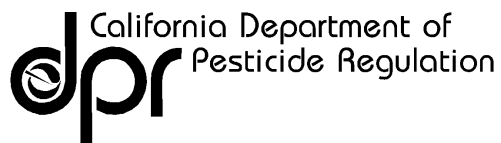


**EVALUATION OF
METHYL ISOTHIOCYANATE
AS A TOXIC AIR CONTAMINANT**



Part A—Environmental Fate



California Environmental Protection Agency
Sacramento, California

August 2002

TAC-2002-01A

**State of California
Department of Pesticide Regulation**

**Paul E. Helliker
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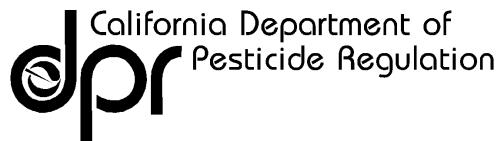
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Part A—Environmental Fate

by
Pamela C. Wales



California Environmental Protection Agency
Sacramento, California

August 2002

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¹ Formerly employed by the Department of Pesticide Regulation

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I. INTRODUCTION

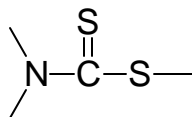
Methyl isothiocyanate (MITC) is a general biocide used to control weeds, nematodes, and soil and wood fungi. Although MITC is no longer registered for use in production agriculture in California, two liquid formulations are registered for use as wood treatments. MITC is also the active principle of three other pesticides: the soil fumigants metam-sodium and dazomet, and the antifoulant/fumigant metam-potassium. On contact with warm, moist soil, metam-sodium, dazomet, and metam-potassium decompose quickly to MITC and other volatile gases, which diffuse upward through the spaces in the soil, and account for the fumigant activity of these soil sterilants. Metam-sodium has been widely used for production agriculture in California, and dazomet use is increasing. While metam-potassium has recently been registered for use as a soil fumigant in California, its current use in that regard is minimal and not widespread.

This report consists of a review of the scientific literature concerning the environmental fate, and some of the physical and chemical characteristics of MITC, metam-sodium and dazomet. This report also includes California-specific information about the use and formulation of pesticide products containing MITC, metam-sodium, metam-potassium, and dazomet, and summarizes the results of several studies that have been conducted in California to measure the airborne concentrations of MITC associated with agricultural applications of metam-sodium.

A. Physical and Chemical Properties of Methyl Isothiocyanate, Metam-sodium, and Dazomet

MITC (Figure I-1a) is marketed as a liquid fungicide for wood treatment and is known by the synonyms MIT and methyl mustard oil (Tomlin, 1997). MITC has pesticidal activity. It is sensitive to oxygen and sunlight. Hydrolysis occurs rapidly in alkaline conditions, and more slowly in acidic and neutral solutions. MITC corrodes natural and synthetic rubber, polyvinyl chloride (PVC), and most metals. Its degradation in moist soil is temperature dependent; degradation and evaporation can occur in three weeks at soil temperatures of 20 °C (Tomlin, 1997). Table I-1 summarizes the physical and chemical properties of MITC.

The primary source of MITC in the environment is the widely-used fumigant metam-sodium (Figure I-1b). Metam-sodium belongs to a class of pesticides called dithiocarbamates—the disulfur analogues of carbamates—characterized by the presence of the following structure (IPCS, 1988):

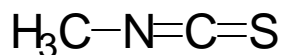


Metam-sodium (Figure I-1b) is known by a variety of synonyms including: metam, metham, metham-sodium, and carbathion (Tomlin, 1997). Although the dithiocarbamates were first recognized as potential fumigants in the United Kingdom during the 1930s, the development and use of metam-sodium occurred during and after World War II (IPCS, 1988). In the United States, the first patent for dithiocarbamate fungicides was issued in 1934. This patent covered the use of all compounds of the formula $\text{X(Y)NCS}_2\text{Z}$ —where X is hydrogen or alkyl, Y is hydrogen, alkyl, or aryl, and Z is metallic in nature—including metam-sodium (IPCS, 1988).

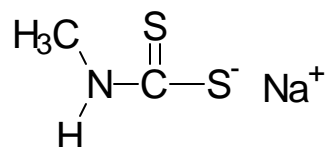
Metam-sodium has the molecular formula $\text{C}_2\text{H}_4\text{NNaS}_2$, and a molecular weight of 129.18. At room temperature, it forms a colorless, crystalline dihydrate with an unpleasant odor similar to that of carbon disulfide. It is corrosive to aluminum, copper, zinc, and brass (Tomlin, 1997; Merck, 1989a).

Metam-sodium is stable in its dry, crystalline state, and in concentrated aqueous solution. When in dilute aqueous solution or on contact with moist soil, metam-sodium rapidly decomposes to MITC and releases hydrogen sulfide and carbon disulfide. Its decomposition is promoted by contact with acids and metal salts (Tomlin, 1997). Table I-2 summarizes the physical and chemical properties of metam-sodium.

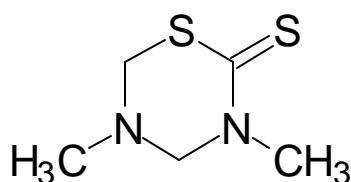
Figure I-1. The Chemical Structures of Methyl Isothiocyanate, Metam-Sodium, and Dazomet



(b) Methyl Isothiocyanate (MITC)



(a) Metam-sodium



(c) Dazomet

Another source of MITC in the environment is the pesticide dazomet (Figure I-1c). Dazomet belongs to the class of chemicals called thiadiazines. Its chemical structure consists of a heterocyclic ring containing carbon, nitrogen, sulfur, and hydrogen. Although initially prepared in 1897, dazomet was first manufactured for commercial use beginning in the 1960s (Forsyth and Morrell, 1995). In California, dazomet is mainly used as a slimicide in pulp and paper manufacture, and as a microbiocide in cooling tower systems. However, one product is registered for use as a soil sterilant. In moist soil, dazomet decomposes to form methyl(methylaminomethyl)dithiocarbamic acid, which then undergoes further degradation to MITC, formaldehyde, hydrogen sulfide, and methylamine (Tomlin, 1997). Table I-3 summarizes the physical and chemical properties of dazomet.

A third source of MITC is the pesticide metam-potassium. In California, metam-potassium is mainly used as an antifoulant for water cooling systems, condensers, and similar equipment. It is also registered for use as a slimicide in the paper manufacturing industry. Two products are registered as soil fumigants for cropland use in California. However, their use is limited and not widespread.

The annual use of dazomet, metam-potassium, and MITC in California is relatively insignificant when compared to that of metam-sodium; nearly 15 million pounds of metam-

sodium were reported used in 1998, contrasted with less than 16,000 pounds of dazomet, less than 9,200 pounds of metam-potassium, and less than 220 pounds of MITC reported used that same year. Therefore, the remainder of this report focuses primarily on the relationship between metam-sodium and MITC, the transformation of metam-sodium into MITC and its subsequent fate in the environment, and monitoring studies conducted in California to measure the airborne concentrations of MITC following agricultural applications of metam-sodium.

B. Regulation of Methyl Isothiocyanate, Metam-Sodium, and Dazomet

DPR regulates both MITC and metam-sodium as restricted materials when they are labeled for the production of agricultural plant commodities (California Code of Regulations, Titles 3 and 26, section 6400). Restricted materials are those that may pose either a danger to public health, or a hazard to farm workers, animals, crops, or the environment based on criteria listed in section 14004.5 (Food and Agricultural Code). Consequently, restricted materials may be possessed and used only by persons who have obtained a permit from their county agricultural commissioner.

MITC and metam-sodium became restricted use pesticides in July 1994, based on the results of air monitoring studies conducted in 1993 and 1994 by DPR and the Air Resources Board (ARB). Air monitoring studies were conducted in response to complaints from people living near metam-sodium-treated fields of illness and irritating odors (ARB, 1994; ARB, 1993; Wofford et al., 1994). The results of these studies revealed that off-site levels of MITC exceeded acceptable levels for the adverse affect of eye irritation when metam-sodium was used at a high application rate and delivered by sprinkler application during certain weather conditions. Thus, people living adjacent to treated fields might be exposed to short-term levels of MITC that could cause eye irritation. Consequently, DPR adopted regulations that designate metam-sodium and MITC to be restricted materials when labeled for the production of agricultural plant commodities (Titles 3 and 26, California Code of Regulations, § 6400).

As of July 24, 2001, both dazomet and metam-potassium are regulated as restricted materials, when labeled for the production of agricultural plant commodities (Titles 3 and 26, California Code of Regulations, § 6400).

Table I-1. Characteristics of Methyl Isothiocyanate

Common Names:	Methyl isothiocyanate, MITC, MIT, methyl mustard oil.
Chemical Names:	Methyl isothiocyanate, Isothiocyanatomethane.
Formulation Types:	Emulsifiable concentrate.
Some Trade Names:	Degussa MITC (Degussa Chemical Company). MITC-Fume™ (Osmose Wood Preserving, Inc).
CAS Registry Number:	556-61-6
Molecular Formula:	C ₂ H ₃ NS
Molecular Weight:	73.1 (Tomlin, 1997).
Physical Form:	Colorless crystals with a horseradish-like odor.
Vapor Pressure:	16.0 mmHg (25 °C) (DPR, 1999). 16.0 mmHg (25 °C) (Tomlin, 1997). 20.3 mmHg (20 °C) (Leistra and Crum, 1990). 19.5 mmHg (20 °C) (Degussa, 1988).
Solubility:	Water: 8.23 × 10 ³ ppm (20 °C) (DPR, 1999). 8.61 × 10 ³ ppm (25 °C) (DPR, 1999). 8.2 × 10 ³ ppm (20 °C) (Tomlin, 1997). Readily soluble in common organic solvents, such as ethanol, methanol, acetone, cyclohexanone, dichloromethane, chloroform, carbon tetrachloride, benzene, xylene, petroleum ether, and mineral oils (Tomlin, 1997).
Octanol/Water Partition Coefficient (K _{ow}):	15.8 (DPR, 1999). 23.5 (Tomlin, 1997).
Henry's Law Constant:	1.79 × 10 ⁻⁴ atm·m ³ /mol (25 °C) (DPR, 1999). 2.4 × 10 ⁻⁴ atm·m ³ /mol (20 °C) (Montgomery, J.H., 1997). 2.66 × 10 ⁻⁴ atm·m ³ /mol (20 °C) (Geddes et al., 1995).
Specific Density:	1.048 g/cm ³ (24°C), with respect to water at 4 °C (Tomlin, 1997).
Aqueous Photolysis Half-life:	51.6 days (pH 7; 23 °C) (DPR, 1999).
Hydrolysis Half-life:	20.4 days (pH 7; 25 °C) (DPR, 1999).
Stability:	Unstable and reactive. Rapidly hydrolyzed by alkalis, more slowly in acidic and neutral solutions. Sensitive to oxygen and to light (Tomlin, 1997).
Degradation and Metabolism:	In moist soil, degradation and evaporation of the bulk of the substance occurred within 3 weeks at 18-20 °C soil temperature, 4 weeks at 6-12 °C, and 8 weeks at 0-6 °C (Tomlin, 1997).

Table I-2. Characteristics of Metam-Sodium

Common Names:	Metam-sodium, Metam, Metham, Metham-sodium, Carbathion.
Chemical Names:	Methyldithiocarbamic acid sodium salt; methylcarbamodithioic acid sodium salt; sodium methyldithiocarbamate.
Formulation Types:	Soluble liquid concentrated, aqueous solutions.
Some Trade Names:	Vaporooter® and Vaporooter® II (Airrigation Engineering Co., Inc.), Amvac® Metam and Metam 426 (Amvac Chemical Corp.), Busan™ 1016, Busan™ 1020, and Busan™ 1236 (Buckman Laboratories, Inc.), Pole-fume® and Vapam® (ICI Americas, Inc.), Nalco® 8964 (Nalco Chemical Co.), Sectagon II® (Oregon-California Chemicals, Inc.), and Woodfume® (Osmose Wood Preserving, Inc.).
CAS Registry Number:	137-42-8
Molecular Formula:	C ₂ H ₄ NNaS ₂
Molecular Weight:	129.2 (Tomlin, 1997).
Physical Form:	Colorless crystalline dihydrate (Tomlin, 1997).
Vapor Pressure:	Non-volatile (Tomlin, 1997).
Solubility:	Water: 9.63×10^4 ppm (at 25 °C) DPR, 1999). 7.22×10^5 ppm (at 20 °C) (Tomlin, 1997). Practically insoluble in most other organic solvents (Tomlin, 1997).
Density:	1.1648 g/mL at 20 °C (Myers, 1985).
Aqueous Photolysis Half-life:	3.75×10^{-2} day (pH 7; 25 °C) (DPR, 1999)
Hydrolysis Half-life:	4.85 days (pH 7; 25 °C) (DPR, 1999).
Anaerobic Soil Metabolism Half-life:	<1 day (pH 7.9; sandy soil) (DPR, 1999).
Aerobic Soil Metabolism Half-life:	1.6×10^{-2} day (pH 6.9; sandy soil) (DPR, 1999).
Field Dissipation Half-life:	2.54 days (pH 6.3; loamy soil) (DPR, 1999). 4.00 days (pH 7.5; sandy loam soil) (DPR, 1999).
Stability:	Stable in concentrated aqueous solution, but unstable when diluted. Decomposition promoted by acids and heavy-metal salts (Tomlin, 1997).
Degradation and Metabolism:	In soil, rapidly decomposes to methyl isothiocyanate, which is volatile and quickly evaporates (Tomlin, 1997).

Table I-3. Characteristics of Dazomet

Common Names:	Dazomet.
Chemical Names:	3,5-dimethyl-1,3,5-thiadiazinane-2-thione; tetrahydro-3,5-dimethyl-2 <i>H</i> -1,3,5-thiadiazine-2-thione.
Formulation Types:	Emulsifiable concentrate.
Some Trade Names:	AMA-224, AMA-35D-P, AMA-420, AMA-424 (Vinings Industries, Inc.); Ameristat 233 (Drew Industrial Div.); Basamid Granular Soil Fumigant, Basamid Pellets (BASF Corp); Bio Solv-25 (Shepard Brothers); Busan 1058, Busan 1059 (Buckman Laboratories, Inc.); EA-224 (Economic Alternatives, Inc.); Metasol D3T-A (Calgon Corp.); Metasol D3T-A (ECC International); Nalcon 248 Microorganism Control (Nalco Chemical Co.); Nuosept 120 Preservative, Nuosept S Preservative (Creanova, Inc.); Slime-trol RX-28 (Betzdearborn, Paper Process Gp, Inc.)
CAS Registry Number:	533-74-4
Molecular Formula:	C ₅ H ₁₀ N ₂ S ₂
Molecular Weight:	162.3 (Tomlin, 1997).
Physical Form:	Colorless crystals.
Vapor Pressure:	4.35 × 10 ⁻⁶ mmHg (20 °C) (DPR, 1999). 9.88 × 10 ⁻⁶ mmHg (25 °C) (DPR, 1999). 2.78 × 10 ⁻⁶ mmHg (20 °C) (Montgomery, J.H., 1997).
Solubility:	Water: 3.63 × 10 ⁻³ ppm (20 °C) (DPR, 1999).
Octanol/Water Partition Coefficient (K _{ow}):	0.15 (no pH reported) (Montgomery, J.H., 1997). 1.4 (pH 7) (Tomlin, 1997).
Henry's Law Constant:	2.57 × 10 ⁻¹⁰ atm·m ³ /mol (20 °C) (DPR, 1999). 2.0 × 10 ⁻¹⁰ atm·m ³ /mol (20 °C) (Montgomery, J.H., 1997).
Specific Density:	1.37 (room temp.) Montgomery, J.H., 1997).
Aqueous Photolysis Half-life:	5.84 × 10 ⁻¹ day (pH 5; 25 °C) (DPR, 1999).
Hydrolysis Half-life:	1.46 × 10 ⁻¹ day (pH 7; 25 °C) (DPR, 1999).
Anaerobic Soil Metabolism Half-life:	14.1 days (pH 5.8; loamy sand soil) (DPR, 1999).
Aerobic Soil Metabolism Half-life:	7.5 × 10 ⁻¹ day (pH 5.8; loamy sand soil) (DPR, 1999).
Field Dissipation Half-life:	<1 day (pH 5.7; loamy sand soil) (DPR, 1999). <1 day (pH 6.4; sandy loam soil) (DPR, 1999). 1.88 × 10 ⁻¹ day (pH 5.4; sandy soil) (DPR, 1999).
Stability:	Stable at temperatures up to 35 °C. Sensitive to temperatures >50 °C, and to moisture. Hydrolyzed in acidic media to carbon disulfide, formaldehyde, and methylamine (Tomlin, 1997).
Degradation and Metabolism:	Metabolism in soil results in formation of formaldehyde, hydrogen sulfide, methylamine, and methyl(methylaminomethyl)dithiocarbamic acid, which further decomposes to MITC (Montgomery, 1997).

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II. USE, METHODS OF APPLICATION, AND FORMULATIONS OF METAM-SODIUM, DAZOMET, METAM-POTASSIUM, AND METHYL ISOTHIOCYANATE

This chapter includes information concerning the use and methods of application of metam-sodium, dazomet, metam-potassium, and MITC, the range of amounts applied, product formulations, and summaries of the historical metam-sodium use patterns in California. As of July 2001, there were twenty-four metam-sodium-containing pesticides, nineteen dazomet-containing pesticides, eighteen metam-potassium-containing pesticides, and two MITC-containing pesticides registered for use in California (DPR, 2001).

A. Uses of Metam-Sodium, Dazomet, Metam-Potassium, and Methyl Isothiocyanate

Metam-sodium has three major uses: it is an agricultural fumigant, a wood preservative, and a root control compound for use in drains and sewers. As a pre-plant soil fumigant, metam-sodium controls disease-causing, soil-borne fungi (e.g., *Rhizoctonia*, *Pythium*, *Phytophthora*, *Verticillium*, and *Sclerotinia*), nematodes, symphyliids, and a variety of annual weeds and grasses. When used as a wood preservative, it arrests internal decay and controls insects in Douglas fir, Western red cedar, and Southern pine poles, and structural timbers such as those used in waterfront structures. As a foaming, non-systemic herbicide, metam-sodium rids sewer lines and drain systems of roots and other organic material (DPR, 1999; Sexton et al., 1991; Highley, 1991; Highley and Eslyn, 1989a and b; Leonard et al., 1974; Ahrens et al., 1970). MITC, the principle breakdown product, accounts for the fumigant activity of metam-sodium.

Dazomet is mainly used as a slimicide in pulp and paper manufacture, and as a microbiocide in cooling tower systems. However, one product is registered for use as a pre-plant soil fumigant. As a soil fumigant, dazomet is used to control a wide variety of weeds, nematodes, and soil-borne, disease-causing fungi. Applied directly to moist soil, it decomposes quickly to several compounds, including MITC, which diffuses upward through the spaces in the soil, and accounts for the fumigant activity (DPR, 2001; BASF, 1989).

Similar to dazomet, metam-potassium is primarily used as an antifoulant/microbiocide in water cooling systems and in the pulp and paper manufacturing process. However, two products are registered for use as pre-plant soil fumigants, prior to planting a limited variety of agricultural commodities. These crops include a few grain crops grown for fodder and forage, tomatoes, potatoes, lettuce, and ornamental crops. As a soil

fumigant, metam-potassium is used to control a variety of weeds, nematodes, and soil-borne, disease causing fungi. As with metam-sodium and dazomet, when applied directly to moist soil, metam-potassium decomposes quickly to release MITC, which accounts for its fumigant activity (DPR, 2001).

MITC was once used as a pre-plant fumigant and along roadsides and other rights-of-way as a weed control agent. However, as of December 1994, MITC is no longer registered for agricultural or rights-of-way use in California. Currently, two MITC products are registered for use in California; both are registered for use as wood preservatives and remedial treatments to control interior decay in large structural timbers (e.g., utility poles, pilings, bridge timbers) and in laminated wood products (DPR, 2001).

B. Methods of Application and Amounts Applied

1. Methods of Application

a. Metam-Sodium

Agricultural application methods for metam-sodium include soil injection, chemigation, rotary tiller, disc, power mulcher, drench and soil-covering methods. Immediately after application by chemigation, users must apply a water seal over the treated area to help confine the fumigant vapors in the soil. To control roots, metam-sodium mixtures are pumped directly into sewer mains, drain lines and other conduits through an upstream manhole, or specially manufactured foam-generating equipment is used to fill the lines with fungicidal foam. To preserve wood, the fumigant is applied either by soaking the wood product in a metam-sodium solution, or by spraying the solution on the affected timber. In treating existing structures, particularly horizontally oriented timbers, metam-sodium may be poured into holes drilled into the timber. Immediately after treatment, the holes must be sealed with tight fitting wooden plugs to confine the fumigant vapors to the treated area (DPR, 2001).

b. Dazomet

Prior to the application of dazomet, the soil must be tilled to a fine crumb structure, and moistened to 60 to 70% of its holding capacity. Dazomet is applied by spreader to the soil surface, and immediately worked into the soil with a rototiller. Following treatment, the

soil must be sealed with a water barrier and covered with tarps, in order to confine the fumigant vapors to the treated area (DPR, 2001; BASF, 1989).

c. Metam-Potassium

When used as a soil fumigant, metam-potassium application methods are similar to those of metam-sodium. Immediately following application, the treated soil must be sealed by one of several methods, including the application of a water barrier, or by rolling, bedding over, tarping, or otherwise compacting the soil to mitigate the loss of MITC vapors from the treated soil (DPR, 2001).

d. Methyl Isothiocyanate

MITC is applied to large structural timbers—e.g., utility poles, pilings, and bridge timbers—by drilling holes into the timber and inserting pre-measured glass tubes of the fumigant into the holes. Immediately after treatment, the holes must be sealed with tight fitting wooden plugs to confine the MITC vapors to the treated area (DPR, 2001).

2. Amounts Applied

a. Metam-Sodium

When used as a soil fumigant, metam-sodium product labels list application rates ranging from 60 to 320 pounds of active ingredient per acre for all crops, including carrots and tomatoes. The recommended application rate depends on several factors. The application rate depends on the soil type to be treated and the position in the soil of the pest to be suppressed or controlled. In general, heavier mineral soils generally require more metam-sodium than do light sandy soils. Soils with high levels of organic matter require higher amounts of the fumigant because of the absorbing effect of the humus. In addition, if the pest is in the upper portion of the soil profile, a lower application rate is generally required than if the pest is deeper in the soil profile. As a wood preservative, the recommended metam-sodium application rate ranges from 0.7 to 1.8 pounds of active ingredient per ton of wood chips treated. When used to treat structural timbers, 2 to 4 pounds of active ingredient per timber may be poured into drilled holes. When used as a root control agent, the application rate depends on sewer pipe capacity and product used. Two metam-sodium containing products are registered for root control; both contain approximately twenty-five percent metam-sodium and two percent dichlobenil. These products are applied

as foam with special foam-generating equipment. The first product is designed to fill the sewer lines with foam, while the other is designed to coat the inside of the line with a 2-inch layer of foam (DPR, 2001).

b. Dazomet

As a soil fumigant, dazomet is intended for pre-planting control of most weeds, nematodes, and soil diseases in: compost piles; golf greens; potting soils; seed and propagation beds; soil heaps and piles; for renovating or establishing turf sites, ornamental sites, and field nurseries; and some non-bearing crops. The recommended label rates range from 222 to 530 pounds active ingredient per acre, and depend on several factors, including: soil moisture and content; soil temperature; and soil type and structure. In general, the label recommends using higher rates in heavier soils, and also when applications are intended to control infestations of stem and cyst nematodes. Dazomet is not registered for application on agricultural commodities other than some non-bearing fruit, nut, and vine crops. When approved crops have been treated, produce must not be harvested for one year following application (DPR, 2001).

c. Metam-Potassium

When used as a soil fumigant, metam-potassium is registered for use prior to planting a few food and forage crops: some grain and forage crops (alfalfa, clover, oats, rye, sudangrass, and wheat); potatoes; tomatoes; and lettuce. It may also be used for preplant soil treatment prior to planting ornamental crops. Product labels specify use rates ranging from 174 to 348 pounds per acre, depending on soil conditions. Similar to metam-sodium or dazomet use, rates increase with heavier soils or those soils with higher organic content (DPR, 2001).

d. Methyl Isothiocyanate

MITC product labels specify use rates of one pre-measured 30-gram tube per pre-drilled hole when treating structural timbers. The number of holes per timber depends on the size of the timber and the degree of interior decay present. However, product labels specify that hole patterns should be bored “at a 45° angle downward to a length of approximately 2½ times the radius of the wood. The first hole should be at the ground line, and succeeding holes approximately 6-8 inches higher, and 90° rotated from the next lower hole (DPR, 2001).”

C. Formulations of Metam-Sodium, Dazomet, Metam-Potassium, and Methyl Isothiocyanate

For use as a soil fumigant, metam-sodium is available as a water-soluble concentrate or as an aqueous solution. Metam-sodium is also available as a water-soluble, surface-active formulation in combination with dichlobenil for use as a non-systemic foaming herbicide to rid sewer lines and drain systems of roots and other organic material (DPR, 2001).

For use as a soil fumigant, dazomet is available as a micro-granular formulated product. It is also marketed in ready-to-use liquid, liquid concentrate, dust/powder, and dry-flowable formulations for use as an algacide or anti-microbial in cooling systems, industrial preservatives, and pulp and paper manufacture (DPR, 2001).

When formulated for use as a soil fumigant, metam-potassium is available as a ready-to-use liquid and as a aqueous concentrate. When marketed as an antifoulant for water cooling systems, it is available as a ready-to-use liquid or as an emusifiable concentrate.

Sold in pre-measured tubes, MITC is available as a ready-to-use liquid (DPR, 2001).

D. Metam-Sodium and Dazomet Use Patterns

With DPR's implementation of full pesticide use reporting in 1990, all users must report the agricultural use of any pesticide to their county agricultural commissioners, who subsequently forward this information to DPR. DPR compiles and publishes the use information in the annual Pesticide Use Report (PUR). Because of California's broad definition for agricultural use, DPR includes data from pesticide applications to parks, golf courses, cemeteries, rangeland, pastures, and along rights-of-way (DPR, 1995). The PUR does not collect use information for home and garden use, or for most industrial and institutional uses (e.g., wood preservative treatments, cooling system treatments, pulp and paper mill use).

1. Metam-Sodium Use Information (1990-1998)

Table II-1 summarizes the use of metam-sodium on each commodity, or site, from 1990 through 1998. Since nearly all metam-sodium is soil applied, users generally report the commodity planted following an application. Growers may report the use as “soil application” when the field is to remain unplanted following treatment. Additionally, growers may report the use as “soil application” when they have not decided what crop to plant following the application, or when they planted a variety of crops in the treated field (DPR, 1990-1999).

While metam-sodium is used on a wide variety of commodities, most applied annually from 1990 through 1998 was used to fumigate soil prior to planting carrots, tomatoes, potatoes, and cotton (Table II-1). In California, use has increased since 1990. The crops that had the greatest increase in use were carrots, tomatoes, cotton, and potatoes. This increase may have been caused by a number of reasons. After DPR suspended most permits for the use of 1,3-dichloropropene (1,3-D) in 1990, metam-sodium use associated with carrot production increased dramatically—from slightly more than 1.2 million pounds in 1990 to nearly 6 million pounds in 1998. Carrot growers had used 1,3-D to control nematodes, the major pests in that crop. Root nematodes cause root stubbing and forking, and lead to the formation of numerous galls on the root, rendering the carrots unmarketable. Metam-sodium probably had replaced the use of 1,3-D as a control for these pests. Additionally, research conducted in the late 1980s and early 1990s demonstrated that it was highly effective in the control of weeds such as nightshade, nutsedge, and morning glory (bindweed) in carrot crops, nightshade in tomato, potato, and cotton crops, and accounts for the increased use in those crops (Wilhoit, et al., 1998).

MITC was once registered for use on a wide variety of commodities; however, most was used to control weeds on rights-of-way. Although MITC is no longer registered for field use as of 1994, individuals may continue to apply the pesticide until their existing supply is exhausted. Reported MITC use has decreased from over 11,500 pounds in 1991 to less than 220 pounds in 1998, and future PUR reports should show a diminishing use of MITC. Because the use of MITC wood preservatives is not considered an agricultural use, applicators of these products are not required to file a pesticide use report (DPR, 1990-1998).

Table II-1. Metam-Sodium Use in Pounds by Commodity (From Annual Pesticide Use Reports, 1990-1998)

Commodity/Site	1990	1991	1992	1993	1994	1995	1996	1997	1998
Carrots	1,243,161	1,395,942	2,729,566	1,764,157	2,161,054	5,178,057	4,619,094	5,847,290	5,844,197
Tomatoes	1,032,223	851,763	2,244,987	2,200,665	3,585,397	3,130,248	3,839,718	3,068,458	2,741,752
Potatoes	322,986	673,108	424,029	486,222	518,834	1,448,609	1,532,892	1,260,222	1,276,679
Leafy Vegetables ^a	434,985	773,567	715,086	862,861	977,487	1,199,473	1,502,033	1,052,119	1,115,282
Melons ^b	157,602	119,160	380,046	408,279	637,203	592,667	403,212	678,109	627,336
All Other Root and Bulb Crops ^c	195,292	166,585	130,640	288,720	425,865	624,326	505,918	512,758	610,848
Cotton	484,266	234,203	1,134,884	1,299,717	1,697,800	1,213,651	1,776,986	1,411,659	467,140
All Other Agricultural Applications ^d	22,412	63,522	67,313	487,630	127,932	157,934	190,459	372,249	245,255
Fruiting Vegetables (Except Tomatoes) ^e	45,704	51,140	101,709	120,626	350,158	319,030	247,688	243,424	229,679
Soil Application, Pre-plant	1,639,412	36,800	51,714	17,574	270,555	650,631	235,749	241,889	222,210
All Other Vegetables ^f	107,476	153,590	166,138	82,524	91,549	150,888	111,972	167,451	183,307
Greenhouse/Nursery	91,447	181,525	196,202	225,067	107,977	154,231	154,889	149,851	174,928
Small Fruits and Berries ⁱ	20,313	14,771	2,560	14,583	38,598	30,181	14,732	20,497	130,920
Non-Agricultural Pest Control	37,570	31,224	49,233	104,836	33,138	54,026	140,629	221,658	128,962
Squash and Cucumbers	49,017	18,802	18,399	46,348	37,112	40,206	46,393	64,958	44,284
Flavoring and Spice Crops ^h	34,299	28,274	77,636	81,400	49,394	26,337	19,441	22,141	14,384
Citrus Fruits ^j	6,327	9,218	1,620	10,891	2,857	8,051	72,171	8,099	13,243
Nut Crops ^g	457	4,958	8,058	19,677	5,270	2,090	12,161	27,516	8,139
Grapes (Table and Wine)	19,603	49,784	5,301	35,026	41,612	66,964	55,275	30,843	7,596
Tree Fruits ^l	1,725	3,025	5,480	22,425	5,428	1,186	4,808	38	7,487
Forage/Feed Crops	535	17,394	49,477	1,593	8,319	783	5,846	1,184	4,443
Grain Crops ^k	5,631	8,980	6,253	8,197	25	81,818	15,850	6,344	1,191
Totals:	5,952,444	4,887,334	8,566,331	8,589,017	11,173,565	15,131,385	15,507,916	15,408,754	14,099,262

a Includes broccoli, Brussels sprouts, cabbage, cauliflower, kale, mus tard, collards, endive, lettuce, cilantro, parsley, spinach, Swiss chard, artichoke, bok choy, and other Chinese greens.

b Includes cantaloupe, watermelon, and other melons.

c Includes celery root, onion, leek, garlic, parsnip, radish, sweet potato, beets, sugar beets, and turnips.

d Includes seed crops, grassland, and uncultivated agricultural areas.

e Includes eggplants and peppers.

f Includes beans, peas, celery, corn, okra, and asparagus.

g Includes almonds, walnuts, and pistachios.

h Includes anise, basil, chilies, dill, marjoram, sage, and tarragon.

i Includes strawberries, blueberries, and raspberries.

j Includes grapefruit, lemon, lime, orange, and tangerine.

k Includes rice, barley, wheat, and oats.

l Includes apples, pears, apricots, cherries, peaches, nectarines, plums, prunes, and dates.

The annual PUR information can be used to identify the seasons during which metam-sodium was most often applied. Table II-2 shows the historical use of metam-sodium by month for the entire state from 1990 through 1998, and Figure II-1 provides a visual representation of the same data. Historically, there are two periods of peak use. The first and heaviest use occurs during late-winter/early-spring—January, February, March, and April. This late-winter/early-spring use is primarily associated with soil pre-plant treatments prior to the planting of tomatoes in Fresno County. A second smaller peak use period occurs during mid-summer through early-fall—July, August, September and October. The majority of this summer use is associated with soil pre-plant treatments prior to the planting of carrots in Kern and Imperial Counties. Tables II-3 (a-i) provides a summary of the annual historical metam-sodium use patterns from 1990 through 1998 on a month-by-month basis. In each annual table, the data are reported for each of the top ten counties per month (DPR, 1990-1998).

