Health & Safety Report

Worker Health and Safety Branch

HS-1862

An Evaluation Of Illnesses Associated With Exposure To Agricultural Uses Of Metam Sodium, Metam Potassium, And Dazomet

By

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September 24, 2007

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AN EVALUATION OF ILLNESSES ASSOCIATED WITH EXPOSURE TO AGRICULTURAL USES OF METAM SODIUM, METAM POTASSIUM, AND DAZOMET

EXECUTIVE SUMMARY

Introduction

Metam sodium, metam potassium, and dazomet are considered viable alternatives to methyl bromide to control weeds, plant diseases, insects, and nematodes in soil prior to planting fruit and vegetable crops in California. They do not appear to affect the stratospheric ozone layer. Metam sodium, metam potassium, and dazomet degrade rapidly to methyl isothiocyanate (MITC), the primary bioactive agent, as well as to methylisocyanate, carbon disulfide, hydrogen sulfide, and methylamine depending on soil pH and other environmental conditions. In agricultural applications, they are used as a pre-plant treatment applied directly to the soil before a crop is planted using sprinklers, soil injection, and flat, bed, or band fumigation. These agents are not applied directly to desired crops. In California, metam sodium, metam potassium, and dazomet products are designated as restricted materials that require a permit to apply. Products containing MITC as the active ingredient are not registered for agricultural use and will not be discussed in this evaluation.

Metam sodium, metam potassium, and dazomet have been designated as toxicity category I for dermal irritation and toxicity category III for acute oral toxicity and eye irritation. Metam sodium has been designated a toxicity category II for acute dermal and toxicity category IV for acute inhalation toxicity. Metam potassium and dazomet have been designated a toxicity category III for acute dermal and acute inhalation toxicity. These agents may be corrosive, damaging to the skin, and/or induce allergic reaction in some individuals. They may be fatal if swallowed, absorbed through the skin, or inhaled, and may cause irritation to the eyes, nose, and/or throat.

Because of the low cost and effectiveness in controlling soil pests, the use of these products (metam sodium, metam potassium, and dazomet) increased about two-fold from 1992 to 2003. Metam sodium accounts for the majority of that increase. During this same time period, several illnesses related to MITC-generating pesticides occurred. This report provides information on illnesses related to the agricultural use of MITC-generating compounds, and the possible risk factors associated with their use patterns.

Methods

The illness cases discussed in this evaluation report were obtained from the Pesticide Illness Surveillance Program (PISP) in the Worker Health and Safety Branch of the California Department of Pesticide Regulation (DPR). California state law mandates physicians to report any illness or injury that they suspect is related to a pesticide exposure to their local county health officer. PISP also receives reports of suspected pesticide exposures from state poison control centers, worker's compensation records, and county agricultural commissioners (CAC). County agricultural commissioners investigate every report of suspected illness related to pesticide exposure and submit an investigation report to DPR. DPR has evaluated, coded, and entered all information into a

database. For this report, a query of the PISP database retrieved incidents that resulted from the agricultural application of MITC-generating compounds from 1992 through 2003.

Results

A total of 777 cases, including both occupational (298 cases or 38%) and non-occupational (479 cases or 62%) from 1992 through 2003, were evaluated for this report.

Of the 298 occupational cases, 139 cases or 47% were workers involved in field activities; 72 (24%) were packaging/processing crops; 31 (10%) cases were applicators, mechanics or mixer/loaders; 6 (2%) involved emergency response personnel; 20 (7%) were doing routine indoor/outdoor activities; and 30 (10%) cases involved other activities. The occupational routine indoor cases took place within a prison, a business service establishment and a farm. The occupational routine outdoor cases took place at an office/business (security guard outside), railroad, and school.

Of the non-occupational cases, most of the reported illness and injury cases involved routine indoor activities (302 cases or 63%), routine outdoor activities (170 cases or 35%), other activities (4 cases or 1%), and 3 unknown activities. The majority of the routine indoor and outdoor cases took place at residences.

Out of 777 cases, symptoms reported were eye injuries (294 cases or 38%), combination of eye, respiratory, and systemic (116 cases or 15%), eye and systemic (112 cases or 14%), eye and respiratory (102 cases or 13%), and other combinations of symptoms (153 cases or 20%).

Conclusions

The use of MITC-generating compounds doubled between 1992 and 2003. Although most metam sodium applications occur each year without reported adverse effects, there were 777 illnesses related to metam sodium exposure from 1992 through 2003. The vast majority of these illnesses occurred during one of the 19 incidents resulting in investigations.

This report identifies several important factors that affect the magnitude of off-site pesticide movement. Inadequate soil moisture before a metam sodium application can result in offsite movement. Multiple-set sprinkler applications were identified as a common factor in several priority illness cases. The probable reason is that treated fields receive inadequate post-application water with this method of application.

From the incidents discussed in this report, it was noted that adequacy of post-application treatment, weather conditions, total acres treated, and distance from occupied structures can contribute to potential human exposure. Careful precautionary measures must be taken when applying MITC-generating products. It is necessary to monitor wind speed and direction, air temperature, and soil moisture status before and during application. In addition, immediate and adequate post-application water treatment could also reduce exposure. The existing labeling and permit conditions, if followed properly, prevent offsite migration of MITC most of the time. However, there are situations where the conditions in place at the time of the incidents were not adequate to prevent offsite movement, causing significant impacts on individuals and communities.

INTRODUCTION

Background

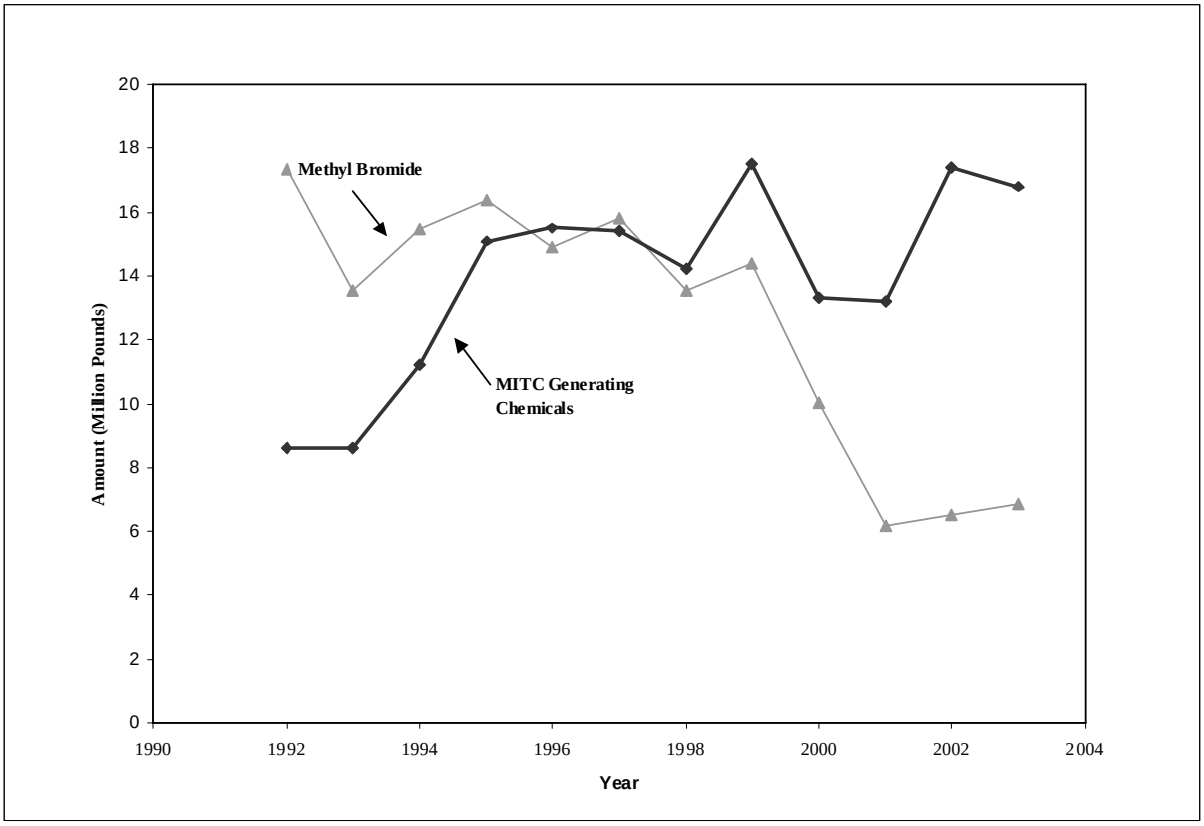
This report describes the reported illnesses evaluated by the California Department of Pesticide Regulation (DPR), Pesticide Illness Surveillance Program (PISP) as related to the agricultural use of methyl isothiocyanate (MITC)-generating pesticides. As farmers sought out alternatives to methyl bromide in California, the annual use of MITC-generating products was increased. This report focuses on illnesses related to agricultural applications of metam sodium, metam potassium, and dazomet products.

Metam sodium, metam potassium, and dazomet are used to control weeds, plant diseases, insects, and nematodes in soil prior to planting fruit and vegetable crops (Braun and Supkoff, 1994; McGovern *et al*., 1996; Roberts *et al*., 1988). In California, Buckman Laboratories first registered metam potassium (Busan 52) in 1974, Ondeo Nalco Company registered dazomet product (Nalcon 248 microorganism control chemical) in 1974; and California Liquid Fertilizer Company registered metam sodium (Calico Brand Vapam) in 1969 (DPR 2006a).

