● FUMIGANT FACTSHEET

Resource ID# 5129

METAM SODIUM

Fumigant Factsheet: Metam Sodium

The soil fumigant metam sodium is the third most commonly used agricultural pesticide in the U.S. After application, metam sodium breaks down rapidly into methylisothiocyanate, the molecule that provides the primary biocidal activity.

Metam sodium fumigants are classified by the U.S. Environmental Protection Agency (EPA) in the agency's most hazardous acute toxicity category. Symptoms of exposure include eye irritation, skin rash, headache, nausea, shortness of breath, and fainting.

In laboratory tests, metam sodium has suppressed the activity of the immune system, caused cancer, increased fetal loss in pregnant animals, and caused birth defects. It is classified by EPA as a "probable human carcinogen" and the agency categorizes it as a "developmental toxicant."

Methylisothiocyanate is very highly toxic to fish and other aquatic animals. Concentrations of one part per trillion have killed tadpoles in laboratory tests.

Fumigation with metam sodium kills beneficial mycorrhizal fungi in the soil. Because these fungi increase the ability of plants to take up essential nutrients, elimination of mycorrhizal fungi in agricultural soil can lead to yield losses or increases in the need for fertilizer. Metam sodium fumigation also kills nitrogen-fixing soil bacteria and recovery can take over three months.

BY CAROLINE COX

Metam sodium (see Figure 1) is a fumigant designed to kill nematodes, soil pathogens, and weeds. It is a member of the dithiocarbamate chemical family.[1] U.S. manufacturers of metam sodium fumigants include Amvac Chemical Corporation, Sundance AG Inc., and UCB Chemicals Corporation.[2]

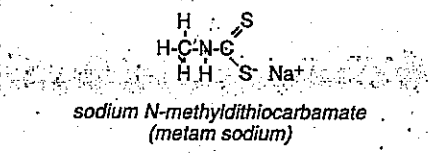
Use

According to 1997 U.S. Environmental Protection Agency (EPA) estimates, metam sodium is the third most commonly used pesticide in the U.S., with agricultural use of 59 million pounds per year.[3] The Pacific Northwest accounts for almost half of the national use, 24 million pounds.[4-7] (See Figure 2.)

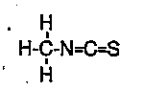
Metam sodium's major uses in the U.S. are for fumigation of potato, peanut, carrot, and tomato fields.[8]

One of the most striking things about metam sodium's use is the rate at which the fumigant is applied. While many pesticides are applied at rates of several pounds per acre, recommended rates for metam sodium applications can be over 300 pounds per acre[9-11] and application rates of over 100 pounds per acre are not uncommon.[8]

Figure 1
Metam Sodium and MITC



sodium N-methyldithiocarbamate (metam sodium)



methylisothiocyanate (MITC)

An Active Breakdown Product

After application, metam sodium degrades (breaks down) rapidly into methylisothiocyanate (MITC). MITC, not metam sodium, is the molecule that is actually active as a pesticide.[12] Because the rapid transformation makes the hazards of metam sodium and MITC hard to separate, this article summarizes hazards of both when available.

Acute toxicity

All metam sodium products are classified by EPA with the signal word "Danger," because they are in the most hazardous acute toxicity category.[13] The primary acute (short-term) symptoms in people who have been exposed to metam sodium are skin irritation, eye irritation, and irritation of the respiratory system.[14] Skin and eye irritation can be severe: MITC is "corrosive" to both.[15] For a complete list of symptoms, see Table 1.

Allergic Reactions

According to laboratory tests, repeated exposure of skin to metam sodium can cause allergic reactions. Based on these tests, EPA has classified metam sodium as a dermal sensitizer.[16] Allergic skin reactions have also been observed in people exposed to metam sodium; MITC is likely the cause of the allergic reaction.[17-18]

Caroline Cox is JPR's editor.

Neurotoxicity

Both short- and long-term exposure to metam sodium cause damage to the nervous system.