Table II-2. Monthly Metam-Sodium Use in Pounds (From Annual Pesticide Use Reports, 1990-1998)

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998
January	874,047	547,675	1,003,330	300,498	1,707,947	147,904	1,752,825	468,962	1,343,459
February	775,923	410,428	632,908	570,913	834,779	1,770,899	573,581	2,142,443	233,243
March	871,421	132,054	1,424,568	1,724,949	2,815,341	1,035,972	2,712,156	3,033,154	1,381,694
April	261,284	577,601	1,150,698	1,487,390	1,063,476	2,347,247	2,014,738	1,151,525	1,296,727
May	270,800	293,849	490,117	541,443	390,949	504,356	584,836	510,104	725,096
June	130,070	138,648	337,809	261,532	202,413	524,849	643,993	852,225	714,993
July	564,338	612,375	548,199	607,769	542,147	1,548,631	1,767,132	1,311,415	1,414,380
August	610,471	709,180	1,012,273	740,306	702,133	2,079,324	1,790,181	1,407,958	1,861,307
September	249,722	479,979	917,152	542,482	1,057,489	1,745,904	1,354,783	1,447,136	2,100,207
October	460,129	273,352	340,446	587,790	660,810	1,462,927	798,790	1,410,379	1,256,887
November	304,082	304,552	322,540	492,683	333,682	656,522	781,268	623,267	779,242
December	580,158	407,643	386,291	731,260	862,400	1,306,851	733,631	1,050,186	992,029
Totals	5,952,444	4,887,334	8,566,331	8,589,017	11,173,565	15,131,385	15,507,916	15,408,754	14,099,262

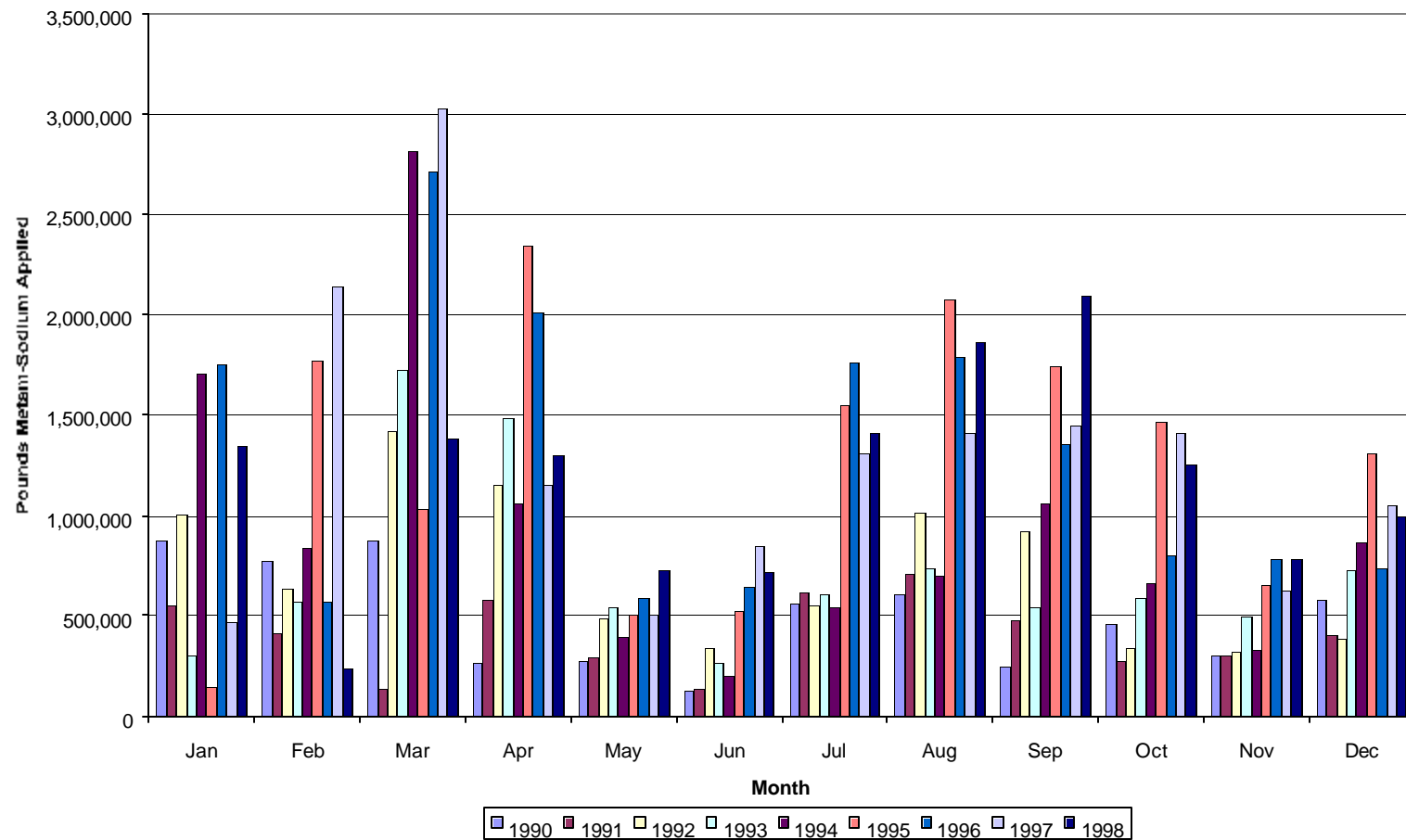
Figure II-1. Historical Metam-Sodium Use in Pounds (From Annual Pesticide Use Reports, 1990-1998)

Table II-3 (a). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1990^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	791.6	Fresno	663.4	Fresno	544.9	Fresno	86.4	Santa Cruz	65.8	Madera	32.2
Kings	42.7	Kern	42.2	Merced	75.5	Yolo	35.2	Monterey	35.8	Monterey	26.3
Kern	19.0	Riverside	19.4	Yolo	75.4	Tulare	33.1	San Joaquin	24.9	Kern	21.9
Alpine	5.3	Merced	13.9	Solano	42.0	Solano	23.8	Santa Barbara	19.5	Ventura	8.8
Contra Costa	5.0	Yolo	10.4	San Joaquin	21.4	Santa Cruz	22.7	Ventura	19.0	San Luis Obispo	8.1
Imperial	2.5	San Benito	9.4	Riverside	19.1	San Joaquin	15.6	San Mateo	17.8	San Benito	4.9
Tulare	2.1	Kings	7.0	Sutter	17.7	Monterey	11.0	Merced	16.5	Stanislaus	4.4
Stanislaus	1.3	Colusa	3.0	Kern	16.2	San Luis Obispo	6.1	San Luis Obispo	14.6	Santa Clara	3.8
Ventura	1.3	Santa Barbara	2.4	Santa Barbara	11.8	Ventura	4.9	Fresno	13.8	Santa Cruz	3.7
San Luis Obispo	1.2	Stanislaus	1.6	Contra Costa	9.2	Sutter	3.4	Tulare	13.2	Imperial	3.5

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	487.9	Kern	453.9	Imperial	150.3	Imperial	203.4	Kern	106.8	Fresno	256.2
San Joaquin	27.4	Ventura	50.9	Ventura	18.9	Kern	108.4	Fresno	78.6	Kern	179.4
Monterey	8.8	Imperial	42.9	Sutter	16.8	San Joaquin	31.7	Santa Barbara	51.8	Contra Costa	85.5
Ventura	7.2	Madera	18.1	Santa Barbara	12.9	San Benito	20.6	Imperial	21.0	Santa Barbara	23.4
Imperial	6.5	Santa Barbara	11.9	Kern	12.2	Santa Barbara	14.9	Contra Costa	17.6	Imperial	21.8
Santa Barbara	5.2	Stanislaus	7.5	San Joaquin	11.0	Colusa	11.9	Ventura	8.9	Tulare	4.2
Stanislaus	4.7	Monterey	7.1	San Luis Obispo	7.9	Siskiyou	11.4	Solano	7.2	Ventura	3.6
San Luis Obispo	4.6	San Luis Obispo	4.9	Monterey	6.0	Ventura	10.1	San Luis Obispo	4.6	San Diego	2.0
Del Norte	4.3	Riverside	4.4	Stanislaus	5.3	Fresno	9.8	Stanislaus	4.4	Santa Cruz	1.4
Fresno	3.8	San Diego	3.8	Solano	3.6	Stanislaus	9.4	Santa Cruz	1.3	Stanislaus	0.9

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (b). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1991^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	390.5	Kern	134.2	Fresno	48.3	Yolo	115.8	Santa Barbara	107.5	San Luis Obispo	23.2
Fresno	57.1	Yolo	125.9	Kern	31.1	Monterey	110.8	Santa Cruz	81.3	Santa Cruz	21.4
Contra Costa	26.8	Fresno	32.0	Yolo	12.5	Fresno	70.5	Monterey	37.6	Fresno	17.9
Imperial	13.3	Solano	31.8	San Luis Obispo	10.4	Solano	60.0	Stanislaus	13.7	Monterey	14.3
Tulare	10.9	Sacramento	16.4	Santa Barbara	8.6	San Joaquin	56.0	San Mateo	12.8	Santa Barbara	9.8
Ventura	8.7	Stanislaus	16.0	Stanislaus	6.7	Sacramento	20.3	Riverside	11.2	Kern	9.6
Monterey	8.4	San Luis Obispo	14.2	Contra Costa	5.8	Sutter	20.2	San Joaquin	9.5	Stanislaus	8.9
Sutter	8.1	Santa Barbara	12.7	San Joaquin	2.9	San Luis Obispo	19.8	San Luis Obispo	7.9	San Bernardino	7.2
Kings	6.3	San Joaquin	4.6	Merced	2.1	Kings	17.8	Ventura	4.4	Tulare	6.1
Yolo	5.0	Contra Costa	4.5	Ventura	1.8	Santa Barbara	15.8	Merced	1.8	San Joaquin	5.1

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	367.6	Imperial	320.5	Imperial	368.4	Imperial	130.7	Kern	170.8	Kern	249.3
Imperial	128.6	Kern	276.6	Kern	54.4	Kern	55.0	Santa Barbara	48.9	Fresno	75.9
Del Norte	29.5	Stanislaus	24.7	Stanislaus	22.3	San Joaquin	20.0	Contra Costa	29.8	Santa Barbara	17.2
Monterey	25.7	Santa Barbara	21.1	Santa Clara	11.5	Stanislaus	13.4	Ventura	13.3	Monterey	15.7
Ventura	18.3	Del Norte	18.4	Ventura	7.0	Ventura	12.5	Fresno	9.1	Imperial	14.5
Stanislaus	16.7	Riverside	12.1	Santa Barbara	4.9	Contra Costa	8.5	Imperial	7.4	San Joaquin	12.9
Santa Cruz	7.0	Ventura	11.4	Monterey	2.9	Monterey	7.8	Monterey	6.3	Ventura	8.8
Santa Barbara	6.5	Tulare	9.6	Solano	2.6	Siskiyou	6.6	San Luis Obispo	5.7	Stanislaus	4.8
Fresno	5.4	Monterey	6.6	Santa Cruz	1.7	Fresno	5.1	Stanislaus	4.5	Mendocino	3.8
San Bernardino	4.3	San Joaquin	2.6	Riverside	1.3	Santa Barbara	3.8	Sacramento	3.8	Santa Cruz	1.7

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (c). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1992^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	541.8	Fresno	367.4	Fresno	898.6	Fresno	450.8	Santa Cruz	85.6	Kern	140.8
Kern	290.8	Kern	147.2	Kings	88.7	Santa Barbara	160.3	Santa Barbara	82.7	San Luis Obispo	40.0
Monterey	37.2	Yolo	21.7	Merced	51.8	Yolo	103.7	Monterey	64.0	Monterey	38.3
Santa Barbara	29.7	Contra Costa	21.4	Kern	42.3	Merced	60.7	Merced	60.7	Santa Barbara	35.6
Contra Costa	28.8	Monterey	17.7	Contra Costa	38.8	Solano	45.5	San Joaquin	43.0	San Joaquin	18.2
Imperial	18.0	Santa Barbara	15.3	Santa Barbara	37.7	Monterey	43.4	Madera	40.5	Riverside	15.9
Riverside	16.3	Riverside	14.4	Modoc	20.3	Madera	40.5	Kings	35.4	Ventura	9.9
Kings	7.5	Kings	12.5	Solano	15.5	Sacramento	40.0	San Luis Obispo	34.6	Stanislaus	9.7
San Benito	7.2	Madera	7.1	San Joaquin	9.7	Kings	35.4	San Mateo	15.4	Santa Cruz	8.1
Stanislaus	5.1	San Luis Obispo	3.0	Riverside	9.5	San Luis Obispo	34.6	Riverside	12.7	Tulare	6.2

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	220.9	Imperial	608.2	Imperial	802.3	Imperial	191.2	Fresno	88.2	Fresno	175.4
Imperial	86.0	Kern	208.5	Ventura	37.9	Ventura	33.2	Kern	86.8	Kern	41.1
Riverside	52.9	Del Norte	47.0	Stanislaus	15.3	Stanislaus	21.3	Yolo	34.2	Imperial	35.9
Del Norte	43.7	Ventura	38.0	Fresno	15.0	Kern	19.5	Santa Barbara	20.6	Santa Barbara	33.4
Santa Barbara	39.7	Santa Barbara	29.2	Kern	13.5	Fresno	16.1	Ventura	15.9	Tulare	22.5
Ventura	21.9	Tulare	24.6	Santa Barbara	9.1	Santa Barbara	14.3	Imperial	14.1	Kings	20.4
Fresno	15.9	Stanislaus	19.6	San Joaquin	8.3	San Joaquin	12.9	San Joaquin	10.7	Ventura	14.2
Monterey	13.7	Riverside	13.5	Riverside	8.1	Santa Clara	9.9	Contra Costa	9.8	Monterey	10.4
Stanislaus	12.6	Solano	8.3	Solano	3.4	Riverside	6.6	Riverside	6.9	San Benito	7.3
Tulare	10.2	San Luis Obispo	6.8	Tulare	1.2	Kings	4.2	Kings	6.7	Contra Costa	4.7

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (d). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1993^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	147.8	Fresno	344.1	Fresno	962.8	Fresno	621.8	Santa Barbara	129.7	Monterey	56.5
Kern	61.7	Kern	129.2	Yolo	181.0	Merced	109.7	Santa Cruz	79.6	Santa Barbara	38.4
Riverside	26.5	Kings	28.6	Kern	137.0	Mono	101.9	Monterey	70.8	Madera	25.6
Imperial	16.8	Ventura	19.4	Merced	86.3	Kings	97.9	Mono	56.9	Riverside	25.3
Tulare	15.1	Santa Barbara	13.7	Solano	64.0	Yolo	81.4	San Joaquin	32.3	Santa Cruz	21.7
Ventura	8.6	Tulare	12.9	Kings	44.0	Modoc	48.9	Riverside	23.6	San Joaquin	19.3
Kings	7.2	Yolo	12.9	Contra Costa	34.0	Santa Barbara	37.6	Stanislaus	21.0	Ventura	17.0
San Benito	4.8	San Luis Obispo	3.4	Stanislaus	28.1	Solano	37.1	Ventura	21.8	San Luis Obispo	16.6
Sutter	4.8	Monterey	1.7	San Luis Obispo	26.5	San Joaquin	35.1	Fresno	18.3	Stanislaus	13.6
Santa Barbara	4.8	Riverside	1.0	Santa Barbara	25.7	Kern	32.1	San Mateo	18.0	San Mateo	9.2

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	273.6	Imperial	368.9	Imperial	397.8	Imperial	186.1	Fresno	233.5	Fresno	423.0
Monterey	52.8	Kern	164.3	Riverside	51.7	Kern	101.7	Contra Costa	86.8	Kern	107.0
Del Norte	49.4	Del Norte	39.8	Santa Barbara	24.5	Fresno	100.2	Imperial	54.1	Imperial	58.7
Fresno	36.0	Santa Barbara	37.3	Stanislaus	20.9	Santa Barbara	71.2	Mono	19.0	Contra Costa	29.5
Imperial	32.5	Stanislaus	33.2	Tulare	14.1	San Joaquin	28.1	Monterey	12.3	Monterey	20.5
Ventura	28.7	Ventura	26.4	Fresno	7.6	Stanislaus	26.5	Santa Barbara	12.3	Riverside	18.8
Santa Barbara	23.0	Fresno	20.2	San Luis Obispo	7.6	Riverside	23.1	Stanislaus	11.7	Ventura	17.1
Riverside	22.8	Riverside	17.2	Kern	6.5	Contra Costa	16.6	Riverside	10.7	Santa Barbara	15.3
Stanislaus	19.3	Tulare	9.6	Ventura	3.5	San Luis Obispo	12.1	Madera	8.4	Santa Clara	14.8
Madera	18.0	Solano	8.0	Sacramento	3.5	Yolo	5.5	Merced	8.1	Tulare	9.8

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (e). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1994^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	1,159.8	Fresno	513.6	Fresno	1,475.0	Merced	243.9	Santa Barbara	69.0	Monterey	36.3
Yolo	162.0	Kern	117.6	Yolo	368.2	Fresno	170.3	Santa Cruz	63.4	San Luis Obispo	20.4
Kern	89.8	Yolo	54.5	Kings	145.1	Mono	92.3	Monterey	50.3	Stanislaus	20.0
Riverside	68.5	Kings	22.6	Merced	125.0	Monterey	53.1	Merced	37.7	Tulare	19.1
Kings	56.5	San Benito	20.6	Solano	122.5	Yolo	49.7	Riverside	27.7	Riverside	18.5
Imperial	38.4	Madera	20.3	San Joaquin	70.3	Kern	41.2	San Joaquin	26.7	Santa Barbara	16.0
Contra Costa	24.8	Colusa	19.6	Kern	60.9	Santa Cruz	39.7	Stanislaus	21.5	Santa Cruz	14.9
Santa Barbara	20.6	Riverside	14.8	Modoc	53.1	Solano	39.5	San Diego	18.1	Ventura	14.0
Tulare	19.3	Ventura	13.0	San Benito	42.4	Santa Barbara	38.9	San Luis Obispo	14.1	Fresno	9.6
Solano	14.3	Monterey	8.1	Stanislaus	39.5	San Joaquin	37.7	Ventura	13.6	San Benito	7.7

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	201.0	Imperial	260.3	Imperial	877.3	Imperial	449.4	Kern	117.7	Fresno	399.5
Imperial	79.9	Kern	224.1	Santa Barbara	36.7	San Joaquin	38.4	Imperial	57.1	Imperial	141.7
Santa Barbara	46.2	Santa Barbara	45.6	Stanislaus	22.6	Kern	38.1	Fresno	41.1	Kern	126.9
Madera	43.0	Ventura	39.7	Ventura	19.9	Santa Barbara	33.9	Contra Costa	36.5	Madera	54.6
Del Norte	35.3	Stanislaus	30.8	Kern	18.5	Riverside	30.1	Santa Barbara	31.3	Contra Costa	49.7
Fresno	32.8	Riverside	29.3	Orange	15.8	Tulare	13.9	Stanislaus	8.3	Santa Barbara	32.9
Ventura	32.6	Del Norte	24.9	Yolo	15.0	Solano	12.7	Riverside	7.3	Tulare	13.7
Stanislaus	18.1	Monterey	14.0	Madera	13.5	San Luis Obispo	11.4	Yolo	7.3	San Diego	9.8
Monterey	15.3	Madera	9.6	San Joaquin	8.1	Ventura	7.3	Ventura	6.4	Ventura	8.7
San Luis Obispo	7.7	Kings	5.4	Tulare	6.7	Napa	7.0	San Luis Obispo	5.9	Monterey	8.1

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (f). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1995^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	1,159.7	Fresno	513.2	Fresno	1,475.1	Mono	92.3	Santa Barbara	69.0	Monterey	36.3
Yolo	162.0	Kern	116.8	Yolo	368.2	Monterey	53.1	Santa Cruz	63.4	San Luis Obispo	20.4
Kern	89.8	Yolo	54.5	Kings	145.1	Yolo	49.5	Monterey	50.3	Stanislaus	19.4
Riverside	68.5	Kings	22.6	Merced	125.0	Santa Cruz	39.7	Merced	37.7	Tulare	19.1
Kings	56.5	Madera	20.3	Solano	122.5	Solano	39.5	Riverside	27.7	Riverside	18.4
Imperial	38.4	San Benito	20.1	San Joaquin	70.3	Santa Barbara	38.9	San Joaquin	26.7	Santa Barbara	16.0
Contra Costa	24.8	Colusa	19.6	Kern	60.9	San Joaquin	37.7	Stanislaus	21.1	Santa Cruz	14.9
Santa Barbara	20.6	Riverside	14.8	Modoc	53.1	Tulare	36.5	San Diego	18.1	Ventura	14.1
Tulare	19.3	Ventura	13.0	San Benito	42.4	Santa Clara	33.7	San Luis Obispo	14.1	Fresno	9.6
Solano	14.3	Monterey	8.1	Stanislaus	39.5	San Benito	29.6	Ventura	13.5	San Benito	6.7

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	201.0	Imperial	260.3	Imperial	877.3	Imperial	449.4	Kern	117.7	Fresno	399.5
Imperial	79.9	Kern	224.1	Santa Barbara	36.7	San Joaquin	38.4	Imperial	57.1	Imperial	141.7
Santa Barbara	46.2	Santa Barbara	45.6	Stanislaus	22.1	Kern	38.0	Fresno	41.1	Kern	126.8
Madera	43.0	Ventura	40.0	Ventura	19.9	Santa Barbara	33.9	Contra Costa	36.5	Madera	54.6
Del Norte	35.3	Stanislaus	30.2	Kern	18.4	Riverside	30.1	Santa Barbara	31.3	Contra Costa	47.1
Fresno	32.8	Riverside	29.3	Orange	15.8	Tulare	13.9	Stanislaus	8.3	Santa Barbara	32.9
Ventura	32.6	Del Norte	24.9	Yolo	15.0	Solano	12.7	Riverside	7.3	Tulare	13.7
Stanislaus	17.3	Monterey	14.0	Madera	13.5	San Luis Obispo	11.4	Yolo	7.3	San Diego	9.8
Monterey	15.3	Madera	9.6	San Joaquin	8.1	Ventura	7.3	Ventura	6.4	Ventura	8.7
San Luis Obispo	7.7	Kings	5.4	Tulare	6.7	Napa	7.0	San Luis Obispo	5.9	Monterey	8.0

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (g). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1996^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	1,237.6	Fresno	301.5	Fresno	1,495.7	Fresno	508.0	Merced	97.3	Kern	372.0
Kern	240.8	Kern	110.3	Yolo	326.6	Merced	353.5	San Luis Obispo	85.6	Santa Barbara	84.3
Kings	73.2	Santa Barbara	24.9	Kern	166.7	Kings	203.0	Santa Barbara	78.1	Riverside	56.3
Riverside	46.5	Yolo	24.6	Kings	130.7	Yolo	194.3	Kern	59.5	San Luis Obispo	31.5
San Luis Obispo	26.7	Kings	21.9	Merced	126.8	Solano	110.6	Santa Cruz	42.9	Orange	30.3
Santa Barbara	26.2	Riverside	16.5	Santa Barbara	96.8	Santa Barbara	90.2	Monterey	34.6	San Bernardino	15.9
Imperial	20.9	San Luis Obispo	14.0	Solano	84.5	Modoc	71.1	Yolo	31.9	Stanislaus	12.5
Monterey	17.3	Monterey	9.6	Stanislaus	49.5	Stanislaus	63.9	San Joaquin	30.8	Monterey	7.2
Yolo	11.7	Ventura	8.9	Tulare	35.8	San Luis Obispo	47.5	Stanislaus	23.4	Santa Cruz	5.8
Tulare	10.0	Santa Clara	7.7	Sutter	28.3	San Joaquin	45.8	Riverside	18.0	Santa Clara	4.6

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	1,141.9	Imperial	847.6	Imperial	886.6	Kern	368.4	Kern	339.4	Kern	323.7
Fresno	286.1	Kern	636.1	Kern	254.6	Imperial	254.2	Imperial	143.8	Fresno	200.2
Santa Barbara	111.7	Santa Barbara	80.1	Santa Barbara	60.1	Santa Barbara	45.4	Fresno	96.1	Imperial	98.1
Riverside	74.5	Del Norte	72.8	Riverside	38.5	Fresno	27.8	Yolo	56.9	Tulare	30.1
Del Norte	32.6	Ventura	37.8	Stanislaus	22.4	Monterey	18.5	Santa Barbara	42.8	Santa Barbara	26.5
Ventura	30.4	Merced	31.5	Monterey	17.8	Stanislaus	17.7	Monterey	16.1	Riverside	10.7
Stanislaus	20.8	Stanislaus	19.4	Fresno	17.0	San Joaquin	16.8	Contra Costa	14.5	Ventura	10.6
Imperial	13.5	Fresno	12.4	Tulare	14.9	Riverside	11.8	San Luis Obispo	14.4	Yolo	8.8
San Diego	12.0	Riverside	11.1	Ventura	11.8	Solano	9.6	Ventura	13.1	Placer	6.3
San Bernardino	11.9	San Luis Obispo	9.5	Colusa	8.4	San Luis Obispo	6.9	Riverside	10.3	San Luis Obispo	5.0

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (h). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1997^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	234.1	Fresno	1,120.0	Fresno	1,478.7	Merced	233.5	Monterey	79.4	Kern	494.1
Kings	71.0	Yolo	270.2	Los Angeles	247.2	Modoc	107.6	Santa Barbara	71.1	Kings	94.5
Riverside	50.9	Kern	197.1	Yolo	198.8	Fresno	100.2	Merced	65.1	Imperial	61.9
Imperial	48.7	Los Angeles	95.1	Merced	198.8	Sacramento	97.8	Tulare	51.9	Santa Barbara	49.3
Santa Barbara	26.7	Kings	91.9	San Luis Obispo	155.9	Stanislaus	66.7	Stanislaus	33.7	Riverside	43.7
Fresno	11.5	Solano	70.7	Solano	135.7	Santa Barbara	55.8	Ventura	33.1	San Diego	15.4
Colusa	7.1	Santa Barbara	53.1	Kings	86.4	Siskiyou	53.1	San Luis Obispo	31.7	San Luis Obispo	13.8
Merced	6.4	Riverside	40.1	Ventura	71.8	San Joaquin	47.1	Riverside	24.9	Orange	13.7
San Diego	4.3	Madera	36.7	Tulare	71.2	Santa Cruz	40.8	Kern	23.0	Merced	11.5
Ventura	3.2	San Luis Obispo	31.7	Kern	66.7	San Mateo	37.7	Santa Cruz	18.8	Ventura	10.9

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	1,018.7	Imperial	535.0	Imperial	975.9	Imperial	734.8	Kern	298.6	Kern	551.0
Santa Barbara	95.6	Kern	412.4	Kern	218.2	Kern	381.4	Imperial	117.1	Fresno	323.1
Riverside	33.6	Riverside	104.5	Santa Barbara	57.5	Stanislaus	37.1	Santa Barbara	37.8	Imperial	65.5
San Luis Obispo	25.7	Del Norte	82.2	Monterey	29.3	Santa Barbara	36.9	San Luis Obispo	37.2	Tulare	44.2
Ventura	22.6	Santa Barbara	74.1	Riverside	25.9	Fresno	36.8	Fresno	25.9	Santa Barbara	20.5
Imperial	20.0	Kings	70.9	Stanislaus	21.5	Solano	29.0	Tulare	24.9	Riverside	12.7
Stanislaus	18.3	Stanislaus	20.6	Madera	20.3	Monterey	27.5	Solano	22.6	Yolo	10.8
San Diego	18.1	Monterey	20.5	Solano	15.3	Los Angeles	23.6	Madera	22.1	Orange	6.8
Monterey	15.0	Madera	20.3	San Luis Obispo	13.5	San Luis Obispo	21.9	San Joaquin	9.7	Ventura	4.4
Del Norte	12.8	Colusa	14.1	Colusa	8.0	Riverside	13.4	Monterey	6.3	Stanislaus	2.9

^a For each month, the top ten counties reporting applications are listed.

Table II-3 (i). Monthly Applications (in Thousands of Pounds) of Metam-Sodium by County for 1998^a

January		February		March		April		May		June	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Fresno	803.7	Fresno	94.7	Fresno	751.5	Merced	212.8	Santa Barbara	127.5	Kern	273.4
Kern	263.2	Los Angeles	51.4	Yolo	196.2	Santa Barbara	187.4	Los Angeles	109.8	San Luis Obispo	101.9
Santa Barbara	73.7	Kern	36.0	San Luis Obispo	66.7	Fresno	157.7	Modoc	58.7	Santa Barbara	82.0
Kings	46.8	Riverside	13.4	Kings	58.2	Yolo	130.3	Riverside	55.8	Riverside	48.0
Los Angeles	46.0	Orange	11.4	Merced	56.9	Modoc	116.1	Kern	45.5	Sonoma	30.1
Riverside	30.5	Monterey	9.4	Solano	40.3	Solano	98.4	Fresno	44.8	Kings	28.6
Tulare	21.7	Yolo	6.6	Riverside	37.7	Siskiyou	96.1	Merced	44.4	Solano	25.4
Imperial	15.9	San Luis Obispo	2.7	Los Angeles	34.4	Stanislaus	62.3	Orange	40.5	Ventura	24.7
Colusa	15.1	Santa Clara	2.1	Stanislaus	28.8	San Luis Obispo	51.4	Monterey	28.5	Orange	21.0
Orange	10.5	El Dorado	1.9	Kern	27.5	Kern	37.8	Santa Cruz	23.4	San Mateo	17.2

July		August		September		October		November		December	
County	Use	County	Use	County	Use	County	Use	County	Use	County	Use
Kern	932.4	Imperial	879.4	Imperial	1,412.2	Imperial	612.1	Kern	277.4	Kern	394.5
Imperial	175.4	Kern	484.0	Santa Barbara	191.1	Kern	384.5	Fresno	238.0	Fresno	344.3
Kings	137.5	Kings	132.7	Kern	172.0	Fresno	54.4	Imperial	107.4	Imperial	175.4
Santa Barbara	37.6	Riverside	114.5	Riverside	105.1	Riverside	51.3	Kings	48.8	Tulare	15.0
Sonoma	30.0	Del Norte	74.6	Orange	75.4	Merced	31.8	Santa Barbara	40.2	Monterey	14.4
Del Norte	21.7	Santa Barbara	36.9	Madera	37.9	Kings	28.4	Riverside	18.1	Santa Barbara	14.1
Stanislaus	16.4	Merced	36.8	San Diego	36.2	Santa Barbara	28.1	Monterey	11.8	San Luis Obispo	10.9
Riverside	14.8	Ventura	22.5	Stanislaus	31.0	Monterey	22.2	Ventura	10.0	Riverside	7.0
Ventura	12.9	Stanislaus	17.9	Monterey	9.9	San Luis Obispo	11.1	San Luis Obispo	5.4	Yolo	6.4
Solano	8.2	Orange	10.6	Ventura	6.1	Solano	8.5	San Joaquin	4.2	Stanislaus	2.0

^a For each month, the top ten counties reporting applications are listed.

Table II-4 shows the annual use of metam-sodium by county for reporting years 1990 through 1998 with respect to the county population based on the 1990 census. Sixty to seventy-two percent of reported use has occurred historically in three counties—Fresno, Imperial, and Kern. Figure II-2 provides a visual image of the same information, and shows locations of metam-sodium cropland use in California based on the 1998 PUR data. The majority of the widespread use occurred in California's Central Valley, with the heaviest use occurring in central Kern, south-central Imperial, and southwestern Fresno Counties.

Table II-4. Metam-Sodium Use From 1990 Through 1998 by County and Their Respective Populations

County	Amount of Metam-Sodium Applied (pounds) ^a									Total Population ^b
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
Alameda	49	8	206	4	1,092	12,703	10,415	841	613	1,279,182
Alpine	5,335	—	—	—	—	—	—	—	—	1,113
Amador	—	—	—	—	—	—	13	—	—	30,039
Butte	143	178	3,593	220	443	191	382	835	—	182,120
Calaveras	311	207	159	—	—	—	114	—	—	31,998
Colusa	16,669	2,977	5,424	—	56,776	26,526	44,578	48,738	21,419	16,275
Contra Costa	119,360	75,817	107,119	184,301	133,137	84,345	24,376	9,033	1,890	803,732
Del Norte	5,411	47,874	90,751	92,508	60,199	119,503	107,662	99,703	96,372	23,460
El Dorado	—	126	—	—	—	—	2,944	1,588	11,033	125,995
Fresno	2,463,262	322,139	2,580,589	2,922,436	3,815,506	3,804,322	4,194,475	3,135,036	2,511,343	667,490
Glenn	—	32	—	—	—	16	—	4,851	402	24,798
Humboldt	—	—	1	—	6	0	229	268	—	119,118
Imperial	460,920	983,422	1,755,879	1,115,498	1,906,805	3,191,832	2,272,907	2,559,666	3,384,552	109,305
Inyo	—	—	—	4,717	—	—	—	—	—	18,281
Kern	1,450,070	1,751,202	1,264,722	1,028,869	1,037,215	3,915,263	4,057,055	3,904,032	3,328,044	543,477
Kings	49,656	24,157	175,405	177,813	263,117	321,584	428,861	441,964	487,392	101,469
Lake	—	—	—	—	—	20	138	34	—	50,631
Lassen	—	—	—	16	2,141	—	—	—	—	27,598

a — indicates no use reported for that year.

b 1990 Census Figures for California.

(continued on next page)

Table II-4. Metam-Sodium Use From 1990 Through 1998 by County and Their Respective Populations (continued)

County	Amount of Metam-Sodium Applied (pounds) ^a									Total Population ^b
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
Los Angeles	1,665	4,684	1,681	1,784	1,288	1,068	23,527	498,173	254,663	8,863,164
Madera	50,485	9,401	50,618	104,946	173,544	81,334	15,759	112,013	50,109	88,090
Marin	—	16	—	—	—	—	2	156	1,083	230,096
Mariposa	—	—	—	—	35	12	—	—	—	14,302
Mendocino	—	3,931	4,541	1,020	8,454	18,654	1,720	148	434	80,345
Merced	110,482	12,754	113,596	214,054	427,069	503,823	623,932	526,264	383,537	178,403
Modoc	—	14,979	36,414	48,855	74,153	48,340	88,842	158,410	178,810	9,678
Mono	—	—	15,616	177,778	126,244	9,051	—	169	—	9,956
Monterey	103,551	240,161	251,154	272,939	222,915	182,825	150,077	239,589	125,313	355,660
Napa	—	—	—	2,142	7,023	—	12	96	—	110,765
Nevada	—	20	—	—	—	34	6,049	4,262	—	78,510
Orange	256	222	32	108	15,857	93,015	55,293	79,752	178,603	2,410,556
Placer	—	—	—	—	675	2,181	20,185	2,822	39	172,796
Plumas	25	—	—	—	—	—	—	—	—	19,739
Riverside	47,472	25,962	236,109	224,759	208,371	327,802	313,899	371,727	506,524	1,170,413
Sacramento	19,923	44,020	50,781	43,065	60,499	12,390	88,438	141,139	44,460	1,041,219
San Benito	40,356	889	23,297	38,358	113,777	13,959	21,476	46,434	12,522	36,697
San Bernardino	276	11,500	156	5,302	—	43,608	48,381	1,076	4,046	1,418,380

a — indicates no use reported for that year.

b 1990 Census Figures for California.