Depending on climatic conditions and soil type, metam sodium, metam potassium, and dazomet decompose to a gaseous fumigant, MITC, as well as, to methylisocyanate, carbon disulfide, hydrogen sulfide, and methylamine (Roberts *et al*., 1988). Currently, farmers use these products extensively as a pre-plant soil treatment in many counties of California for a wide variety of fruit and vegetable crops, such as melons, peppers, tomatoes, potatoes, strawberries, grapes, artichokes, asparagus, and carrots (UC, 1996).

All MITC-generating products are water-soluble and can be applied by a number of application methods, including chemigation, flat or bed fumigation and applied via broadcast or in a band (Adams and Johnston, 1983; Adams *et. al*., 1983; ICI 1992; Browne *et al*., 2002; Nohling, 1998; McGovern *et al*., 1998; UCB Chemicals, 2002). With the phase out of methyl bromide, MITC-generating product uses have generally increased over the years; annual pesticide use data clearly illustrate this trend in Figure 1 (DPR 2005).

Figure 1. Agricultural use of methyl isothiocyanate (MITC)-generating products and methyl bromide, 1992 - 2003[a]



[a]DPR (2005).

Physical and Chemical Properties of MITC-Generating Products

Metam Sodium

Metam sodium is also known as sodium N-methyldithiocarbamate, methyldithiocarbamic acid sodium salt, and methylcarbamodithioic acid sodium salt. Metam sodium's chemical structure is shown in Figure 2. Physical and chemical properties of metam sodium are listed in Table 1.

Figure 2. Metam sodium chemical structure

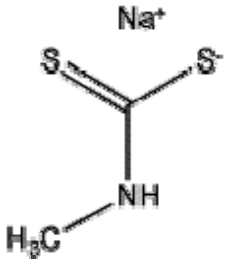


Table 1. Physical and chemical properties of metam sodium end-use products

Chemical Property	**Value**
Empirical Formula	$C_2H_4NNaS_2$
Molecular Weight	129.18
CAS Registry Number(s)	6734-80-1, 137-42-8
Physical Appearance: Technical grade active ingredient (TGAI) End-use	 Solid, colorless crystalline dihydrate[a] Liquid, colorless to faint yellow-green
Density: TGAI End-Use	Not available 1.1648 g/cm^3 at 20 °C[b]
Odor: TGAI End-Use	Acrid, garlic-like Rotten egg, mercaptan-like[b]
Boiling Point (°C): TGAI End-Use	Not available 111 at 783 mm Hg
Melting Point (°C): TGAI End-Use	Decomposes without melting[a] 0 °C[d]
pH: TGAI End-Use	9.0-10.5[c] 9.5-11.0[d]
Specific Gravity: TGAI End-Use	Not available 1.21 g/ml at 68/39 °F[d]
Flash Point: TGAI End-Use	Not available None at 110 °C
Water Solubility: TGAI End-Use	722 g/L H_2O at 20 °C Miscible[d]
Vapor Pressure: TGAI End-Use	Not available 24 mm Hg at 25 °C (77 °F)[d]
Henry's Law Constant: TGAI End-Use	Not available 4.3 x 10^{-6} (atm-m^3/mole, 25 °C)
Corrosion Characteristics: TGAI End-Use	Not available Corrosive to brass, copper, zinc, and aluminum. May soften or discolor iron[c]

[a]Tomlin (1997),
[b]Myers and Johnson (1985)
[c]OR-CAL (1987)
[d]Amvac Chemical Corporation (1992)

Metam sodium end-use products are stable at a pH values above 8.8 and readily convert to carbon disulfide and amine salts when the pH is below 7.0. If acidified, it may form hydrogen sulfide gas. Metam sodium is stable at ambient temperatures and atmospheric pressure. Heating will cause metam sodium decomposition to form MITC and carbon disulfide. Prolonged exposure to air will result in gradual decomposition to form MITC (OR-CAL, 1987).

Metam Potassium

Metam potassium is also known as potassium N-methyl dithiocarbamate. The chemical structure of metam potassium is shown in Figure 3. Physical and chemical properties of metam potassium are listed in Table 2.

Figure 3. Chemical structure of metam potassium

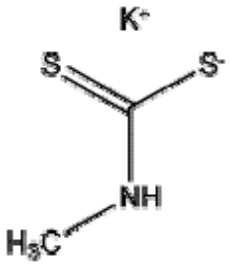


Table 2. Physical and chemical properties of metam potassium[a] end-use product

Chemical Property	**Value**
Empirical Formula	$C_2H_4NKS_2$
Molecular Weight	145
CAS Registry Number	137-41-7
Physical Appearance	Liquid, yellow to yellow-green
Density	1.27 g/cm^3 at 20 °C[b]
Odor	Essentially odorless to fairly strong odor of amine and sulfur
Boiling Point	112 °C at 783 mm Hg
Melting Point	Not available
pH	9.0-11.5
Specific Gravity	1.27 g/mL at 20 °C/4 °C (68 °F/39 °F)
Water Solubility	Miscible
Vapor Pressure	24 mm Hg at 25 °C (77 °F)

[a]Amvac Chemical Corporation (1992);
[b]Myers and Johnson (1985).

Dazomet

Dazomet is also known as tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione. The chemical structure of dazomet is shown in Figure 4. Physical and chemical properties of dazomet are listed in Table 3.

Figure 4. Chemical structure of dazomet

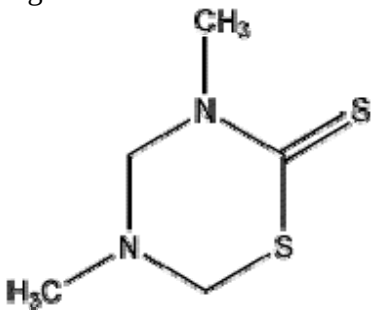


Table 3. Physical and chemical properties of dazomet[a] end-use products

Chemical Property	**Value**
Empirical Formula	$C_5H_{10}N_2S_2$
Molecular Weight	162.3
CAS Registry Number	533-74-4
Physical Appearance:	White/yellowish solid
Relative Density	1.3 (water=1)
Boiling/Melting Point	104 °C at 760 mm Hg
Specific Gravity	0.6 – 0.8 kg/L
Water Solubility	0.3 g/100 mL at 20 °C
Vapor Pressure	0.0000058 mm Hg at20 °C
Hydrolysis Half Life	3.63 days at 20 °C
Aerobic Soil Half-Life	7.5 days at 20 °C
Anaerobic Soil Half-Life	14.0 days at 20 °C
Henry's Law Constant	2.57 k_H at 20 °C
Vapor Pressure Constant	4.35 mmHg at 20 °C
[a]BASF Corporation (1995)	

Use of MITC-generating products in California

Metam sodium products
As of May 24, 2006, there were 20 products containing metam sodium actively registered in California (DPR, 2006a). All registered metam sodium products in California are restricted materials. Metam sodium products are not federally restricted use materials when labeled for production of agricultural commodities. Metam sodium products are registered for use as fungicides, insecticides, herbicides, bactericides, and nematicides. The annual use of metam sodium in California increased from 8.6 million pounds in 1992 to 14.8 million pounds in 2003 (Table 4). During this period, the highest use was in 1999 totaling 17.5 million pounds, and the lowest use was in 1992 totaling 8.6 million pounds. In 1999, it was reported that 6.6 million pounds of metam sodium were applied to carrots, 4.1 million pounds were applied to tomatoes, 2.1 million pounds were applied on potatoes, 0.7 million pounds were applied on cotton, and 4.0 million pounds for all other applications (DPR 2006b).

In California, metam sodium is used throughout the year with two distinct peak-use periods; January to April and July to October. The two low-use periods are from May to June and November to December.

Metam sodium is typically injected, incorporated into the soil using a rotary tiller, or applied by chemigation, 14 to 21 days before planting. Once metam sodium is in the soil, it degrades rapidly to MITC, the principal bioactive ingredient that kills weeds, fungi, insects, and nematodes.

Metam potassium products
Like metam sodium, metam potassium products are also intended for use as bactericides, fungicides, herbicides, insecticides, and nematicides. As of May 24, 2006, there were 14 actively registered products containing metam potassium available in California (DPR 2006a). Metam potassium products are restricted materials in California, but not federally restricted use pesticides. Metam

potassium is typically injected, incorporated into the soil using a rotary tiller, or applied by chemigation, 14 to 21 days before planting. Metam potassium is primarily used on tomatoes, potatoes, watermelon, Brussels sprouts, and head lettuce. There was no reported agricultural use of metam potassium from 1992 through 1996 or in 1999. However, its annual use has steadily increased since 2000, when methyl bromide was identified as an ozone-depleting compound. Metam potassium use in California has increased more than 800-fold from 1997 (2283 pounds) to 2003 (1.9 million pounds) (Table 4).

Dazomet products

Dazomet is registered for forestry, rangeland, and right-of-way uses as a pre-plant pesticide for the control of weeds, nematodes, and soil-borne diseases. High application rates are also effective against millipedes, and soil insects such as armyworms, cutworms, and wireworms. As of May 24, 2006, there were 18 actively registered products containing dazomet available in California (DPR, 2006). Dazomet products are restricted materials in California, but they are not federally restricted use pesticides. Unlike metam sodium and metam potassium, dazomet is tilled or injected as a dry granule, or liquid into the soil, or applied to the soil surface, and watered into the soil to activate. The annual use of dazomet has increased slightly from 15,062 pounds in 1992 to 44,798 pounds in 2003 (Table 4). The highest use of dazomet was in 2002 (45,268 pounds), and the lowest use was in 1993 (2,570 pounds).