In a short-term study of mice, metam sodium caused neurotoxic symptoms immediately after exposure: hyperactivity followed by mild lethargy.[19] A study of rats found that single oral exposures to metam sodium reduced walking and movement at every dose tested.[20]

In a long-term (two year) study of rats exposed through their drinking water, metam sodium caused degeneration of the sciatic nerve.[21]

Effects on the Circulatory System

In mice, oral exposure for ten or fourteen days reduced blood levels of hemoglobin, the oxygen-carrying molecules in blood. In addition, hematocrit (the percentage of blood volume occupied by cells) decreased.[19] Hematocrit levels also decreased at all doses tested in a three month study of rats exposed to metam sodium through their drinking water.[22]

Effects on Reproduction

Four laboratory studies submitted to EPA as part of metam sodium's registration process have shown that exposure to metam sodium affects reproduction.[23]

In a study of rats, completed in 1987, skeletal "variations, retardations, and anomalies" increased at the lowest dose tested. In a second study of rats, completed in 1997, fetal loss increased at the lowest dose tested and skeletal abnormalities increased at all but the lowest dose.[23]

In a study of rabbits (1987), fetal loss increased at all but the lowest dose tested. In a second study (1993), skeletal abnormalities increased at all but the lowest dose tested and fetal loss increased at the high dose.[23]

In both rats and rabbits, spinal cord and brain defects occurred in animals exposed to high doses of metam sodium.[24]

Based on these studies, EPA concluded that metam sodium is a "developmental toxicant."[23] Metam sodium has also been classified by California EPA as a chemical "known to cause reproductive toxicity."[25]

MITC reduced fetal growth in laboratory studies of pregnant rabbits.[26]

Hormone Disruption

Hormones are natural chemicals that travel in the bloodstream and regulate development, reproduction, and behavior. In the last decade, public and scientific concern that synthetic chemicals might be interfering with the function of natural hormones has intensified.[27] Recent EPA research with metam sodium indicates that it may be one of these hormone disrupting chemicals.[28]

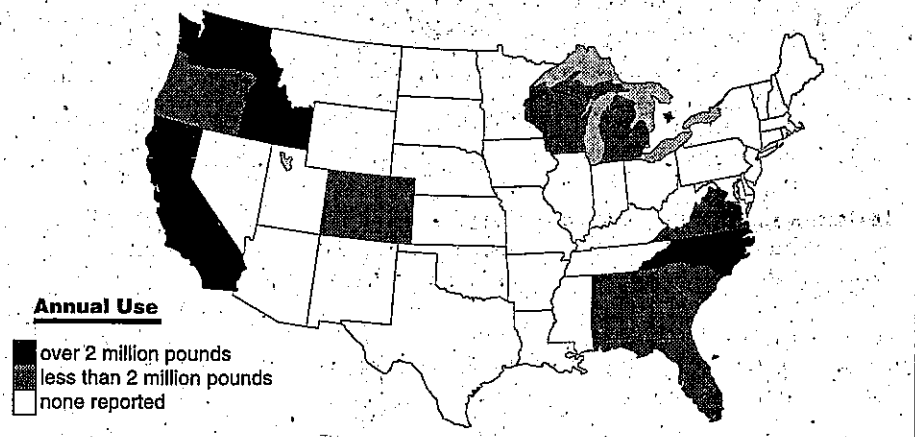
In many mammals, a sharp increase in the levels of a sex hormone, luteinizing hormone, triggers ovulation. A single injection of metam sodium in rats a few hours prior to the expected time of this hormone surge suppressed the surge and caused in a drop in the percentage of females who ovulated. The metam sodium injection also lowered levels of the hormone norepinephrine. MITC had similar, but not identical effects.[28]

Effects on the Immune System

Recent laboratory studies have shown that metam sodium is toxic to the immune system. In mice, oral exposure for as little as three days decreased the weight of the thymus, the organ in which immune system cells called lymphocytes mature. The number of immature white blood cells in both the thymus and the spleen decreased. In addition, the activity of natural killer (NK) cells in the spleen decreased. NK cells, part of the immune system, "constitute an important component in protection of the host from viruses and neoplasia [tumors]."[19]

Because workers are often exposed to

Figure 2
Agricultural Uses of Metam Sodium in the U.S.



