• FUMIGANT FACTSHEET

SULFURYL FLUORIDE

The fumigant sulfuryl fluoride is widely used to kill termites and other unwanted insects in buildings, ships, railroad cars, and wood products.

Sulfuryl fluoride is "an extremely hazardous gas." Typical symptoms of exposure include nose, eye, and throat irritation, weakness, nausea, difficult or painful breathing, seizures, and kidney injury. With repeated exposure or higher concentrations, breathing failure occurs. There is no known antidote for sulfuryl fluoride poisoning. Sulfuryl fluoride is also toxic to the nervous system. Neurological symptoms include muscle aching and fatigue, coordination problems, depression, slurred speech, dizziness, and stumbling, weaving, and staggering when walking.

Sulfuryl fluoride has adversely affected reproduction in laboratory animals. When rats inhaled sulfuryl fluoride for a period spanning two generations, the weight of the offspring was reduced in both the first and the second generation. Sulfuryl fluoride was not tested for its ability to cause cancer as part of the registration process.

All tests for effects on nontarget animals and plants, as well as all environmental fate tests were waived during the registration process. It is, however, clearly toxic to nontarget animals and plants.

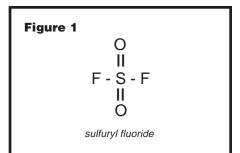
Regulatory agencies and the courts have found that repeated violations of fumigation safety have occurred during sulfuryl fluoride treatments. According to one judge, the practices of a major extermination company were "nothing short of scary."

BY CAROLINE COX

Sulfuryl fluoride (see Figure 1) is an odorless and colorless gas¹ that is used to fumigate buildings, ships, railroad cars and wood products.² It was first registered in 1959 and completed the U.S. Environmental Protection Agency's (EPA's) reregistration process in 1993. It is produced by one manufacturer, DowElanco, under one trade name, Vikane.² It has a broad spectrum of toxicity; target pests include termites, clothes moths, cockroaches, ticks, snails, and rats.^{2,3}

The available statistics indicate that sulfuryl fluoride is widely used. About 85 percent of the structural fumigations in the U.S. use sulfuryl fluoride.³ Total use is estimated at between 3 and 4 million pounds annually in the U.S.⁴ In California over 1,700,000 pounds were used in 1995, the last year for which data are available.⁵ Use has increased because use

Caroline Cox is JPR's editor.



of another fumigant, methyl bromide, has decreased. (See Figure 2.)

Mode of Action

Sulfuryl fluoride has a complex mode of action. It is thought to be toxic primarily through the action of the fluoride ion which it contains. It inhibits oxygen uptake, disturbs the normal phosphate balance, and inhibits hydrolysis (breakdown) of fatty acids. The fluoride ion in sulfuryl fluoride is thought to bind to calcium (leading to spasms and seizures) as well as potassium and magnesium.⁶ Enzymes which require a magnesium ion for their normal function are inhibited

by sulfuryl fluoride; these enzymes include enolases (used to metabolize sugar) and ATPase, an enzyme that is important in cellular energy metabolism.⁷ The end result is that sulfuryl fluoride prevents stored fats from being utilized, and there is insufficient energy for survival.³

Acute Toxicity

Sulfuryl fluoride is "an extremely hazardous gas." The most straightforward demonstration of its acute toxicity are the classifications and restrictions placed on its use by the U.S. Environmental Protection Agency (EPA). EPA classifies sulfuryl fluoride as a restricted use pesticide. This means that the pesticide must be used by or under the supervision of a certified applicator who is wearing protective clothing. Sulfuryl fluoride is also labeled with the signal word "Danger" by EPA, meaning that it is in the most acutely toxic category of pesticides.