Table 4. Annual use of metam sodium, metam potassium, and dazomet in California, 1992-2003[a].

Year	Metam sodium (pounds)	Metam potassium (pounds)	Dazomet (pounds)	TOTAL (pounds)
1992	8,566,331	0	15,062	8,589,909
1993	8,589,017	0	2,570	8,592,080
1994	11,173,565	0	3,026	11,178,810
1995	15,131,385	0	5,877	15,137,385
1996	15,507,916	0	12,851	15,520,767
1997	15,408,754	2,283	16,399	15,427,788
1998	14,126,467	9,143	15,246	14,151,076
1999	17,480,786	0	12,488	17,493,890
2000	13,228,478	105,364	10,526	13,347,691
2001	12,703,694	464,882	44,333	13,215,780
2002	16,076,771	1,267,737	45,268	17,393,287
2003	14,815,687	1,911,698	44,798	16,772,731
TOTAL	162,808,850	3,761,107	228,444	166,821,194
AVERAGE	13,567,404	313,426	19,037	13,901,766

[a]DPR (2005);

Regulatory History

U.S. Environmental Protection Agency

In the United States, metam sodium was first registered in 1954 (U.S. EPA, 1994). The availability of risk assessments for metam-sodium, metam-potassium, and dazomet was announced in the Federal

Register (Vol. 69, No. 106, pages 31104-31106) in June of 2004. The U.S. EPA developed these documents for making pesticide reregistration eligibility decisions.

California Department of Pesticide Regulation
In July 1994, following an interim evaluation of human risk from agricultural use, the DPR listed metam-sodium as a restricted material (Title 3, California Code of Regulations [3CCR], section 6400). Metam potassium and dazomet were listed as restricted materials in August 2001. Thus, these materials require a use permit from the county agricultural commissioner. Permit conditions may require buffer zones, reduced application rates, and acreage limitations depending on specific local conditions. As restricted materials, metam sodium, metam potassium, and dazomet may only be used under the supervision of a certified applicator.

Acute Toxicity Studies (technical grade)

Metam sodium, metam potassium and dazomet are considered toxicity category III for acute oral toxicity and primary eye irritation, and toxicity category III or IV for acute inhalation toxicity (Moore, 1994, 1995, 1997; Corlet and Rubin, 1996; Berliner and Patterson, 1995) (Table 5). However, for dermal irritation, they are considered category I. Metam sodium is considered category II for acute dermal toxicity, where as metam potassium and dazomet are considered category III for acute dermal toxicity. Metam sodium can cause mild eye and severe skin irritation (UCB Chemicals, 2000). Metam sodium has the potential to cause dermal sanitization or allergic reactions due to prolonged or frequent exposure. Similar effects may also be observed from metam potassium and dazomet since both active ingredients produce MITC, like metam sodium when injected into the soil.

Table 5. Toxicity categories for metam sodium, metam potassium, and dazomet.

Route of exposure	Metam sodium	Metam potassium	Dazomet
Acute oral	III	III	III
Acute inhalation	IV	III	III
Acute dermal	II	III	III
Primary eye irritation	III	III	III
Primary dermal irritation	I	I	I

Signs and Symptoms of Poisoning

MITC has a strong pungent odor that smells like horseradish. MITC has a fairly low toxicity if swallowed or absorbed through the skin. It is a severe skin irritant. People who have pre-existing skin rashes or breaks in the skin may be more susceptible to skin irritation. High concentrations of MITC in the air can quickly cause eye, nose, and throat irritation, headaches, and nausea (UCB Chemicals, 2000). However, these symptoms are generally not lasting, and usually disappear within a few hours of exposure. Common symptoms of MITC exposure include headache, dizziness, eye irritation, nose and throat irritation, nausea, diarrhea, shortness of breath, and chest tightness. Symptoms may be delayed a week or more and may also include weakness, diarrhea, cough, and rash. Exposure to MITC can pose a significant health hazard and has resulted in a number of illness incidents. This can quickly move from a relatively minor nuisance to a significant acute health effect.

MATERIALS AND METHODS

The illness case reports discussed in this evaluation were obtained from the Pesticide Illness Surveillance Program (PISP) in the Worker Health and Safety Branch (WHS) of California Department of Pesticide Regulation (DPR). California state law mandates that physicians report any illness or injury that they suspect is related to a pesticide exposure to their local county health officer who forwards the reports to the local county agricultural commissioner (CAC) and to DPR and other state agencies. DPR also receives reports of suspected pesticide-related illness from state poison control centers, and worker's compensation records. The CAC investigates every suspected pesticide related illness report and submits an investigation report to DPR. DPR abstracts all the information submitted by the CAC and enters it into a database.

DPR evaluates and classify these reports based on the likelihood that the resulting symptoms were due to exposure to the suspected pesticide(s). The criteria used for evaluating the relationship between the suspected pesticide exposure and the resulting illness/injury is described below (DPR, 2002):

Definite: High degree of correlation between pattern of exposure and resulting symptomatology. Requires both medical evidence (such as measured cholinesterase inhibition, positive allergy tests, characteristic signs observed by medical professional) and physical evidence of exposure (environmental and/or biological samples, exposure history) to support the conclusions.
Probable: Relatively high degree of correlation exists between the pattern of exposure and the resulting symptomatology. Either medical, or physical evidence is inconclusive or unavailable.
Possible: Some degree of correlation evident. Medical and physical evidence are inconclusive or unavailable.
Unlikely: A correlation cannot be ruled out absolutely. Medical, and/or physical evidence suggest a cause other that pesticide exposure.
Unrelated: Definite evidence of cause other than pesticide exposure including exposures to chemicals other than pesticides**.**
Asymptomatic: Exposure occurred, but did not result in illness/injury
Indirect: Pesticide exposure is not responsible, but pesticide regulations, or product label requirements contributed in some way, (*e.g*., heat stress while wearing chemical resistant clothing).
Not Applicable: A relationship cannot be established because the necessary information is either unavailable, or not provided.

For this report, a query of the PISP database was conducted to retrieve cases that definitely, probably, or possibly resulted from the agricultural application of MITC-generating compounds from 1992 through 2003. The cases discussed in this report were selected based on the following criteria: 1) metam sodium, metam potassium, or dazomet was used as an active ingredient in the application; 2) the cases that were examined by DPR and determined to be related to agricultural use; and (3) the resulting illness was determined to be definitely, probably, or possibly related to exposure.

RESULTS

Illness and Injuries in California

A total of 777 acute illnesses/injuries were attributed to exposure to metam sodium, metam potassium, and dazomet as reported in California from 1992 through 2003 (Table 6). From 1992 through 2003, there were 44 illness/injury cases definitely, 676 probably, and 57 possibly related to exposure to MITC-generating compounds. Since MITC is considered a toxic substance, volatile in the environment, and a major degradation product of metam-sodium, metam potassium, and

dazomet, it is assumed that the majority of illnesses, or injuries were caused by the exposure to MITC.

Table 6. Case reports received by the California Pesticide Illness Surveillance Program in which health effects were classified as to their correlation with exposure to metam sodium, metam potassium, or dazomet during 1992-2003[a].

Year	Illness/injury relationship			Total
	Definite[b]	Probable[c]	Possible[d]	
1992	0	8	6	14
1993	12	4	0	16
1994	3	4	1	8
1995	19	15	0	34
1996	7	41	0	48
1997	1	34	9	44
1998	0	2	1	3
1999	0	149	33	182
2000	1	6	1	8
2001	0	2	1	3
2002	1	376	5	382
2003	0	35	0	35
Total	44	676	57	777

[a]Orr (2005)
[b]*Definite*: High degree of correlation between pattern of exposure, and resulting symptomatology. Requires both medical evidence (such as measured cholinesterase inhibition, positive allergy tests, characteristic signs observed by medical professional) and physical evidence of exposure (environmental, and/or biological samples, exposure history) to support the conclusions.
[c]*Probable*: Relatively high degree of correlation exists between the pattern of exposure and the resulting symptomatology. Either medical, or physical evidence is inconclusive or unavailable.
[d]*Possible*: Some degree of correlation evident. Medical and physical evidence are inconclusive, or unavailable.

Metam sodium exposure resulted in 757 illness/injury cases from 1992 through 2003. Exposure to the other MITC-generating products combined resulted in 20 illnesses and injuries (Table 7). The highest number of metam sodium illness/injury cases was reported in 2002 (382), and the next highest number of cases was reported in 1999 (182). Metam potassium exposure resulted in 19 and dazomet exposure resulted in one illness/injury from 1992 through 2003. Therefore, metam sodium has a higher potential exposure concern than any other MITC-generating product.

Table 7. Case reports received by the California Pesticide Illness Surveillance Program in which health effects were attributed to exposure following agricultural use of metam sodium, metam potassium, or dazomet during 1992-2003.

Year	Metam sodium	Metam potassium	Dazomet	Total
1992	14			14
1993	16			16
1994	8			8
1995	34			34
1996	48			48
1997	43		1	44
1998	2	1		3
1999	182			182
2000	8			8
2001	3			3
2002	382			382
2003	17	18		35
Total	757	19	1	777

Priority investigations for human effects are those that involve death, serious illness (any pesticide illness requiring hospital admission as in-patient status), or any injury, or illness involving five, or more persons. There are 19 priority investigations involving MITC-generating pesticides reported from 1992 through 2003, with a total of 727 illness/injury cases (Table 8). Metam sodium was the pesticide responsible in 18 incidents, while metam potassium was involved in 1 incident.