Source: National Center for Food and Agricultural Policy. Undated. NCFAP pesticide use in various commodities for 1991-1994. Database. http://ext.agn.uiuc.edu/data/ncfap.html.

Agricultural uses of metam sodium in the U.S. are concentrated in the Pacific Northwest.

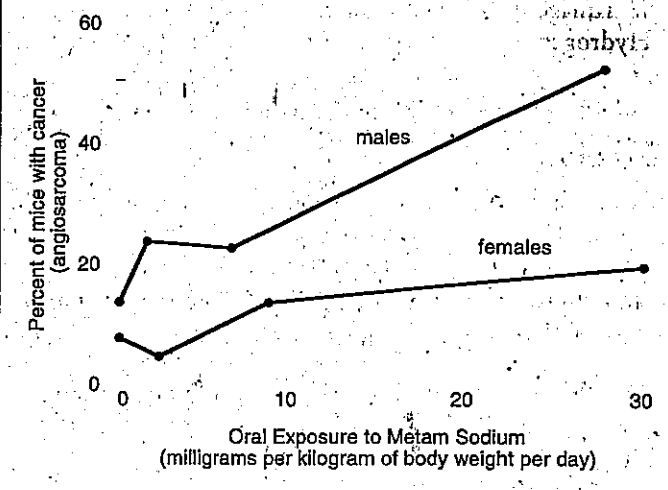
Table 1
Symptoms of Exposure to Metam Sodium

skin rash	throat irritation
nausea	sore throat
vomiting	breathing difficulties
eye irritation	shortness of breath
burning eyes	fainting
headaches	

Sources:
U.S. EPA. 1998. Incident data system: Summary report by chemical (metam sodium). Washington D.C., Oct. 29.
Darcey Publications. 1999. Metam sodium drift in Earlimart, California forces evacuation. *Pesticide Report* (Nov. 30): 7-8.
Gomex, S. 1999. Ventura County perspective: Preparedness lessons from a neighbor. *Los Angeles Times* (Sept. 15):B19.

"If no adequate human data are present, positive effects in animal cancer studies are a basis for assessing the carcinogenic hazard to humans. This assumption is a public health conservative policy, and it is both appropriate and necessary given that we do not test for carcinogenicity in humans."
— EPA

Figure 3
Effect of Metam Sodium on Cancer Rates



Source: U.S. EPA. Office of Prevention, Pesticides, and Toxic Substances. 1995. Carcinogenicity peer review of metam sodium. Washington, D.C., May 1.

In laboratory tests of mice, metam sodium exposure increases the frequency of a cancer, angiosarcoma.

metam sodium through the skin, these studies included dermal exposure. Dermal exposure decreased thymus weight, the number of immature white blood cells, and NK cell activity.[19]

Follow-up studies which compared the effects of metam sodium to the effects of MITC showed that both chemicals are toxic to the immune system, but in different ways. MITC, like metam sodium, decreased thymus weight and decreased the number of immature lymphocytes. However, it did not decrease NK cell activity; this effect is apparently caused by metam sodium.[29]

Mutagenicity

Metam sodium's mutagenicity (ability to cause genetic damage) was tested as part of its EPA registration process. One of the four tests, one using human blood cells, was positive. It showed that metam sodium damaged chromosomes, causing breaks and fragmenting.[30]

Chronic Toxicity

In a chronic (long-term) study of rats, metam sodium caused a variety of abnormalities in the nose: inflammation, degeneration of the lining, enlargement of one gland, and atrophy of another.[21]

Carcinogenicity

EPA evaluated metam sodium's carcinogenicity (ability to cause cancer) in 1995 and concluded that metam sodium should be classified as Group B2, a probable human carcinogen.[31] This classification was based on laboratory tests using mice and rats given metam sodium in their drinking water. In the test with mice, metam sodium caused angiosarcomas (a cancer involving the lining of a blood vessel[32]) in the liver and spleen. (See Figure 3.) An increased incidence of a similar cancer, hemangiosarcoma, was found in a test using male rats.[31]

Metam sodium has also been classified by the California EPA as a chemical "known to the state to cause cancer."[25]