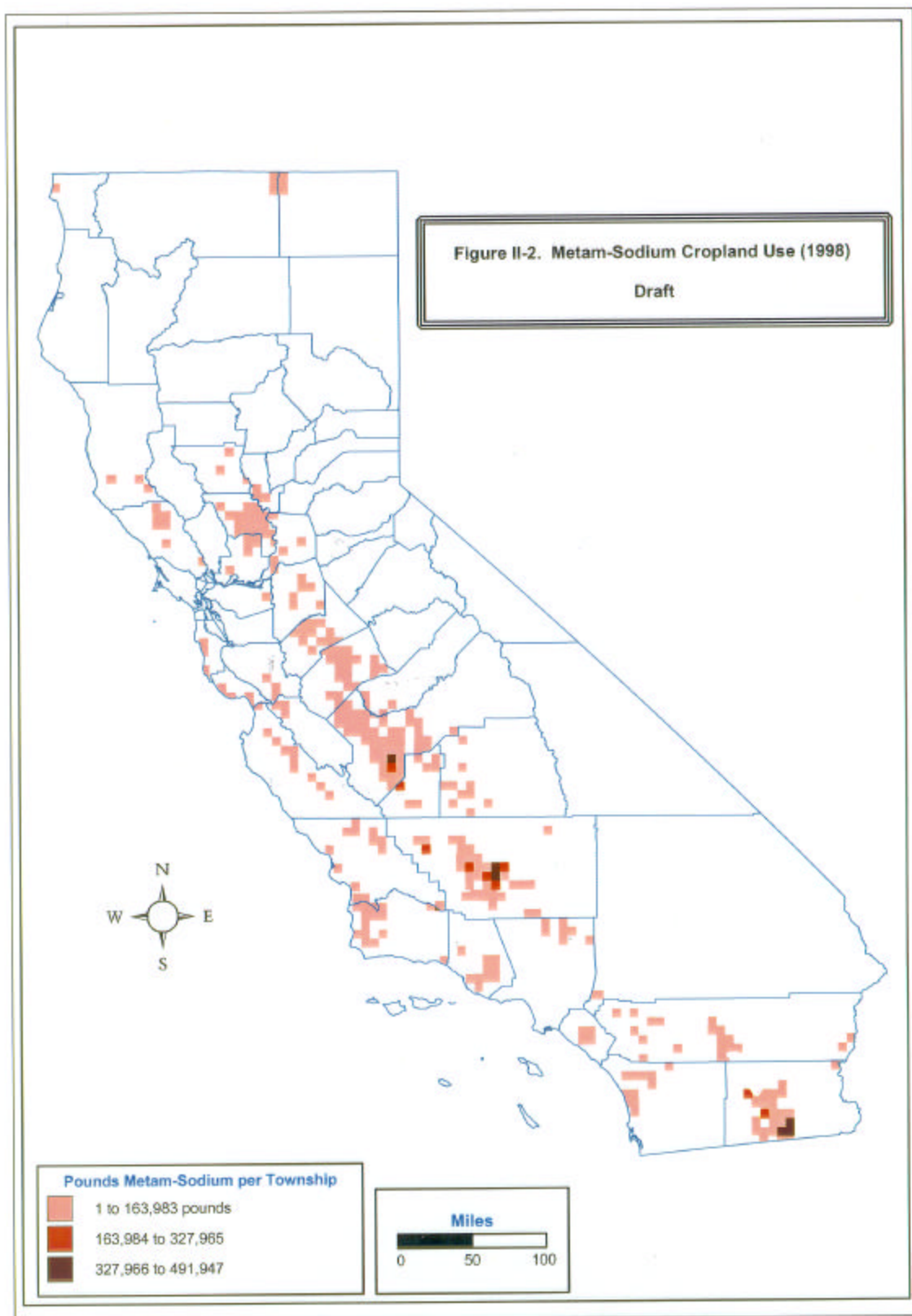
(continued on next page)

Table II-4. Metam-Sodium Use From 1990 Through 1998 by County and Their Respective Populations (continued)

County	Amount of Metam-Sodium Applied (pounds) ^a									Total Population ^b
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
San Diego	12,894	7,096	10,617	50,129	43,875	55,226	31,683	67,901	112,229	2,498,016
San Francisco	482	86	—	—	—	—	—	2,559	13	732,959
San Joaquin	134,497	117,448	123,632	124,386	199,654	157,442	122,836	122,535	36,379	480,628
San Luis Obispo	61,357	94,300	127,693	104,574	100,576	176,661	265,622	375,641	301,153	217,162
San Mateo	23,062	22,383	30,823	49,207	32,816	27,950	26,889	83,818	40,592	649,623
Santa Barbara	157,481	258,091	507,598	433,521	415,365	645,413	767,246	639,102	839,303	369,623
Santa Clara	8,888	13,449	11,939	49,287	71,448	20,863	65,336	25,322	27,301	1,497,577
Santa Cruz	98,429	123,669	130,399	121,156	125,404	78,473	70,184	63,926	28,309	229,734
Shasta	357	4	—	576	1,552	5	293	—	67	147,036
Sierra	—	64	—	—	—	—	—	2,822	—	3,318
Siskiyou	11,449	6,843	8,975	—	1,768	—	43,024	60,526	104,917	43,531
Solano	88,332	95,694	80,458	127,348	196,228	95,130	226,190	294,314	194,910	340,421
Sonoma	574	810	207	8,201	15,215	35,521	3,667	9,668	85,195	388,362
Stanislaus	48,898	146,326	144,500	208,265	205,642	239,885	242,171	254,590	195,094	370,522
Sutter	37,900	31,231	13,785	31,516	47,889	24,125	61,144	47,112	12,626	64,415
Tehama	491	—	13	—	—	11	—	—	83	49,625
Trinity	—	—	—	—	—	—	—	—	—	13,063
Tulare	57,613	26,892	105,654	120,080	121,974	107,874	134,951	214,051	59,940	311,921
Tuolumne	—	—	—	—	—	—	—	—	239	48,456
Ventura	140,930	99,242	190,966	193,328	216,023	186,311	187,143	209,860	118,837	669,016
Yolo	123,068	266,743	310,972	305,951	661,794	466,045	657,796	538,888	358,098	141,092
Yuba	64	287	255	—	—	46	—	7,298	778	58,228
Totals	5,952,444	4,887,334	8,566,331	8,589,017	11,173,565	15,131,385	15,507,916	15,408,754	14,099,262	29,769,178

a — indicates no use reported for that year.

b 1990 Census Figures for California.



2. Dazomet Use Information (1990-1998)

Table II-5 summarizes the use of dazomet on each commodity, or site, from 1990 through 1998. Most of the dazomet reported used in California was associated with nursery and greenhouse applications. These applications usually involve treatment of potting soils, soil media and heaps, and may occur inside greenhouses, or to outside nursery areas. Dazomet is not currently registered for use on food crops (DPR, 1990-1998).

Because water system treatments, pulp and paper mill use, and industrial biocide treatments are not considered agricultural uses, applicators of these products are not required to file a pesticide use report (DPR, 1995). Therefore, it is unknown how much dazomet is used for these situations.

The annual PUR information can be used to identify the seasons during which agricultural applications of dazomet most often occurred. Table II-6 shows the historical use of dazomet by month for the entire state from 1990 through 1998, and Figure II-3 presents a graphical representation of the same data. The majority of the use occurs in the summertime. This summer use is associated with pre-plant treatments prior to the planting of nursery crops in San Diego County (DPR, 1990-1998).

Table II-7 shows the annual use of dazomet by county for reporting years 1990 through 1998 with respect to the county population based on the 1990 census. Use patterns have fluctuated over the past nine years, however in 1998, nearly ninety percent of reported use occurred historically in three counties—San Diego, Tulare, and San Mateo.

Table II-5. Dazomet Use in Pounds by Commodity (From Annual Pesticide Use Reports, 1990-1998)

Commodity/Site	1990	1991	1992	1993	1994	1995	1996	1997	1998
Structural Pest Control	40	— ^a	—	—	—	—	3	—	—
Landscape/Ornamental Turf	351	149	350	344	649	650	334	108	97
Research Commodity	—	—	594	1	—	—	—	3,168	—
Greenhouse/Nursery	22,278	21,275	14,025	117	2,377	5,226	10,534	12,936	10,458
Strawberry	—	—	—	—	—	—	792	186	—
Gai Lon	—	—	—	—	—	—	990	—	—
Preplant Soil Application	—	—	93	—	—	—	—	—	87
Uncultivated Agricultural Areas	—	—	—	594	—	—	—	—	1,485
Uncultivated Non-agricultural Areas	—	74	—	1,515	—	—	198	—	3,119
Totals	22,669	21,498	15,062	2,570	3,026	5,877	12,851	16,399	15,246

^a — Indicates no use reported for that year.

Table II-6. Monthly Dazomet Use in Pounds (From Annual Pesticide Use Reports, 1990-1998)

Month	1990	1991	1992	1993	1994	1995	1996	1997	1998
January	—	—	73	—	743	—	436	162	238
February	20	50	—	—	7	504	19	500	143
March	34	162	54	71	83	229	708	513	386
April	—	554	139	—	85	434	1,123	775	1,230
May	—	50	—	50	10	500	496	441	2,030
June	—	228	771	15	609	1,000	2,929	647	1,659
July	18,860	15,642	—	1,291	70	637	2,097	4,555	1,486
August	3,119	3,227	13,246	79	1,337	515	987	785	4,005
September	297	485	277	767	5	470	2,365	3,855	2,810
October	93	282	428	297	62	1,116	1,287	2,765	670
November	248	818	74	—	16	132	103	801	400
December	—	—	—	—	—	339	302	600	190
Totals	22,669	21,498	15,062	2,570	3,026	5,877	12,851	16,399	15,246

Figure II-3. Historical Dazomet Use in Pounds (From Annual Pesticide Use Reports, 1990-1998)

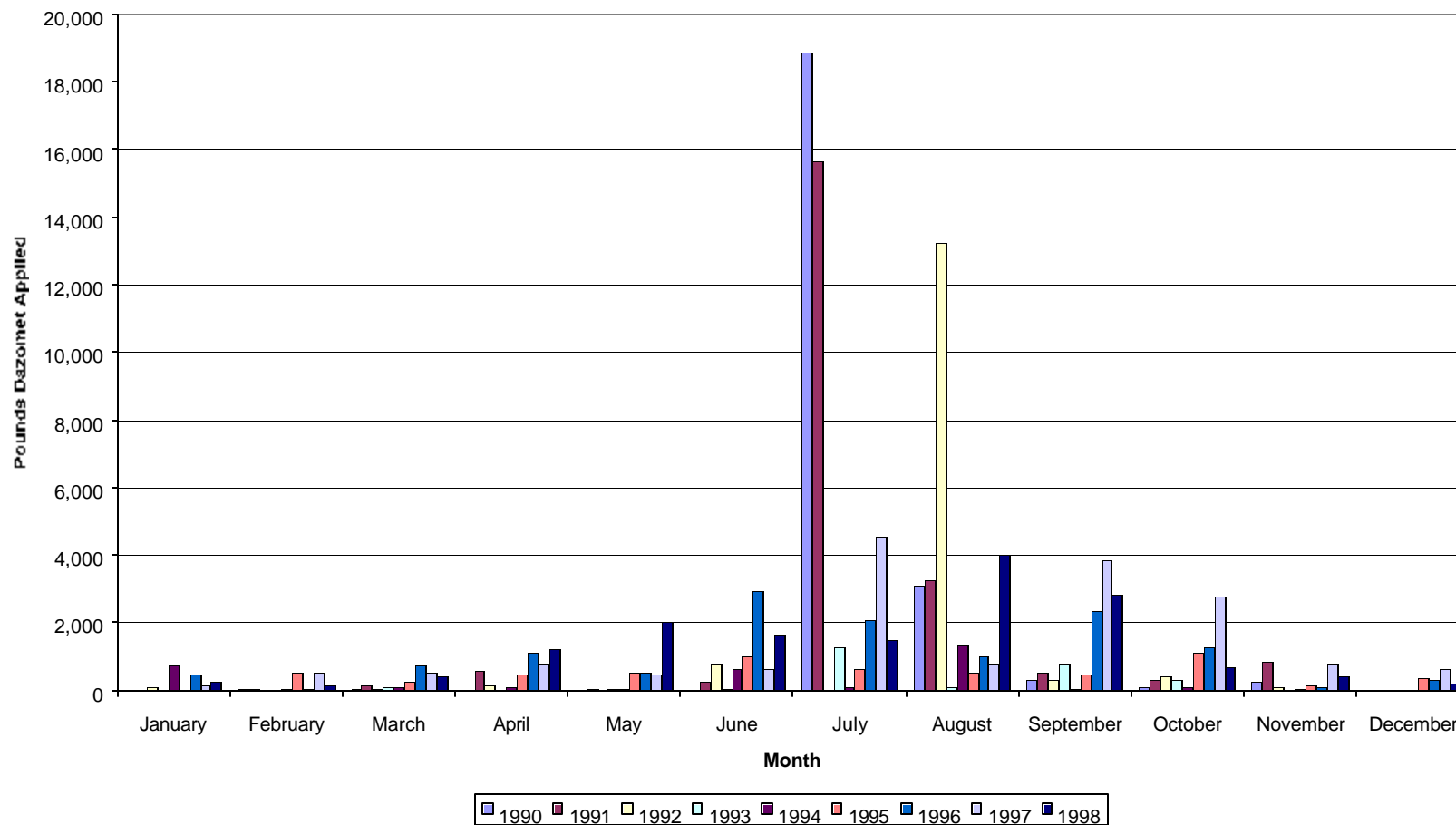


Table II-7. Dazomet Use From 1990 Through 1998 by County and Their Respective Populations

County	Amount of Dazomet Applied (pounds) ^a									Total Population ^b
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
Alameda	—	—	—	—	—	743	—	—	—	1,279,182
Del Norte	21,978	18,563	12,652	—	—	—	—	—	—	23,460
El Dorado	—	—	—	—	—	—	—	—	87	125,995
Humboldt	266	1,845	416	—	1,485	767	—	297	—	119,118
Inyo	—	—	—	—	—	—	7	—	—	18,281
Los Angeles	34	—	44	—	71	104	164	360	515	8,863,164
Madera	—	—	—	—	—	99	—	—	—	88,090
Marin	—	—	848	—	—	—	—	—	—	230,096
Monterey	—	818	50	117	574	—	693	2,079	—	335,660
Orange	—	—	—	72	10	6	94	15	12	2,410,556
Riverside	84	149	350	272	248	188	102	353	89	1,170,413
San Bernardino	—	—	—	—	—	—	7	—	—	2,498,016
San Diego	248	—	—	—	15	3,087	5,016	6,419	5,851	732,959
San Joaquin	—	—	—	—	—	—	45	—	—	217,162
San Luis Obispo	—	—	74	—	—	—	—	—	—	649,623
San Mateo	—	—	—	—	—	—	—	894	3,283	649,623
Santa Barbara	—	—	—	—	—	—	—	147	131	369,623
Santa Clara	—	—	—	1	43	26	1,008	605	7	1,497,577
Santa Cruz	40	50	35	—	580	218	567	292	658	229,734
Solano	—	74	—	—	—	—	—	—	—	340,421
Sonoma	—	—	—	—	—	—	4,851	3,960	—	388,362
Tulare	—	—	594	2,109	—	—	—	792	4,604	311,921
Ventura	20	—	—	—	—	297	297	186	9	669,016
Yuba	—	—	—	—	—	342	—	—	—	58,228
Totals	22,669	21,498	15,062	2,570	3,026	5,877	12,851	16,399	15,246	29,769,178

a — indicates no use reported for that year.

b 1990 Census Figures for California.

Note: Counties not listed did not report any use from 1990-1998.

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III. PERSISTENCE AND FATE OF METAM-SODIUM, DAZOMET, AND METHYL ISOTHIOCYANATE IN THE ENVIRONMENT

This section contains a review of the scientific literature regarding the transformation of metam-sodium and dazomet to MITC, and the subsequent fate of MITC in the environment. This review includes the results of several air monitoring studies that were conducted by the State of California to measure the airborne concentrations of MITC associated with agricultural applications of metam-sodium. No studies have been conducted which measure the airborne concentrations of MITC associated with agricultural applications of dazomet or metam-potassium.

A. The Transformation of Metam-Sodium and Dazomet to Methyl Isothiocyanate

1. Transformation of Metam-Sodium

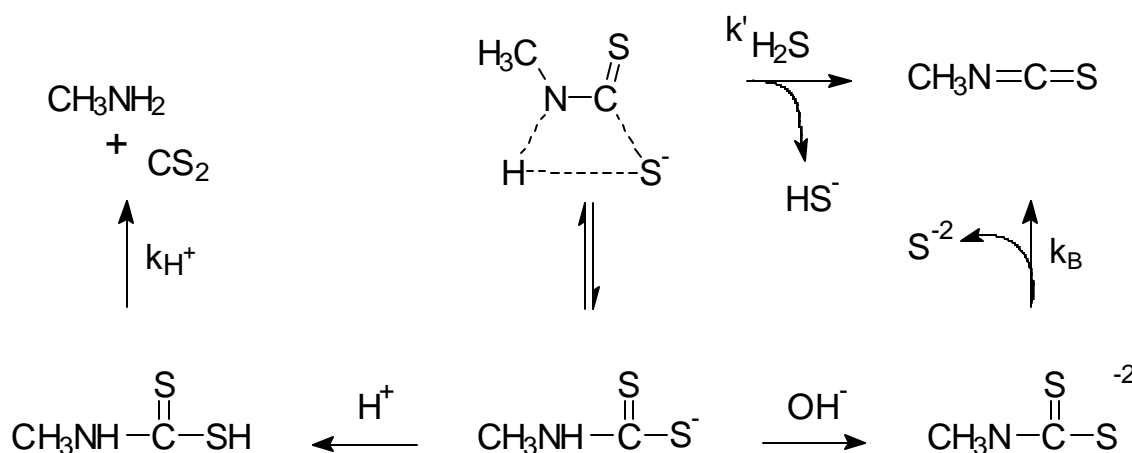
Conducted since the early 1960s, research demonstrates that:

- In the soil environment, metam-sodium decomposes quickly to its primary breakdown product, MITC, usually within one hour to one day following application.
- Metam-sodium's decomposition rate depends strongly on soil temperature, soil composition, and soil moisture.
- Sunlight plays an important role in determining metam-sodium's persistence in water.
- Metam-sodium is more stable in water than in either soil or air.

In general, the rapid and complete breakdown of metam-sodium results in a soil solution containing mainly MITC, the biologically active product (Ericson, 1990; Haag, 1989; Munnecke et al., 1967; Munnecke et al., 1962; Lloyd, 1962; Gray, 1962; Hughes, 1960). Draper and Wakeham (1993) summarized the major neutral, acid-catalyzed, and base-catalyzed hydrolysis reactions of metam-sodium (Figure III-1). In an acidic medium ($\text{pH} < 5$), metam-sodium is cleaved, resulting in methylamine (CH_3NH_2) and carbon disulfide (CS_2). Under basic conditions ($\text{pH} > 11$), metam-sodium decomposes primarily to MITC and sulfur. At near-neutral pH, two possible decomposition mechanisms exist: 1) an oxidation pathway, wherein metam-sodium is first oxidized to form the intermediate dimethyl thiuram disulfide, which undergoes further oxidation to MITC, and 2) a non-oxidative monomolecular cleavage process that results in MITC and hydrogen sulfide (H_2S) (Draper and Wakeham, 1993; Joris et al., 1970; Turner and Corden, 1963). Joris et al. (1970) noted

that the first mechanism is not thermodynamically favored when the pH is less than 9.5; consequently, the second process would be expected to dominate.

Figure III-1. Decomposition Pathways for Metam-Sodium in Water Under Neutral, Acid-Catalyzed, and Base-Catalyzed Conditions (Draper and Wakeham, 1993)



The decomposition rate of metam-sodium depends strongly on soil temperature, soil composition, and soil moisture. In general, low soil moisture, warm soil temperatures, increased concentrations of clay or organic matter, and smaller soil particle-size facilitate the rapid conversion of metam-sodium to MITC. The conversion follows first-order kinetics and occurs with an efficiency ranging from 87 to 95 percent in all of the soils tested—often occurring faster in previously treated soils (Smelt et al., 1989; Burnett and Tambling, 1986; Gerstl et al., 1977; Leistra et al., 1974; Leistra, 1974; Smelt and Leistra, 1974; Turner and Corden, 1963). The conversion exhibited a half-life of less than 30 minutes in soils with low moisture content, and high clay or organic matter content (Gerstl et al., 1977). When soil temperatures increase from 10°C to 40°C, decomposition time decreases from 7 to 1.5 hours (Turner and Corden, 1963). Similarly, when soil moisture content decreased from 20 to 6 percent, decomposition time decreased from 7 to 2.5 hours (Turner and Corden, 1963). Other reported transformation times ranged from slightly less than one hour to a full day. However, most investigators noted that complete conversion occurred within a few hours (Smelt et al., 1989; Haag et al., 1989; Burnett and Tambling, 1986; Leistra et al., 1974; Leistra, 1974; Smelt and Leistra, 1974; Turner and Corden, 1963). Wet conditions coupled with low soil temperatures aggravate the decomposition process to the point that the treatment became largely ineffective because the conversion to MITC virtually ceased.

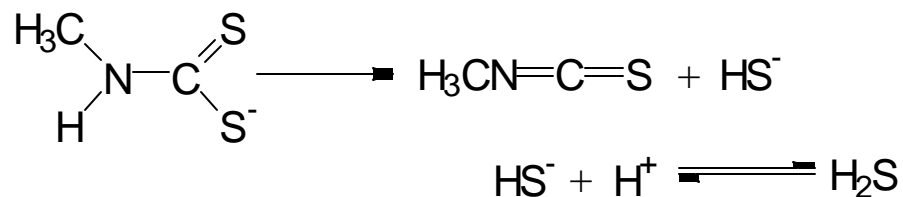
Consequently, when metam-sodium was applied to fields in the Netherlands in late autumn or winter, significant metam-sodium concentrations were still present in those fields the following spring. These residual concentrations resulted in biocidal concentrations of MITC in the spring, when the onset of warmer, drier soil conditions induced the decomposition of metam-sodium (Smelt and Leistra, 1974; Leistra, 1974).

In laboratory studies, Haag et al. (1989) exposed non-radioactive metam-sodium on thin films of soil to light in a closed photoreactor for two hours. The rate of metam-sodium decomposition and the products formed were similar in the light as in the dark, and suggests that photolysis does not occur in the soil environment.

Smelt and Leistra (1974) found the highest conversion rates occurred in loamy soils; complete conversion occurred within three hours at 12°C. In humic sandy soils at 12°C, the conversion required six hours to reach completion. However, when soil temperatures were raised to 21°C, conversion time decreased to four hours. In trace amounts, iron and copper salts accelerate the decomposition of metam-sodium to MITC in soil. Conversely, in trace concentrations, zinc, calcium, and nickel decrease conversion times (Ashley and Leigh, 1963).

Sunlight plays an important role in determining metam-sodium's persistence in water. Draper and Wakeham (1993) measured the photodecomposition half-life of metam-sodium in shallow water. Metam-sodium exhibited a half-life of less than one hour when it was exposed to midsummer, midday sunlight. Aqueous metam-sodium solutions were photochemically unstable in spite of the weak chromophore. When in aqueous solution and irradiated with a laboratory photoreactor, the half-lives ranged from 2.9 to 8.4 minutes as light intensity increased. In the dark, the major decomposition pathway involves a cleavage reaction yielding MITC and hydrogen sulfide (Figure III-2). It was reported that in the

Figure III-2. The Decomposition of Metam-Sodium to Yield MITC and Hydrogen Sulfide (Joris et al., 1970)



absence of light, the degradation half-life was 35 hours at pH 7 and 25°C, and that suspended sediments accelerated metam-sodium decomposition. Other reported half-lives ranged from 30 minutes to 1.6 hours for aqueous metam-sodium exposed to sunlight (Tomlin, 1997; Spurgeon, 1990).

Chang et al. (1985) studied the hydrolysis and photolysis of metam-sodium in dilute, buffered aqueous solution using a photolytic reactor equipped with a UV light source. At pH 5, the primary hydrolysis products of metam-sodium included MITC, carbon disulfide, and methylamine. At pH 7, the major photolysis products included MITC, N-methylthioformamide, methylamine, and elemental sulfur. Reported hydrolysis half-lives for metam-sodium at 25°C were 23.8 hours (pH 5), 180.0 hours (pH 7), and 45.6 hours (pH 9); at 40°C, half-lives of 7.8 hours (pH 5), 27.4 hours (pH 7), and 19.4 hours (pH 9) were reported. Ericson (1990) found the hydrolysis half-lives of metam-sodium in dilute aqueous buffered solution stored in dark, sterile conditions (25°C) to be 2 days, 2 days, and 4.5 days at pH 5, 7, and 9, respectfully. At pH 7, the major hydrolysis product was MITC.

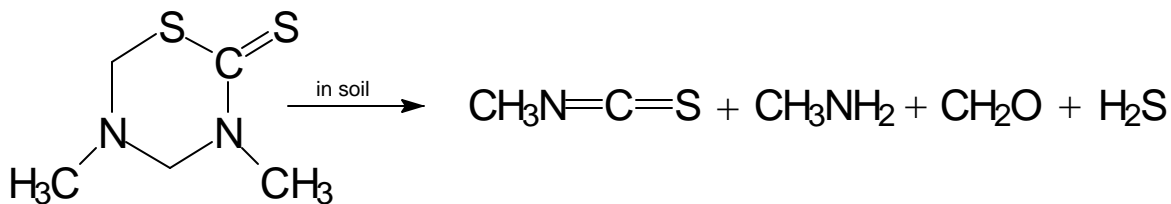
2. Transformation of Dazomet

Several factors influence the decomposition of dazomet. Research suggests that:

- In the soil, dazomet decomposes rapidly to form MITC, formaldehyde, hydrogen sulfide, and monomethylamine.
- In soil, dazomet degradation depends strongly on soil moisture content, soil temperature, soil pH, and soil type.
- In water, dazomet rapidly decomposes with half-lives ranging from less than two hours to nearly nine hours.

In the soil, dazomet decomposes rapidly (Figure III-3) to form MITC, formaldehyde, hydrogen sulfide, and monomethylamine (Tomlin, 1997; Cremlyn, 1991; Drescher and Otto, 1968; Torgeson et al., 1957). According to the manufacturer of one dazomet product, it is this combination of volatile gases that results in the fumigant activity (BASF, 1989). The decomposition of dazomet can occur in as little as 10 to 15 minutes (Thomson, 1989).

Figure III-3. In Soil, the Decomposition of Dazomet Results in the Formation of MITC, Monomethylamine, Formaldehyde, and Hydrogen Sulfide (Cremlyn, 1991)



Soil moisture may be the key factor in dazomet decomposition. However, soil temperature, pH, moisture content, and soil type all have an effect on the rate of degradation (Munnecke and Martin, 1964; Sczerzenie et al., 1987). Munnecke and Martin (1964) studied the effects of temperature, soil moisture content, and soil pH on the rate of dazomet decomposition. Warm soil temperatures facilitated the decomposition of dazomet. Decomposition occurred faster at 23°C than at 1°C; although the authors noted that the same amounts of MITC were eventually produced at all temperatures tested. Decomposition increased with increased soil moisture (up to approximately 80% of soil saturation). Decomposition proceeded fastest at pH 6.5, and declined at lower or higher pH levels.

Soil type seems to affect dazomet decomposition. Clays may act as catalysts in the initial breakdown of dazomet to MITC (Sczerzenie et al., 1987). The addition of peat moss to soil affected decomposition, presumably due to the sorption of dazomet to the peat moss. Dazomet decomposition decreased as peat moss content increased (Munnecke and Martin, 1964).

There is little information regarding the fate of dazomet in water. Sczerzenie et al. (1987) summarized several studies regarding dazomet's persistence in water. In contrast with its fate in soil, pH appears to be the key factor affecting the decomposition of dazomet in water. In aqueous solution at pH levels of 5, 7 and 9, dazomet decomposed with half-lives of 8.6, 2.6, and 1.46 hours, respectively. No temperatures were given. The half-life of dazomet in aqueous solution at pH 5 under irradiation was four hours, in comparison to a dark control, which had a half-life of 11 hours. Again, no temperatures were reported; however, MITC and carbon disulfide were identified as the decomposition products. Another study indicated that increased temperature or the presence of acid in water increased hydrolysis and yielded one molecule of carbon disulfide, two molecules of formaldehyde,

and two molecules of monomethylamine per molecule of dazomet, and suggests that decomposition in water gives rise to different products than those formed during the decomposition in the soil (Figure III-3). An aqueous photolysis half-life of 0.584 day (at pH 5 and 25°C) and a hydrolysis half-life of 0.146 day (at pH 7 and 25°C) were reported by the registrant (DPR, 1999a).

B. The Persistence of Metam-Sodium, Dazomet, and Methyl Isothiocyanate in Plants

Scant information exists in the open literature concerning the metabolism of metam-sodium, dazomet, and MITC in plants presumably because of the fumigants' toxic, non-specific nature. One recent study assessed the possible side effects of metam-sodium applications on fungi and vascular plants outside the target application area (de Jong et al., 1995). It was concluded that stunting and growth abnormalities might occur in non-target plants in areas of widespread agricultural use largely due to the highly volatile nature of MITC.

A group of pesticide manufacturers and registrants conducted a series of twenty studies on the magnitude of metam-sodium residues on a variety of raw agricultural commodities (Metam-Sodium Task Force, 1990). In the analyses of snap beans, cantaloupes, sweet corn, cucumbers, garlic, head lettuce, leaf lettuce, peppermint, potatoes, spinach, strawberries, tomato fruit, and tobacco samples, residues were found to be below the detection limit of 0.05 ppm for the parent compound and below the detection limit of 0.02 ppm for MITC, in all samples. Broccoli, cabbage, mustard greens, green onions, bulb onions, radishes, and turnips contained no detectable MITC residues (detection limit = 0.02 ppm). However, metam-sodium residues were detected in all of these crop samples, and ranged from 0.051 ppm in cabbage to 3.50 ppm in mustard greens (detection limit = 0.05 ppm).

C. The Persistence of Methyl Isothiocyanate in the Soil Environment

In soil, the primary MITC transport and transformational pathways are volatilization and hydrolysis (Geddes et al., 1995). In general, current research suggests:

- MITC loss from the soil is primarily due to volatilization.
- The potential for ground water contamination by MITC is low due to its low leaching and fast degradation characteristics.
- The persistence of MITC in soil depends on the soil temperature, type, pH, moisture content, and application method.
- MITC decomposition reactions follow first-order kinetics.
- Intensive, frequent use of MITC may result in adaptation of the soil microorganisms and the enhanced degradation of MITC.
- Application of organic amendments may reduce the volatilization from soil.
- Microbiological organisms may play a role in the decomposition of MITC at very low concentrations in soil.

MITC leaves the soil primarily due to volatilization. While the parent compound (metam-sodium or dazomet) has a negligible vapor pressure, MITC has a relatively high vapor pressure (16.0 mmHg at 25°C), which allows it to readily volatilize and enter the atmosphere. In one greenhouse study, when compared to the total amount of metam-sodium injected into the soil, approximately 60 percent volatilized into the air as MITC over a 14-day period (Leistra and Crum, 1990).

Saeed et al. (1996) investigated the influence of soil water content and irrigation on the leaching, distribution, and persistence of MITC in a Wisconsin sandy soil following sprinkler applications of metam-sodium. In this temperature-controlled laboratory study, soil columns made of teflon-lined PVC pipe were filled with a sandy soil and maintained at 2 °C over the course of the study (a low temperature was reported to be typical of the temperature in Wisconsin during the season that metam-sodium is normally applied in that state). MITC persisted in the soil for 15 days at 2 °C with the highest residues detected in the top 25-cm layer of all soil columns. It was concluded that the potential for ground water contamination by MITC would be low due to its low leaching and fast degradation characteristics.

Specific factors affect the rate of MITC loss from treated soils. In order of importance, these factors include soil temperature, soil type, soil pH, and soil moisture content (Ashley et al., 1963). Warmer soils favor MITC volatilization, while cooler, wetter conditions result in lower volatilization rates from soil (Van den Berg et al., 1999). The loss of MITC could be as much as 50 percent greater in soils at 15°C than at 10°C (Ashley et al.,

1963). Clay and sandy-loam soils facilitate the volatilization of MITC; conversely, peaty soils impede its loss. In general, MITC adsorption was relatively low for all soils. However, soils high in organic matter and clay adsorbed more MITC than soils with little or no clay and organic matter (Gerstl et al., 1977; Ashley et al., 1963).

The loss of MITC increased with an increase in pH in treated soils. Ashley et al. (1963) amended metam-sodium-treated soils with lime to raise the soil pH and found acid soils tended to retain MITC longer than neutral soils. While investigating the degradation of MITC under field conditions, Verhagen et al. (1996) reported that clay and silt loam soils with a pH > 7 showed such a rapid degradation of MITC that the pesticide would be unlikely to control nematodes effectively under those conditions.

Drier soils lose MITC faster than water-saturated soils of equivalent type (Smelt and Leistra, 1974; Ashley et al., 1963). When soil treatment occurred during wet soil conditions—such as those found in peat soils—or was followed by precipitation, the vapor diffusion of MITC was very slow and resulted in an uneven distribution of MITC in the soil. These results suggested that much of the MITC may have decomposed before it could volatilize (Smelt and Leistra, 1974).