Table 8. Number of priority investigations and individual illnesses resulting from MITC-generating pesticide exposure from 1992 through 2003[a]

Year	Number of priority investigations	Number of illnesses
1992	2	11
1993	2	11
1994	0	0
1995	3	39
1996	2	40
1997	1	35
1998	0	0
1999	2	178
2000	0	0
2001	0	0
2002	3	378
2003	4	35
Total	19	727

[a]Orr (2005)

The following is a discussion of each of the 19 priority investigations. Additional details of each priority investigation are included in Appendix 1.

Santa Barbara County, 1992

On January 20 and 21, 1992, a 40-acre field was treated with metam sodium at a rate of 318 lb ai/acre. The January 20 application began at 0800 hours and ended at 1700 hours. On January 21, the application resumed at 0600 hours and was completed at 0900 hours. The material was applied using shanks that injected the material at depths from five to 15 inches, followed by a ring roller pulled behind the application rig. At the completion of the application, the application equipment was rinsed and the rinsate was applied back to the field. No additional water was applied following the application because the pest-control advisor felt that the soil, moist from recent rains, in combination with the roller was sufficient to seal the soil. Six residents of a house 25 feet from the field noticed a very strong onion-like smell the evening of January 21, and experienced eye and throat irritation, dizziness, and nausea. The residents stated that they had not noticed the smell earlier in the day, only in the evening when the wind picked up. All six persons sought medical attention. The doctor told the residents to stay out of their house for three days and return for a follow-up check. They returned to the doctor on January 23, and the doctor found everyone to be fine. However, the grower paid for the family to stay an additional night at a hotel to be sure there would be not additional problems.

The investigator initially thought that there might be a violation of the Food and Agricultural Code (FAC) Section 12003(f), applicator failure to evaluate surrounding properties to determine likelihood of harm; or to the California Code of Regulations (CCR) Section 6614, applicator failure to evaluate surrounding properties to determine likelihood of harm. The house was not noted on the advisor's recommendation. The advisor explained that he did not list the house because the applicator knew the house was there, and also he didn't think he needed to be so concise with a non-restricted material. The investigator determined that all necessary precautions were taken and no violations occurred.

Riverside County, 1993

One five-acre block was treated with metam sodium on March 15 and two additional five-acre blocks were treated on March 16, 1993. No application times are noted on the investigation. Each application was made by sprinkler irrigation. The March 15 application was mistakenly made at a rate of 372 lb ai/acre, which exceeds the maximum application rate of 318 lb ai/acre stated on the label. The applicator could not read the fluid line on the storage tank and did not properly gauge the amount of metam sodium that was being injected. Both March 16 applications were made at a rate of 222 lb ai/acre. Following each treatment, clean water was supplied through the irrigation lines and sprinklers were run for 30 minutes. The March 15 application was made to the block nearest the affected residences, and treatments on the following day were made progressively further from the residences. At approximately 2000 hours on March 16, six residents living 40 feet from the nearest treated field complained of odor, dizziness, sore throat, headache, eye irritation, breathing difficulties, and vomiting. The residents sought medical attention for their symptoms. The investigator found that the lid to the metam sodium bulk storage tank had been left open from 1700 to 2000 on March 16. This storage tank was located approximately 150 feet from the residences. Several violations were identified: FAC Section 12973, use of a pesticide in conflict with its labeling; 3CCR Section 6626, failure to submit pesticide use reports; 3CCR Section 6672(b), improper storage of pesticides; 3CCR Section 6734, failure to maintain washing facilities at pesticide mix/load site; 3CCR Section 6736, failure to provide clean work clothing for employees handling pesticides in toxicity category I or II; 3CCR Section 6738(b)(1)(B), failure to provide and require employees to wear eye protection when adjusting or repairing equipment containing pesticides; 3CCR Section 6738(h), failure to provide and ensure that employees wear respirators and to inform

employees of medical conditions, which may interfere with wearing a respirator; 3CCR Section 6742, failure to maintain equipment in good repair and in an operable condition, and 3CCR Section 6776(a)(3), failure to post warning signs prior to pesticide application. The CAC assessed an Agricultural Civil Penalty for violations to FAC Section 12973, 3CCR Section 6738, and 3CCR Section 6672(b).

San Joaquin County, 1993

Twenty-five acres were treated on November 5, 1993, with metam sodium at a rate of 254 lb ai/acre. The application was made by spraying undiluted metam sodium directly in front of rotovator blades, which break up soil and turn it over. The surface spray was incorporated into the soil to a depth of approximately five inches. A press roller followed after the rotovator. The application was completed at 1715 hours. Beginning at approximately 1800 hours, a resident of a home nearly a quarter mile from the treated field saw a fog-like cloud over a nearby house and called the sheriff. Five people developed symptoms that included burning eyes, headache, throat irritation, nausea, and itchy skin. They were examined in the emergency room and released. The investigator noted that the cloud dispersed over a two- to three-mile area. The cause of the fog-like cloud is not known, but the applicator, CAC, and DPR representatives speculated that it was probably the result of an inversion layer that developed shortly after the application was completed. No violations were noted.

San Joaquin County, 1995

On September 26, 1995, at 0630 hours, 14 employees of a rubber company complained of burning eyes, headache, nausea, and difficulty breathing due to an odor in the air. All 14 went to a doctor to be examined. It was determined by the local sheriff's office that the odor was due to a metam sodium application underway. The field under treatment was approximately 660 feet from the rubber company. The sprinkler application to 22 acres began at 0400 hours. The application rate was 318 lb ai/acre. An application to another 22 acres was completed three days earlier at the same location with no reported problems. When notified by the sheriff of the offsite odor problem, the applicator stopped the application and began applying water. It was determined that an inversion had developed at 0500 hours that morning. No violations were noted.

San Joaquin County, 1995

On October 27, 1995, at approximately 2100 hours, eight staff and 11 inmates at two California Youth Authority institutions noticed a sulfur-like smell and developed teary eyes, nose and throat irritation, nausea, and vomiting. A sprinkler metam sodium application, which began at 1700 hours, was underway at a five-acre field east of the facility. The California Youth Authority was located approximately ½ mile from the treated field. The application rate is unknown. When the grower noticed that the wind shifted toward the facility (time not noted in investigation), he began clearing the injection lines to stop the application. However, it took 18 to 24 minutes to clear the lines. No violations were noted. Six employees of a rubber company also developed the same symptoms. They were familiar with the odor and irritation, due to a prior drift incident from an application by a different grower. These employees sought medical attention and returned to work two-hours later.

San Joaquin County, 1996

As part of an application to a 129-acre field, metam sodium was applied by sprinkler irrigation at a rate of 318 lb ai/acre. The applicator's log showed that two sets of sprinklers were run, each on about 16 acres. The first set ran September 7 from 0730 to 1530 hours. The second set began that evening at 1800 hours and ran until 0200 hours the following morning. According to the applicator, the irrigation lines were flushed after each set, and a water application was made for about one hour. A second water application was made three to five hours later. Both water applications were completed

before beginning the metam sodium application to the next set. Prior to the application, the ground had been cultivated to break up dirt clods, formed into seedbeds, and pre-irrigated to moisten the soil down to 10 to 12 inches. The applicator estimated that the soil moisture was at 60% field capacity at the time of the metam-sodium application. The application site was approximately 0.8 miles from a youth authority facility. Beginning at 2330 hours on September 7, youth authority staff members complained of a bad odor and developed nausea, breathing problems and burning eyes. They called the fire department who responded and found that the odor was coming from the treated field. Eleven persons were affected. Weather data showed a slight wind direction change toward the facility during the application. The investigator noted a violation of 3CCR Section 6630, which requires the service rig to be identified with the company name and license number.

Fresno County, 1996

A 20-acre field was treated with metam sodium on October 16, 1996. The metam sodium was applied at a rate of 298 lb ai/acre, using shanks that injected the material at depths of nine and 15 inches. A separate tractor with a ring roller followed directly behind the injector. The investigation does not state what time the application was completed. Seven days prior to the application, the field was irrigated. Soil moisture was over 50% of field capacity on the day of the application. On the morning of October 17, between 0715 and 0735 hours, 34 children were waiting for a school bus approximately 1/8 mile from the treated field when they noticed an odor; 29 children developed symptoms of burning and watery eyes. The investigation does not state how many children were seen by a doctor. A violation of 3CCR Section 6434 was noted for the grower's failure to resubmit a Notice of Intent (NOI) after the original NOI had expired. The original proposed date of application was October 10.

Kern County, 1997

A metam-sodium application began at 1000 hours on June 24, 1997, and was completed by 2000 hours the same day. The application rate was 128 lb ai/acre, using shanks that injected the material at depths of 12, eight, and four inches into the soil. Immediately following the injection, twelve-inch shovels covered the beds and injection sites with soil. There were several homes surrounding the treatment site, less than 0.2 miles from the site, but no buffer zone was required. Beginning at 2005 hours the day of the application, residents began calling the fire department to complain of a strong odor. The fire department called the CAC office to report the incident at 2130. The responding firemen experienced burning/watering eyes and trouble breathing. Residents from four homes reported symptoms and decided to voluntarily evacuate. Thirty-five people developed symptoms, including the two emergency responders. The grower began rolling the field with a cultapacker at 0130 hours on June 25, completing the rolling at 0930 hours. No offsite odor was detectable after the rolling was completed. A violation was noted for the applicator's failure to complete the Kern County Metam Sodium fumigation summary.