Because of sulfuryl fluoride's acute toxicity, all entrances to the fumigated areas must be posted with a skull and crossbones sign. No one is permitted in

the treated area without self-contained breathing apparatus until it has been thoroughly ventilated according to approved procedures and concentrations of sulfuryl fluoride have been measured at less than 5 parts per million.⁹

Typical symptoms of exposure to sulfuryl fluoride include nose, eye, and throat irritation, weakness, nausea, difficult or painful breathing, coughing, restlessness, muscle twitching, seizures, and kidney injury. 10 With repeated exposure or higher concentrations, breathing failure occurs. 11 Other symptoms that have been observed in people exposed to sulfuryl fluoride include intense itching, tingling of extremities (arms and legs),12 anorexia, inadequate blood oxygen, heart fibrillations, 13 accumulation of fluid in the lungs, and spasms of the hands and feet.⁶ There is no known antidote for sulfuryl fluoride poisoning.11

In laboratory tests, exposure to 4507 parts per million (ppm) sulfuryl fluoride (17.5 milligrams per liter (mg/l) of air) for one hour caused death. If exposure occurred for four hours the lethal concentration was lowered by a factor of eight (to 650 ppm or 2.5 mg/l of air).²

Neurotoxicity

EPA "has a concern for neurotoxicity associated with inhalation exposure to sulfuryl fluoride."2 This concern was first documented in 1986 when the National Institute for Occupational Safety and Health researchers found that fumigators who used "sulfuryl fluoride reported a greater number of symptoms and reduced performance on cognitive tests"14 compared to workers from the fumigation industry who did not work directly with sulfuryl fluoride or other fumigants. The symptoms reported included muscle aching and fatigue, coordination problems, depression, slurred speech, dizziness, and stumbling, weaving, and staggering when walking.

More recently (1997), DowElanco reported that sulfuryl fluoride exposure causes central nervous system depression followed by excitation accompanied by slowed movement, reduced awareness,

Figure 2
Use of Sulfuryl Fluoride in California

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Source: California Environmental Protection Agency. Dept. of Pesticide Regulation. Annual pesticide use report indexed by chemical. Sacramento, CA. (For 1991, 1993, and 1995)

Sulfuryl fluoride use is increasing as use of an alternate fumigant, methyl bromide, decreases.

and slow or garbled speech.¹¹

In laboratory animals, "daily inhalation exposure of rats and rabbits to SO₂F₂ [sulfuryl fluoride] resulted in treatmentrelated neurotoxicity" in 14- and 90-day tests conducted by DowElanco. Softening of brain tissue and the formation of cavities in brain tissue was observed in both species. In the 90-day study of rabbits, effects were found at all but the lowest exposure tested (30 ppm). At higher exposures, convulsions and hyperactivity were observed. 15 In another 90-day inhalation study with rats, slowing of nervous system responses was observed at all but the lowest exposure.2 In a 90-day study with dogs, brain lesions, tremors, incoordination, and salivation were observed at an exposure of 200 ppm.²

Subchronic Toxicity

Following "prolonged exposure", symptoms of sulfuryl fluoride poisoning include lung irritation, accumulation of fluid in the lungs, nausea, and abdominal

pain.11

In laboratory animals, the brain, the lungs, and the kidney were the target organs for sulfuryl fluoride toxicity. ¹⁶

Adverse effects noted in laboratory rats following 2-week exposure to sulfuryl fluoride include an increased white blood cell count at all exposures. Teeth fluorosis (mottling) and pale spotting of the lungs (caused by abnormal macrophages, cells that perform clean-up functions) was observed in rats in a 90-day test at all but the lowest exposure tested. At the highest exposure, decreased body weight, lesions in the nasal passages and lungs, and slightly excessive growth of the kidney (females only) were observed.

In rabbits, decreased body weights, decreased liver weights, and mottled teeth were observed at all but the lowest exposure in a 90-day test.² At the highest exposure tested lung lesions,² decreased food consumption, and inflammation of nasal membranes¹⁵ were observed.

