, dizziness, stomach problems, nausea, and headache. She also noted having a skin rash that looked like chicken pox. No dermatitis was noted on examination at Sierra View District Hospital.



Sprinkler set	Application date	Application time	Estimated flux between 1700 -1900 hours on November 13
6	11/13/1999	1500-1930	204 $\mu\text{g}/\text{m}^2/\text{sec}$
5	11/13/1999	0730-1330	74 $\mu\text{g}/\text{m}^2/\text{sec}$
4	11/12/1999	0845-1455	30 $\mu\text{g}/\text{m}^2/\text{sec}$

Figure 3 - ISC modeling performed by Barry²³ for sprinkler sets 4, 5, and 6. Iso-concentration bars are labeled in estimated ppm of MITC. Axes are labeled with Universal Transverse Mercator (UTM), or global positioning, coordinates. Estimated contributions of each sprinkler set to the flux (evaporation/unit of area) are as shown in the accompanying table.

Table 8 – Summary of violations noted in enforcement investigation following community exposure to metam-sodium byproducts on November 13, 1999.

<p>The applicator was cited for failure to maintain records of soil temperature in the treated field for applications on November 9, 10, 11, 12 and 13.</p>
<p>The applicator was cited for failure to apply an adequate amount of water for the applications on November 9, 10, 11, 12 and 13. The water applied was calculated to be equivalent to 0.16 inches of water rather than the 0.25 inches of water required.</p>
<p>The applicator was cited for applying during inappropriate meteorological conditions "not conducive to the application". Evidence cited included data from the Famoso weather station showing the change in wind direction between 5:00 and 6:00 p.m. in the evening. The probability of a thermal inversion was also cited.</p>
<p>The applicator was cited for failure to adequately monitor the off-site migration of odor.</p>
<p>The applicator was cited for failure to properly maintain pesticide application records.</p>
<p>The grower was cited for failure to post warning signs at appropriate intervals on the edge of the treated field.</p>

Table 9: Procedure for determining presence of a temperature inversion

The presence of fog definitely indicates the occurrence of an inversion.
Daytime applications in the absence of fog are permissible.
For nighttime applications, over cast skies indicate the occurrence of favorable dispersion conditions.
Sprinkler applications are not permitted at night if overcast skies are absent.
If overcast skies are not present, the decision depends on the type of irrigation; applications are permissible using shank, drip or flood irrigation if the wind speed exceeds 7 mph.

* Source of Data: Pesticide Use Enforcement Branch, Fresno District Office. Identical to the information contained in the Metam Sodium Task Force Quarterly Newsletter, Spring 2001-“How Do You Identify an Inversion? Why is it Important to Avoid Applying by Shank Injection or Chemigation During an Inversion Condition?” – available at www.metampsc.com/newsletters.htm.

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