Santa Barbara County 1999

At 2030 hours on May 17, 1999, the mother of a family of six called the fire department from an automotive garage to report a strong odor that caused five of them to develop burning eyes and sore throats. When fire personnel arrived, they were unable to detect the odor, but a sheriff's officer traced the odor to a nearby field later that night. On May 19, in the morning (time not specified in the investigation), the fire department was called to the elementary school with complaints that five staff and 17 students smelled an odor; eight students experienced nausea, vomiting, headaches, sore throats, burning eyes and fainting. As a precautionary measure, students were transported to the local high school where classes were held for the remainder of the 19th and the 20th. Classes were canceled

on the 21st. The elementary school was located approximately 500 feet from the edge of a field recently treated with metam sodium. The automotive garage was approximately ½ mile from the elementary school, with the school between the garage and the treated field.

Metam sodium was applied using sprinkler to a 100-acre field over a three-day period, from May 14 through May 16. Twenty-five acres were left untreated, acting as a buffer zone between the field and the school. All applications were made at a rate of 213 lb ai/acre. There is no information concerning the volume or length of post-treatment, water applications. The applications were as follows:

- On May 14, 25 acres were treated between 1900 and 2100 hours, with water application ending at 0600 hours on May 15. A second water application was applied later on May 15.
- On May 15, 25 acres were treated between 1900 and 2100 hours with water application ending at 0600 hours on May 16. A second water application was applied later on May 16.
- On May 16, 25 acres were treated between 1100 and 1300 hours with a water application ending at 2100 hours.
- A third water application was made to all 75 acres on the morning of May 17. A fourth water application was made on May 18, and a fifth water application was made on May 19.

From May 17 through May 19, an additional 100 acres were treated. This site is ½ mile further from the school than the previously treated sites. All applications made at a rate of 213 lb ai/acre. There is no information concerning the volume or length of post application, water applications. The applications were as follows:

- On May 17, 1/3 of the field was treated between 1900 and 2200 hours, with water application ending at about 0400 hours on May 18. A second water application was made later (time not specified) on May 18.
- On May 18, 1/3 of the field was treated between 0400 and 0800 hours, with water application ending at 0200 hours on May 19. During the metam sodium application, the injection line broke, and about five gallons of material spilled on the soil. The applicator scooped up this soil and put it in the treated area to be watered in. A second water application was applied at 1800 hours.
- On May 19, the final third 1/3 of the field was treated between 1200 and 0300 hours, with water application ending around 0900 hours on May 20. A second water application was made later that afternoon.

The following is a summary of the grower's noncompliance:

- Application equipment used did not meet regulatory and Technical Information Bulletin (TIB) specifications requiring closed systems
- Monitoring for offsite movement did not take place as required by the TIB
- No metam sodium application or monitoring records were kept as required by the TIB
- Failure to wait the specified interval after metam sodium application prior to planting
- Grower did not have application specific information for handlers or fieldworkers
- Pesticide containers not properly rinsed
- Pesticide use reports not submitted for a five-month period
- Grower made a subsequent (May 24 – 26) sprinkler application in violation of an interim permit condition put into place following the May 17 incidents
- Some fields were misidentified on records, or the grower failed to amend the permit to include them.

The investigator concluded that current restrictions were not sufficient to protect against the occurrence of odor complaints from metam sodium sprinkler applications. Following this incident, the CAC prohibited sprinkler applications of metam sodium within one mile of an occupied structure.

Tulare County, 1999

Metam sodium was applied to a 75-acre field through sprinklers over a five-day period, November 9 – 13, 1999. The application rate was 177 lbs ai/acre. The field was approximately 1800 feet from the edge of a town. One application was made on each of the first four days, and two applications were made on November 13. All applications were completed during the daylight hours except for the second application made on November 13, which finished at 1930 hours. After each metam sodium application, water was run through the sprinklers for 45 minutes. Water pressure at the pump was 60 – 70 pounds per square inch (psi) and 55 psi pressure at the end of the sprinkler line. The applicator stated that no further post-application water was applied because there was no odor. Twelve to 16 days before the application, the field had been pre-irrigated over a period of six days with a 24-hour run for each section of sprinklers. On November 13, 1999, at approximately 1900 hours, the CAC was notified that persons were becoming ill, possibly from a pesticide application. First calls to fire department were at 1730 hours. Responding firemen noticed that their eyes were burning. Residents experienced irritation of throat and eyes, headache, and nausea. Fire department personnel began a voluntary evacuation. One hundred seventy people developed symptoms as a result of this incident. A Notice of Violation was issued to the applicator for the following violations:

- FAC Section 12973, pesticide use in violation with the labeling. The violations were: 1) a second water application was not made the day following the pesticide application; and 2) not enough water was applied immediately after the application. The TIB stated that 0.25 inches of water might be adequate for sandy or light soil. The CAC office calculated that 0.15 inches of water was applied.
- 3CCR Section 6600(b)(c)(d)(e), general standards of care was not followed because the applicator did not stop the application when odor occurred. Also, the application was not properly monitored or the monitoring was not properly recorded.
- 3CCR Section 6614(a)(b)(1)(3), the applicator did not adequately protect persons during the pesticide application. The application was made under meteorological conditions unsuitable for proper application. The investigator concluded that the application was made when conditions favored an inversion, based on DPR's Environmental Monitoring Branch's review of weather data.
- 3CCR Section 6619(d), no pesticide application completion notices submitted.

The following violation was discovered against the grower:

- 3CCR Section 6776, field was not properly posted.

The Department and the applicator reached a $150,000 settlement agreement, and the Department and the grower reached a $10,000 settlement agreement over this incident.

Kern County, 2002

A sprinkler application of metam sodium was made to 25 acres in two sets at an application rate of 160 lb ai/acre. The first set began at 2000 hours on June 5, 2002, was completed at 2400 hours, and was followed by a one-hour water application. The second set began on June 6 at 0200 hours, was completed at 0600 hours and was also followed by an hour water application. A second water application was made at 0900 hours on June 6, and a third water application was made at 1400 hours.

At 0530 hours on June 6, 138 employees began working in a grape vineyard approximately 200 feet from the field under treatment. They noticed an odor immediately after beginning work.

The foreman moved the crew to another part of the field where three more crews were working, approximately ½ mile further from the field under treatment. These three crews were also experiencing burning and tearing eyes. The foreman moved everybody to another part of the field, approximately one mile from the application. A total of 123 persons reported symptoms, and one worker with nausea and vomiting saw a doctor (illness symptoms for the other 15 could not be determined). The vineyard manager said that he noticed a distinct layer of brown air on the morning of June 6, indicating the possibility of an inversion. Five violations were noted:

- FAC Section 12973, applicator failure to use a pesticide in accordance with registered label
- 3CCR Section 6723(b), applicator failure to make copies of Pesticide Safety Information Series leaflets accessible to employees
- 3CCR Section 6724(a), applicator failure to have a written training program
- 3CCR Section 6434, grower failure to notify commissioner prior to use of a pesticide requiring a permit
- 3CCR Section 6776(d), grower failure to properly post treated field.

<u>Kern County, 2002</u>

On July 8, 2002, at 2116 hours, residents of a small subdivision called 911 to complain of an odor and burning/tearing eyes. Employees of a nearby packing shed also experienced the same symptoms. One of the residents sought medical attention due to difficulty breathing. Two employees of the packing shed also were examined. A total of 250 persons reported symptoms of burning/tearing eyes, sore throats, cough, headaches, nausea, and vomiting. The responding fire department personnel did not smell any odor and did not develop symptoms, and began checking nearby fields to determine the cause of the problem. The local Environmental Health Department and the CAC joined in, and determined that the source of the problem was from a field 500 feet from the homes that had been treated with metam sodium earlier that day. Applications began at 0745 hours on July 8 and were completed at 1520 hours, using three rigs each equipped with shanks injecting at depths of 6, 9, and 12 inches below the soil surface. The application rate was 191 lbs ai/acre. A total of 100 acres were treated. Because the three rigs used to make the application were far ahead of the irrigators, there was a delay in completing post-application water treatments on the last 15 acres treated. The application was completed at approximately 1520 hours; the post-application water treatments were completed by 1830 hours (O'Malley *et. al*, 2005). The CAC provided weather information to DPR's Environmental Monitoring Branch to use in an air dispersion model. The model estimated that exposure to MITC associated with the July 8 application of metam sodium was the likely cause of the eye and throat irritation experienced by residents and packing shed employees. However, the MITC movement from the 15 acres that had a delayed post-application water treatment was not likely to have been sufficient to cause the observed symptoms in the entire neighborhood. The applicator was cited for the following violations:

- FAC Section 12973, use of a pesticide in conflict with it's registered labeling

3CCR Section 6600(c), using methods and equipment not suitable to insure proper pesticide application.

The grower was cited for the following violations:

- FAC Section 12973, use of a pesticide in conflict with it's registered labeling
- 3CCR Sections 6776(a)(d)(f), improper posting of a treated field
- 3CCR Section 6723.1, no application-specific information displayed at a central location within 24 hours of the completion of application.