Application method affects the volatilization rates of MITC from soil. Van den Berg et al. (1999) studied the volatilization of MITC from soil following the application of metam-sodium to a gleyic podsol soil using two different application techniques. The first technique involved blade injection at 0.19 m followed by smoothing of the surface soil with a rototiller to a depth of 0.05 m, and subsequent soil compaction with a roller. The second method involved injecting metam-sodium at 0.10 m followed by thorough mixing of the top 0.2 m with a rotavator, then by compaction with the same roller. These studies were designed to assist with the development of a computer model being developed to evaluate the effect of different factors on the volatilization of fumigants and other soil-incorporated pesticides from homogeneous non-cracking soils. Two plots, each 30 m long and 9 m wide, were treated with 300 L ha⁻¹ metam-sodium solution containing 0.51 kg metam-sodium L⁻¹. Each plot was treated twice, first in October 1989, followed by a second treatment in November 1989. Metam-sodium was applied each time using the two techniques described above. The highest volatilization rates were measured following the application with injection followed by rototilling. During the October applications, the volatilization rate following blade injection was approximately 0.15 kg hectare⁻¹day⁻¹ during the first day, peaked at approximately 0.45 kg hectare⁻¹day⁻¹ during the second day, and tailed off over the subsequent two days. However, the volatilization rate following rotovation was highest

during the first day, with rates at approximately $60 \text{ kg hectare}^{-1} \text{ day}^{-1}$, diminishing to approximately $15 \text{ kg hectare}^{-1} \text{ day}^{-1}$ by the second day, and tailing off over the following two days. For the November application, similar volatilization patterns were reported; however, because of the cooler, wetter soil conditions, the actual rates were reduced. Following blade injection, the volatilization rate peaked at approximately $0.12 \text{ kg hectare}^{-1} \text{ day}^{-1}$, while the peak volatilization rate was about $12 \text{ kg hectare}^{-1} \text{ day}^{-1}$ following rotoovation.

In soil, the decomposition of MITC follows first-order kinetics and depends on soil conditions and temperature (Gan et al., 1998; Smelt et al., 1989; Gerstl et al., 1977; Smelt and Leistra, 1974; Ashley, 1963). In laboratory incubation studies, Smelt et al. (1989) measured the decomposition rate of MITC at 15°C in fifteen different soils including those from frequently fumigated greenhouses and field test plots. The decomposition time varied considerably, with half-lives ranging from 0.5 to 50 days. Decomposition occurred the slowest in humic, sandy soils, and occurred the fastest in previously treated soils.

Smelt and Leistra (1974) studied the decomposition of MITC in moist soil at 4°C , 13°C , and 21°C . The half-life of MITC ranged from 8 to 14 days at 13°C depending on soil composition. Decomposition occurred faster in loamy soils, and slower in sandy soils. The decomposition rate depended strongly on soil temperature; MITC decomposed faster in warmer soils. The reported first-order rate constants ranged from 0.02 day^{-1} at 4°C , to 0.19 day^{-1} at 21°C . Ashley et al. (1963) obtained similar results, reporting rate constants ranging from 0.07 day^{-1} to 0.19 day^{-1} at 15°C .

Intensive, frequent use of MITC may result in adaptation of soil microorganisms and the enhanced degradation of the fumigant. Smelt et al. (1989) compared MITC transformation rates from previously non-fumigated soils to the rates in soils that received repeated applications of metam-sodium. The transformation rate varied considerably; reported half-lives ranged from 0.5 to 50 days. In general, MITC was transformed much faster in soils previously fumigated than in those never treated. In the previously treated soils, more than 99 percent of the MITC was transformed within two to fourteen days following treatment, depending on soil type. In many of the previously treated soils, transformation was rapid with no distinct period of approximate first-order decrease. In other soils, the period in which the transformation approximated first-order was only a few days; thereafter, transformation accelerated.

Verhagen et al. (1996) investigated the enhanced biodegradation of MITC in soils that had been previously subjected to intensive fumigation. All soils showed enhanced

degradation following repeated fumigation; however, the extent of enhanced degradation depended on the physical and chemical properties of the soil. In general, sand and peat soils exhibited less enhanced degradation following fumigation than did clay and silt loam soils. Clay and silt loam soils, with a pH above 7 and an organic matter content ranging from 1.8 to 3.8 percent, showed a very high rate of natural degradation of MITC that was further enhanced by repeated applications. These clay and silt loam soils showed such a rapid degradation of MITC that the chemical would be rendered largely inefficacious, particularly following repeated fumigations.

Gan et al. (1998) investigated the potential of reducing the volatilization of MITC from treated soils by the application of organic waste to the soil surface. Composted manure-, or biosolid-manure-amended soil mixtures were applied to the surface of soil columns containing a sandy loam soil. Applying a five percent mix of composted manure to top five centimeters of surface soil in packed columns almost eliminated the volatilization of MITC. MITC exhibited a half-life of 3.4 days in untreated soil. At a manure:soil ratio of 1:40, the half-life was reduced to 0.4 day. At a >1:8 ratio, the half-life was less than 2 hours. Sterilizing the amended soils greatly reduced the degradation rate. In amended soil (1:8), first-order decomposition rate constants decreased from 8.1 day^{-1} for non-sterile soil, to 1.5 day^{-1} following sterilization. This inhibitory effect suggests that microbial degradation may contribute to the overall degradation of MITC.

Boesten et al. (1991) investigated the transformation rate of MITC in four different water-saturated sandy sub-soils that were collected between two and four meters below the soil surface. Each of the four subsoil types was subjected to two different sets of laboratory incubation conditions. Throughout the entire procedure, one set of samples was stored at 10°C —the normal temperature of subsoil in the Netherlands, where the study was conducted. The transformation half-life of MITC was calculated to be between 6 to 35 days, depending on the soil type. A second set of the same four soil samples was unintentionally exposed to temperatures of 30°C for one full day near the beginning of the study. Thereafter, the samples were held at 10°C . For the second set of samples, the half-lives were calculated to be between 150 to 570 days. Based on the premise that the transformation of MITC in the soil occurs largely by microbial processes, it was speculated that the exposure to the higher temperatures in the second set of samples led to the inactivation of a large fraction of the microorganisms responsible for degradation. However, no attempt was made to identify the degradation products, or the microorganisms responsible for degradation.

D. The Persistence of Methyl Isothiocyanate in the Water Environment

In water, the stability of MITC depends on pH and the presence of sediment. Hydrolysis is slow in water, but increases significantly when in contact with sediments similar to those found in rivers, ponds or lake bottoms. Using buffered aqueous MITC solutions at pH 4, 7, and 10, Geddes et al. (1994) investigated the hydrolysis of dissolved MITC under several conditions: 1) at two different temperatures—10 °C and 25 °C; 2) with or without the presence of river sediment; and 3) agitated or non-agitated. For the samples held at 10 °C, hydrolysis half-lives were 67, 178, and 10 days at pH 4, 7, and 10, respectively. When the temperature was increased to 25 °C, the hydrolysis half-lives decreased to 15, 65, and 0.7 days at pH 4, 7, and 10, respectively. The presence of sediment increased the rate of hydrolysis at 10 °C by 69 percent; under these conditions the half-life was 55 days.

E. The Persistence of Methyl Isothiocyanate in Air

In air, the primary MITC transport and transformational pathway is gas phase photolysis (Geddes et al, 1995). In general, the persistence of MITC in air depends upon:

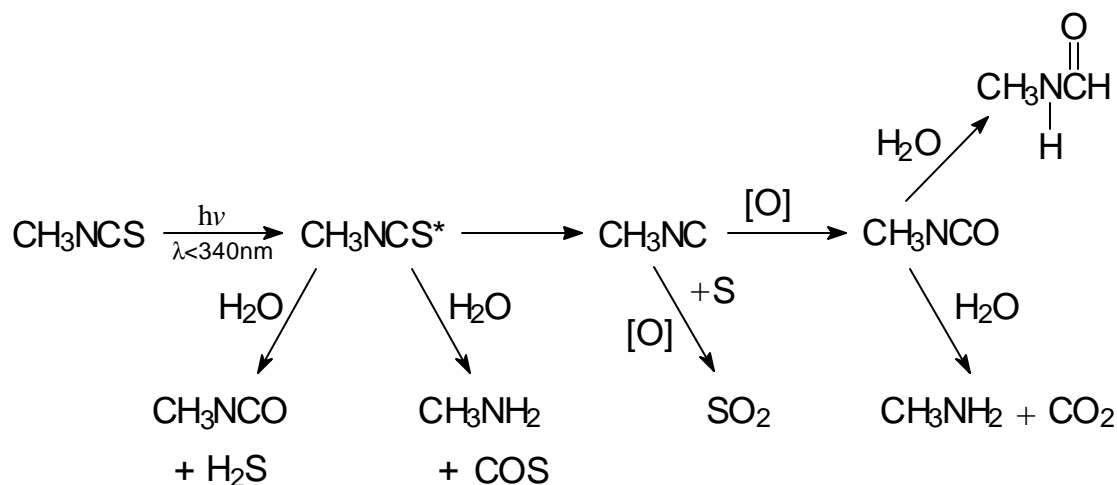
- the rate of photodissociation.
- the reactivity with OH radical, NO₃ radical, and ozone in the atmosphere.

Northrup and Sears (1990) investigated the photodissociation of alkyl-substituted compounds containing N=C=S using laser induced fluorescence at 248 and 193 nm (these short wavelengths are not environmentally relevant and may lead to processes which do not occur in the atmosphere). These compounds occur in two isomeric forms—alkyl isothiocyanates (R-NCS), and alkyl thiocyanates (R-SCN), where R is equal to H, CH₃, and C₂H₅. It was determined that the photolysis of MITC at these short wavelengths results in small amounts of CN radicals.

Alvarez and Moore (1994) measured a photolysis quantum yield of 0.98 ± 0.24 at 308 nm (a wavelength present in solar radiation in the troposphere and hence atmospherically relevant) and at total pressures <20 torr. The authors showed that at this wavelength the quantum yield at atmospheric pressure is within 20 percent of the low pressure value. Their data suggests that the photolysis quantum yield is 1.0 (unity). Using a quantum yield of 1.0 at all wavelengths >295 nm, the authors calculated a photolytic lifetime of 41 hours for noontime conditions on July 1 at 40°N latitude, indicating that photolytic degradation would be an effective removal pathway.

The primary transformational pathway for MITC involves gas phase photolysis. Geddes et al. (1995) studied the photodecomposition of MITC under two different sets of conditions. The first set of conditions included the use of filtered air, either natural sunlight or a xenon arc solar simulator, and either Tedlar, borosilicate, or quartz chambers. In the laboratory, with an artificial xenon arc source, MITC exhibited half-lives ranging from 8.9 (\pm 2.4) to 13.1 (\pm 2.4) hours. The second portion of the study was conducted outdoors using ambient light and either Tedlar, borosilicate, or quartz chambers with samples exposed continuously over several days and nights. Using ambient solar radiation, they measured MITC half-lives ranging from 29 to 39 hours—over twenty times faster than its half-life in sunlight when dissolved in water. These values are in reasonable agreement with the calculated half-life under those ambient solar radiation conditions using a photolysis quantum yield of 1.0. The half-lives MITC measured with xenon arc and solar radiation were consistent with the differing light intensities of the xenon arc source and solar radiation.

Geddes et al. (1995) used a gas chromatograph (equipped with a nitrogen-phosphorus detector and a flame photometric detector) and a gas chromatograph/mass spectrometer to determine the photodecomposition products. During the laboratory experiments, the photodecomposition of MITC resulted in the production of methyl isocyanate, methyl isocyanide, methylamine, N-methyl formamide, sulfur dioxide, hydrogen sulfide, and carbonyl sulfide. The following photolysis pathway was proposed (Figure III-2). Carbon disulfide was detected in both the irradiated samples and the dark control, and therefore, is probably not a photoproduct. More than 80 percent of the loss of MITC resulted in the formation of methyl isocyanide, which was rapidly consumed during subsequent secondary photochemical processes. Methyl isocyanate (MIC) increased over time, which demonstrated that it may be photochemically stable in the atmosphere. While MITC's gas phase transformation occurred via direct photolysis, the fate of the photoproducts is uncertain. Further, the conversion process of methyl isocyanide to methyl isocyanate occurred slower when methyl isocyanide was irradiated in the absence of SO₂. Therefore, it was concluded that the presence of sulfur dioxide (SO₂) might facilitate this conversion process because SO₂ has an appreciable absorbance in sunlight and is a singlet oxygen sensitizer. Other atmospheric oxidants, including hydroxyl radical, ozone or oxygen, may facilitate the conversion of isocyanides to isocyanates. However, the photoproducts were determined from the xenon arc irradiations, and therefore their formation and behavior may not reflect the situation in the ambient atmosphere.

Figure III-4. The Photolysis Pathway of MITC (Geddes et al., 1995)

CH₃NCS* = excited-state MITC

F. The Atmospheric Persistence of Hydrogen Sulfide and Carbon Disulfide

Hydrogen sulfide (H₂S) is volatile and leaves the soil to enter the atmosphere. The importance of H₂S as an air pollutant is due primarily to its toxicity and its unpleasant odor. H₂S is generated during the burning of coal and fuel oil, from stockyards and manure and refuse storage facilities, from Kraft pulp mills, from leather processing, and in the production of heavy water for nuclear reactors (Natusch and Slatt, 1978). Carbon disulfide (CS₂) was once registered for use in California as a pesticide. However, as of January 1, 1987, it is no longer registered for use.

The dominant reactions of H₂S and CS₂ in the atmosphere are by daytime reaction with the OH radical. Based on the literature rate constants for the reactions of the OH radical with H₂S and CS₂ (Atkinson et al., 1997) and using a 24-hr tropospheric average OH radical concentration of 1×10^6 molecule cm⁻³ (Hein et al., 1997), then the calculated half-lives of H₂S and CS₂ are 2.5 days and approximately 2 weeks, respectively.

G. Airborne Levels of Methyl Isothiocyanate Reported in the Literature

Researchers have measured airborne concentrations of MITC following the soil-injected application of metam-sodium to fields in the northeastern part of the Netherlands. Van den Berg (1993) conducted studies in the fall of 1986 and the fall of 1987 to measure the airborne MITC concentrations associated with soil-injected applications of metam-sodium. Several one-hour samples were collected over a seven to nine day period near two fields—one in October 1986 (field A), and the second in September 1987 (field B). At each field, metam-sodium was injected approximately 0.18 m (7 inches) into the soil at the rate of 153 kg active ingredient (a.i.) per hectare (136 lb/acre). Injection was followed by compressing the soil with a roller. During the first few weeks after application, the soil temperatures of each field ranged from 11°C to 12°C. The reported airborne MITC concentrations ranged from below the detection limit ($2.0 \mu\text{g}/\text{m}^3$) to $3.1 \mu\text{g}/\text{m}^3$ for the measurements taken in field A (5.9 hectares [14.6 acres]). For field B (3.4 hectares [8.4 acres]), the MITC concentrations ranged from below the detection limit ($1.0 \mu\text{g}/\text{m}^3$) to $3.1 \mu\text{g}/\text{m}^3$.

Van den Berg et al. (1994) investigated the ambient air concentrations of MITC near several residences located adjacent to fields in the northeastern part of the Netherlands—a region subjected to extensive agricultural use of metam-sodium. Using automatic samplers, a series of 6-hour samples was collected at each of two locations during the months of September through November in 1986 and again in 1987. Each year, the samplers were positioned from 0.20 to 0.25 km (0.12 to 0.16 mi) away from a residence. Measured airborne MITC concentrations were below the detection limit ($2.0 \mu\text{g}/\text{m}^3$) in 96 percent ($n=88$) of the samples acquired during the fall of 1986. In the remaining 4 percent ($n=4$), MITC concentrations ranged from 3.2 to $96 \mu\text{g}/\text{m}^3$. In contrast, MITC concentrations exceeded the detection limit ($1.0 \mu\text{g}/\text{m}^3$) in 48 percent ($n=49$) of the samples collected in the fall of 1987. MITC concentrations ranged from 1.0 to $10.0 \mu\text{g}/\text{m}^3$ for those samples with positive detections.

H. Monitoring Airborne Concentrations of Methyl Isothiocyanate Following Agricultural Applications of Metam-Sodium in California

This section summarizes nine air monitoring studies conducted in California to document the airborne concentrations of MITC associated with metam-sodium agricultural applications. California's Air Resources Board's (ARB's) Engineering and Laboratory Branch conducted four of the studies—one ambient study in 1993, two application-site studies in 1993, and a fourth application-site study in 1995. In 1993, DPR's Environmental Monitoring and Pest Management Branch conducted an application-site study in response to statewide complaints from people living near fields treated with metam-sodium of odor and irritation. Rosenheck (1993) conducted an application-site study to measure off-site movement of MITC following an application of metam-sodium. In 1998, an ambient air monitoring study was jointly coordinated and conducted by DPR, ARB, and the Lompoc Interagency Working Group to investigate the potential causes of respiratory illnesses in Lompoc, California. The study was conducted for 12 specific pesticides, including MITC. In 1998, Seiber et al. measured the ambient airborne residues of MITC in door and outdoor air in townships near fields treated with metam-sodium. In 1999, Merricks measured the airborne concentrations of MITC following sprinkler irrigation and shank injection applications of metam-sodium in fields near Bakersfield, California.

Current metam-sodium technical information bulletins, which are part of the label when metam-sodium is used in California, specifically require the soil to be “sealed” immediately following application to minimize off-site movement of odors. During four of the nine studies mentioned above, the soil was not “sealed” following application, as is currently required. Therefore, the air concentrations measured during these applications may not be representative of current practices. These four studies were included in this report to provide historical perspective.

Several air-monitoring studies were conducted following the derailment of a railroad car north of Dunsmuir, California on July 14, 1991, when approximately 19,000 gallons of metam-sodium spilled into the Sacramento River (Taylor et al., 1996; Geddes et al., 1994; Alexeeff et al., 1994; del Rosario, 1994; Segawa et al., 1991). In the days following the spill, air and surface water samples were collected and analyzed for the presence of MITC. Data from the ARB indicated that air levels along the river on the fourth day ranged from 0.2 to 37 ppb on the fourth day, and from below the detection level to 2.6 ppb on the fifth through tenth days, following the spill (Alexeeff, et al., 1994). MITC concentrations in water samples collected following the spill reached a maximum of 5500 ppb three days after the spill at the northernmost inlet of Shasta Lake, and decreased to 8 ppb six days later. No

MITC was detected at the southern end of Shasta Lake (Segawa et al., 1991). The degradation products detected following the spill were MITC, carbonyl sulfide, methyl sulfide, and traces of methylamine. None of these degradation products were detected one week following the spill (del Rosario et al., 1994).

Air dispersion modeling was used to estimate MITC air concentrations associated with a 78-acre sprinkler application of metam-sodium that resulted in the evacuation of several residences in Earlimart, California, in November 1999. The application consisted of six sprinkler sets spread over five days from November 9 through 13, 1999, with two sets occurring on the final day. Inversion conditions during the application, coupled with a shift in wind direction, resulted in off-site movement of MITC into a nearby residential area, and resulted in a number of evacuations on the night of November 13, 1999. Estimated 1-hour time-weighted average (TWA) air concentrations during this incident ranged from 0.5 ppm to 1.0 ppm in the evacuation area (Barry, 2000a; Barry, 2000b).

Not only did these studies provide additional insight into the environmental fate of metam-sodium and MITC, the estimated levels of airborne MITC established a basis for understanding the relationship between dose and adverse effect under **specific** conditions. Thus, the studies were useful in the toxicity evaluation of this report (Part C). Nonetheless, the Toxic Air Contaminant Act mandates the determination of pesticides that qualify as TACs based on their *pesticidal* use. Therefore, the airborne MITC concentrations measured following the spill are not representative of concentrations present following agricultural applications of metam-sodium or MITC in California.

1. Ambient Monitoring

DPR and ARB design ambient monitoring studies to measure the concentrations of a particular pesticide in the ambient air during the time and in the region of peak use. Ambient monitoring studies are not associated with a specific application, but are designed to provide an estimate of the exposures that people living in proximity to pesticide applications might experience. In general, locations such as schools, fire stations, or other public buildings are selected as the monitoring sites. DPR relies on historical PUR data as a means to target appropriate monitoring seasons and locations.

Seiber, et al. (1999) measured the ambient airborne residues of MITC in indoor and outdoor air, near Kern County fields treated with metam-sodium. This study was conducted in two parts; the first during the Summer of 1997 and the second during the Winter of 1998.

This section summarizes three California ambient studies:

- Kern County—July 20 to 30, 1993 (ARB, 1994b).
- Santa Barbara County—August 17 to September 14, 1998 (DPR, 1999b).
- Kern County—Summer 1997 and Winter 1998 (Seiber et al., 1999).

a. Kern County—July 20 through 30, 1993 (Air Resources Board, 1994b)

The ARB conducted a two-week ambient monitoring program to determine the concentrations of MITC present in the ambient air at the time of peak use of metam-sodium. The 1991 PUR (the most recent data available at the time the study was conducted) was used to determine possible areas of high usage and peak periods of application within California. According to the PUR, in Kern County growers historically used the highest amounts of metam-sodium in July; nearly 370,000 pounds of metam-sodium were applied during July 1991 (please refer to Table II-3 (b) on page 17 of this report). Therefore, four sites were selected in Kern County, near anticipated application areas. Three of these sites were on the rooftops of schools, or school district offices, in the communities of Weed Patch, Lamont, and Shafter. The fourth site was established at the ARB Ambient Monitoring Station in Bakersfield. Ambient air monitoring began on July 20, 1993, and concluded on July 30, 1993. At each location, eight (24-hour) primary samples and eight (24-hour) duplicate samples—sixty-four total samples—were collected (Table III-1). MITC residues were detected in eighty-eight percent of the samples. The concentrations ranged from below the MDL (less than 0.01 $\mu\text{g}/\text{m}^3$ for a 24-hour sample) to 18 $\mu\text{g}/\text{m}^3$.

The 1993 PUR provides information regarding the amount of metam-sodium that was reported used in Kern County during July 1993 (please refer to Table II-3 (d) on page 19 of this report). Nearly 274,000 pounds of metam-sodium were applied in Kern County during July 1993, consistent with use in previous years. However, it should be noted that metam-sodium use patterns began to shift beginning in 1992. During 1992 through 1997 (the most recent available data) metam-sodium use increased significantly during the months of March, April, August, and September of those years (please refer to Tables II-3 (a-h) on pages 16-23 of this report). An analysis of the PUR revealed that no applications of dazomet or MITC occurred in Kern County during the monitoring period.

Table III-1. Results of MITC Ambient Air Monitoring in Kern County. Samples (24-hour) Were Collected From July 20 Through July 30, 1993 (ARB, 1994b)

Sample Date	Amount MITC Detected mg/m ³ (ppb) ^a				Maximum Positive
	Sampling Sites				
	Bakersfield	Lamont	Shafter	Weed Patch	
7/20/93	0.45 (0.15)	0.98 (0.33)	0.40 (0.13)	2.5 (0.84)	2.5 (0.84)
7/21/93	0.31 (0.10)	1.1 (0.37)	ND ^b (ND)	1.9 (0.64)	1.9 (0.64)
7/22/93	5.8 (1.9)	10 (3.3)	2.2 (0.74)	12 (4.0)	12 (4.0)
7/23/93	6.0 (2.0)	17 (5.7)	0.029 (0.0097)	18 (6.0)	18 (6.0)
7/27/93	2.1 (0.70)	7.8 (2.6)	ND (ND)	11 (3.7)	11 (3.7)
7/28/93	0.92 (0.31)	5.7 (1.9)	ND (ND)	10 (3.3)	10 (3.3)
7/29/93	0.34 (0.11)	0.43 (0.14)	ND (ND)	3.0 (1.0)	3.0 (1.0)
7/30/93	1.2 (0.40)	4.5 (1.5)	0.070 (0.023)	8.4 (2.8)	8.4 (2.8)
Maximum Positive	6.0 (2.0)	17 (5.7)	2.2 (0.74)	18 (6.0)	18 (6.0)

a $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb = parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.

b ND = Not detected. Minimum detection limit (MDL) = 0.030 $\mu\text{g}/\text{sample}$ or 0.01 $\mu\text{g}/\text{m}^3$ (0.0033 ppb) for a 24-hour sample.

Although this ambient study was not conducted during the period of absolute highest use in 1993, it was conducted during a period of high use in the location of highest use during that period. Tables III-2 (a-d) show the applications that occurred in each section where a monitoring station was located, and the eight sections immediately surrounding the station section during the course of the ambient monitoring study. The smallest unit of resolution possible from the PUR data is a section—one square mile of land. The location of a section is determined by its township, range, and section number. One township consists of 36 sections, normally arranged in a square, six sections wide by six sections long (Figure III-5). Sections are numbered beginning in the upper right-hand corner.

Figure III-5. A Typical Township Showing the Arrangement and Numbering of Sections

R16E

T23S

	36	31	32	33	34	35	36	31
1	6	5	4	3	2	1	6	
12	7	8	9	10	11	12	7	
13	18	17	16	15	14	13	18	
24	19	20	21	22	23	24	19	
25	30	29	28	27	26	25	30	
36	31	32	33	34	35	36	31	
1	6	5	4	3	2	1	6	

For example, the shaded section number 21 in the example to the left would be identified as:

T23S/R16E/21

Table III-3 contrasts the results of the ambient air monitoring study with the amounts of metam-sodium applied in Kern County. Nearly 274,000 pounds of metam-sodium were applied in Kern County during July 1993. Over 157,000 pounds were applied during the period beginning five days before the onset of monitoring to the end of the monitoring study. Figure III-6 visually contrasts the results of the ambient air monitoring study with the amounts of metam-sodium applied in Kern County. Figure III-7 illustrates the locations of metam-sodium applications that occurred in Kern County beginning five days prior to the onset and through the end of the ambient monitoring study. It shows the sum of the pounds that were applied in each one square mile section during the course of the monitoring study.

No dazomet or MITC was reported applied in Kern County during the course of this monitoring study. Because of the limited number of samples collected and limited number of sampling periods, and the lack of meteorological data, it is difficult to draw many conclusions from this study. However, it is interesting to note that measurable concentrations of MITC were detected in the samples collected at the Bakersfield station even though the nearest reported applications of metam-sodium occurred some five to six miles distant, as shown in Figure III-7. Also, ambient residues followed a pattern roughly consistent with that of applications that occurred in the area (Figure III-6). MITC detections increased with a lag time of about one day following increases in use. This suggests that MITC may persist in the soil and/or air for about a day before transforming.

Table III-2 (a). Metam-Sodium Use in the One Square Mile Section Immediately Surrounding the Shafter Ambient Air Monitoring Station, and the Eight Adjacent Sections During the Monitoring Study. Sections are Designated by Township, Range, and Section Numbers (T/R/S).^a

Date	Township/Range/Section (Pounds Applied)									Total Pounds Used	Ambient Air Concentrations (mg/m ³)
	28S/25E/3	28S/25E/4	28S/25E/5	28S/25E/8	28S/25E/9 ^b	28S/25E/10	28S/25E/15	28S/25E/16	28S/25E/17		
15-Jul-93	0	0	0	0	0	0	0	0	0	0	
16-Jul-93	0	0	0	0	0	0	0	0	0	0	
17-Jul-93	0	0	0	0	0	0	0	0	0	0	
18-Jul-93	0	0	0	0	0	0	0	0	0	0	
19-Jul-93	0	0	0	0	0	0	0	0	0	0	
20-Jul-93	0	0	0	0	0	0	0	0	0	0	0.4
21-Jul-93	0	0	0	0	0	0	0	0	0	0	ND ^c
22-Jul-93	0	0	0	0	0	0	0	0	0	0	2.2
23-Jul-93	0	0	0	0	0	0	0	0	0	0	0.029
24-Jul-93	0	0	0	0	0	0	0	0	0	0	
25-Jul-93	0	0	0	0	0	0	0	0	0	0	
26-Jul-93	0	0	0	0	0	0	0	0	0	0	
27-Jul-93	0	0	0	0	0	0	0	0	0	0	ND
28-Jul-93	0	0	0	0	0	0	0	0	0	0	ND
29-Jul-93	0	0	0	0	0	0	0	0	0	0	ND
30-Jul-93	0	0	0	0	0	0	0	0	0	0	0.07
Total Pounds Used	0	0	0	0	0	0	0	0	0	0	

a Monitoring dates are indicated by gray shading: July 20-23, 1993 and July 27-30, 1993.

b Location of monitoring station.

c ND=Not detected.

Table III-2 (b). Metam-Sodium Use in the One Square Mile Section Immediately Surrounding the Bakersfield Ambient Air Monitoring Station, and the Eight Adjacent Sections During the Monitoring Study. Sections are Designated by Township, Range, and Section Numbers (T/R/S).^a

Date	Township/Range/Section (Pounds Applied)									Total Pounds Used	Ambient Air Concentrations (mg/m ³)
	29S/27E/25	29S/27E/26	29S/27E/35	29S/27E/36 ^b	29S/28E/30	29S/28E/31	30S/27E/1	30S/27E/2	30S/28E/6		
15-Jul-93	0	0	0	0	0	0	0	0	0	0	
16-Jul-93	0	0	0	0	0	0	0	0	0	0	
17-Jul-93	0	0	0	0	0	0	0	0	0	0	
18-Jul-93	0	0	0	0	0	0	0	0	0	0	
19-Jul-93	0	0	0	0	0	0	0	0	0	0	
20-Jul-93	0	0	0	0	0	0	0	0	0	0	0.45
21-Jul-93	0	0	0	0	0	0	0	0	0	0	0.31
22-Jul-93	0	0	0	0	0	0	0	0	0	0	5.8
23-Jul-93	0	0	0	0	0	0	0	0	0	0	6.0
24-Jul-93	0	0	0	0	0	0	0	0	0	0	
25-Jul-93	0	0	0	0	0	0	0	0	0	0	
26-Jul-93	0	0	0	0	0	0	0	0	0	0	
27-Jul-93	0	0	0	0	0	0	0	0	0	0	2.1
28-Jul-93	0	0	0	0	0	0	0	0	0	0	0.92
29-Jul-93	0	0	0	0	0	0	0	0	0	0	0.34
30-Jul-93	0	0	0	0	0	0	0	0	0	0	1.2
Total Pounds Used	0	0	0	0	0	0	0	0	0	0	

a Monitoring dates are indicated by gray shading: July 20-23, 1993 and July 27-30, 1993.

b Location of monitoring station.

Table III-2 (c). Metam-Sodium Use in the One Square Mile Section Immediately Surrounding the Lamont (Mountain View School) Ambient Air Monitoring Station, and the Eight Adjacent Sections During the Monitoring Study. Sections are Designated by Township, Range, and Section Numbers (T/R/S).^a

Date	Township/Range/Section (Pounds Applied)									Total Pounds Used	Ambient Air Concentrations (mg/m ³)
	30S/28E/24	30S/28E/25	30S/28E/36	30S/29E/19	30S/29E/20	30S/29E/29	30S/29E/30 ^b	30S/29E/31	30S/29E/32		
15-Jul-93	0	0	0	0	0	0	0	0	0	0	
16-Jul-93	0	0	0	0	0	0	0	0	0	0	
17-Jul-93	0	0	0	0	0	0	0	0	0	0	
18-Jul-93	0	0	0	0	0	0	0	0	0	0	
19-Jul-93	0	0	0	0	0	0	0	0	0	0	
20-Jul-93	1,320	0	0	0	0	0	0	0	0	1,320	0.98
21-Jul-93	1,320	0	0	0	0	0	0	0	0	1,320	1.1
22-Jul-93	1,320	0	0	0	0	0	0	0	0	1,320	10
23-Jul-93	1,508	0	0	0	0	0	0	0	0	1,508	17
24-Jul-93	1,508	0	0	0	0	0	0	0	0	1,508	
25-Jul-93	1,508	0	0	0	0	0	0	0	0	1,508	
26-Jul-93	0	0	0	0	0	0	0	0	0	0	
27-Jul-93	0	0	0	0	0	0	0	0	0	0	7.8
28-Jul-93	0	0	0	0	0	0	0	0	0	0	5.7
29-Jul-93	1,508	0	0	0	0	0	0	0	0	1,508	0.43
30-Jul-93	0	0	0	0	0	0	0	0	0	0	4.5
Total Pounds Used	9,992	0	0	0	0	0	0	0	0	9,992	

a Monitoring dates are indicated by gray shading: July 20-23, 1993 and July 27-30, 1993.

b Location of monitoring station.

Table III-2 (d). Metam-Sodium Use in the One Square Mile Section Immediately Surrounding the Weed Patch (Vineland School) Ambient Air Monitoring Station, and the Eight Adjacent Sections During the Monitoring Study. Sections are Designated by Township, Range, and Section Numbers (T/R/S).^a

Date	Township/Range/Section (Pounds Applied)										Total Pounds Used	Ambient Air Concentrations (mg/m³)
	31S/29E/7	31S/29E/8	31S/29E/9	31S/29E/16	31S/29E/17 ^b	31S/29E/18	31S/29E/19	31S/29E/20	31S/29E/21			
15-Jul-93	0	0	0	0	0	0	0	0	0	0		
16-Jul-93	0	0	0	0	0	0	0	0	0	0		
17-Jul-93	0	0	0	0	0	0	0	0	0	0		
18-Jul-93	0	0	0	0	0	0	0	0	0	0		
19-Jul-93	0	0	0	0	0	0	0	0	0	0		
20-Jul-93	0	0	0	0	0	0	0	0	0	0	2.5	
21-Jul-93	0	0	0	0	0	0	0	0	0	0	1.9	
22-Jul-93	0	0	0	0	0	0	0	0	0	0	12	
23-Jul-93	0	0	0	0	0	0	0	0	0	0	18	
24-Jul-93	0	0	0	0	0	0	0	0	0	0		
25-Jul-93	0	0	0	0	0	0	0	0	0	0		
26-Jul-93	0	0	0	0	0	0	0	0	0	0		
27-Jul-93	0	0	0	0	0	0	0	0	0	0	11	
28-Jul-93	0	0	0	0	0	0	0	0	0	0	10	
29-Jul-93	0	0	7,926	0	0	0	0	0	0	7,926	3.0	
30-Jul-93	0	0	0	0	0	0	0	0	0	0	8.4	
Total Pounds Used	0	0	7,926	0	0	0	0	0	0	7,926		

^a Monitoring dates are indicated by gray shading: July 20-23, 1993 and July 27-30, 1993.