An association of metam sodium manufacturers is challenging EPA's B2 classification of metam sodium.[33] They claim that the evidence for metam sodium's carcinogenicity comes from animal, not human studies. They also state that metam sodium breaks down quickly into MITC, which "has not been identified by the U.S. EPA, California, or other health organizations as either a carcinogen or a reproductive toxicant."[2]

In response to the first criticism it is important to note EPA's conclusions about the importance of animal tests for carcinogenicity: "If no adequate human data are present, positive effects in animal cancer studies are a basis for assessing the carcinogenic hazard to humans. This assumption is a public health conservative policy, and it is both appropriate and necessary given that we do not test for carcinogenicity in humans."[34] EPA also states that "nearly all of the agents known to cause cancer in humans are carcinogenic in animals in tests with appropriate protocols"[34] and that "the mechanisms of control of cell growth and differentiation are remarkably homologous [similar] among species."[34]

In response to the second criticism, EPA states that two studies of MITC did not find increased cancer rates, but they used inadequate dose levels.[35]

Metabolites Other than MITC

When metam sodium breaks down into MITC, a number of other chemicals are formed including, methylamine, carbon disulfide, and hydrogen sulfide.[36]

Methylamine can cause burns to the eyes and skin, difficult breathing, and chemical bronchitis.[37] In laboratory studies it has caused genetic damage[37] and decreased white blood cell counts.[29]

Carbon disulfide is toxic to the central

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nervous system, with damage that can be permanent. It has damaged sperm production in exposed people and caused genetic damage in human blood cells.[38]

Hydrogen sulfide causes eye and respiratory system irritation, nausea, diarrhea, headache, and cardiac arrhythmia.[26]

Contaminants

N,N'-dimethylthiourea is a contaminant of the metam sodium product Vapam.[12] In laboratory tests, N,N'-dimethylthiourea injures lungs,[39] reduces fertility, and causes birth defects.[40]

Synergy

Synergy occurs when the combined effect of two chemicals is greater than the effect of either chemical alone. Such interactions have been observed for metam sodium with lead, and MITC with ethylene thiourea (a breakdown product of the fungicide nabam).[41,42]

When laboratory animals are exposed to both metam sodium and lead, the concentration of lead in their brains increases to five times the level found when exposed to lead alone. Since lead is "a well-known neurotoxic agent"[41] the consequences of this synergy could be serious.

MITC, in combination with ethylene thiourea, caused the nervous system of toads to develop abnormally. Neither compound alone caused the abnormalities.[42]

Effects on Aquatic Animals

MITC is "very highly toxic to fish and aquatic invertebrates" according to EPA.[43] For some species, MITC's toxicity is stunning. For example, in a study of South African clawed toad tadpoles, exposure to one part per trillion for 12 hours caused 100 percent mortality.[42]

Effects on Crop Plants

As a broad spectrum biocide, it is not surprising that metam sodium kills plants growing in soil that is fumigated. In addition, it has more subtle effects on soil microorganisms that can affect growth of crops that are planted after the fumigation has occurred. These include effects on mycorrhizae, nitrogen fixation, decomposition of organic matter, and the abundance of pest nematodes.

• Mycorrhizae are widespread beneficial fungi that colonize plant roots and increase plants' uptake of necessary minerals. This process can be disrupted by metam sodium. (See Figure 4.) For example, University of California researchers, in collaboration with extension farm advisors, looked at the impact of metam sodium fumigation on mycorrhizal fungi in cotton fields. They found that effects depended on how large the populations of mycorrhizal fungi were. In fields with average or low numbers of mycorrhizae, fumigation reduced the percentage of cotton roots containing mycorrhizae and the size of the plants two months after fumigation. At one of the three sites studied, metam sodium fumigation led to an 18 percent reduction in cotton yields.[44]