Fresno County, 2002

A 183-acre site was treated with metam sodium over an eight-day period, beginning on September 12, 2002. Approximately 20 to 23 acres were treated each day by sprinkler at an application rate of 213 lb ai/acre. On September 19, application began at 0700 hours and was completed at 1000 hours, with a post application water treatment completed by 1130 hours. On September 19 at approximately 0830 hours, five persons began working at an aqueduct pumping station within 600 feet of the 20 acres under treatment. The workers smelled an odor and experienced burning eyes, breathing difficulty, and burning skin. A violation of FAC Section 12973 was noted for the following: 1) the permit stated that a person not involved in the application process should conduct odor monitoring (the applicator was also responsible for odor monitoring); 2) soil temperature readings were not taken before, during, and at the completion of the application as required by the Technical Information Bulletin and Fresno County's metam sodium permit conditions; and 3) post application monitoring must be done every 2-4 hours for a 12-hour period (post-application monitoring was only conducted for 8 hours).

Kern County, 2003

On January 18 and 19, 2003, a metam sodium application was made to a field approximately 150 feet away from a group of homes in a rural neighborhood. Metam sodium was applied by shank injection at a rate of 213 lb ai/acre, using shanks that introduced the material at depths of three, six, and nine inches below the soil surface. A ring roller attached to the tool bar sealed the soil. The application began on January 18 at 0600 hours and was completed on January 19 at approximately 1030 hours. A total of 80 acres were treated. Because of the homes located nearby, the grower requested that the applicator leave a 500-foot buffer on the side of the field nearest the homes. The pest control advisor did not recommend a buffer zone, but did note on his recommendation to be cautious of the homes near the field. On the evening of January 19, 15 nearby residents and their visitors developed sore throats, watery eyes, headaches, and stomach and joint pain after noticing a manure-like smell. However, the residents did not notify the CAC until January 27. Three residents sought medical attention. A 13-year-old with a history of asthma began visiting a pulmonary specialist on January 24 due to increased asthma attacks. Two siblings, 13 and 8 years old, visited a doctor because they have had flu-like symptoms for 11 days following their exposure. Two violations were noted: FAC Section 12973, use of any pesticide in conflict with labeling because the grower did not conduct post application monitoring as required by permit conditions; and 3CCR, Section 6776(c)(3), failure to remove warning signs within three days after the end of the restricted entry interval. The CAC determined that there were no non-compliances found in the pest-control-advisor's recommendation. If an application is within ½ mile of a sensitive area, the permit conditions only required the placement of sprinkler irrigation lines in the treatment area; the residences where the complainants lived were not defined as a sensitive area according to the CAC's metam sodium, permit conditions.

Riverside County, 2003

A metam potassium sprinkler application began on September 25, 2003. Application rate was 149 lb ai/acre. The 36-acre field was treated in two sets. The first application set was from 1900 to 2100 hours, followed by an hour water application. The second application set began at 2200 and ran until 2400 hours, followed by an hour water application. Then water was continually applied from midnight until 0400 hours the next morning, alternating every hour between the two sets. Additional water applications began at 0700 hours on September 26 and ran until 1100 hours. On the night of September 25, at approximately 2330 hours, nearby residents (the investigation does not give a distance) heard a loud noise and went outside to see what happened. They experienced burning eyes and coughs and called 911. One of the emergency responders noticed a cloud of gas coming toward him; he also experienced eye irritation. A total of 18 persons experienced symptoms. The investigator concluded that:

- the soil was too dry prior to application
- the metam sodium was not diluted enough during application (applied too fast)
- the "two-set" irrigation design promotes off-gassing problems since a water application cannot be applied while the second set is running.
- Due care by the applicator could have prevented this incident.

Four violations were noted: FAC Section 12973, failure to follow technical information bulletin procedures; 3CCR Section 6406, failure to provide adequate supervision at the site; 3CCR 6600(b), failure to perform pest control in a careful or effective manner; and 3CCR 6614(a), failure to evaluate equipment conditions, property, or surrounding properties to determine the likelihood of harm or damage during application.

Imperial County, 2003

On August 6, 2003, a drip metam sodium application began at 0900 hours, at a rate of 64 lb ai/acre. Because the application was proceeding with no problems, the applicator left the site to get a drink. At approximately 1300 hours, the pressure relief valve broke; spraying metam sodium on the irrigation pump mechanic monitoring the irrigation system. He was wearing coveralls, chemical resistant gloves, and a full-face respirator at the time. He felt dizzy, nauseous, and vomited. He was taken to the hospital, observed, and released. Eight days later he returned to the hospital due to breathing difficulty and was admitted. A violation of FAC Section 12973 was noted, use of pesticide in conflict with label. The permit states that a certified applicator shall be on site to conduct all aspects of the application and sealing process. The CAC proposed a civil penalty against the grower.

Table 9 summarizes the cases by the type of exposure and activity. Most of the illness/injury cases were related to drift, or offsite movement (692 cases). At the time of exposure, 43 percent of those exposed via drift (298 cases) conducted routine indoor activities, 22% (150 cases) participated in routine outdoor activities and 18% (126 cases) were field workers. From this table, it can be concluded that the main source of exposure to metam sodium was from drift (89%). Exposure to residue contributed 7% (57 cases), and other exposure mechanisms combined for 2%.

Table 9. Case reports received by the California Pesticide Illness Surveillance Program, 1992 – 2003, in which health effects were associated with exposure to MITC-generating pesticides used in agricultural applications summarized by the type of activity and type of exposure.

Activity[a]	Type of Exposure[b]						
	Drift	Residue	Direct/ spray/ squirt	Spill/ other direct	Multiple	Other/ Unknown	Total
Applicator	5	0	0	5	3	7	20
Field worker	126	10	1	1	0	1	139
Mechanical	0	0	0	3	0	0	3
Mixer/loader	1	0	0	4	0	3	8
Packing/processing	72	0	0	0	0	0	72
Routine indoor	298	16	0	0	0	0	314
Routine outdoor	150	28	0	0	0	0	178
Other	31	3	0	0	0	0	34
Unknown	3	0	0	0	0	0	3
Total	692	57	1	13	3	11	777

[a]Activities included:
Applicator: Applies pesticides by any method or conducts activities considered ancillary to the application (*e.g.*, cleans spray nozzles in the field).
Field worker: Works in an agricultural field performing tasks such as advising, scouting, harvesting, thinning, irrigating, driving tractor (except as part of an application), field packing, conducting cultural work in a greenhouse, *etc*.
Mechanical: Maintains (*e.g.*, cleans, repairs or conducts maintenance) pesticide contaminated equipment used to mix, load, or apply pesticides, as well as the protective equipment used by individuals involved in such activities. This excludes the following: 1) maintenance performed by applicators on their equipment incidental to the application; 2) maintenance performed by mixer/loaders on their equipment incidental to mixing and loading; 3) decontamination by HAZMAT teams.
Mixer/loader: Mixes, and/or loads pesticides. This includes: 1) removing a pesticide from its original container; 2) transferring the pesticide to a mixing or holding tank; 3) mixing pesticides prior to application; 4) driving a nurse rig; or 5) transferring the pesticide from a mix/holding tank, or nurse rig to an application tank.
Packing/processing: Handles (packs, processes, or retails) agricultural commodities from the packinghouse to the final market place.
Routine indoor: Conducts activities in an indoor environment with minimal expectation for exposure to pesticides. This includes people in offices and businesses, residential structures, *etc*., who are not handling pesticides.
Routine outdoor: Conducts activities in an outdoor environment with minimal expectation for exposure to pesticides. This includes gardeners who are not handling pesticides.
Other: Activity is not adequately described by any other activity category. This includes: 1) being inside a vehicle; 2) individuals handling pesticide-treated wood; 3) two or more activities with potential for pesticide exposure.
Unknown: Activity is not known.
[b]Type of Exposure
Drift: Spray, mist, fumes, or odor carried from the target site by air. Drift must be related to an application or mix/load activity.
Residue: The part of a pesticide that remains in the environment for a period of time following an application or drift. This includes odor after the completion of an application.
Direct spray/squirt: Material propelled by the application, or mix/load equipment. Contact with the material can be by direct projection, or ricochet. This includes exposure of mechanics working on application, or mix/load equipment when the material is forced out by pressure.
Spill/other direct: Any of the following: 1) contact made during an application, or mixing/loading operation where the material is not propelled by the equipment; and 2) leaks, spills, *etc*., not related to an application.
Other/Unknown: Other known, or unknown route of exposure not included in other exposure categories.

Illness/injury cases attributed to MITC-generating pesticides are shown by activity and year in Table 10. There were a total of 382 illness/injury cases reported in 2002 and 182 cases reported in 1999. Of the 777 illness/injury cases reported from 1992 through 2003, 314 cases were conducting routine indoor activities at the time of exposure, 178 cases were participating in routine outdoor activities, and 139 were field workers. Most of these exposures occurred in 1999 and 2002.

Table 10. Case reports received by the California Pesticide Illness Surveillance Program, 1992 – 2003, classified by activity of the individual at the time of exposure.