^b Location of monitoring station.

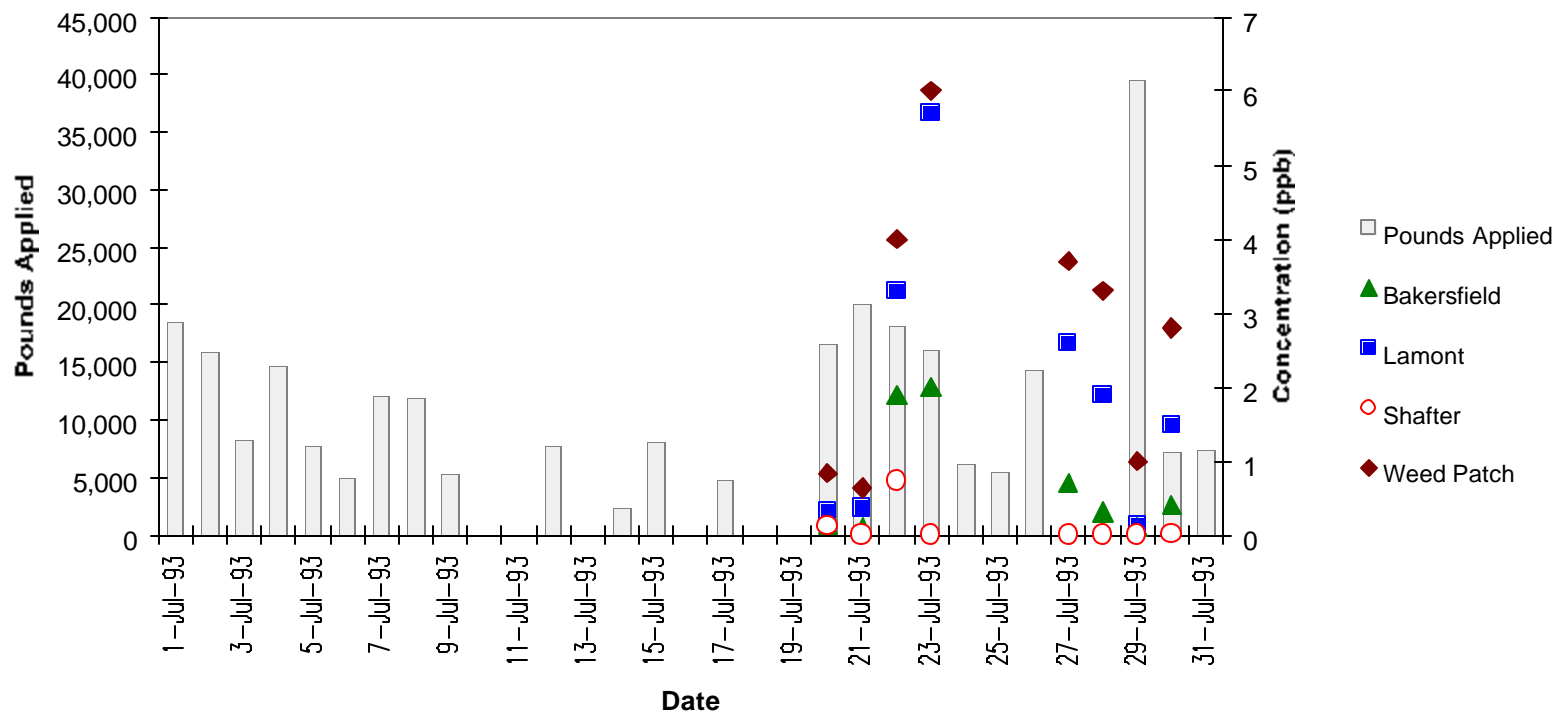
Table III-3. MITC Ambient Air Monitoring Results and Metam-Sodium Use in Kern County From July 1 to 31, 1993.

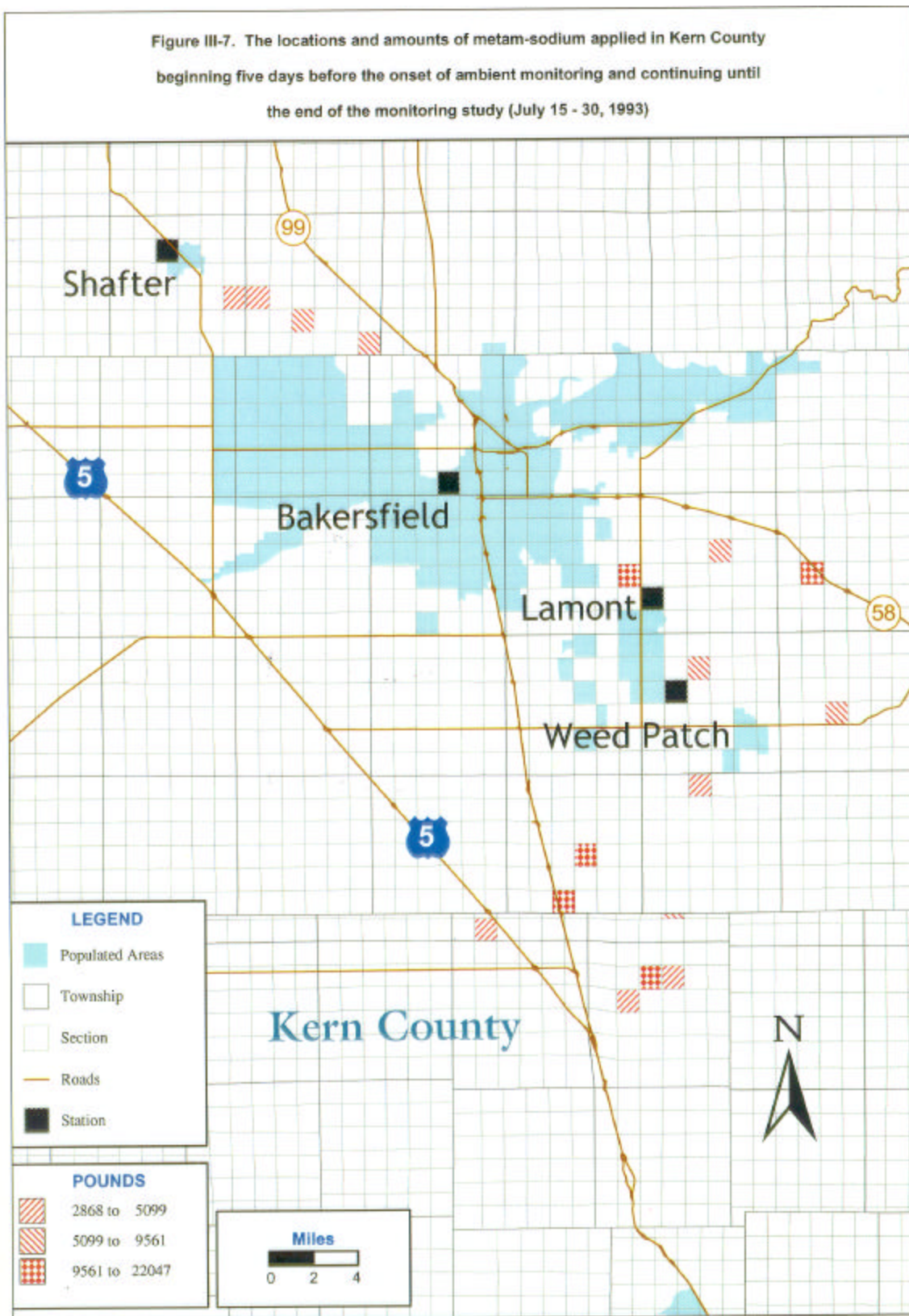
Date	Pounds Metam-Sodium Applied	Amount MITC Detected (ppb)			
		Bakersfield	Lamont	Shafter	Weed Patch
1-Jul-93	18,563	— ^a	—	—	—
2-Jul-93	15,968	—	—	—	—
3-Jul-93	8,276	—	—	—	—
4-Jul-93	14,774	—	—	—	—
5-Jul-93	7,651	—	—	—	—
6-Jul-93	5,027	—	—	—	—
7-Jul-93	12,034	—	—	—	—
8-Jul-93	11,896	—	—	—	—
9-Jul-93	5,238	—	—	—	—
10-Jul-93	0	—	—	—	—
11-Jul-93	0	—	—	—	—
12-Jul-93	7,649	—	—	—	—
13-Jul-93	0	—	—	—	—
14-Jul-93	2,390	—	—	—	—
15-Jul-93	8,170	—	—	—	—
16-Jul-93	0	—	—	—	—
17-Jul-93	4,851	—	—	—	—
18-Jul-93	0	—	—	—	—
19-Jul-93	0	—	—	—	—
20-Jul-93	16,611	0.15	0.33	0.13	0.84
21-Jul-93	20,022	0.10	0.37	ND ^b	0.64
22-Jul-93	18,211	1.9	3.3	0.74	4.0
23-Jul-93	16,041	2.0	5.7	0.0097	6.0
24-Jul-93	6,248	—	—	—	—
25-Jul-93	5,444	—	—	—	—
26-Jul-93	14,363	—	—	—	—
27-Jul-93	0	0.70	2.6	ND	3.7
28-Jul-93	0	0.31	1.9	ND	3.3
29-Jul-93	39,558	0.11	0.14	ND	1.0
30-Jul-93	7,255	0.40	1.5	0.023	2.8
31-Jul-93	7,365	—	—	—	—

a — indicates no sample taken.

b Not detected (Minimum detection limit = 0.0033 ppb for a 24-hour sample).

Figure III-6. MITC Ambient Air Monitoring Results and Pounds of Metam-Sodium Applied in Kern County (July 1993)





b. Santa Barbara County, Lompoc Pesticide Monitoring Program—August 31 through September 13, 1998 (DPR, 1999b).

In 1998, DPR formed an interagency organization called the Lompoc Interagency Working Group (LIWG) to investigate respiratory illnesses in Lompoc, California. Ambient air samples were collected for twelve specific pesticides, including MITC, as well as for certain metals. The MITC air monitoring portion of this study was conducted by an ARB contractor and DPR staff, in coordination with DPR and the LIWG. The MITC samples were analyzed by the Center for Environmental Sciences and Engineering at the University of Nevada at Reno (UNR).

The MITC ambient monitoring portion of this study was conducted from August 31 through September 13, 1998. Five sites were selected in Lompoc. All sites were located near the city limits near the ag-urban interface in a pattern that surrounded the city. Sampling sites were identified by their location around the city perimeter: Northwest, Northeast, West, Southwest, and Central. Samples were collected on August 31, 1998, and then continuously from September 9-13, 1998. At each location, two 12-hour samples were collected daily in duplicate during the course of the monitoring study for a total of sixty duplicate samples. Twenty-three percent of the samples collected contained detectable levels of MITC. The concentrations ranged from “not detected” to 0.34 ppb ($1.0 \mu\text{g}/\text{m}^3$) (Table III-4). No detection limit or quantitation limit was provided. Higher concentrations were detected during nighttime hours, compared to daylight hours, and could be due to the lower inversion height at night.

Table III-4. Results of MITC Air Monitoring Study Conducted in Lompoc, California (DPR, 1999b)

Amount MITC Detected mg/m ³ (ppb) ^a														
Sampling Interval ^b														
Site	1	2	3	4	5	6	7	8	9	10	11	12	Maximum Positive	
	Southwest	ND ^c	ND	ND	ND	ND	0.167 (0.06)	ND	0.262 (0.09)	0.087 (0.03)	0.044 (0.01)	ND	ND	0.262 (0.09)
	West	ND	ND	ND	ND	1.005 (0.34)	0.502 (0.17)	ND	0.362 (0.12)	ND	0.054 (0.02)	ND	ND	1.005 (0.34)
	Northwest	ND	ND	ND	ND	ND	0.040 (0.01)	ND	0.185 (0.06)	ND	ND	ND	ND	0.185 (0.06)
	Northeast	ND	ND	ND	ND	ND	ND	ND	0.188 (0.06)	ND	ND	0.067 (0.02)	ND	0.188 (0.06)
	Central	ND	ND	ND	ND	ND	0.583 (0.20)	ND	0.151 (0.05)	ND	ND	ND	ND	0.583 (0.20)
Maximum Positive	ND	ND	ND	ND	1.005 (0.34)	0.583 (0.20)	ND	0.362 (0.12)	0.087 (0.03)	0.054 (0.02)	0.067 (0.02)	ND	1.005 (0.34)	

a ng/m³ = milligrams per cubic meter; ppb=parts per billion. The equation used for the conversion from ng/m³ to ppb is shown in Appendix A.

b Interval 1: 8/31/98 (day); Interval 2: 8/31/99 (night); Interval 3: 9/9/98 (day); Interval 4: 9/9/98 (night); Interval 5: 9/10/98 (day); Interval 6: 9/10/98 (night); Interval 7: 9/11/98 (day); Interval 8: 9/11/98 (night); Interval 9: 9/12/98 (day); Interval 10: 9/12/98 (night); Interval 11: 9/13/98 (day); Interval 12: 9/13/98 (night).

c ND = Not detected (no detection limit reported). All sample times were approximately 12 hours.

Several problems were noted regarding the reliability of the sample results for this study. The major problems concerned poor sample and equipment handling and lack of appropriate QA/QC measures, both in the field and in the laboratory. At the request of DPR, the ARB Quality Assurance Section (QAS) in conjunction with staff from the U.S. Environmental Protection Agency Region IX, and DPR's Worker Health and Safety Branch performed a quality assurance evaluation of the laboratories that analyzed the data collected during the Lompoc study (ARB, 1999). According to the evaluation:

"Lack of funding prevented the DPR from establishing contracts, which define data objectives, analytical requirements, and QA/QC procedures, with the participating laboratories until immediately prior to the initiation of sampling.

The MITC data...from the UNR seemed questionable because of sampling handling practices and insufficient QA/QC safeguards. No samples were shipped to the laboratory until after all samples were collected.

The UNR contract with the DPR...reported 79% of MITC after 2+ months storage at -20°C. Concurrent stability studies indicated greater than 80% MITC recovery after about 2 months storage at -20°C. Stauffer Chemical Company Method RRC-82-35 reported an average recovery of 85% after 14 days storage under refrigeration.

This raises the question of storage stability [of MITC]. Additionally, chain-of-custody forms were not used, only a single point flow verification was performed by the UNR of the sampling flow meters (this is recommended, not required), which were calibrated by the factory, and there was incomplete laboratory documentation of sample handling and laboratory practices."

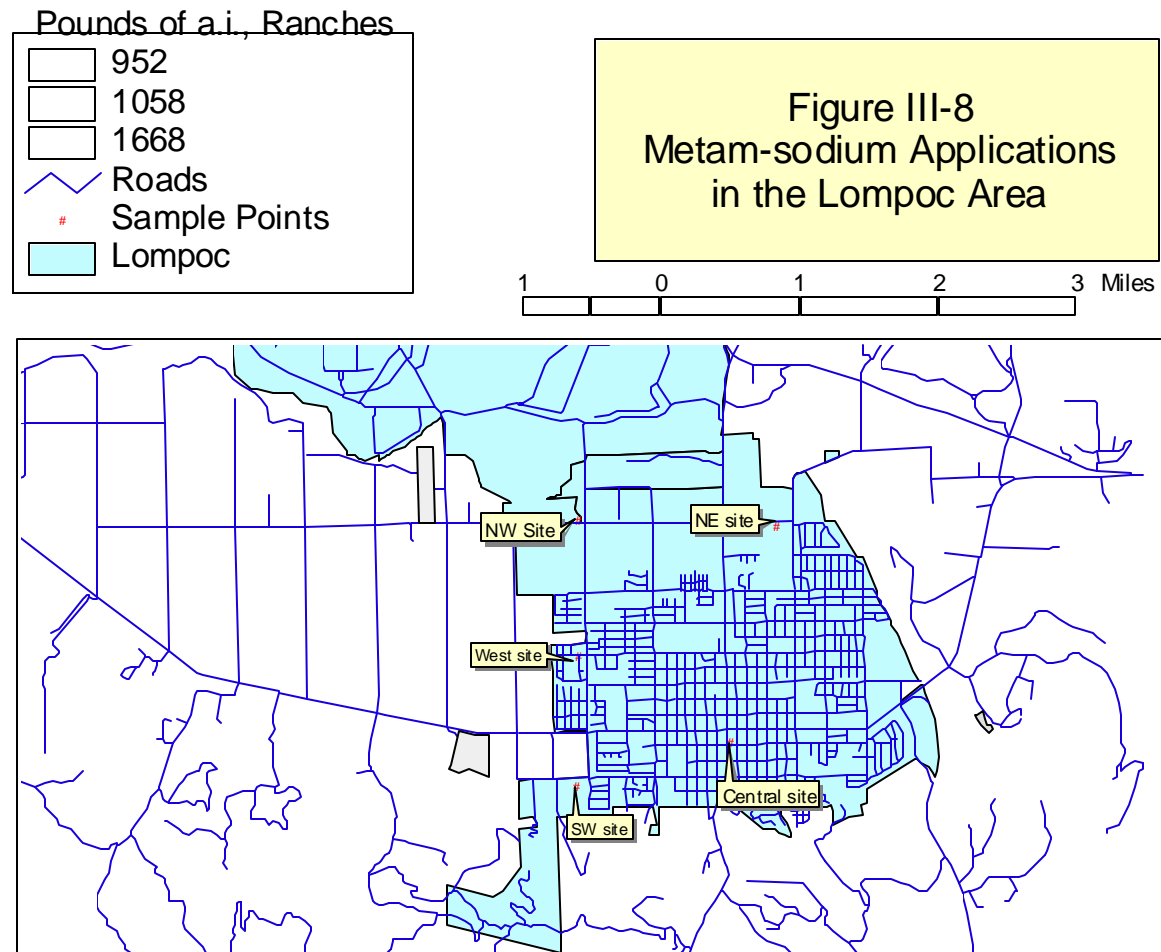
Table III-5 contrasts the results of the Lompoc monitoring study with the amounts of metam-sodium applied in the Lompoc area. No applications of metam-sodium were reported in the 15 days immediately before the onset of monitoring. The first samples were collected on August 31, 1998. The last application that occurred before the onset of monitoring was made on August 15, 1998 (as shown in Table III-5). Figure III-8 illustrates the locations of metam-sodium applications that occurred in the Lompoc area during the ambient monitoring study. It shows the sum of the pounds that were applied and the application locations relative to the location of the detectors during the course of the monitoring study.

Table III-5. MITC Ambient Air Monitoring Results (August 31 – September 13, 1998) and Metam-Sodium Use in Lompoc Area

Date	Pounds	Amount Detected (ppb)					Maximum Positive (ppb)
	Applied	Southwest	West	Northwest	Northeast	Central	
8/15/98	1,058	— ^a	—	—	—	—	—
8/31/98		ND ^b	ND	ND	ND	ND	ND
		ND	ND	ND	ND	ND	ND
9/9/98		ND	ND	ND	ND	ND	ND
		ND	ND	ND	ND	ND	ND
9/10/98	952	ND	0.34	ND	ND	ND	0.34
		0.06	0.17	0.01	ND	0.20	0.20
9/11/98		ND	ND	ND	ND	ND	ND
		0.09	0.12	0.06	0.06	0.05	0.12
9/12/98	1,668	0.03	ND	ND	ND	ND	0.03
		0.01	0.02	ND	ND	ND	0.02
9/13/98		ND	ND	ND	0.02	ND	0.02
		ND	ND	ND	ND	ND	ND
Maximum Positive (ppb)		0.09	0.34	0.06	0.06	0.20	0.34

a — indicates no sample taken

b Not detected (no detection limit reported)



c. Kern County—Summer 1997 and Winter 1998 (Seiber et al., 1999)

Seiber et al. (1999) measured the airborne concentrations of MITC near Kern County applications of metam-sodium during two monitoring periods; the first period was during the summer of 1997 and the second period was during the winter of 1998. They collected samples of both outdoor and indoor air in three towns during the summer monitoring period—Shafter, Lamont, and Weedpatch. During the wintertime, they collected indoor and outdoor air samples in Lamont, Weedpatch, and Arvin. For the summer samples, the number of measurable residues was greatest during the months of May through July, with some of the highest residues occurring during June and July. For the winter samples, the greatest number of measurable levels and the greatest residue levels occurred in January. Detectable concentrations were measured in both indoor (residential) and outdoor air, with the highest concentrations occurring in outdoor air during the summer months, when warm, dry temperatures, and the increased use of metam-sodium occur. It is interesting to note that indoor residential air concentrations were similar in magnitude (and sometimes exceeded) outdoor concentrations, both during the summer and winter studies. However, the authors did not note if residents kept their windows opened or closed, or used heating or air conditioning during the study periods. Considering the climate in Kern County, it is reasonable to assume that the residents may have opened their windows during March, May, or June, while they may have relied on air-conditioning during the mid-summer months and heat during January. Proximity to the treated fields and prevailing wind directions seemed to be the contributing factors with respect to detected ambient concentrations.

1. Summer 1997

During a series of four 5-day sampling periods from May 20 through August 21, 1997, duplicate 12-hour samples were collected at several indoor and outdoor locations. Each sampling period was one week long, and one sampling period occurred each month. Indoor samples were collected inside homes in Lamont and Shafter. Outdoor samples were collected immediately adjacent to one home in Lamont, and outdoor ambient samples were collected in Lamont, Weedpatch, and Shafter. Indoor samples were collected one meter apart at a height of one meter near an inside wall in the living or dining room. The outdoor house samples were collected one meter apart near the top of a six-foot chain-link fence, approximately six feet from the side of the house. Outdoor ambient samples (termed “environmental samples” by the authors) were collected at a variety of locations and at a variety of heights (as noted in Table III-6). At each ambient location, collocated samplers were located one meter apart.

Over the course of four months, 208/34/96 (indoor/outdoor house/ambient) duplicate samples were collected, for a total of 416/68/192 (indoor/outdoor house/ambient) samples. Duplicate samples were averaged, and the reported concentrations ranged from <LOQ to 18.00 $\mu\text{g}/\text{m}^3$ (<LOQ to 6.02 ppb) for the indoor samples, from <LOQ to 10.60 $\mu\text{g}/\text{m}^3$ (<LOQ to 3.55 ppb) for the outdoor house samples, and from <LOQ to 31.10 $\mu\text{g}/\text{m}^3$ (<LOQ to 10.41 ppb) for the outdoor ambient samples (Table III-6). The limit of quantitation (LOQ) was ~55 ng/sample or 6.2×10^{-2} $\mu\text{g}/\text{m}^3$ (2.1×10^{-2} ppb) for a 12-hour sample collected at a sampling rate of about 1.2 L/min. Over 75 percent of the samples collected in the summer of 1997 had measurable concentrations of MITC.

The authors provided several detailed maps showing the date and locations of metam-sodium applications that occurred during this study. They reported about 47 metam-sodium applications occurred in the area around the summer sampling sites, with the wind direction from the treated fields toward the sampling sites occurring about 0-44 percent of the time during the various sampling periods. Figures III-9 (a-d) visually contrasts the results of the ambient (environmental) samples with the amounts of metam-sodium applied in Kern County during the summer study (note that the scale of the Y1 and Y2 axes for May 1997 are each an order of magnitude less than the scale of the same axes in the June-August figures). An analysis of the PUR for this portion of the monitoring study revealed that no dazomet or MITC was applied in Kern County during the course of the monitoring study.

Table III-6. MITC Air Concentrations for the Sampling Periods During the Summer of 1997^a (Seiber et al., 1999)**May 20-24, 1997**

Sampling Dates:			05/20/97		05/21/97		05/22/97		05/23/97		05/24/97		Maximum Positive (ppb)
Township	Location	Sample Time	mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		
Lamont	House #1 indoor	AM	— ^b	—	0.26	0.09	0.48	0.16	0.13	0.04	<LOQ	<LOQ	0.16
		PM	0.28	0.09	0.16	0.05	0.52	0.17	0.20	0.07	—	—	0.17
	House #1 outdoor	AM	—	—	0.18	0.06	<LOQ	<LOQ	0.10	0.03	<LOQ	<LOQ	0.06
		PM	0.77	0.26	0.26	0.09	0.52	0.17	0.07	0.02	—	—	0.26
	House #2 indoor	AM	—	—	0.45	0.15	0.12	0.04	0.12	0.04	0.19	0.06	0.15
		PM	0.50	0.17	0.18	0.06	0.46	0.15	0.12	0.04	—	—	0.17
	House #3 indoor	AM	—	—	0.38	0.13	0.22	0.07	0.32	0.11	0.40	0.13	0.13
		PM	0.51	0.17	0.36	0.12	0.58	0.19	0.56	0.19	—	—	0.19
Ambient outdoor	AM	—	—	—	—	<LOQ	<LOQ	0.14	0.05	<LOQ	<LOQ	0.05	
	PM	1.00	0.33	0.90	0.30	0.93	0.31	0.08	0.03	—	—	0.33	
Weedpatch	Ambient outdoor	AM	—	—	0.40	0.13	—	—	—	—	—	—	0.13
		PM	—	—	—	—	—	—	—	—	—	—	—
Shafter	House #1 indoor	AM	—	—	0.16	0.05	<LOQ	<LOQ	0.06	0.02	<LOQ	<LOQ	0.05
		PM	0.08	0.03	0.10	0.03	0.06	0.02	0.09	0.03	—	—	0.03
	House #2 indoor	AM	—	—	0.24	0.08	<LOQ	<LOQ	0.06	0.02	<LOQ	<LOQ	0.08
		PM	0.20	0.07	0.08	0.03	—	—	0.10	0.03	—	—	0.03
	House #3 indoor	AM	—	—	1.56	0.52	0.44	0.15	0.14	0.05	<LOQ	<LOQ	0.52
		PM	0.19	0.06	0.12	0.04	0.13	0.04	0.18	0.06	—	—	0.06
	Ambient outdoor	AM	—	—	1.46	0.49	<LOQ	<LOQ	0.07	0.02	<LOQ	<LOQ	0.49
		PM	0.08	0.03	0.04	0.01	0.05	0.02	0.06	0.02	—	—	0.03
Maximum Positive (ppb)			0.33		0.52		0.31		0.19		0.13		0.52

a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours.
Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Shafter: 1.2 meters above a 1.8 meter brick wall.

b — indicates no sample.

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Table III-6 continued. MITC Air Concentrations for the Sampling Periods During the Summer of 1997^a (Seiber et al., 1999)

June 16-20, 1997

Sampling Dates:			06/16/97		06/17/97		06/18/97		06/19/97		06/20/97		Maximum Positive (ppb)
Township	Location	Sample Time	mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		
Lamont	House #1 indoor	AM	1.06	0.35	1.14	0.38	0.46	0.15	0.40	0.13	— ^b	—	0.38
		PM	1.54	0.52	0.84	0.28	1.64	0.55	1.12	0.37	<LOQ	<LOQ	0.55
	House #1 outdoor	AM	<LOQ	<LOQ	1.28	0.43	0.18	0.06	0.10	0.03	—	—	0.43
		PM	4.60	1.54	0.65	0.22	3.00	1.00	3.11	1.04	<LOQ	<LOQ	1.54
	House #2 indoor	AM	1.17	0.39	1.24	0.41	5.16	1.73	1.48	0.50	—	—	1.73
		PM	2.43	0.81	18.00	6.02	16.80	5.62	3.90	1.30	<LOQ	<LOQ	6.02
	House #3 indoor	AM	1.98	0.66	1.92	0.64	6.49	2.17	2.90	0.97	—	—	2.17
		PM	3.92	1.31	16.40	5.49	7.30	2.44	3.80	1.27	<LOQ	<LOQ	5.49
Ambient outdoor	AM	0.20	0.07	0.52	0.17	0.17	0.06	0.26	0.09	—	—	0.17	
	PM	6.10	2.04	1.64	0.55	9.18	3.07	6.72	2.25	<LOQ	<LOQ	3.07	
Weedpatch	Ambient outdoor	AM	<LOQ	<LOQ	0.22	0.07	0.28	0.09	<LOQ	<LOQ	—	—	0.09
		PM	5.06	1.69	0.48	0.16	6.26	2.09	8.04	2.69	<LOQ	<LOQ	2.69
Shafter	House #1 indoor	AM	0.13	0.04	0.12	0.04	0.08	0.03	<LOQ	<LOQ	—	—	0.04
		PM	<LOQ	<LOQ	0.20	0.07	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.07
	House #2 indoor	AM	0.10	0.03	<LOQ	<LOQ	0.11	0.04	<LOQ	<LOQ	—	—	0.04
		PM	0.07	0.02	0.48	0.16	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.16
	House #3 indoor	AM	0.48	0.16	0.38	0.13	0.39	0.13	<LOQ	<LOQ	—	—	0.16
		PM	0.36	0.12	0.07	0.02	0.32	0.11	0.11	0.04	<LOQ	<LOQ	0.12
	Ambient outdoor	AM	0.14	0.05	0.15	0.05	—	—	<LOQ	<LOQ	—	—	0.05
		PM	<LOQ	<LOQ	0.08	0.03	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.03
Maximum Positive (ppb)			2.04		6.02		5.62		2.69		<LOQ		6.02

- a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours. Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Shafter: 1.2 meters above a 1.8 meter brick wall.

- b — indicates no sample.

(continued on next page)

Table III-6 continued. MITC Air Concentrations for the Sampling Periods During the Summer of 1997^a (Seiber et al., 1999)

July 20-24, 1997

Sampling Dates:			07/20/97		07/21/97		07/22/97		07/23/97		07/24/97		Maximum Positive (ppb)
Township	Location	Sample Time	mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		
Lamont	House #1 indoor	AM	— ^b	—	0.79	0.26	2.12	0.71	1.72	0.58	2.14	0.72	0.71
		PM	2.07	0.69	0.94	0.31	2.54	0.85	6.70	2.24	<LOQ	<LOQ	2.24
	House #1 outdoor	AM	—	—	0.26	0.09	2.29	0.77	0.58	0.19	0.32	0.11	0.77
		PM	2.16	0.72	1.10	0.37	4.87	1.63	10.60	3.55	<LOQ	<LOQ	3.55
	House #2 indoor	AM	—	—	0.26	0.09	1.88	0.63	0.99	0.33	1.00	0.33	0.63
		PM	1.20	0.40	0.30	0.10	1.42	0.48	5.22	1.75	<LOQ	<LOQ	1.75
	House #3 indoor	AM	—	—	1.18	0.39	<LOQ	<LOQ	2.16	0.72	2.32	0.78	0.78
		PM	1.88	0.63	1.11	0.37	3.52	1.18	4.07	1.36	<LOQ	<LOQ	1.36
Ambient outdoor	AM	—	—	0.32	0.11	2.77	0.93	0.94	0.31	1.10	0.37	0.93	
	PM	1.60	0.54	0.26	0.09	4.46	1.49	6.30	2.11	<LOQ	<LOQ	2.11	
Weedpatch	Ambient outdoor	AM	—	—	0.32	0.11	4.78	1.60	0.63	0.21	0.96	0.32	1.60
		PM	2.74	0.92	19.90	6.66	7.22	2.42	9.20	3.08	<LOQ	<LOQ	6.66
Shafter	House #1 indoor	AM	—	—	<LOQ	<LOQ	1.06	0.35	<LOQ	<LOQ	10.10	3.38	3.38
		PM	0.24	0.08	<LOQ	<LOQ	0.18	0.06	0.81	0.27	<LOQ	<LOQ	0.27
	House #2 indoor	AM	—	—	<LOQ	<LOQ	1.54	0.52	<LOQ	<LOQ	27.80	9.30	9.30
		PM	0.17	0.06	<LOQ	<LOQ	0.50	0.17	1.30	0.43	<LOQ	<LOQ	0.43
	House #3 indoor	AM	—	—	0.38	0.13	0.73	0.24	0.73	0.24	11.10	3.71	3.71
		PM	0.50	0.17	0.40	0.13	1.21	0.40	<LOQ	<LOQ	<LOQ	<LOQ	0.40
	Ambient outdoor	AM	—	—	<LOQ	<LOQ	1.54	0.52	<LOQ	<LOQ	31.10	10.41	10.41
		PM	0.10	0.03	0.14	0.05	<LOQ	<LOQ	1.61	0.54	<LOQ	<LOQ	0.54
Maximum Positive (ppb)			0.92		6.66		2.42		3.55		10.41		10.41

- a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours. Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Shafter: 1.2 meters above a 1.8 meter brick wall.
- b — indicates no sample.