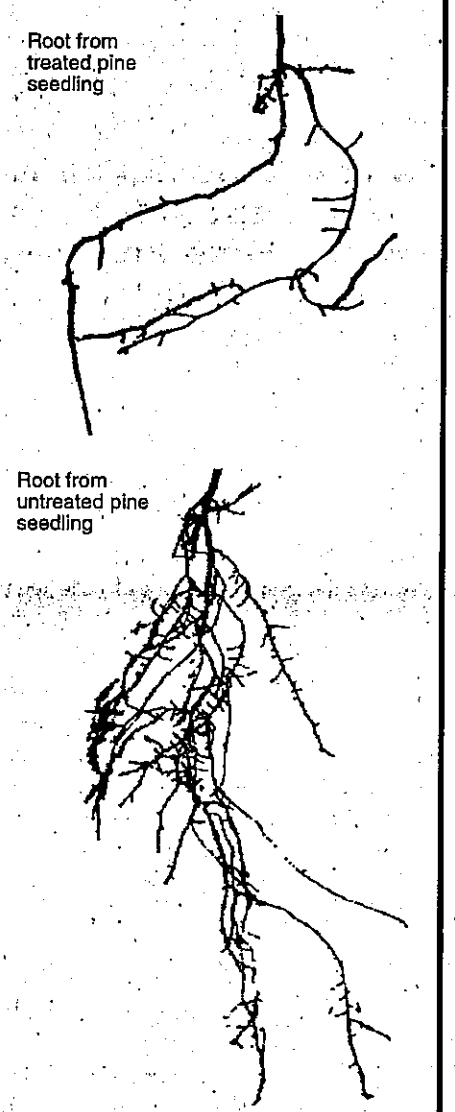
Similar results were found in a study of corn grown in fumigated fields. (The corn was fumigated with both metam sodium and methyl bromide, another common soil fumigant.) Unless the fumigation was followed by application of phosphorous fertilizer, the fumigation reduced both corn weight and corn yield.[45]

Metam sodium's disruption of mycorrhizae can also have more complex effects. In a study of onions, for example, metam sodium fumigation reduced the percentage of plants colonized with mycorrhizae. Plant height was reduced about 50 percent, and onion yields were reduced between 47 and 56 percent. The pest targeted by the fumigation, the pathogenic bacteria *Fusarium*, was also reduced, but without mycorrhizae the onion plants were unable to withstand another pathogenic bacteria, *Pseudomonas*, found in the irrigation water (treated urban sewage). Rot caused by *Pseudomonas* was responsible for about half of the yield reduction in fumigated fields.[46]

• Nitrogen fixation is the process by which nitrogen gas is transformed into nitrogen compounds that are usable by plants. Most plants rely on bacteria as a source of these nitrogen compounds which are essential for plant growth.[47] Metam sodium impacts bacteria responsible for two steps in the nitrogen cycle, the transformation of ammonia into nitrites and the transformation of nitrites into nitrates.[48,49]

These impacts can be both severe and long-lasting. A study of Japanese

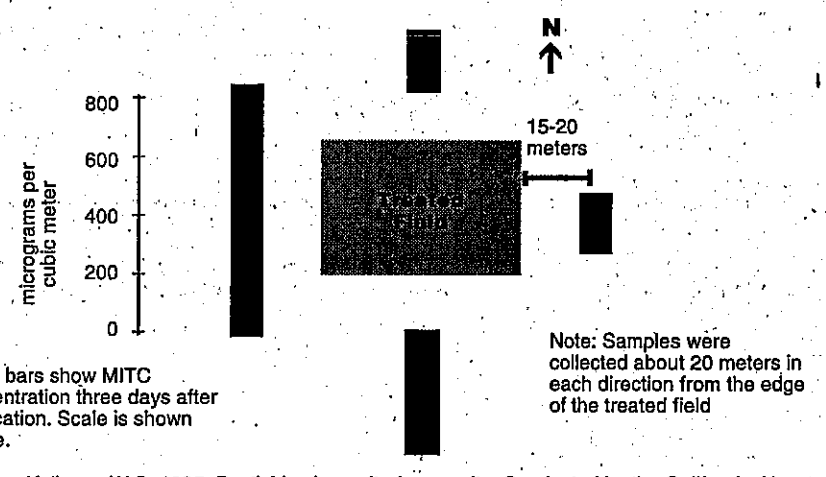
Figure 4
Effect of Metam Sodium on Root Development



Source: Iloba, C. 1977. The effect of Vapam on the ectotrophic mycorrhizae of pine seedlings. *E. Afr. Agric. For. J.* 43:18-24.