Activity[a]	Year												Total
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
Occupational Cases													
Applicator	0	1	3	1	2	1	1	1	2	3	4	1	20
Emergency Response	0	0	0	0	0	3	0	2	0	0	0	1	6
Field Worker	1	1	3	0	0	6	1	3	0	0	123	1	139
Mechanical	0	0	1	0	0	2	0	0	0	0	0	0	3
Mixer/Loader	2	3	1	0	2	0	0	0	0	0	0	0	8
Packaging/Processing	0	0	0	0	0	0	0	0	0	0	72	0	72
Routine Indoor	0	0	0	8	0	0	0	3	1	0	0	0	12
Routine Outdoor	0	0	0	0	0	0	0	3	0	0	5	0	8
Other	0	0	0	14	12	4	0	0	0	0	0	0	30
Total	**3**	**5**	**8**	**23**	**16**	**16**	**2**	**12**	**3**	**3**	**204**	**3**	**298**
Nonoccupational Cases													
Routine Indoor	5	10	0	11	4	24	1	131	5	0	103	8	302
Routine Outdoor	6	0	0	0	28	3	0	37	0	0	74	22	170
Unknown/other	0	1	0	0	0	1	0	2	0	0	1	2	7
Total	**11**	**11**	**0**	**11**	**32**	**28**	**1**	**170**	**5**	**0**	**178**	**32**	**479**

[a]Activity included:
Applicator: Applies pesticides by any method, or conducts activities considered ancillary to the application (*e.g.*, cleans spray nozzles in the field).
Emergency response: Police, fire, ambulance, and HAZMAT personnel responding to a fire, spill, accident, or any other pesticide incident in the line of duty.
Field worker: Works in an agricultural field performing tasks such as advising, scouting, harvesting, thinning, irrigating, driving tractor (except as part of an application), field packing, conducting cultural work in a greenhouse, *etc*. Researchers performing similar tasks in an agricultural field are also included.
Mechanical: Maintains (*e.g.*, cleans, repairs, or conducts maintenance) pesticide contaminated equipment used to mix, load, or apply pesticides, as well as the protective equipment used by individuals involved in such activities.
Mixer/loader: Mixes, and/or loads pesticides. This includes: 1) removing a pesticide from its original container; 2) transferring the pesticide to a mixing, or holding tank; 3) mixing pesticides prior to application; 4) driving a nurse rig; or 5) transferring the pesticide from a mix/holding tank, or nurse rig to an application tank.
Packaging/processing: Handles (packs, processes, or retails agricultural commodities from the packing house to the final market place.
Routine indoor: Conducts activities in an indoor environment with minimal expectation for exposure to pesticides. This includes people in offices and businesses, residential structures, *etc*., who are not handling pesticides.
Routine outdoor: Conducts activities in an outdoor environment with minimal expectation for exposure to pesticides. This excludes field workers in agricultural fields. This includes gardeners who are not handling pesticides.
Other: Activity is not adequately described by any other activity category. This includes: 1) being inside a vehicle; 2) individuals handling pesticide-treated wood; and 3) two, or more activities with potential for pesticide exposure.
Unknown: Activity is not known.

Of the 777 illnesses reported from 1992 through 2003, 294 (38%) of these cases involved eye injury alone, 116 (15%) reported eye, respiratory, or systemic symptoms, and 112 (15%) reported eye and systemic injuries, and the remaining 255 (33%) reported a combination of skin, eye, respiratory, and/or systemic symptoms (Table 11).

Table 11. Case reports related to exposure to metam sodium, metam potassium, or dazomet after application to soil for agricultural purposes by type of illness from 1992 through 2003 received by the California Pesticide Illness Surveillance Program by type of illness

Type of illness	Number of cases	Percent of total
Skin	21	3
Eye	294	38
Skin, eye	3	>1
Respiratory	14	2
Skin, respiratory	4	>1
Eye, respiratory	102	13
Skin, eye, respiratory	4	>1
Systemic	34	4
Skin, systemic	11	1
Eye, systemic	112	14
Skin, eye, systemic	5	>1
Respiratory, systemic	32	4
Skin, respiratory, systemic	4	>1
Eye, respiratory, systemic	116	15
Skin, eye, respiratory, systemic	21	3
Total	777	100.0

DISCUSSION

A review of priority illness investigations over a 12-year span provides some insight into circumstances that have lead to exposure to MITC. Twelve of the 19 priority incidents involved sprinkler application of metam sodium, and one incident occurred during a drip irrigation application. Of the five shank applications, three used a ring roller to compact the soil after application; one application was followed by shovels that covered beds and injection sites with soil, and a post-application water treatment. One application method was unique from all others; application was made by spraying undiluted tank mix directly in front of rotovator blades, followed by a press roller.

In four priority incidents, an inversion layer developed either during, or after treatment. These applications resulted in 307 illnesses. During one of these incidents, a fog-like cloud formed and resulted in offsite movement over a three-mile area. MITC is volatile. Therefore, even with containment measures such as soil compaction or post-application watering, MITC can be lost to the atmosphere. Exposure potential is then compounded by a temperature inversion. During a temperature inversion, vertical mixing of air is suppressed. A parcel of air cannot rise and disperse, resulting in a higher concentration of MITC in the air. Because the air parcel can only move downward or laterally, there is an increase in the potential for off-target effects, and an increase in the distance at which off-target effects can be observed.

Of the incidents involving sprinkler application, one incident was probably the result of an over-application, two incidents were due to a shift in wind direction during application, and three incidents were probably due to the formation of an inversion layer. Sprinkler applications resulted in the two incidents that affected a total of 285 persons. In one incident, the application was still ongoing when the crews arrived to begin work in a vineyard approximately 200 feet from the field under treatment. In the other incident applications were made daily over a five-day period; all were made during daylight hours except for the last one, which was completed approximately 2½ hours after sunset. One hundred-seventy seven persons developed symptoms following this application. Computer modeling, using the Industrial Source Complex (ISC) short-term version 3 dispersion model, estimated MITC concentrations during the incident exceeded the 800 ppb ocular irritation threshold. The probable cause of the MITC offsite movement was the applicator's failure to apply adequate post-application water. This was compounded by the fact that the application was made when conditions favored an inversion (O'Malley *et al*., 2004).

A common factor in seven of the priority illness incidents involving sprinkler application was the "multiple-set" irrigation design. This is an application technique where the field to be treated is divided into sections, with sections treated sequentially. Post-application water applications are usually made to the just-treated section of the field before treatment to the next section begins. As one CAC investigator noted, the "multiple-set" irrigation design often results in off-gassing problems since a sufficient volume of water is not always applied before and while the next set is running. A study by the Metam Sodium Task Force (Sullivan, 2000) suggests that a single ½-inch application of water is not a very effective method of retaining metam sodium in the soil. In five of these incidents, the post-application watering lasted for one hour or less. This demonstrates the importance of ensuring that there is adequate post-application water applied. From the review of these cases, it appears that the volume delivered in one hour was not adequate. The investigations often do not provide enough information to determine the volume of water applied post-application.

Only one incident occurred during a drip application. During this incident, the pressure relief valve for the irrigation system broke, spraying metam sodium on the pump mechanic.

Eight of the priority incidents were the result of exposure during application. In three of the cases, the offsite movement of metam sodium was likely due to an inversion layer developing during the application. In two incidents, wind shifts towards occupied buildings during sprinkler applications resulted in a total of 36 persons developing symptoms. In one of these cases, the occupied structure was 0.8 miles (4224 feet) from the field under treatment. One incident involved 138 persons working in a vineyard 200 feet from an ongoing sprinkler application. In another incident, the investigator concluded that offsite movement was most likely due to the soil being too dry prior to the sprinkler application, and that the material was applied too fast. During another incident involving a sprinkler application, five persons working at an aqueduct pumping station 600 feet from a field under treatment smelled an odor and developed symptoms.

Eight of the priority incidents were the result of exposure after applications were completed. In one case, the offsite movement of metam sodium was likely due to an inversion layer developing shortly after the application was completed. Another incident was due to a combination of activities: an application above the maximum label rate, and the lid had been left off the metam sodium bulk storage tank located 150 feet from a group of homes. Three incidents were the result of applications made to fields near homes. The structures were 25 feet, 500 feet, and an unspecified distance from the treated fields. In all these cases, the applications were made following CAC permit conditions. Since these occurrences, the CAC from the counties where these incidents occurred have modified

their permit conditions to restrict metam sodium applications near occupied structures. In another incidence, a multiple-set sprinkler irrigation application was made approximately 2640 feet from a school, with a 25-acre buffer zone left between the field and the school. The investigator concluded that restrictions in place at the time of the application were not sufficient to protect against the occurrence of odor complaints from metam sodium sprinkler applications. Following this incident, the CAC prohibited metam sodium sprinkler applications within one mile of an occupied structure. One incident involved 34 children waiting for a school bus 660 feet from a field treated the previous day. There was no obvious reason for the offsite movement in this case. Another incident resulted in 250 persons who developed symptoms from a treatment made earlier in the day. Following this incident, WHS participated in a community evaluation to further investigate the incident (O'Malley *et al*., 2005). Residents in a four-block area were interviewed, and staff from the DPR's Environmental Monitoring Branch developed a computer model to evaluate the MITC dispersion. MITC concentration was estimated during the incident using the ISC short-term version 3 dispersion models. The 1-hour 200 parts-per-billion (ppb), no observable effect level (NOEL) and 800 ppb lowest observable effect level (LOEL) from a human eye irritation study were applied to interpret the results of the air modeling estimates. No definite reason for the MITC offsite movement was determined. A 500-foot buffer zone was allowed between the fumigated field and the neighborhood. Wind direction was found to be an important consideration. During the period of the highest number of complaints, computer modeling suggests that the plume of MITC from the fumigated field was moving directly toward the affected neighborhood.