(continued on next page)

Table III-6 continued. MITC Air Concentrations for the Sampling Periods During the Summer of 1997^a (Seiber et al., 1999)

August 17-21, 1997

Sampling Dates:			08/17/97		08/18/97		08/19/97		08/20/97		08/21/97		
Township	Location	Sample Time	mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		Maximum Positive (ppb)
Lamont	House #1 indoor	AM	— ^b	—	0.52	0.17	1.06	0.35	0.60	0.20	0.51	0.17	0.35
		PM	0.82	0.27	2.08	0.70	0.23	0.08	1.08	0.36	<LOQ	<LOQ	0.70
	House #1 outdoor	AM	—	—	<LOQ	<LOQ	—	—	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
		PM	<LOQ	<LOQ	2.02	0.68	<LOQ	<LOQ	0.76	0.25	<LOQ	<LOQ	0.68
	House #2 indoor	AM	—	—	<LOQ	<LOQ	—	—	0.18	0.06	0.36	0.12	0.12
		PM	<LOQ	<LOQ	4.56	1.53	<LOQ	<LOQ	1.08	0.36	<LOQ	<LOQ	1.53
	House #3 indoor	AM	—	—	1.00	0.33	2.22	0.74	0.38	0.13	<LOQ	<LOQ	0.74
		PM	1.50	0.50	2.50	0.84	0.16	0.05	0.82	0.27	<LOQ	<LOQ	0.84
Ambient outdoor	AM	—	—	<LOQ	<LOQ	0.94	0.31	0.34	0.11	0.25	0.08	0.31	
	PM	0.38	0.13	5.18	1.73	<LOQ	<LOQ	0.74	0.25	<LOQ	<LOQ	1.73	
Weedpatch	Ambient outdoor	AM	—	—	<LOQ	<LOQ	0.24	0.08	<LOQ	<LOQ	<LOQ	<LOQ	0.08
		PM	<LOQ	<LOQ	0.86	0.29	<LOQ	<LOQ	0.54	0.18	1.34	0.45	0.45
Shafter	House #1 indoor	AM	—	—	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
	House #2 indoor	AM	—	—	<LOQ	<LOQ	0.18	0.06	<LOQ	<LOQ	<LOQ	<LOQ	0.06
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
	House #3 indoor	AM	—	—	0.79	0.26	1.14	0.38	0.92	0.31	0.86	0.29	0.38
		PM	0.92	0.31	1.84	0.62	0.15	0.05	0.51	0.17	<LOQ	<LOQ	0.62
	Ambient outdoor	AM	—	—	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Maximum Positive (ppb)			0.50		1.73		0.74		0.36		0.45		1.73

- a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours. Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Shafter: 1.2 meters above a 1.8 meter brick wall.

b — indicates no sample.

Figure III-9. MITC Ambient (Environmental) Air Monitoring Results and Pounds of Metam-Sodium Applied in Kern County During Four Summer Sampling Periods (Seiber et al., 1999)

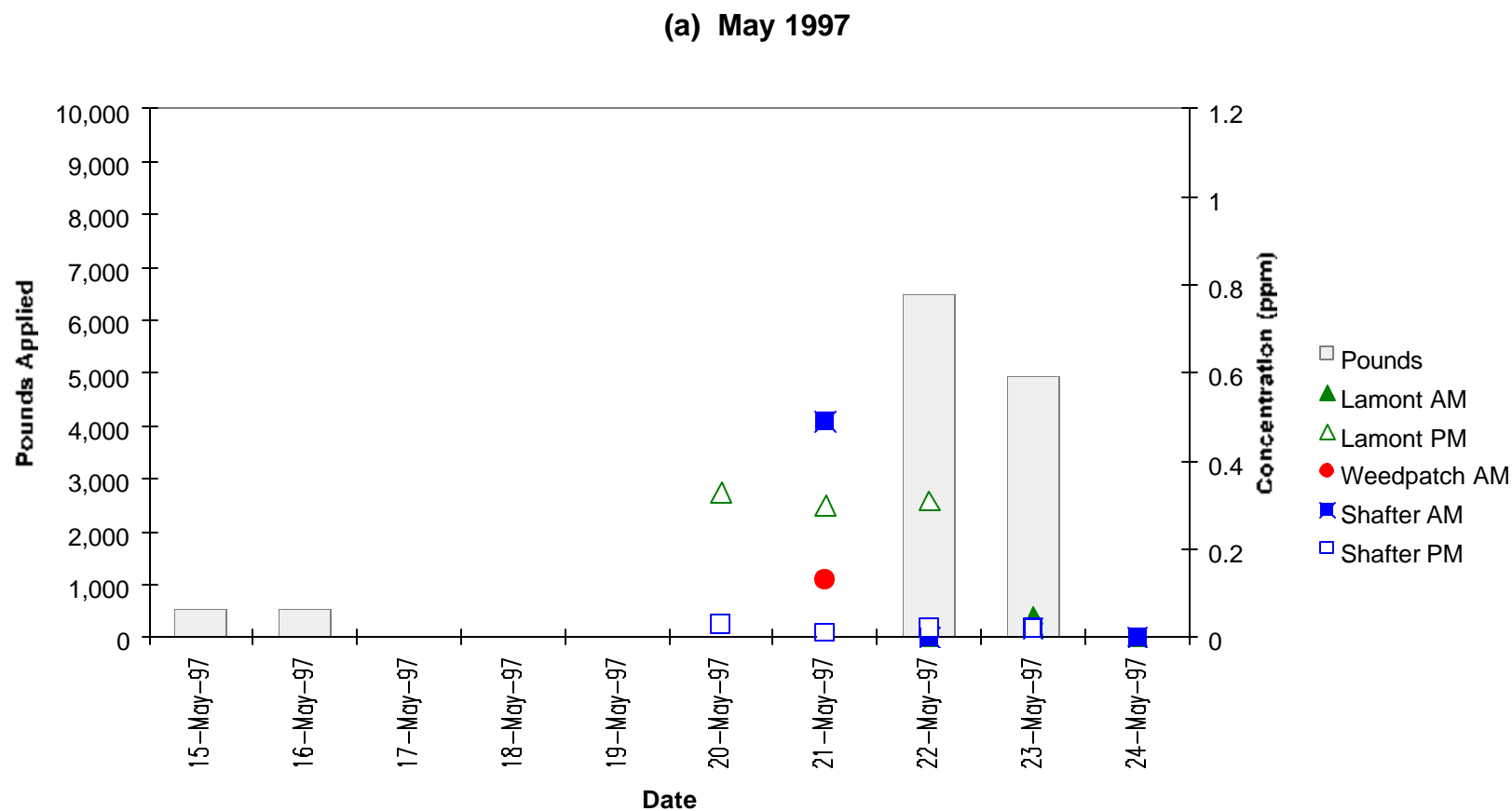


Figure III-9 (continued).

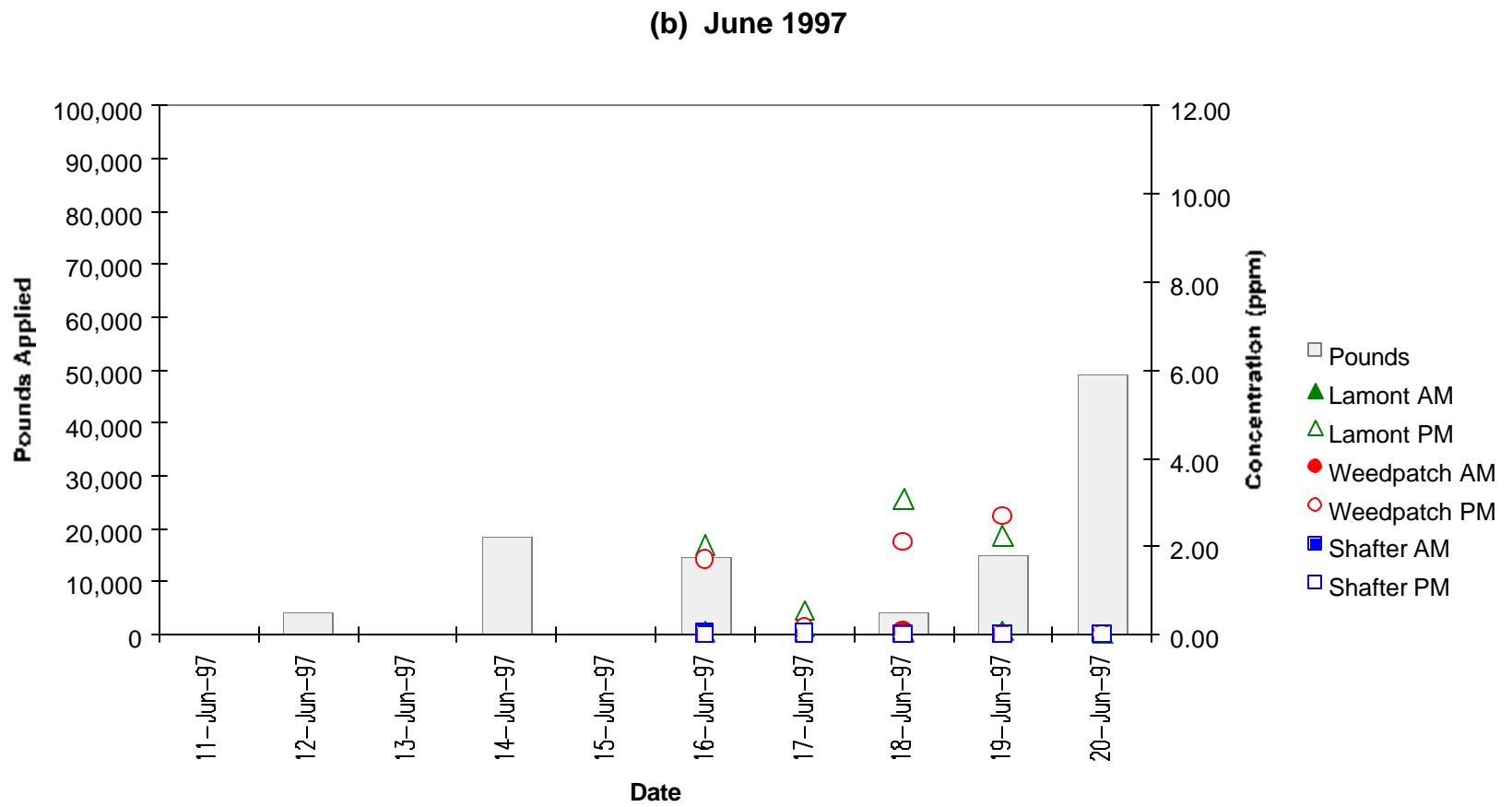


Figure III-9 (continued).

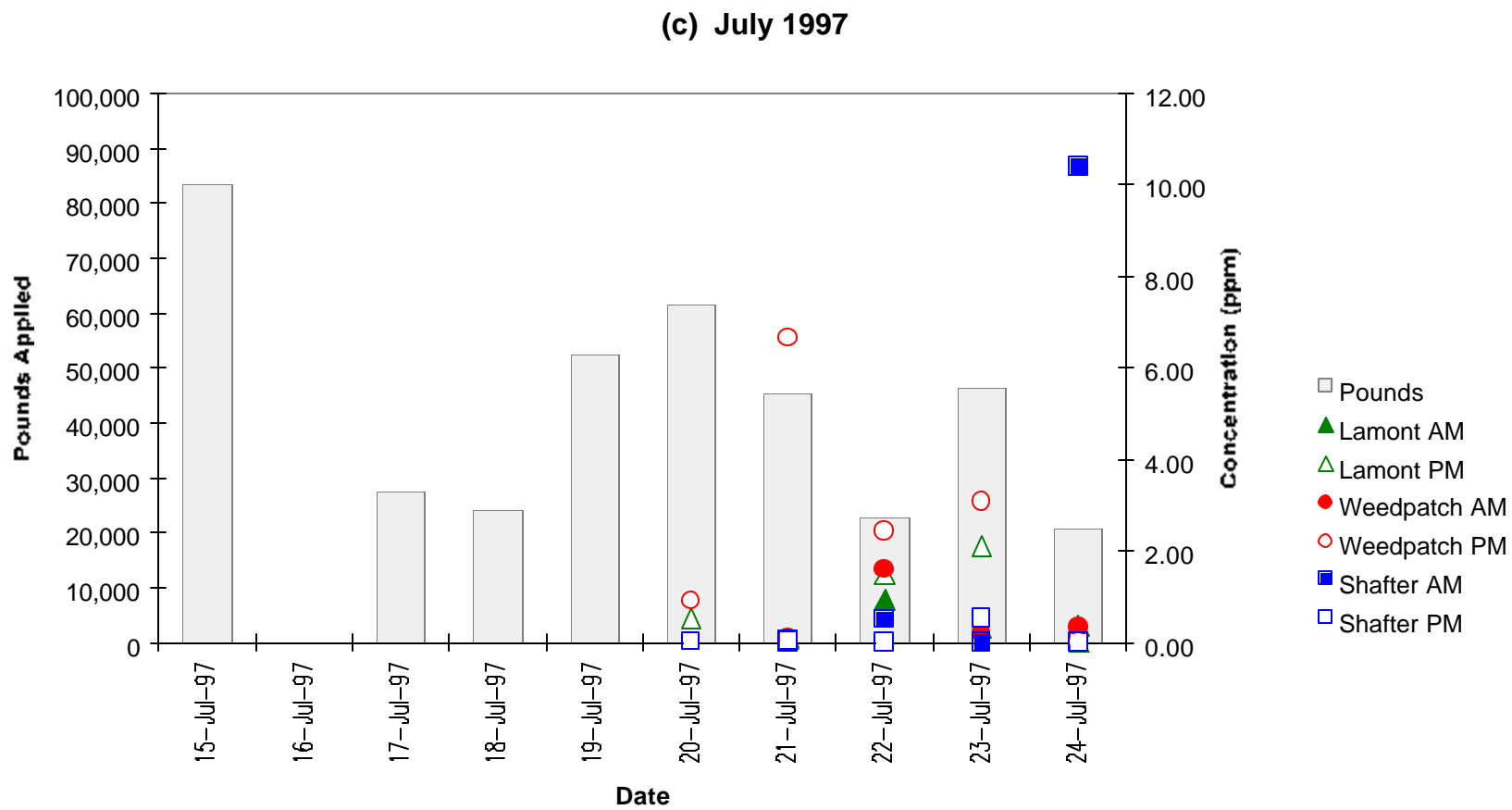
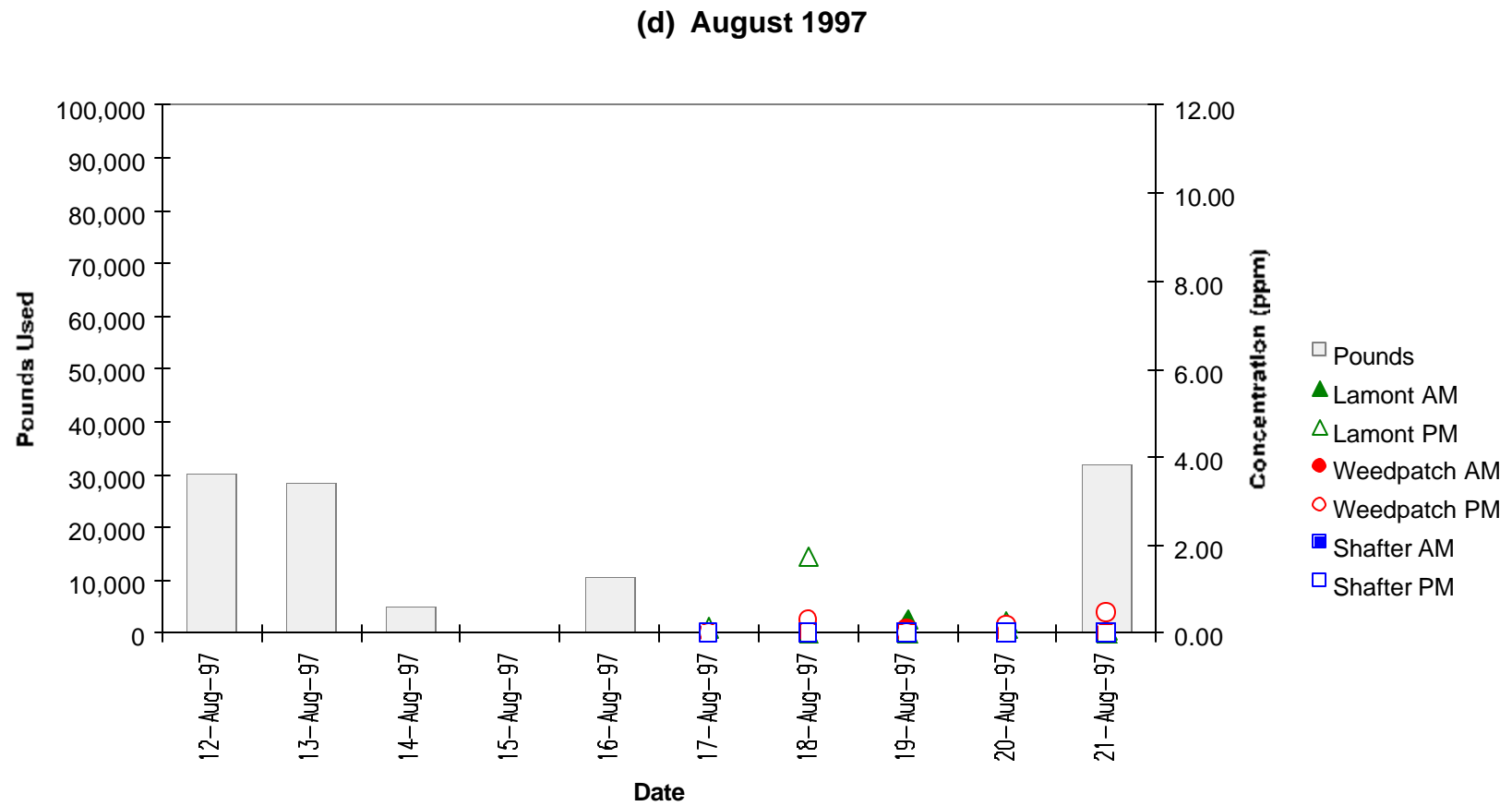


Figure III-9 (continued).



1. Winter 1998

The winter portion of this study occurred in January and March of 1998. Samples were collected over one 4-day period in January and over one 5-day period in March. Again, the investigators collected samples inside homes, outside homes, and at outdoor ambient locations. Indoor samples were collected inside homes in Lamont and Arvin. Outdoor samples were collected adjacent to homes in Lamont and Arvin, and outdoor ambient samples were collected in Lamont, Weedpatch, and Arvin. Indoor samples were collected one meter apart at a height of one meter near an inside wall in the living or dining room. The outdoor house samples were collected one meter apart approximately six feet from the side of the house. Outdoor ambient samples (termed “environmental samples” by the authors) were collected at a variety of locations and at a variety of heights (as noted in Table III-7). At each ambient location, collocated samplers were located one meter apart.

Over the course of this portion of the study, 68/67/44 (indoor/outdoor house/ambient) duplicate samples were collected, for a total of 136/134/88 (indoor/outdoor house/ambient) samples. Duplicate samples were averaged, and the reported concentrations ranged from <LOQ to 3.69 $\mu\text{g}/\text{m}^3$ (<LOQ to 1.23 ppb) for the indoor samples; from <LOQ to 4.53 $\mu\text{g}/\text{m}^3$ (<LOQ to 1.52 ppb) for the outdoor house samples, and from <LOQ to 4.06 $\mu\text{g}/\text{m}^3$ (<LOQ to 1.36 ppb) for the outdoor ambient samples (Table III-7). The limit of quantitation (LOQ) was ~55 ng/sample or $6.2 \times 10^{-2} \mu\text{g}/\text{m}^3$ (2.1×10^{-2} ppb) for a 12-hour sample collected at a sampling rate of about 1.2 L/min. Nearly 67 percent of the samples collected in the winter of 1998 had measurable concentrations of MITC.

The authors provided detailed maps showing the date and locations of metam-sodium applications that occurred during this study. They reported about 6 metam-sodium applications occurred in the area around the winter sampling sites, with the wind direction from the treated fields toward the sampling sites occurring about 2-16 percent of the time during the various sampling periods. Figure III-10 (a-b) visually contrasts the results of the ambient (environmental) samples with the amounts of metam-sodium applied in Kern County during the winter study (note that the scale of the Y1 and Y2 axes for March 1998 are each an order of magnitude less than the scale of the same axes for the January 1998 chart). An analysis of the PUR for this portion of the monitoring study revealed that no dazomet or MITC was applied in Kern County during the sampling periods of the winter monitoring study.

Table III-7. MITC Air Concentrations for the Sampling Periods During the Winter of 1998^a (Seiber et al., 1999)**January 26-29, 1998**

Sampling Dates:			01/26/98		01/27/98		01/28/98		01/29/98		
Township	Location	Sample Time	mg/m ³ ppb		mg/m ³ ppb		mg/m ³ ppb		mg/m ³ ppb		Maximum Positive (ppb)
Lamont	House #1 indoor	AM	1.84	0.62	1.63	0.55	3.69	1.23	1.36	0.46	1.23
		PM	1.90	0.64	2.47	0.83	2.17	0.73	0.99	0.33	0.83
	House #1 outdoor	AM	— ^b	—	0.26	0.09	4.53	1.52	0.81	0.27	1.52
		PM	2.18	0.73	3.93	1.31	1.28	0.43	0.77	0.26	1.31
	House #3 indoor	AM	2.10	0.70	1.57	0.53	1.20	0.40	0.62	0.21	0.07
		PM	1.30	0.43	1.23	0.41	1.18	0.39	0.46	0.15	0.43
	House #3 outdoor	AM	1.92	0.64	0.35	0.12	1.27	0.42	0.23	0.08	0.64
		PM	1.32	0.44	1.89	0.63	0.46	0.15	0.42	0.14	0.63
	Ambient outdoor	AM	1.78	0.60	0.73	0.24	1.00	0.33	0.08	0.03	0.60
		PM	1.10	0.37	1.52	0.51	0.24	0.08	0.40	0.13	0.51
Weedpatch	Ambient outdoor	AM	3.80	1.27	0.98	0.33	3.19	1.07	<LOQ	<LOQ	1.27
		PM	4.06	1.36	2.09	0.70	2.20	0.74	1.35	0.45	1.36
Arvin	House #1 indoor	AM	—	—	0.80	0.27	1.01	0.34	0.19	0.06	0.34
		PM	1.06	0.35	0.46	0.15	0.88	0.29	0.31	0.10	0.35
	House #1 outdoor	AM	3.68	1.23	0.81	0.27	0.98	0.33	<LOQ	<LOQ	1.23
		PM	0.75	0.25	0.22	0.07	0.69	0.23	0.33	0.11	0.25
	House #2 indoor	AM	1.75	0.59	0.98	0.33	0.96	0.32	0.73	0.24	0.59
		PM	1.18	0.39	1.31	0.44	1.06	0.35	0.50	0.17	0.44
	House #2 outdoor	AM	3.48	1.16	0.50	0.17	1.24	0.41	<LOQ	<LOQ	1.16
		PM	0.72	0.24	0.71	0.24	0.57	0.19	0.56	0.19	0.24
	Ambient outdoor	AM	0.71	0.24	0.51	0.17	0.58	0.19	<LOQ	<LOQ	0.24
		PM	0.53	0.18	0.45	0.15	0.71	0.24	—	—	0.24
Maximum Positive (ppb)			1.36		1.31		1.52		0.46		1.52

a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours.

Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Arvin: Atop and Air Pollution Control District trailer.

b — indicates no sample.

(continued on next page)

Table III-7 continued. MITC Air Concentrations for the Sampling Periods During the Winter of 1998^a

March 15-19, 1998

Sampling Dates:			03/15/98		03/16/98		03/17/98		03/18/98		03/19/98		
Township	Location	Sample Time	mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		mg/m³ ppb		Maximum Positive (ppb)
Lamont	House #1 indoor	AM	— ^b	—	0.23	0.08	1.25	0.42	0.33	0.11	<LOQ	<LOQ	0.42
		PM	0.17	0.06	0.33	0.11	0.51	0.17	<LOQ	<LOQ	<LOQ	<LOQ	0.17
	House #1 outdoor	AM	—	—	0.16	0.05	<LOQ	<LOQ	0.20	0.07	<LOQ	<LOQ	0.07
		PM	<LOQ	<LOQ	0.14	0.05	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.05
	House #3 indoor	AM	—	—	0.18	0.06	0.27	0.09	0.86	0.29	0.32	0.11	0.29
		PM	<LOQ	<LOQ	0.26	0.09	0.62	0.21	0.34	0.11	<LOQ	<LOQ	0.21
	House #3 outdoor	AM	—	—	0.21	0.07	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.07
		PM	<LOQ	<LOQ	0.09	0.03	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.03
Ambient outdoor	AM	—	—	0.18	0.06	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.06	
	PM	<LOQ	<LOQ	0.22	0.07	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.07	
Weedpatch	Ambient outdoor	AM	—	—	0.27	0.09	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.09
		PM	0.80	0.27	0.57	0.19	0.29	0.10	<LOQ	<LOQ	<LOQ	<LOQ	0.19
Arvin	House #1 indoor	AM	—	—	0.15	0.05	<LOQ	<LOQ	0.19	0.06	<LOQ	<LOQ	0.06
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
	House #1 outdoor	AM	—	—	0.07	0.02	<LOQ	<LOQ	0.13	0.04	<LOQ	<LOQ	0.04
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
	House #2 indoor	AM	—	—	0.17	0.06	<LOQ	<LOQ	0.10	0.03	<LOQ	<LOQ	0.06
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.24	0.08	<LOQ	<LOQ	0.08
	House #2 outdoor	AM	—	—	0.17	0.06	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.06
		PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.16	0.05	<LOQ	<LOQ	0.05
Ambient outdoor	AM	—	—	0.07	0.02	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.02	
	PM	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	
Maximum Positive (ppb)			0.27		0.19		0.42		0.29		0.11		0.42

- a Each concentration is the average of two collocated samples. Sample time was approximately 12 hours. Sample heights for ambient outdoor samples: Lamont: 1.5 meters above a one-story building; Weedpatch: 2 meters; Arvin: Atop and Air Pollution Control District trailer.
- b — indicates no sample.

Figure III-10. MITC Ambient (Environmental) Air Monitoring Results and Pounds of Metam-Sodium Applied in Kern County During Two Winter Sampling Periods (Seiber et al., 1999)

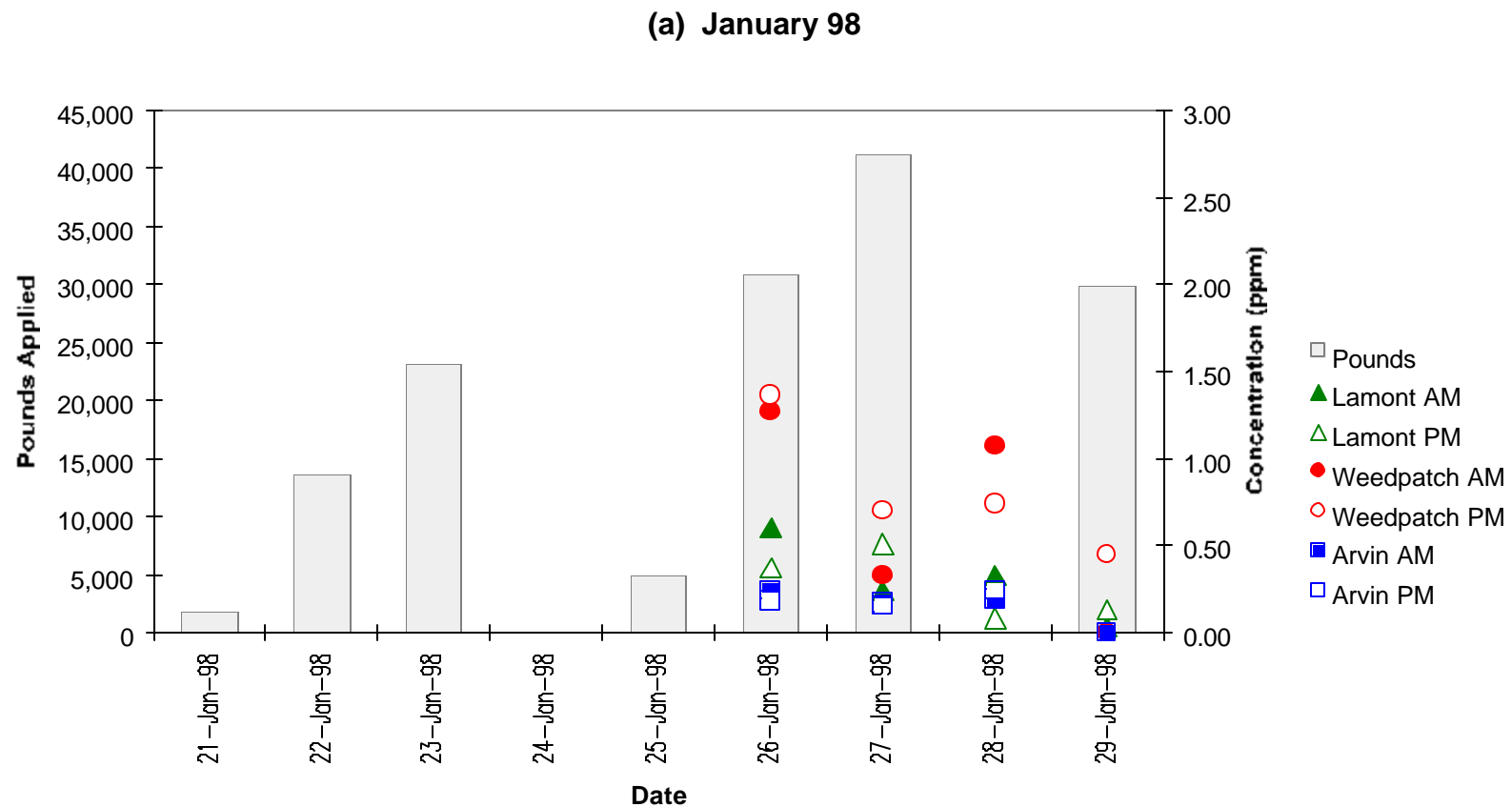
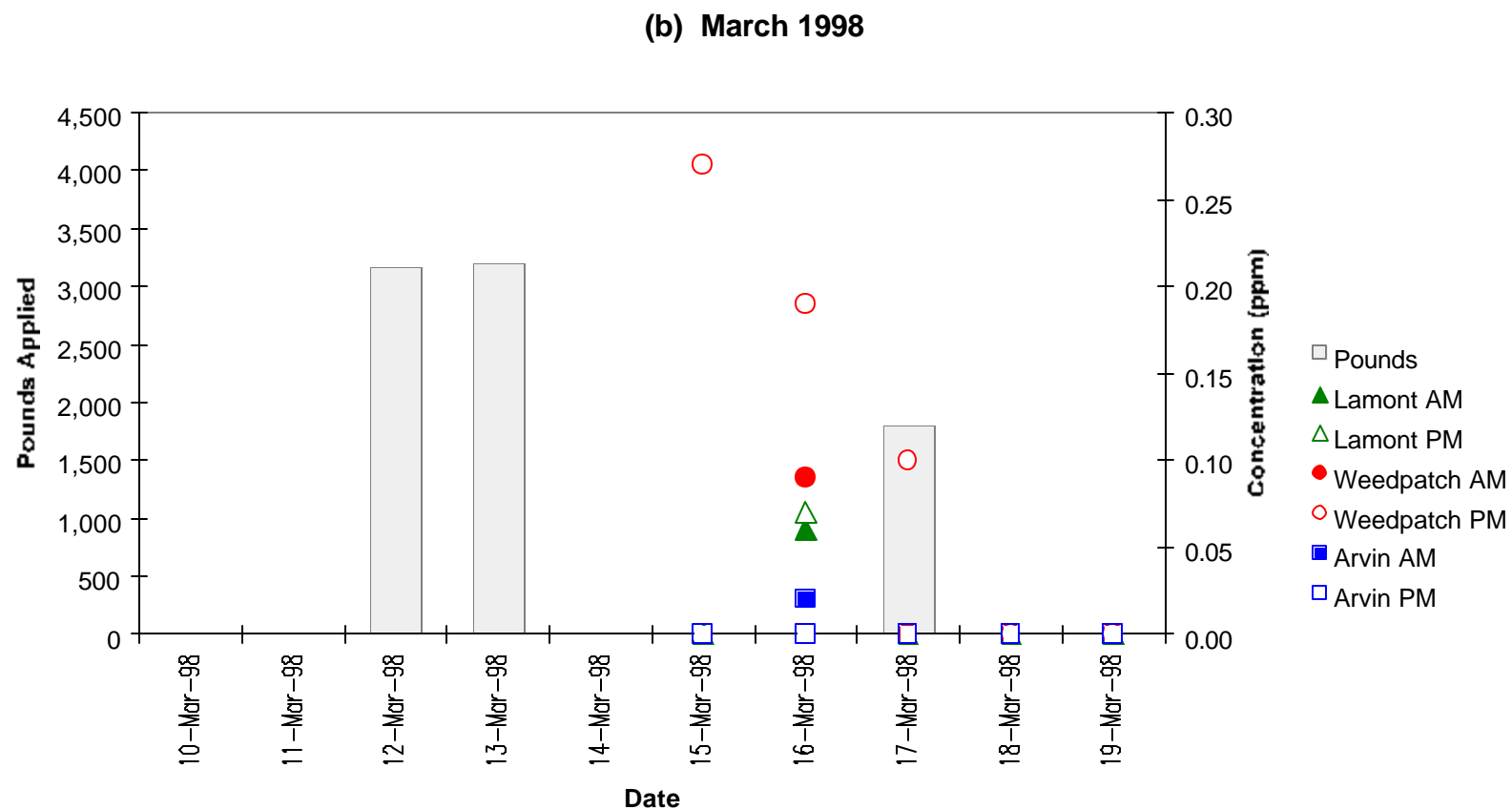


Figure III-10 (Continued).



2. Application-Site Monitoring

Application-site monitoring studies are conducted to measure the concentrations that are present in the air associated with a specific pesticide application. Generally, application-site studies are conducted at a specific field, where the pesticide is applied at the highest allowed label rates.

Six application monitoring studies have been conducted in California. However, in California, applications of metam-sodium must comply with instructions included in the technical information bulletin (TIB), which is part of the product label. The current TIB (February 1999) specifically requires the soil to be “sealed” immediately following applications of metam-sodium to mitigate off-site movement of odors. Only two of the six studies were conducted under conditions representative of current practices, and are summarized in this section. The other four studies are included in this report to provide historical perspective, and are summarized later in this section.