Metam sodium treatment of soil kills beneficial mycorrhizal fungi leading to stunting and inhibition of the roots of crops planted after fumigation.

Figure 5
MITC Air Contamination Following a Metam Sodium Application to a Carrot Field



Source: Kollman, W.S. 1995. Pesticide air monitoring results: Conducted by the California Air Resources Board 1986-1995. Sacramento CA: Calif. EPA. Dept. of Pesticide Regulation. Environmental Monitoring and Pest Management Branch.

MITC was found in all air samples collected three days after a metam sodium application to a California carrot field.

agricultural soils showed that metam sodium fumigation at typical agricultural rates caused a ten thousandfold reduction in the number of bacteria that transformed ammonia into nitrites and that this reduction did not show any recovery 105 days later. Metam sodium also caused a thousand fold reduction in the number of bacteria that transformed nitrites into nitrates with only "some indication" of recovery 105 days later.[49]

• Decomposition of organic matter is one activity performed by microorganisms in healthy soil. In a study of a California agricultural soil, the microorganisms that broke down cellulose, the molecule that makes up most of the woody parts of plants, were "severely inhibited" by metam sodium fumigation.[50]

• Pest nematodes are a common agricultural problem. In certain soils, called suppressive soils, nematode populations are not crop-damaging because of high populations of fungi that parasitize the nematodes. Metam sodium can kill the fungi and cause nematode populations to increase. In a study of sugar beet nematodes, fumigated soils contained twice as many nematode eggs and juvenile nematodes as did unfumigated soils.[51]

Air Contamination

Relative to other pesticides, MITC is volatile (evaporates easily) and persists in the environment. This means that it can contaminate the air outside of target areas.[52] For example, MITC air monitoring during the application season in four California counties where metam sodium use is high found MITC in nearly all (87 - 100 percent) of the samples taken.[53] (See Figure 5 for one example.)

A graphic example of MITC air contamination occurred in Earlimart, California, in November, 1999, when dozens of people were treated at hospitals following a metam sodium application via irrigation water to a nearby field.[54] MITC contamination of air can be insidious because it makes people ill at concentrations too low to smell.[26]

Health and Environmental Effects of a Spill

Metam sodium made headlines on July 14, 1991, when a freight train derailed on a bridge over the Sacramento River near Dunsmuir, California.[55] A tank car carrying metam sodium from a manufacturing plant in Commerce, California, to potato fields near Pasco, Washington,[56] fell into the river. Almost twenty thousand gallons of metam sodium leaked from the car, was transformed into MITC, and contaminated 40 miles of the Sacramento River. Prior to the spill, this part of the Sacramento River had been world famous for its wild trout.[55]

For the residents of Dunsmuir, there were both immediate and longer term effects on their health. Nausea, headaches, eye irritation, dizziness, vomiting, and shortness of breath were reported by Dunsmuir residents in the first five days after the spill.[36] About 14 percent of Dunsmuir residents consulted a medical professional in the month following the spill.[26] MITC exposure caused the development of persistent asthma in some patients, and exacerbated existing asthma in others. Symptoms persisted over a year in some of these patients.[57] In addition, the California Department of Health Services reported, but was unable to confirm, a high rate of miscarriages among women who were in the spill area during the first trimester of a pregnancy.[58]

The ecology of the Sacramento River was "severely affected."[26] Nearly all plants and animals in the river were killed for 40 miles downstream.[55] The California Department of Fish and Game (CDFG) reported fish kills in the "hundreds of thousands."[26] The spill impacted microorganisms just as severely: zooplankton populations in the river decreased 99.9 percent[59] and a study of the riparian microbial community showed that the spill caused persistent changes.[60]

Some species recovered in a matter of years, others took (and are taking) much longer. Sculpin, a bottom-dwelling fish that had been the most abundant fish in the river prior to the spill, crayfish, the Pacific giant salamander, and over 40 species of clams and snails were identified by CDFG as slow to recover.[61] Slowest to recover are the mature trees that once lined the river; state officials estimated 50 years for mature trees killed by the spill to be replaced.[55]

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