Sixty-five percent of the priority illness/injury cases discussed in this paper reported that they noticed an odor. To minimize release of these odors, EPA-approved labeling requires treated fields to be sealed immediately. There are several methods to accomplish this, including applying water by sprinkler irrigation, tarping, packing soil with a roller, drag or press wheel, or covering with an adequate amount of untreated soil. In August 1993, the Environmental Hazards Assessment Program of DPR monitored an application made under the worst-case scenario: sprinkler application made during high air temperature, low humidity, warm soil temperature, and at the highest allowable application rate. The application began at 1930 hours at a rate of 388 lb ai/acre and continued for six hours, followed by a post-application water treatment of 1½ hours (which included flushing the lines). Samples were collected at the following intervals: during the application, during the post-application water treatment, for three six-hour intervals following the water treatment, and for an additional four 12-hour intervals. Samples were collected at distances ranging from 5 to 150 m (16.4 to 492 feet) from each side of the field. According to the study, maximum MITC concentration occurred during the application period, where downwind levels measured 2450 ppb at 5 m and 1320 ppb at 150 m from the field edge. MITC air concentrations were low during the post-application water treatment, with the highest level of 539 ppb collected 5 m from the field. MITC concentrations increased during the six hours following the post-application water treatment, with 1050 ppb detected 5 m from the field. However, this level was 50% of the air concentration detected immediately following the application, and all other samples collected during this time interval ranged from 12.7 to 548 ppb. The half-life of metam sodium in this study was estimated as 7.3 to 7.6 hours (Wofford *et al*, 1994).

CONCLUSIONS

The over all uses of MITC-generating compounds have doubled from 1992 to 2003. Although many metam sodium applications occur each year without adverse effects, there have been a total of 777 illnesses related to MITC-generating pesticide exposure from 1992 through 2003. The vast majority

(94%) of these illnesses occurred during one of the 19 incidents resulting in priority investigations. Sixty-five percent of the priority illness/injury cases discussed in this paper reported that they noticed an odor. To minimize the off-site movement of these odors, treated fields must be sealed immediately following application. There are several methods to accomplish this, including applying water by sprinkler irrigation, tarping, packing soil with a roller, drag or press wheel, or covering with an adequate amount of untreated soil. The Wofford *et al*, 1994 study suggests that post-application water treatment was a factor in reducing MITC ambient air concentrations.

This report identifies several other important factors that affect the magnitude of off-site pesticide movement. Inadequate soil moisture before a metam sodium application can result in offsite movement. Multiple-set sprinkler applications were identified as a common factor in several priority illness cases; the probable reason is that treated fields receive inadequate post-application water with this method of application.

Applying MITC-generating pesticides near occupied structures also resulted in a number of persons becoming ill. This situation is often made worse with changing meteorological conditions, such as the presence of a light wind, and/or temperature inversion during and after an application. Persons 25 – 4224 feet from legally treated fields noted an odor, and some of these individuals developed adverse symptoms.

MITC-generating product users should carefully adhere to label directions, regulations, and permit requirements. Once MITC is released, drift may occur. Individuals exposed to sufficient levels of MITC may smell strong odors and experience symptoms that may include eye, nose, and throat irritation, headaches, nausea, and vomiting.

The detection of an odor should be treated as a warning sign for individuals to immediately stop further application, start post-application water treatment of the treated area, and vacate the affected area. However, people can become acclimated to the odor and their sensitivity to the smell reduced or completely lost. Monitoring using humans to smell a chemical can result in a false sense of security if they lose the ability to smell the chemical. The odor of hydrogen sulfide at sufficient levels can produce some of the same symptoms as noted for MITC exposure. Applicators and growers should consider using the relatively new Draeger tubes to measure MITC at the edge of the buffer zone to ensure public safety.

From the incidents discussed in this report, it can be noted that adequacy of post-application water, weather conditions, number of acres treated and distance from occupied structures can contribute to potential human exposure. Careful precautionary measures must be taken when applying MITC-generating products. It is necessary to monitor wind speed and direction, air temperature, humidity, and soil moisture status before and during application. In addition, immediate and adequate post-application treatment could also reduce exposure. The existing labeling and permit conditions, if followed properly, prevent offsite migration of MITC most of the time. However, as discussed above, there are situations where the conditions in place at the time of the incidents were not adequate to prevent offsite movement, causing significant impacts on individuals and communities.

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Appendix 1. Summary of incidental information at the time of illness/injury from 16 priority investigation cases during 1992 to 2003.

County, year of occurrence	Affected victims (number affected)	Distance from application site (feet)[a]	Product/ Rate (lb ai/a)[b]	Pesticide application method	Type of post application treatment	# of post application water treatment	Area treated (acres)	Environmental conditions during pesticide application	Reported violations	Time from application end to illness onset (hrs)
Santa Barbara, 1992	Residents (6)	25	Vapam/ 318	Shank Injection (5-15" deep)	Ring roller	NR[c]	40	Wind: calm Air temp: <90 F Soil temp: < 90 F	No violations	~9 hours
Riverside, 1993	Residents (6)	40	Vapam/ 372 & 222	Sprinkler	Sprinkler	1 (0.5 hr)	15	Wind: calm Air temp: <90 F Soil temp: < 90 F	Use in conflict with label; improper storage of metam sodium; failure to maintain equipment; and many worker safety violations	<12
San Joaquin, 1993	Residents (5)	1320	Vapam/ 254	Surface Spray	Rotavator & press roller	NR	25	Wind: windy Air temp: cool, probable inversion	No violations	0.75
San Joaquin, 1995	Factory workers (14)	660	Vapam/ 318	Sprinkler	Sprinkler	1	22	Wind: calm Air temp: cool, probable inversion	No violations	0[d]
San Joaquin, 1995	Inmates, Staff, and employees (25)	2640	Vapam/ application rate unknown	Sprinkler	Sprinkler	Unknown[e]	5	Wind: calm Air temp: 48 F Soil temp: < 90 F	No violations	<4
San Joaquin, 1996	Correctional officers (11)	4224	Vapam/ 318	Sprinkler (60% soil moisture at time of application)	Sprinkler	1	16	Wind: 2-5 mph Air temp: 59-89 F Soil temp: 65 F	One violation unrelated to the application	0
Fresno, 1996	School children (29)	660	Vapam/ 298	Shank Injection (9-15' deep) (50% soil moisture at time of application)	Ring roller	NR	22	Wind: calm Air temp: <90 F Soil temp: < 90 F	Notice of intent had expired.	Unknown, but probably <24.
Kern, 1997	Residents and emergency responders (35)	<1056	Nemasol/ 128	Shank Injection (4-12" deep)	12" shovels	NR	25	Wind: calm Air temp: 88 F Soil temp: 76 F	Failure to complete the Kern County metam sodium fumigation summary	0
Santa Barbara, 1999[d]	Auto repair garage(5); School children and staff (22);	500 plus 25 acres buffer zone[f]; 3140	Nemasol/ 213	Sprinkler	Sprinkler	5 auto 2 school	75 auto 175 school	Wind: calm Air temp: <90 F Soil temp: < 90 F	Application equipment inadequate; no offsite monitoring; no application or monitoring records; other violations not contributing to drift incidents.	<12 10

Tulare, 1999	Residents (170)	1,795	Sectagon/ 177	Sprinkler	Sprinkler	None	75	Air temp: cool, inversion	Use in violation with the label; application not monitored; monitoring not recorded; inadequate water seal; application made when conditions favored an inversion; paper work violations	0
Kern, 2002	Field workers (123)	200	Sectagon/ 160	Sprinkler	Sprinkler		25	Wind: calm Air temp: <90 F Soil temp: < 90 F Possible inversion	Use in conflict with the label; failure to submit a notice of intent to apply; failure to post the treated field, other violations not contributing to the drift incident.	0
Kern, 2002	Residents, packing shed workers (250)	500	Vapam/ 191	Shank Injection (6-12" deep)	Sprinkler	1	100	Wind: calm Air temp: <90 F Soil temp: < 90 F	Use in conflict with the label; using improper methods and equipment; other violations not contributing to drift incidents	6
Fresno, 2002	Aquaduct workers (5)	600	Vapam/ 213	Sprinkler	Sprinkler	1	183	Wind: 1.9 mph Air temp: 80 F	Use in conflict with the label and/or permit conditions.	0
Kern, 2003	Residents (15)	500	Vapam/ 213	Shank Injection (3-9" deep)	Ring roller	NR	80	Wind: calm Air temp: <90 F Soil temp: < 90 F	Use in conflict with the label-did not conduct post application monitoring;	Unknown; probably <2
Riverside, 2003	Residents (18)	200	Vapam/ 149	Sprinkler	Sprinkler	3	125	Wind: calm Air temp: <90 F Soil temp: < 90 F	Use in conflict with the label (and technical information bulletin - part of the label); performing pest control in a hazardous manner; failure to evaluate the conditions prior to application.	0
Imperial, 2003	Worker (1)	0 (on application site)	Vapam/ 64	Drip	None	None	Unknown	Wind: calm Air temp: <90 F Soil temp: < 90 F	Use in conflict with the label – no certified applicator on site.	0

[a] Distance from pesticide application site to illnesses/injuries site.
[b] lbai/a: Pound active ingredient per acre
[c] NR: Not required.
[d] Illnesses reported during the application
[e] Unknown. Applicators probably did not complete post application water treatment before onset of illnesses.
[f] Illnesses occurred at two locations on two different days: (1) the auto repair garage illnesses were reported on May 17 following application to 100 acres plot of which 75 acres treated, and 25 acres left untreated as a buffer zone; (2) the school illnesses were reported on May 19 following application to an additional 100 acres.