This section summarizes two California application-site studies, which were conducted in conditions representative of current application practices:

- Kern County—August 3 to 6, 1993 (Wofford et al., 1994)
- Kern County—June 1999 (Merricks, 1999)

In August 1993, DPR measured the airborne concentrations of MITC, hydrogen sulfide, and carbon disulfide after a sprinkler application of metam-sodium in Kern County (Wofford et al., 1994). In June 1999, Merricks (1999) measured the airborne MITC concentrations following two different applications: one by sprinkler irrigation and a second by shank injection.

a. Kern County—August 3 to 6, 1993 (Wofford et al., 1994)

DPR conducted this study in response to complaints of odor, eye irritation, nausea and headaches that were filed with California county agricultural commissioners by people living or working adjacent to metam-sodium treated fields. Wofford et al. (1994) studied the effects of a metam-sodium application under conditions expected to result in the highest levels of MITC—when metam-sodium application occurs via chemigation at the highest allowable rate, coupled with conditions of high air temperature, low humidity, and warm soil temperatures. Samples were collected before, during, and for 66 hours after application.

Vapam®[†] was applied at the highest label rate of 935 l/hectare—318 lbs metam-sodium per acre—via chemigation. The application began in the evening and took six hours to complete. Ten samplers were placed around the perimeter of the treatment area at three approximate distances, as shown in Figure III-11. 4 samplers were placed at 5 meters (one on each side of the field), 2 samplers were positioned at 150 meters from the field (one on the north and one on the south), and four samplers were positioned at about 75 meters (each located at the corners of the treated area). In addition, a weather station was positioned at the southwest corner of the treatment area. Wind direction, wind speed, ambient air temperature, and relative humidity were measured, and all measurements were reported as one-minute averages, except for wind direction, which was taken as an instantaneous measurement once every minute.

Eighty-eight primary samples and some duplicate and quality assurance samples were collected during the monitoring periods (Table III-8). Sixty-nine percent of the samples collected contained detectable residues of MITC (MDL = 2 ppb [$5.95\mu\text{g}/\text{m}^3$] for 12-hr samples). Positive MITC concentrations measured during this study ranged from 2.27 to 2,450 ppb (6.75 to $7,290\mu\text{g}/\text{m}^3$). The highest MITC concentrations occurred primarily during the application and immediately following the watering-in (soil sealing) periods. Concentrations during application ranged from 78.3 to 2450 ppb at 5 meters from the field edge and 11.7 to 1320 ppb 150 meters from the field, with the highest concentrations measured in the downwind direction. Generally, MITC concentrations gradually decreased over the course of the study. The lowest concentrations occurred 54-66 hours following application. The dissipation half-life of MITC was estimated to be 7.3 to 7.6 hours.

Samples were collected from 1-4, from 5-7, and from 21-24 hours post-application to measure the levels of H₂S. Measurable concentrations of H₂S above the detection limit (3 ppb) were detected up to 21 hours after the start of the application (Table III-9). Because H₂S is a minor breakdown product of metam-sodium, relatively low concentrations were expected to be present as metam-sodium degraded. The highest level detected (76 ppb) occurred during application (interval 1) indicating that metam-sodium was rapidly degrading, as would be expected given the soil conditions during this study. No detectable residues were found during the watering-in period, and in following sampling periods until the afternoon following application (interval 5), at which time downwind levels ranged from 3 to 8 ppb.

[†] Vapam® is a registered product of ICI Americas, Inc. Wilmington, DE. The product contains 3.18 lbs metam-sodium per gallon.

Air samples for carbon disulfide were collected during intervals 1, 2, 3 and 5 at five meters from the edge of the field. All samples were below the laboratory quantification limit of 4 ppb.

Although this study was conducted in 1993, it followed practices that would be representative of practices described in the current TIB. The application occurred in the evening, and at a distance greater than one-half mile from an occupied structure. The soil type was Cerini loam. The current TIB specifies that one-quarter inch of water must be applied immediately following application to loamy soils. According to the study, watering-in occurred for 1.5 hours immediately following the application. The water delivery rate during the watering-in period was not reported, however, the delivery rate during application was reported as 5,680 liters/minute. Based on the reasonable assumption that the water delivery rate during the watering-in period was the same as the delivery rate during application, more than one-quarter inch of water was applied during the watering-in period.

Information provided to DPR during the preparation of this report indicates the potential of an inversion during the period of the application. The presence of an inversion would be inconsistent with current requirements. However, The on-site meteorological measurements (air temperatures at two heights) necessary to establish unambiguously the presence or absence of an inversion on that particular night do not exist. Therefore, the ability to determine whether an inversion was present during the application cannot be made. Given this uncertainty, caution should be taken with respect to the air concentrations and other values calculated from the study. Even so, because sprinkler applications are still allowed at night, this study appears to be representative of current practices (Barry and Johnson, 2001).

Figure III-11. Diagram of Application Site (From Wofford et al., 1994)

Figure 1. Application site

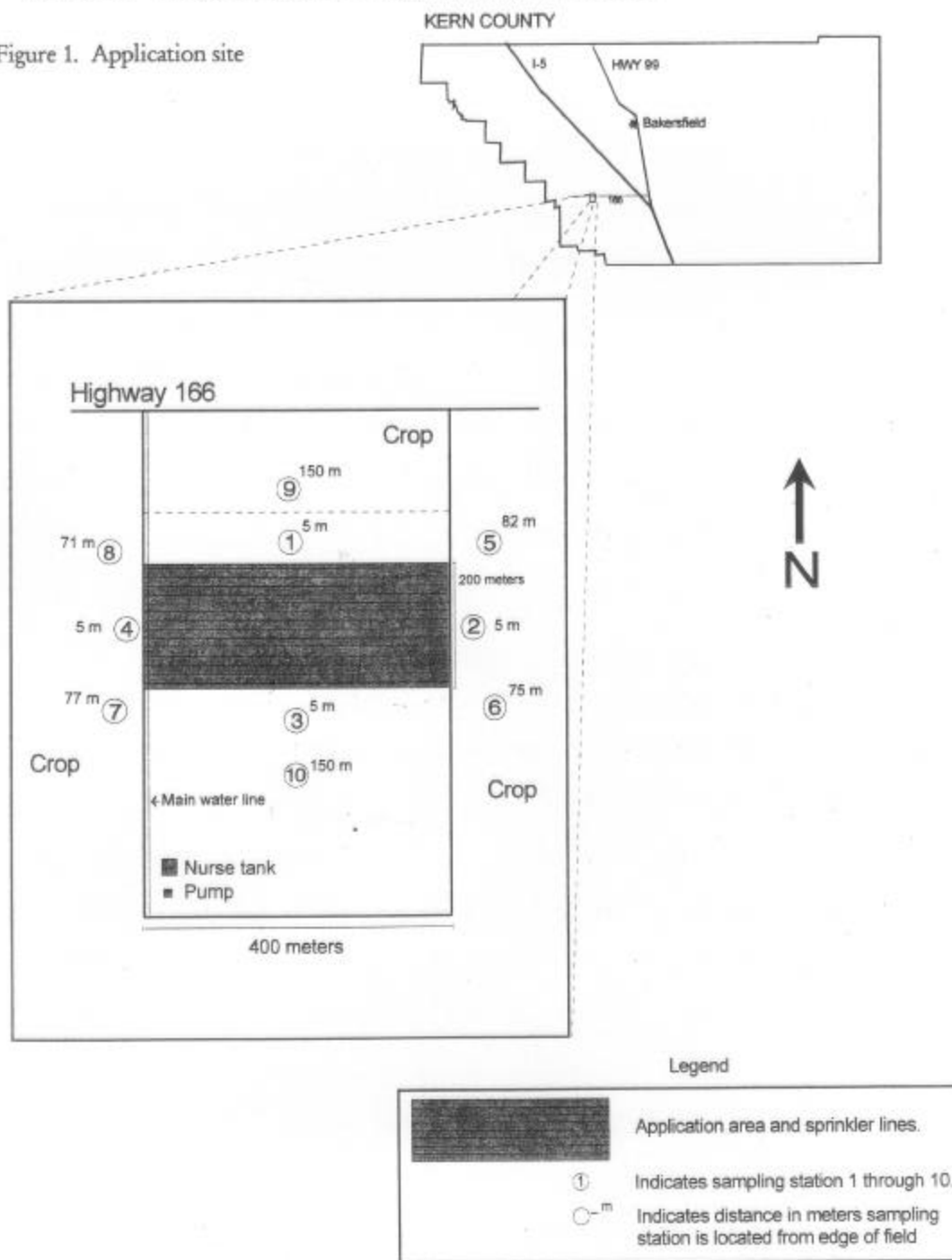


Table III-8. Summary of MITC Air Monitoring Following a Sprinkler Application of Metam-Sodium; Conducted in Kern County (Wofford et al., 1994)^a

mg/m ³ (ppb) ^b											
Sampling Interval ^c											
Site	1	2	3	4	5	6	7	8	9	10	Maximum Positive
N-5	ND ^d	7290 (2450)	1600 (539)	—	30.0 (10.1)	140 (47.1)	345 (116)	23.2 (7.81)	18.5 (6.22)	ND	7290 (2450)
N-150	— ^e	3930 (1320)	1410 (473)	148 (49.7)	ND	ND	24.0 (8.06)	—	—	—	3930 (1320)
NE/82	—	6280 (2110)	1090 (367)	1630 (548)	ND	141 (47.4)	396 (133)	17.1 (5.75)	43.1 (14.5)	ND	6280 (2110)
E/5	—	6370 (2140)	431 (145)	3120 (1050)	137 (46.0)	711 (239)	387 (130)	54.4 (18.3)	48.8 (16.4)	6.78 (2.28)	6370 (2140)
SE/75	—	132 (44.2)	ND	106 (35.7)	19.4 (6.51)	126 (42.3)	6.75 (2.27)	23.4 (7.85)	ND	ND	132 (44.2)
S-5	ND	233 (78.3)	913 (307)	527 (177)	315 (106)	437 (147)	24.3 (8.16)	59.5 (20.0)	ND	6.81 (2.29)	913 (307)
S-150	—	34.8 (11.7)	227 (76.4)	37.8 (12.7)	14.0 (4.69)	19.3 (6.50)	ND	ND	ND	ND	227 (76.4)
SW-77	—	14.0 (4.71)	622 (209)	71.7 (24.1)	19.8 (6.64)	ND	16.9 (5.68)	ND	ND	ND	622 (209)
W-5	—	244 (82.1)	1530 (514)	530 (178)	36.3 (12.2)	ND	ND	ND	ND	ND	1530 (514)
NW-71	—	71.1 (23.9)	1530 (513)	132 (44.2)	ND	ND	6.81 (2.29)	ND	ND	ND	1530 (513)
Maximum Positive	ND	7290 (2450)	1600 (539)	3120 (1050)	315 (106)	711 (239)	396 (133)	59.5 (20.0)	48.8 (16.4)	6.81 (2.29)	7290 (2450)

- a Total Area Treated: 7.7 hectares (19 acres); Application Rate: 318 lbs a.i. per acre; Application Method: chemigation. Samplers were positioned between 5 and 150 meters from edge of application area. The first letter(s) of sampler I.D. indicates sampler location, digit(s) indicates distance (in meters) sampler was located from edge of treated area (e.g., a sampler identified as N-5 would be located 5 meters from the north edge of the treated area).
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: Background (0730-1930; 8/3/93); Interval 2: During application (1930-0130, 8/3-4/93); Interval 3: Watering-In (0130-0300; 8/4/93); Interval 4: 0-6 hours post-application (0300-0900, 8/4/93); Interval 5: 6-12 hours post-application (0900-1500, 8/4/93); Interval 6: 12-18 hours post-application (1500-2100, 8/4/93); Interval 7: 18-30 hours post-application (2100-0900, 8/4-5/93); Interval 8: 30-42 hours post-application (0900-2100, 8/5/93); Interval 9: 42-54 hours post-application (2100-0900, 8/5-6/93); Interval 10: 54-66 hours post-application (0900-2100, 8/6/93).
- d Not detected; the minimum detection limits: 2 ppb (12-hr sample); 4 ppb (6-hr sample); 13 ppb (1.5-hr sample).
- e — indicated no samples were taken at the sampling site during this sampling period.

Table III-9. Summary of H₂S Detected Following a Sprinkler Application of Metam-Sodium; Conducted in Kern County (Wofford et al., 1994)^a

H ₂ S Range (ppb) ^b				
Sample Time After Start of Application				Maximum Positive
Site	1-4 hrs	5-7 hrs	21-24 hrs	
N-5	22-69	— ^c	8	69
N-150	—	—	3	3
NE/82	66-76	—	4	76
E/5	44-50	—	3	50
SE/75	50-72	—	—	72
S-5	—	—	—	—
S-150	—	—	—	—
SW-77	—	—	—	—
W-5	—	—	—	—
NW-71	—	—	—	—
Maximum Positive	76	—	8	76

a Total Area Treated: 7.7 hectares (19 acres); Application Rate: 318 lbs a.i. per acre; Application Method: chemigation. Samplers were positioned between 5 and 150 meters from edge of application area. The first letter(s) of sampler I.D. indicates sampler location, digit(s) indicates distance (in meters) sampler was located from edge of treated area (e.g., a sampler identified as N-5 would be located 5 meters from the north edge of the treated area).

b ppb=parts per billion. The equation used for the conversion from mg/m³ to ppb is shown in Appendix A.

c — indicates not detected; the minimum detection limit: 3 ppb

b. Kern County—June 1999 (Merricks, 1999)

In June of 1999, Merricks (1999) measured the airborne MITC concentrations following applications of metam-sodium to two bareground fields. In each of these studies, application occurred by either the sprinkler irrigation or the shank injection method—the two primary methods used to apply metam-sodium in California.

1. Sprinkler Irrigation Study

A 96-hour sprinkler irrigation study was conducted from June 15 to June 19, 1999. An 80-acre field was divided into four 20-acre plots. A 20-acre plot was treated with metam-sodium (Vapam HL[‡]) at the highest label rate of 319.5 lbs a.i. metam-sodium per acre by sprinkler irrigation each day for 4 days, beginning on June 15, 1999. Each application began in the morning (at approximately 7:00 am) and took approximately six hours to complete. A half-inch water seal was applied to each plot immediately following application; a second half-inch water seal was applied to each plot within 24 hours following application.

Eight sample stations were positioned on the eastern side of the field—two at 150 meters, three at 300 meters, and three at 700 meters from the east edge of the field (as shown in Figure III-12). Two additional samplers were positioned on the western side of the field, each at 970 meters from the west edge of the field. A weather station was positioned near sampler C-700, on the east side of the field, to monitor air temperature, vertical and horizontal wind velocities and direction, soil temperature, relative humidity, and precipitation. The degree of cloud cover was documented.

Two hundred and sixty two samples were collected during the monitoring periods (Table III-10). Seventy-one percent of the samples collected contained detectable residues of MITC (MDL = 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for 4-hr samples). Positive MITC concentrations measured during this study ranged from 0.13 to 280 ppb (0.4 to $839\mu\text{g}/\text{m}^3$).

Predicting that prevailing winds would be from the west, Merricks grouped most of the samplers on the eastern edge of the field. However, the predominant wind directions were from the north and the west, moving MITC residues from the treated fields in a south to southwesterly direction, where there were few or no samplers. The highest MITC concentrations occurred mostly during the late night and early morning monitoring periods (from 23:00 to 07:30) of each day. The highest concentrations generally occurred at the southwest (“A-150”) sampling location. MITC was also detected in samples collected 970 meters west of the field, mostly during the nighttime periods. Merricks attributed the high late night results to several meteorological factors, such as inversions that occurred each night during the course of the study, high humidity at night, and low wind speeds. He

[‡] Vapam® HL is a registered product of Amvac Chemical Corporation, Los Angeles, CA. The product contains 4.26 lbs metam-sodium per gallon.

speculated that perhaps MITC moves offsite in all directions during periods of low wind and inversion.

Figure III-12. Diagram of Irrigation Application Site (From Merricks, 1999)

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Figure 1: Plot Design – Site 1

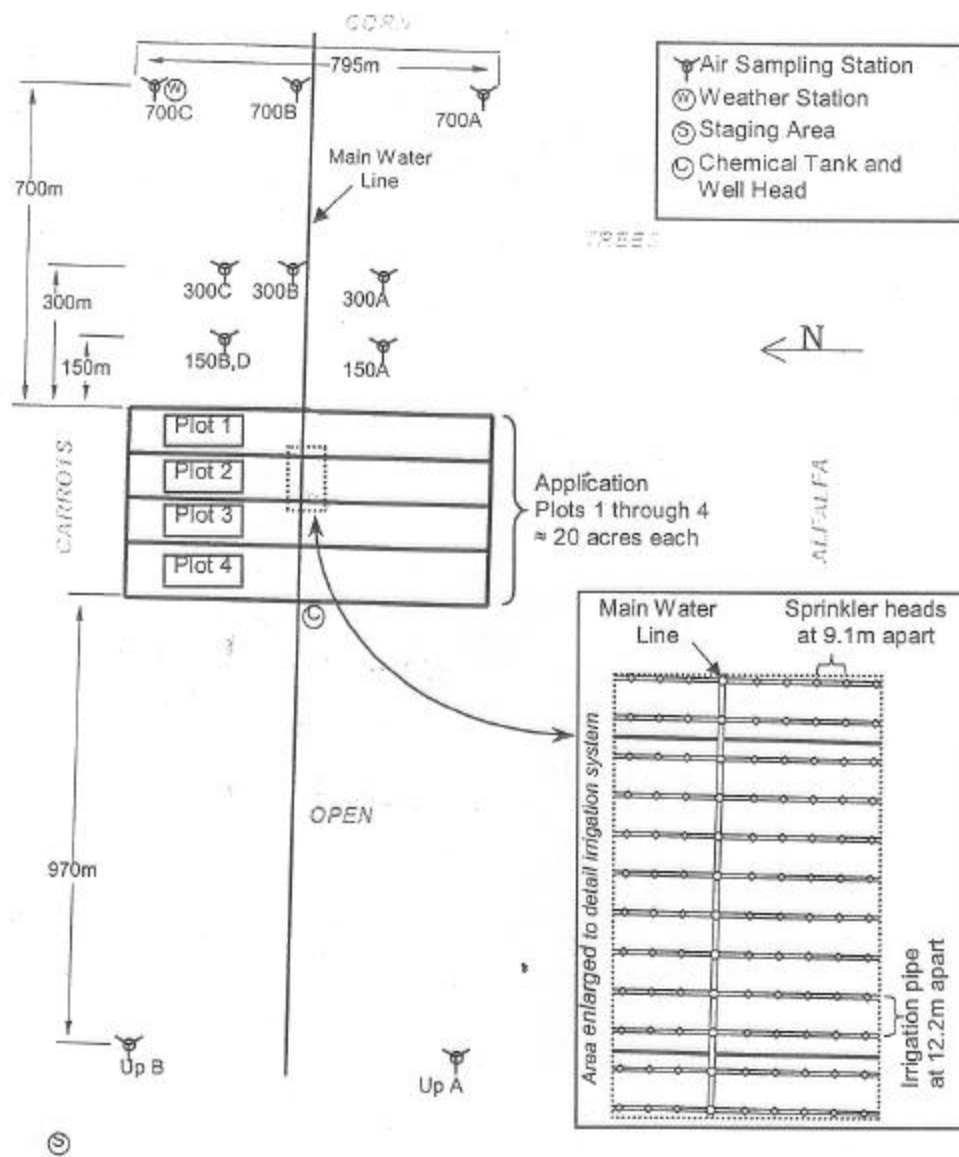


Table III-10. Summary of MITC Air Monitoring Following a Sprinkler Application of Metam-Sodium; Conducted in Kern County (Merricks, 1999)^a

Sample Site (Number Indicates Distance from Edge of Treated Area in Meters)												
Sample Interval ^c	<u>East Side</u> mg/m ³ (ppb) ^b									<u>West Side</u> mg/m ³ (ppb)		Maximum Positive
	A-150	B-150	D-150	A-300	B-300	C-300	A-700	B-700	C-700	UpA-970	UpB-970	
1	76.2	20.1	18.0	25.3	5.7	ND ^d	2.2	ND	ND	ND	ND	76.2
	(25.50)	(6.73)	(6.02)	(8.47)	(1.91)	ND	(0.74)	ND	ND	ND	ND	(25.50)
2	26.7	7.0	6.9	5.7	0.9	ND	ND	ND	ND	ND	ND	26.7
	(8.93)	(2.34)	(2.31)	(1.91)	(0.30)	ND	ND	ND	ND	ND	ND	(8.93)
3	32.5	45.4	43.7	23.1	0.8	ND	ND	ND	ND	ND	ND	45.4
	(10.87)	(15.19)	(14.62)	(7.73)	(0.27)	ND	ND	ND	ND	ND	ND	(15.19)
4	696.8	66.5	57.7	238.0	45.2	4.3	39.8	ND	ND	ND	ND	696.8
	(233.15)	(22.25)	(19.31)	(79.63)	(15.12)	(1.44)	(13.32)	ND	ND	ND	ND	(233.15)
5	302.9	220.0	190.2	157.7	145.3	ND	51.7	50.7	39.2	ND	ND	302.9
	(101.35)	(73.61)	(63.64)	(52.77)	(48.62)	ND	(17.30)	(16.96)	(13.12)	ND	ND	(101.35)
6	606.6	242.4	246.7	345.4	205.6	132.2	152.0	73.2	27.5	1.3	3.7	606.6
	(202.97)	(81.11)	(82.55)	(115.57)	(68.79)	(44.23)	(50.86)	(24.49)	(9.20)	(0.43)	(1.24)	(202.97)
7	29.1	12.9	19.5	17.6	29.1	22.9	3.3	4.9	2.2	ND	ND	29.1
	(9.74)	(4.32)	(6.52)	(5.89)	(9.74)	(7.66)	(1.10)	(1.64)	(0.74)	ND	ND	(9.74)
8	15.0	2.3	3.4	2.1	0.4	ND	ND	ND	ND	ND	ND	15.0
	(5.02)	(0.77)	(1.14)	(0.70)	(0.13)	ND	ND	ND	ND	ND	ND	(5.02)
9	10.1	ND	ND	0.4	ND	ND	ND	ND	ND	ND	ND	10.1
	(3.38)	ND	ND	(0.13)	ND	ND	ND	ND	ND	ND	ND	(3.38)
10	603.6	500.4	511.7	351.6	285.8	257.2	296.6	183.0	150.2	1.2	68.9	603.6
	(201.96)	(167.43)	(171.21)	(117.65)	(95.63)	(86.06)	(99.24)	(61.23)	(50.26)	(0.40)	(23.05)	(201.96)
11	561.2	304.1	283.0	442.3	268.9	197.8	241.6	135.0	40.8	38.6	120.9	561.2
	(187.78)	(101.75)	(94.69)	(147.99)	(89.97)	(66.18)	(80.84)	(45.17)	(13.65)	(12.92)	(40.45)	(187.78)
12	92.7	170.2	165.9	33.2	63.7	93.3	7.6	3.6	2.6	11.3	30.5	170.2
	(31.02)	(56.95)	(55.51)	(11.11)	(21.31)	(31.22)	(2.54)	(1.20)	(0.87)	(3.78)	(10.21)	(56.95)

(continued on next page)

- a Total Area Treated: 80 acres, divided into four 20-acre plots; Application Rate: 319.5 lbs a.i. per acre; Application Method: sprinkler irrigation. Samplers were positioned at 150, 300, and 700 meters east of the field, and 970 meters west of the field.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: 1130-1530 (6/15/99); Interval 2: 1530-1930 (6/15/99); Interval 3: 1930-2330 (6/15/99); Interval 4: 2330-0330 (6/15-16/99); Interval 5: 0330-0730 (6/16/99); Interval 6: 0730-1130 (6/16/99); Interval 7: 1130-1530 (6/16/99); Interval 8: 1530-1930 (6/16/99); Interval 9: 1930-2330 (6/16/99); Interval 10: 2330-0330 (6/16-17/99); Interval 11: 0330-0730 (6/17/99); Interval 12: 0730-1130 (6/17/99); Interval 13: 1130-1530 (6/17/99); Interval 14: 1530-1930 (6/17/99); Interval 15: 1930-2330 (6/17/99); Interval 16: 2330-0330 (6/17-18/99); Interval 17: 0330-0730 (6/18/99); Interval 18: 0730-1130 (6/18/99); Interval 19: 1130-1530 (6/18/99); Interval 20: 1530-1930 (6/18/99); Interval 21: 1930-2330 (6/18/99); Interval 22: 2330-0330 (6/18-19/99); Interval 23: 0330-0730 (6/19/99); Interval 24: 0730-1130 (6/19/99).
- d ND = not detected. Minimum quantitative limit was 1.0 μg per sample, or 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for a 4-hr sample.

Table III-10. Continued.

Sample Site (Number Indicates Distance from Edge of Treated Area in Meters)												
Sample Interval	East Side mg/m ³ (ppb) ^b									West Side mg/m ³ (ppb)		Maximum Positive
	A-150	B-150	D-150	A-300	B-300	C-300	A-700	B-700	C-700	UpA-970	UpB-970	
13	48.7 (16.30)	73.6 (24.63)	68.6 (22.95)	25.1 (8.40)	26.4 (8.83)	24.4 (8.16)	6.3 (2.11)	9.9 (3.31)	8.6 (2.88)	0.6 (0.20)	10.8 (3.61)	73.6 (24.63)
14	11.6 (3.88)	1.7 (0.57)	1.7 (0.57)	2.2 (0.74)	0.9 (0.30)	ND	ND	ND	0.4 (0.13)	ND	ND	11.6 (3.88)
15	26.3 (8.80)	ND	ND	1.7 (0.57)	ND	ND	ND	ND	ND	ND	ND	26.3 (8.80)
16	82.8 (27.70)	230.0 (76.96)	232.5 (77.79)	24.6 (8.23)	50.8 (17.00)	73.3 (24.53)	8.0 (2.68)	13.4 (4.48)	46.9 (15.69)	28.2 (9.44)	1.6 (0.54)	232.5 (77.79)
17	387.5 (129.66)	820.2 (274.44)	839.0 (280.73)	258.9 (86.63)	596.2 (199.49)	579.8 (194.00)	56.5 (18.90)	188.6 (63.11)	32.7 (10.94)	8.2 (2.74)	6.2 (2.07)	839.0 (280.73)
18	139.2 (46.58)	326.3 (109.18)	316.7 (105.97)	93.3 (31.22)	153.3 (51.29)	218.5 (73.11)	8.6 (2.88)	80.0 (26.77)	93.7 (31.35)	ND	0.7 (0.23)	326.3 (109.18)
19	24.4 (8.16)	22.9 (7.66)	23.8 (7.96)	17.9 (5.99)	16.7 (5.59)	13.4 (4.48)	7.7 (2.58)	5.2 (1.74)	4.3 (1.44)	ND	ND	24.4 (8.16)
20	4.5 (1.51)	0.8 (0.27)	0.8 (0.27)	1.3 (0.43)	ND	ND	ND	ND	ND	ND	ND	4.5 (1.51)
21	5.0 (1.67)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.0 (1.67)
22	350.3 (117.21)	164.9 (55.18)	171.4 (57.35)	215.2 (72.01)	128.4 (42.96)	45.5 (15.22)	115.6 (38.68)	16.8 (5.62)	31.5 (10.54)	— ^e	—	350.3 (117.21)
23	172.3 (57.65)	248.2 (83.05)	224.1 (74.98)	106.7 (35.70)	171.3 (57.32)	179.7 (60.13)	21.1 (7.06)	64.2 (21.48)	78.3 (26.20)	ND	ND	248.2 (83.05)
24	60.4 (20.21)	116.1 (38.85)	105.8 (35.40)	46.2 (15.46)	72.5 (24.26)	75.6 (25.30)	8.5 (2.84)	32.4 (10.84)	32.0 (10.71)	43.1 (14.42)	38.8 (12.98)	116.1 (38.85)
Maximum Positive	696.8 (233.15)	820.2 (274.44)	839.0 (280.73)	442.3 (147.99)	596.2 (199.49)	579.8 (194.00)	296.6 (99.24)	188.6 (63.11)	150.2 (50.26)	43.1 (14.42)	120.9 (40.45)	839.0 (280.73)

- a Total Area Treated: 80 acres, divided into four 20-acre plots; Application Rate: 319.5 lbs a.i. per acre; Application Method: sprinkler irrigation. Samplers were positioned at 150, 300, and 700 meters east of the field, and 970 meters west of the field.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: 1130-1530 (6/15/99); Interval 2: 1530-1930 (6/15/99); Interval 3: 1930-2330 (6/15/99); Interval 4: 2330-0330 (6/15-16/99); Interval 5: 0330-0730 (6/16/99); Interval 6: 0730-1130 (6/16/99); Interval 7: 1130-1530 (6/16/99); Interval 8: 1530-1930 (6/16/99); Interval 9: 1930-2330 (6/16/99); Interval 10: 2330-0330 (6/16-17/99); Interval 11: 0330-0730 (6/17/99); Interval 12: 0730-1130 (6/17/99); Interval 13: 1130-1530 (6/17/99); Interval 14: 1530-1930 (6/17/99); Interval 15: 1930-2330 (6/17/99); Interval 16: 2330-0330 (6/17-18/99); Interval 17: 0330-0730 (6/18/99); Interval 18: 0730-1130 (6/18/99); Interval 19: 1130-1530 (6/18/99); Interval 20: 1530-1930 (6/18/99); Interval 21: 1930-2330 (6/18/99); Interval 22: 2330-0330 (6/18-19/99); Interval 23: 0330-0730 (6/19/99); Interval 24: 0730-1130 (6/19/99).
- d ND = not detected. Minimum quantitative limit was 1.0 μg per sample, or 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for a 4-hr sample.
- e — = no sample. Not analyzed, wet sample.

2. *Shank Injection Study*

A 96-hour sprinkler irrigation study was conducted from June 27 to July 1, 1999 (Merricks, 1999). A 79-acre field was treated with metam-sodium (Vapam HL[‡]) by shank injection at a depth of approximately 10 inches and at the highest label rate of 319.5 lbs a.i. metam-sodium per acre. A final soil cap was formed. Application began about 7:00 am and took approximately 5 hours to complete. A half-inch water seal was applied to the field immediately following application.

Eight sample stations were positioned on the eastern side of the field—two at 150 meters, three at 300 meters, and three at 500 meters from the east edge of the field (as shown in Figure III-13). Two additional samplers were positioned on the western side of the field, each at 837 meters from the west edge of the field. A weather station was positioned near sampler C-300, on the east side of the field, to monitor air temperature, vertical and horizontal wind velocities and direction, soil temperature, relative humidity, and precipitation. The degree of cloud cover was documented.

Two hundred and sixty four samples were collected during the monitoring periods (Table III-11). Eighty nine percent of the samples collected contained detectable residues of MITC (MDL = 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for 4-hr samples). Positive MITC concentrations measured during this study ranged from 0.13 to 281 ppb (0.4 to $840\mu\text{g}/\text{m}^3$).

The predominant wind directions were from the west and the north, moving MITC residues from the treated fields in a southwesterly direction, where there were few or no samplers. As in the sprinkler irrigation study, the highest MITC concentrations occurred mostly during the late night and morning monitoring periods (from 23:00 to 11:30) of each day. The highest concentrations generally occurred at either the southwest sampling location (“A-150”), or at one of the samplers located on the west side of the field. Substantial MITC levels were detected during the night of all 4 days of monitoring. Once again, the author attributed the high late night results to several meteorological factors, such as inversions that occurred each night during the course of the study, high humidity at night, and low wind speeds. He speculated that perhaps MITC moves offsite in all directions during periods of low wind and inversion.

[‡] Vapam® HL is a registered product of Amvac Chemical Corporation, Los Angeles, CA. The product contains 4.26 lbs metam-sodium per gallon.

Figure III-13. Diagram of Shank Injection Application Site (From Merricks, 1999)

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Figure 2: Plot Design: -Site 2

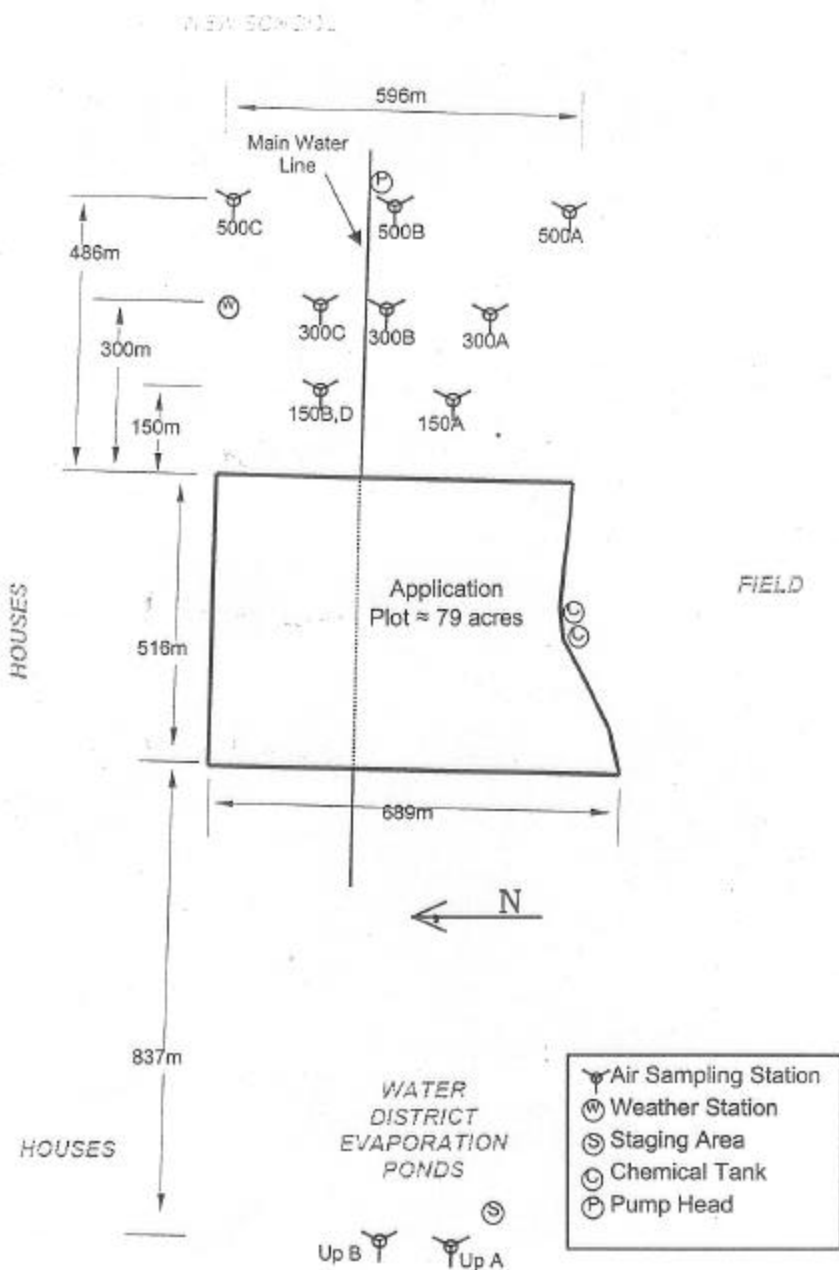


Table III-11. Summary of MITC Air Monitoring Following a Shank Injection Application of Metam-Sodium; Conducted in Kern County (Merricks, 1999)^a

Sample Site (Number Indicates Distance from Edge of Treated Area in Meters)												
Sample Interval ^c	East Side mg/m ³ (ppb) ^b									West Side mg/m ³ (ppb)		Maximum Positive
	A-150	B-150	D-150	A-300	B-300	C-300	A-500	B-500	C-500	UpA-837	UpB-837	
1	12.1 (4.05)	10.5 (3.51)	10.7 (3.58)	8.3 (2.78)	10.8 (3.61)	9.3 (3.11)	6.3 (2.11)	4.6 (1.54)	4.2 (1.41)	7.5 (2.51)	10.6 (3.55)	12.1 (4.05)
2	23.7 (7.93)	2.5 (0.84)	2.1 (0.70)	5.0 (1.67)	0.7 (0.23)	ND ^d ND	1.5 (0.50)	ND ND	ND ND	ND ND	ND ND	23.7 (7.93)
3	36.9 (12.35)	6.0 (2.01)	5.0 (1.67)	9.0 (3.01)	1.9 (0.64)	0.4 (0.13)	2.7 (0.90)	ND ND	ND ND	ND ND	ND ND	36.9 (12.35)
4	441.8 (147.83)	200.3 (67.02)	220.2 (73.68)	336.4 (112.56)	134.6 (45.04)	151.4 (50.66)	149.8 (50.12)	152.2 (50.93)	74.8 (25.03)	8.1 (2.71)	3.6 (1.20)	441.8 (147.83)
5	570.7 (190.96)	338.2 (113.16)	399.2 (133.57)	257.1 (86.03)	184.0 (61.57)	199.4 (66.72)	164.2 (54.94)	126.9 (42.46)	117.7 (39.38)	209.6 (70.13)	130.5 (43.67)	570.7 (190.96)
6	186.8 (62.50)	97.1 (32.49)	99.7 (33.36)	9.8 (3.28)	18.0 (6.02)	11.2 (3.75)	5.7 (1.91)	4.4 (1.47)	24.7 (8.26)	423.7 (141.77)	723.3 (242.02)	723.3 (242.02)
7	3.3 (1.10)	2.3 (0.77)	2.3 (0.77)	1.8 (0.60)	1.8 (0.60)	1.6 (0.54)	1.7 (0.57)	1.7 (0.57)	1.7 (0.57)	5.8 (1.94)	14.7 (4.92)	14.7 (4.92)
8	11.5 (3.85)	4.6 (1.54)	4.9 (1.64)	3.6 (1.20)	2.8 (0.94)	1.6 (0.54)	2.4 (0.80)	1.9 (0.64)	0.9 (0.30)	ND ND	ND ND	11.5 (3.85)
9	10.0 (3.35)	1.6 (0.54)	1.6 (0.54)	2.2 (0.74)	0.6 (0.20)	ND ND	1.0 (0.33)	ND ND	ND ND	ND ND	ND ND	10.0 (3.35)
10	839.8 (281.00)	359.3 (120.22)	412.4 (137.99)	643.9 (215.45)	300.6 (100.58)	189.5 (63.41)	593.4 (198.55)	325.4 (108.88)	138.8 (46.44)	ND ND	ND ND	839.8 (281.0)
11	606.1 (202.80)	389.9 (130.46)	429.6 (143.74)	233.8 (78.23)	135.1 (45.20)	151.2 (50.59)	107.0 (35.80)	55.0 (18.40)	56.8 (19.01)	58.8 (19.67)	124.5 (41.66)	606.1 (202.80)
12	74.3 (24.86)	134.4 (44.97)	149.9 (50.16)	40.0 (13.38)	29.6 (9.90)	58.9 (19.71)	10.8 (3.61)	18.9 (6.32)	85.4 (28.57)	87.2 (29.18)	360.4 (120.59)	360.4 (120.59)

(continued on next page)

- a Total Area Treated: 79 acres; Application Rate: 319.5 lbs a.i. per acre; Application Method: shank injection. Samplers were positioned at 150, 300, and 500 meters east of the field, and 837 meters west of the field.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: 1130-1530 (6/27/99); Interval 2: 1530-1930 (6/27/99); Interval 3: 1930-2330 (6/27/99); Interval 4: 2330-0330 (6/27-28/99); Interval 5: 0330-0730 (6/28/99); Interval 6: 0730-1130 (6/28/99); Interval 7: 1130-1530 (6/28/99); Interval 8: 1530-1930 (6/28/99); Interval 9: 1930-2330 (6/28/99); Interval 10: 2330-0330 (6/28-29/99); Interval 11: 0330-0730 (6/29/99); Interval 12: 0730-1130 (6/29/99); Interval 13: 1130-1530 (6/29/99); Interval 14: 1530-1930 (6/29/99); Interval 15: 1930-2330 (6/29/99); Interval 16: 2330-0330 (6/29-30/99); Interval 17: 0330-0730 (6/30/99); Interval 18: 0730-1130 (6/30/99); Interval 19: 1130-1530 (6/30/99); Interval 20: 1530-1930 (6/30/99); Interval 21: 1930-2330 (6/30/99); Interval 22: 2330-0330 (6/30-7/1/99); Interval 23: 0330-0730 (7/1/99); Interval 24: 0730-1130 (7/1/99).
- d ND = not detected. Minimum quantitative limit was 1.0 μg per sample, or 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for a 4-hr sample.

Table III-11. Continued.

Sample Site (Number Indicates Distance from Edge of Treated Area in Meters)												
Sample Interval	East Side mg/m ³ (ppb) ^b									West Side mg/m ³ (ppb)		Maximum Positive
	A-150	B-150	D-150	A-300	B-300	C-300	A-500	B-500	C-500	UpA-837	UpB-837	
13	3.3 (1.10)	3.5 (1.17)	3.5 (1.17)	3.9 (1.30)	3.8 (1.27)	3.6 (1.20)	3.7 (1.24)	3.9 (1.30)	3.6 (1.20)	11.6 (3.88)	14.5 (4.85)	14.5 (4.85)
14	3.0 (1.00)	1.1 (0.37)	1.0 (0.33)	1.1 (0.37)	0.7 (0.23)	ND	0.6 (0.20)	ND	ND	ND	ND	3.0 (1.0)
15	3.7 (1.24)	1.8 (0.60)	1.7 (0.57)	1.6 (0.54)	0.9 (0.30)	0.5 (0.17)	0.9 (0.30)	ND	ND	ND	ND	3.7 (1.24)
16	211.8 (70.87)	80.2 (26.83)	103.4 (34.60)	171.1 (57.25)	86.6 (28.98)	48.8 (16.33)	109.8 (36.74)	80.1 (26.80)	17.1 (5.72)	ND	0.8 (0.27)	211.8 (70.87)
17	202.8 (67.86)	128.9 (43.13)	155.9 (52.16)	166.0 (55.54)	133.0 (44.50)	130.0 (43.50)	108.7 (36.37)	122.3 (40.92)	113.4 (37.94)	92.4 (30.92)	82.8 (27.70)	202.8 (67.86)
18	57.0 (19.07)	36.9 (12.35)	37.9 (12.68)	25.5 (8.53)	26.1 (8.73)	27.3 (9.13)	17.3 (5.79)	18.4 (6.16)	22.8 (7.63)	129.3 (43.26)	135.7 (45.41)	135.7 (45.41)
19	1.9 (0.64)	1.9 (0.64)	1.8 (0.60)	2.1 (0.70)	2.0 (0.67)	1.9 (0.64)	2.2 (0.74)	1.8 (0.60)	1.8 (0.60)	10.4 (3.48)	7.4 (2.48)	10.4 (3.48)
20	0.6 (0.20)	0.5 (0.17)	0.5 (0.17)	ND	ND	ND	ND	ND	0.5 (0.17)	0.9 (0.30)	0.8 (0.27)	0.9 (0.30)
21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22	3.3 (1.10)	1.2 (0.40)	1.2 (0.40)	2.4 (0.80)	1.2 (0.40)	1.0 (0.33)	0.7 (0.23)	1.1 (0.37)	0.9 (0.30)	ND	ND	3.3 (1.10)
23	49.5 (16.56)	41.2 (13.79)	41.9 (14.02)	57.6 (19.27)	50.8 (17.00)	42.4 (14.19)	75.2 (25.16)	54.8 (18.34)	50.2 (16.80)	18.4 (6.16)	19.0 (6.36)	75.2 (25.16)
24	2.2 (0.74)	1.5 (0.50)	1.5 (0.50)	2.0 (0.67)	1.9 (0.64)	1.5 (0.50)	2.3 (0.77)	1.8 (0.60)	1.7 (0.57)	11.3 (3.78)	8.0 (2.68)	11.3 (3.78)
Maximum Positive	839.8 (281.00)	389.9 (130.46)	429.6 (143.74)	643.9 (215.45)	300.6 (100.58)	199.4 (66.72)	593.4 (198.55)	325.4 (108.88)	138.8 (46.44)	423.7 (141.77)	723.3 (242.02)	839.8 (281.00)

- a Total Area Treated: 79 acres; Application Rate: 319.5 lbs a.i. per acre; Application Method: shank injection. Samplers were positioned at 150, 300, and 500 meters east of the field, and 837 meters west of the field.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: 1130-1530 (6/27/99); Interval 2: 1530-1930 (6/27/99); Interval 3: 1930-2330 (6/27/99); Interval 4: 2330-0330 (6/27-28/99); Interval 5: 0330-0730 (6/28/99); Interval 6: 0730-1130 (6/28/99); Interval 7: 1130-1530 (6/28/99); Interval 8: 1530-1930 (6/28/99); Interval 9: 1930-2330 (6/28/99); Interval 10: 2330-0330 (6/28-29/99); Interval 11: 0330-0730 (6/29/99); Interval 12: 0730-1130 (6/29/99); Interval 13: 1130-1530 (6/29/99); Interval 14: 1530-1930 (6/29/99); Interval 15: 1930-2330 (6/29/99); Interval 16: 2330-0330 (6/29-30/99); Interval 17: 0330-0730 (6/30/99); Interval 18: 0730-1130 (6/30/99); Interval 19: 1130-1530 (6/30/99); Interval 20: 1530-1930 (6/30/99); Interval 21: 1930-2330 (6/30/99); Interval 22: 2330-0330 (6/30-7/1/99); Interval 23: 0330-0730 (7/1/99); Interval 24: 0730-1130 (7/1/99).
- d ND = not detected. Minimum quantitative limit was 1.0 μg per sample, or 0.14 ppb [$0.42\mu\text{g}/\text{m}^3$] for a 4-hr sample.

Four additional studies have been included in this report for historical perspective. In August 1995, ARB measured airborne MITC concentrations following a ground injection of metam-sodium in Kern County (ARB, 1997). In May 1992, Rosenheck measured the airborne concentrations of MITC following a sprinkler application of metam-sodium. Two additional studies were conducted by the ARB to measure “worst-case” concentrations of MITC following applications of metam-sodium. In March 1993, ARB monitored MITC air concentrations following an application of metam-sodium in Contra Costa County. Conducted in July 1993, the second ARB application-site study monitored MITC air concentrations following a ground injection application of metam-sodium in Kern County. Metam-sodium product labels and TIBs specifically require the soil to be “sealed” following application to reduce the reduce the off-site movement of odors. However, in all of these studies the soil was not sealed following application as is current practice, and therefore the levels of MITC measured during these studies may not be representative of current practices. These four studies include:

- Kern County—August 23 to 27, 1995 (ARB, 1997)
- Madera County—May 2 to 4, 1992 (Rosenheck, 1993)
- Contra Costa County—March 8 to 11, 1993 (ARB, 1993)
- Kern County—July 27 to 30, 1993 (ARB, 1994a)

c. Kern County—August 23 to 27, 1995 (Air Resources Board, 1997)

Recent laboratory research has indicated that MIC may be an atmospheric breakdown product of MITC (Geddes et al., 1995). Therefore, ARB conducted this study to measure the airborne MITC and methyl isocyanate (MIC) concentrations following a summertime application of metam-sodium in Kern County. The primary focus of this study was to determine if MIC is a breakdown product of MITC under the conditions that occur after a field application of metam-sodium. Samples were also collected to determine the levels of MITC present. Samples were collected before, during, and following application. An 80-acre field was treated with a metam-sodium/fertilizer mixture at a rate of 155 lbs metam-sodium per acre, injected to a depth of 10-12 inches. The mixture also contained a 10-34-0 liquid fertilizer and a zinc chelate liquid fertilizer, which were applied at a rate of 50 pounds per acre and 0.5 gallons per acre, respectively. The application was made by tractor, began midday August 23, and was complete by nightfall the following day.

Including background samples, thirty-three total MITC samples and thirty-five total MIC samples were collected during seven sampling periods as shown Tables III-12 (a) and

(b), respectively. Measurable residues of MITC and MIC were detected in 100 percent of the samples collected ($MDL_{MITC} = 0.03$ ppb [$0.088 \mu\text{g}/\text{m}^3$] for a 12-hour sample; $MDL_{MIC} = 0.005$ ppb [$0.015 \mu\text{g}/\text{m}^3$] for a 12-hour sample). The positive MITC concentrations ranged from 0.21 to 84 ppb (0.24 to $250 \mu\text{g}/\text{m}^3$). MIC sample concentrations ranged from 0.09 to 2.5 ppb (0.2 to $5.8 \mu\text{g}/\text{m}^3$). The highest levels of MITC were detected during the application periods and in the day following application (intervals 3-5). The highest MIC levels occurred during from one day to one and a half days post application (intervals 5-6). This would indicate that MITC was breaking down to MIC. Both MITC and MIC were detected in the background samples, possibly due to other nearby pesticide applications.

Table III-12 (a). Concentrations of MITC in the Air Following an August Application of Metam-Sodium to a Field in Kern County (ARB, 1997) ^a

Site	mg/m^3 (ppb) ^b Sampling Interval ^c							Maximum Positive
	1	2	3	4	5	6	7	
West	0.53 (0.18)	0.84 (0.28)	71 (24)	1.0 (0.33)	1.0 (0.33)	0.94 (0.31)	2.2 (0.74)	71 (24)
South 1	0.24 (0.080)	19 (6.4)	NS ^d	11 (0.37)	1.9 (0.64)	2.3 (0.77)	1.2 (0.40)	19 (6.4)
South 2	0.44 (0.15)	26 (8.7)	NS	17 (5.7)	2.5 (0.84)	2.1 (0.70)	1.1 (0.37)	26 (8.7)
East	0.46 (0.15)	7.1 (2.4)	39 (13)	20 (6.7)	200 (67)	4.9 (1.6)	7.5 (2.5)	200 (67)
North	0.53 (0.18)	0.64 (0.21)	250 (84)	8.1 (2.7)	170 (57)	3.2 (1.1)	20 (6.7)	250 (84)
Maximum Positive	0.53 (0.18)	26 (8.7)	250 (84)	20 (6.7)	200 (67)	4.9 (1.6)	20 (6.7)	250 (84)

a Total Area Treated: 90 acres; Application Rate: 155 lbs a.i. per acre; Application Method: soil injection. Sampler distance from field: East (E) 12 yards, South (S1, S2) 13 yards, West (W) 20 yards, North (N) 13 yards.

b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.

c Interval 1: Background (1900-0730; 8/23-24/95); Interval 2: During application (1230-1830, 8/24/95); Interval 3: During application (1830-0700); 8/24-25/95); Interval 4: Post application (0700-1830, 8/25/95); Interval 5: Post application (1830-0730, 8/25-26/95); Interval 6: Post application (0730-1730, 8/26/95); Interval 7: Post application (1730-0700, 8/26-27/95).

d No sample.

Table III-12 (b). Concentrations of MIC in the Air Following an August Application of Metam-Sodium to a Field in Kern County (ARB, 1997) ^a

ug/m ³ (ppb) ^b								
Sampling Interval ^c								Maximum Positive
Site	1	2	3	4	5	6	7	
West	0.2 (0.09)	2 (0.9)	1 (0.6)	0.8 (0.3)	1 (0.4)	2.2 (0.94)	1.4 (0.60)	2.2 (0.94)
	0.5 (0.2)	0.6 (0.3)	1.8 (0.77)	1 (0.4)	1 (0.4)	1.8 (0.77)	0.6 (0.3)	1.8 (0.77)
	0.3 (0.1)	2 (0.9)	2.2 (0.94)	2.3 (0.99)	1.4 (0.60)	2.2 (0.94)	1.8 (0.77)	2.3 (0.99)
	0.5 (0.2)	2 (0.9)	2 (0.86)	1 (0.4)	5.8 (2.5)	3.0 (1.3)	1.7 (0.73)	5.8 (2.5)
	0.4 (0.2)	2 (0.9)	2.5 (1.1)	1 (0.4)	4.1 (1.8)	2.0 (0.86)	1 (0.4)	4.1 (1.8)
Maximum Positive	0.5 (0.2)	2 (0.9)	2.5 (1.1)	2.3 (0.99)	5.8 (2.5)	3.0 (1.3)	1.8 (0.77)	5.8 (2.5)

a Total Area Treated: 90 acres; Application Rate: 155 lbs a.i. per acre; Application Method: soil injection. Sampler distance from field: East (E) 12 yards, South (S1, S2) 13 yards, West (W) 20 yards, North (N) 13 yards.

b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.

c Interval 1: Background (1900-0730; 8/23-24/95); Interval 2: During application (1230-1830, 8/24/95); Interval 3: During application (1830-0700); 8/24-25/95); Interval 4: Post application (0700-1830, 8/25/95); Interval 5: Post application (1830-0730, 8/25-26/95); Interval 6: Post application (0730-1730, 8/26/95); Interval 7: Post application (1730-0700, 8/26-27/95).

d. Madera County—May 2 to 4, 1992 (Rosenheck, 1993)

Rosenheck (1993) studied the potential for off-site movement of MITC during sprinkler applications of metam-sodium. The study was conducted in the Central Valley of California near Firebaugh, California on May 2 through May 4, 1992. A 6.69-acre site was treated with metam-sodium at the maximum label rate of 305 lbs per acre using fixed-set sprinklers. The application occurred during early evening hours and lasted approximately four hours. The soil type was classified as a Calhi Loamy Sand.

Samplers were positioned perpendicular to the prevailing northwest wind direction at 5, 25, 125, and 500 meters from the downwind edge of application swath. Samples were collected every four hours during, and for 48 hours following the application. A total of 104 samples were collected. Nearly 100 percent of the samples contained measurable concentrations of MITC (Table III-13). Positive MITC concentrations measured during this study ranged from 1.29 to 435 ppb (3.86 to 1,300 $\mu\text{g}/\text{m}^3$). Overall concentrations were highest from four to eight hours post-application, at the 5- and 25-meter stations.

Table III-13. Summary of MITC Air Monitoring Results Following a Sprinkler Application of Metam-Sodium to a Field in Madera County (Rosenheck, 1993).^a

mg/m ³ (ppb) ^b									
Site (Distance from Application Swath)									
Sampling Interval (hrs)	5m		25m		125m		500m		Maximum Positive
0-4 hours	405 ^c (136)	328 (110)	539 (180)	181 (60.6)	277 (92.7)	271 (90.7)	45.6 (15.3)	51.8 (17.3)	539 (180)
4-8 hours	(405)	(435)	(333)	(364)	(261)	(248)	(54.9)	(54.2)	(435)
8-12 hours	66.2 ^{c,d} (22.2)	35.3 ^d (11.8)	41.3 ^d (13.8)	35.2 ^d (11.8)	ND ^{d,f} (ND)	60.4 ^c (20.2)	25.3 (8.47)	18.9 (6.32)	66.2 (22.2)
12-16 hours	1074 ^c (359)	902 (302)	895 (299)	895 (299)	780 (261)	856 (286)	130 (43.5)	183 (61.2)	1074 (359)
16-20 hours	362 ^c (121)	344 (115)	395 (132)	347 (116)	89.0 (29.8)	102 (34.1)	11.1 (3.71)	10.6 (3.55)	395 (132)
20-24 hours	304 ^c (102)	369 (123)	337 (113)	384 (129)	131 (43.8)	102 (34.1)	8.64 (2.89)	8.90 (2.98)	384 (129)
24-28 hours	150 ^c (50.2)	155 (51.9)	202 (67.6)	218 (72.9)	120 (40.2)	116 (38.8)	41.7 (14.0)	39.4 (13.2)	218 (72.9)
28-32 hours	139 ^c (46.5)	138 (46.2)	185 (61.9)	162 (54.2)	117 (39.2)	102 (34.1)	16.6 (5.55)	17.6 (5.89)	185 (61.9)
32-36 hours	64.6 ^c (21.6)	78.2 (26.2)	117 (39.2)	107 (35.8)	72.9 (24.4)	76.5 (25.6)	19.5 (6.52)	21.5 (7.19)	117 (39.2)
36-40 hours	74.1 ^c (24.8)	78.8 (26.4)	21.4 (7.16)	62.1 (20.8)	39.4 (13.2)	35.3 (11.8)	6.71 (2.25)	6.50 (2.17)	78.8 (26.4)
40-44 hours	51.4 ^{c,e} (17.2)	55.3 ^e (18.5)	48.7 ^e (16.3)	46.5 ^e (15.6)	16.6 ^e (5.55)	16.4 ^e (5.49)	3.86 (1.29)	3.86 (1.29)	55.3 (18.5)
44-48 hours	57.1 ^c (19.1)	48.3 (16.2)	39.4 (13.2)	45.2 (15.1)	7.88 (2.64)	13.1 (4.38)	4.26 (1.43)	4.26 (1.43)	57.1 (19.1)
48-52 hours	25.8 ^c (8.63)	27.1 (9.07)	31.1 (10.4)	30.6 (10.2)	18.5 (6.19)	19.4 (6.49)	5.50 (1.84)	5.50 (1.84)	31.1 (10.4)
Maximum Positive ^g	1300 (435)		1089 (364)		856 (286)		183 (61.2)		1300 (435)

a Total Area Treated: 6.69 acres; Application Rate: 305 lbs a.i. per acre; Application Method: fixed-set sprinkler. Samplers were positioned perpendicular to the prevailing northwest wind direction at 5, 25, 125, and 500 meters from the downwind edge of application swath. During each sampling interval, two samples were collected at each distance.

b mg/m^3 = milligrams per cubic meter; ppb=parts per billion. The equation used for the conversion from mg/m^3 to ppb is shown in Appendix A.

c The average of duplicate injections.

d Due to mechanical failure, generator operating 5, 25, and 125 m stations ran for approximately 2 hours instead of full 4 hours.

e Due to low oil, generator operating 5, 25, and 125m stations quit 15 minutes early.

f ND = not detected. Minimum quantitative limit was 1.0 μg per sample.

g Maximum positive result from all samples collected at each sampling distance.

e. Contra Costa County—March 8 to 11, 1993 (Air Resources Board, 1993)

ARB conducted this study to measure the airborne MITC concentrations following a springtime application of metam-sodium in Contra Costa County. This study measured MITC concentrations following the application of metam-sodium under conditions expected to result in the lowest levels of MITC emissions. These conditions include cool air and cool soil temperatures combined with the soil injection method of application. Samples were collected before, during, and after application. Metam-sodium (Vapam®[†]) was applied at a rate of 57.2 lbs. a.i. per acre at a depth of 8 inches to a 95-acre field. Applications were made only during the daylight hours. Metam-sodium product labels specifically require the soil to be sealed following application to reduce the loss of MITC from the treatment site and increase its effectiveness. However, the soil was not sealed following application.

Forty-eight samples were collected during eight sampling periods as shown in Table III-14. Measurable concentrations were detected in eighty-eight percent of the samples collected (MDL = 0.017 ppb [0.054 µg/m³] for a 12-hour sample). Positive airborne MITC concentrations ranged from 0.017 to 81.0 ppb (0.051 to 242 µg/m³). The highest concentrations were detected on the second and third days of the study during application. Generally, airborne MITC concentrations decreased during the final monitoring period.

[†] Vapam® is a product of ICI Americas, Inc. Wilmington, DE. The product contains 3.18 lbs. of metam-sodium per gallon

Table III-14. Summary of MITC Air Monitoring Results Following a March Application of Metam-Sodium to a Field in Contra Costa County (ARB, 1993); Each Value Is an Average Concentration (N=2) ^a

mg/m ³ (ppb) ^b									
Sampling Interval ^c									
Site	1	2	3	4	5	6	7	8	Maximum Positive
North	ND ^d	1.39 (0.465)	2.63 (0.880)	6.99 (2.34)	70.5 (23.6)	22.1 (7.39)	5.82 (1.95)	20.2 (6.76)	70.5 (23.6)
Southeast	ND	0.064 (0.021)	6.39 (2.14)	2.12 (0.709)	111.0 (37.1)	105.0 (35.1)	153.0 (51.2)	21.8 (7.29)	153.0 (51.2)
Southwest	ND	0.051 (0.017)	12.4 (4.15)	242.0 (81.0)	224.0 (74.9)	77.7 (26.0)	23.2 (7.76)	8.41 (2.81)	242.0 (81.0)
Maximum Positive		1.39 (0.465)	12.4 (4.15)	242.0 (81.0)	224.0 (74.9)	105.0 (35.1)	153.0 (51.2)	21.8 (7.29)	242.0 (81.0)

- a Total Area Treated: 95 acres; Application Rate: 57.2 lbs a.i. per acre; Application Method: soil injection. All samplers were positioned approximately 15 yards from the edge of the field. Application occurred during daylight hours. Overnight samples were taken during the period following the daily application and prior to beginning application on the next day.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: background (0900-1130; 3/8/93); Interval 2: During application (1230-1600, 3/8/93); Interval 3: Overnight (1600-0600; 3/8-9/93); Interval 4: During application (0600-1700, 3/9/93); Interval 5: Overnight (1700-0630, 3/9-10/93); Interval 6: During application (0630-1100, 3/10/93); Interval 7: During application (1100-1700, 3/10/93); Interval 8: Overnight (1700-0830, 3/10-11/93).
- d Not detected; minimum detection limit = 0.075 μg per sample (0.02 $\mu\text{g}/\text{m}^3$; 0.06 ppb for a 12-hour sample).

f. Kern County—July 27 to 30, 1993 (Air Resources Board, 1994a)

This study was conducted to measure the airborne MITC concentrations following a summertime application of metam-sodium in Kern County. In contrast to the conditions described in Section 1, this study measured MITC concentrations that result from injecting metam-sodium at a high rate into the soil during conditions of warm air and warm soil temperatures. Samples were collected before, during, and after application. An 85-acre field was treated with a liquid metam-sodium/fertilizer mixture at a rate of 155 lbs metam-sodium per acre. Each 150 gallons of the mixture contained 50 gallons of metam-sodium (Soil-Prep®[†]), 45 gallons of a 10-34-0 liquid fertilizer, and 1.75 gallons of a 9 percent zinc chelate liquid fertilizer. The remaining volume (53.25 gallons) was made up with water. The

application occurred only during the daylight hours, and took about three days to complete. Metam-sodium product labels specifically require the soil to be sealed following application to reduce the loss of MITC from the treatment site and increase its effectiveness. However, the soil was not sealed following application.

Seventy-two total samples were collected during nine sampling periods as shown in Table III-15. Measurable residues were detected in 100 percent of the samples collected during this study (MDL = 0.007 ppb [$0.021 \mu\text{g}/\text{m}^3$] for a 12-hour sample). The positive MITC concentrations ranged from 1.1 to 270 ppb (3.2 to $880 \mu\text{g}/\text{m}^3$). Application occurred daily throughout nearly the entire study, which complicates analysis of these samples. Also, the samples collected during intervals four and five were unintentionally exposed to ambient temperatures exceeding 100°F for an unknown length of time. The reported values for these samples were probably lower than the actual concentrations would have been had the samples been handled properly. However, the highest concentrations were detected on the second and third days of the study during overnight sampling, approximately 12 hours following application.

[†] Soil-Prep® is a product of Wilbur-Ellis Co. Fresno, CA. The product contains 3.1 lbs metam-sodium per gallon.

Table III-15. Summary of MITC Air Monitoring Results Following a Summertime Application of Metam-Sodium to a Field in Kern County (ARB, 1994a); Each Value Is an Average Concentration (N=2) ^a

mg/m ³ (ppb) ^b										
Sampling Interval ^c										Maximum Positive
Site	1	2	3	4	5	6	7	8	9	
West	3.6 (1.2)	2.3 (0.77)	580 (190)	120 ^d (40)	1.2 ^d (0.40)	200 ^e (67)	94 (31)	1.2 (0.40)	880 (290)	880 (290)
	3.2 (1.1)	2.3 (0.77)	26 (8.7)	3.9 ^d (1.3)	70 ^d (23)	800 (270)	90 (30)	51 (17)	210 (70)	800 (270)
East	3.2 (1.1)	1.5 (0.50)	4.7 (1.6)	2.4 ^d (0.80)	5.8 ^d (1.9)	100 (33)	9.0 (3.0)	120 (40)	200 (67)	200 (67)
	2.6 (0.87)	6.5 (2.2)	26 (8.7)	26 ^d (8.7)	26 ^d (8.7)	250 (84)	8.1 (2.7)	8.6 (2.9)	430 (140)	430 (140)
Maximum Positive	3.6 (1.2)	6.5 (2.2)	580 (190)	120 ^d (40)	70 ^d (23)	800 (270)	94 (31)	120 (40)	880 (290)	800 (270)

- a Total Area Treated: 85 acres; Application Rate: 155 lbs a.i. per acre; Application Method: soil injection. All samplers were positioned approximately 20 yards from the edge of the field, except the sampler on the east side, which was positioned 40 yards from the field's edge. Application occurred during daylight hours. Overnight samples were taken during the period following the daily application and prior to beginning application on the next day.
- b $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter; ppb=parts per billion. The equation used for the conversion from $\mu\text{g}/\text{m}^3$ to ppb is shown in Appendix A.
- c Interval 1: background (0700-0915; 7/27/93); Interval 2: During application (1215-1830, 7/27/93); Interval 3: Overnight (1830-0630; 7/27-28/93); Interval 4: During application (0630-1200, 7/28/93); Interval 5: During application (1200-1730, 7/28/93); Interval 6: Overnight (1730-0700, 7/28-29/93); Interval 7: During application (0700-1300, 7/29/93); Interval 8: During application (1300-1800, 7/29/93); Interval 9: Overnight (1800-0700, 7/29-30/93).
- d After the collection of all of the samples, this sample was unintentionally left in an ice chest over the weekend. It was exposed to ambient temperatures exceeding 100°F for an unknown length of time. The reported value for this sample is probably lower than the actual.
- e This sample was analyzed ten weeks past the hold-date (although it was stored in a freezer) and the reported value may be low.

I. Summary and Conclusions

In the environment, metam-sodium decomposes rapidly to form MITC. The transformation rate of metam-sodium to MITC depends strongly on soil temperature, soil moisture, and soil composition. Warm soil temperatures, increased concentrations of organic material or clay, small soil particle size, and low soil moisture facilitate metam-sodium's rapid conversion. Nearly complete conversion can occur in less than 30 minutes.

MITC is highly volatile. Its high vapor pressure allows it to readily volatilize from the soil and enter the atmosphere. Warm, dry soil conditions coupled with clay and sandy-loam soils favor the volatilization of MITC from soil.

Once in the air, MITC transforms by gas-phase photolysis, with a photolytic half-life between 3 to 4 days. The primary photodecomposition products include MIC, H₂S, and CS₂, all of which are volatile. MIC may be photochemically stable in the atmosphere. However, H₂S and CS₂ both react with OH radicals in the atmosphere, with calculated half-lives of 2.5 days and approximately 2 weeks, respectively.

In nine studies conducted in California, MITC was detected in the air at the application-site following soil-injection or sprinkler applications of metam-sodium, and in ambient air near locations where applications were occurring. During one application study, MITC and H₂S were detected within an hour after the application began, indicating that metam-sodium was rapidly breaking down. This high rate of decomposition is expected, especially during the monitoring studies conducted in Kern County, where clay soils with small particle size are common, and in the summer, warm soils with low moisture content prevail. During the most recent ambient study (Seiber et al., 1999), MITC was detected in areas near where applications of metam-sodium were occurring. Detectable concentrations were measured in both indoor (residential) and outdoor air, with the highest concentrations occurring during the summer months, when warm, dry temperatures, and the increased use of metam-sodium contribute to MITC's presence in ambient air. During the most recent application-site study (Merricks, 1999), the highest MITC levels were detected during the late night and early morning. MITC may move offsite in all directions during periods of low wind and inversion.

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Appendix A. Equation used to convert mg/m³ to parts per billion (ppb).

- All ARB Studies
- Rosenheck Study
- Lompoc Study
- Seiber Study
- Wofford Study
- Merricks Study

$$ppb = \left(\frac{\text{mg}}{\text{m}^3} \right) \times \frac{\left(8.21 \times 10^{-2} \text{ liter} \cdot \text{atm} / \text{mole} \cdot \text{K} \right) (298 \text{ K})}{\left(73.12 \text{ gram} / \text{mole} \right) (1 \text{ atm})} = \frac{\text{mg}}{\text{m}^3} \times 0.3346$$