In dogs, decreased body weights were observed at the highest exposure in a 90-day test.²

With longer exposures, adverse effects occur at lower exposures. Rats, guinea pigs, and mice exposed to 20 ppm of sulfuryl fluoride over a six month period suffered kidney damage, lung injury, and some fluorosis.¹⁷

Effects on Reproduction

Sulfuryl fluoride has adversely affected reproduction in laboratory animals. When rats inhaled sulfuryl fluoride for a period spanning two generations, the weight of the offspring was reduced in both the first and the second generation at the highest exposure tested (150 ppm).2 In a single generation study, the number of fetal resorptions (fetuses that died, and then were absorbed into mother's body) increased about 30 percent at all exposures tested. However, this increase was "not analyzed statistically" by DowElanco, who conducted the study. 16 In addition, the incidence of abnormal vertebrae in the offspring of rats in this study was increased at all exposures tested. According to DowElanco, these results were "not considered reflective of fetotoxicity."16

Mutagenicity

Three studies of the ability of sulfuryl fluoride to cause genetic damage were submitted to EPA by DowElanco in support of sulfuryl fluoride's registration. All three were negative (no genetic damage observed).² However, there are no publicly-available independently-conducted mutagenicity tests of sulfuryl fluoride.

Carcinogenicity

Sulfuryl fluoride was not tested for its ability to cause cancer as part of the registration process.² No publicly-available tests of carcinogenicity have been completed.

Hazards of Illegal Applications

On September 28, 1986 an elderly Virgina man, ¹³ Hubert Watson, ¹⁸ died of heart failure shortly after being brought to a hospital emergency room. It was not until three days later when his wife was admitted to the hospital after spending three days unable to get out of bed, and then died suddenly with similar symptoms, that doctors suspected that a toxin might be the cause. Autopsy showed high levels of fluoride in her blood. The following week, Orkin Extermination notified state officials that they had fumigated the house at the end of September. ¹³

In brief, here is the tragic sequence of events that ended the Watsons' lives. Their house was fumigated on September 25. A security guard watched the house until the following morning so that no one would enter the house. Then the fumigation tarps were removed, and fans ventilated the house for 2 1/2 hours. In midafternoon, the house was approved for reentry, and the Watsons returned home about 5:00. After several hours they left home to watch a football game, then returned to sleep. By the next day both were feeling ill, and the following day Hubert Watson died.¹³

In the litigation that followed, testimony showed that Orkin had not moni-

tored air levels of sulfuryl fluoride (as required by the Vikane label) before authorizing reentry, Also, Orkin employees did not remove a waterproof mattress cover from the Watsons' bed when ventilating the house. This meant that when the Watsons slept on the mattress it still contained dangerous amounts of sulfuryl fluoride.¹⁹

Orkin eventually pleaded guilty to violating the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) in this incident. The company was fined 500,000 dollars and placed on probation. A portion of the fine (150,000 dollars) was suspended, providing that Orkin changed its procedures to follow the law.²⁰

The story did not end with the sentencing; five years later, Orkin and EPA were back in court. EPA had evidence that Orkin had committed 306 violations of pesticide laws, including 119 violations of the probation agreement, in 17 states since being placed on probation. At least 17 times, EPA wrote, "Orkin committed the same violations of fumigation safety requirements for which the company was convicted and sentenced." 20

"It's nothing short of scary the way the company was handling its business," said the district court judge who heard the case. 18

Hazards of Legal Applications

Two human health concerns arise when sulfuryl fluoride fumigations are conducted according to label directions. First, some materials often used in homes absorb sulfuryl fluoride, then release it over long intervals. This means that people can be exposed for a prolonged period. Second, the concentrations of sulfuryl fluoride currently considered acceptable for residents when they reenter their homes may not protect them against sulfuryl fluoride's neurotoxicity.

Persistence in Household Materials: When researchers looked at the capability of some common household objects to absorb, and then release sulfuryl fluoride, several materials were able to release significant amounts of the fumigant. These materials included polystyrene in-

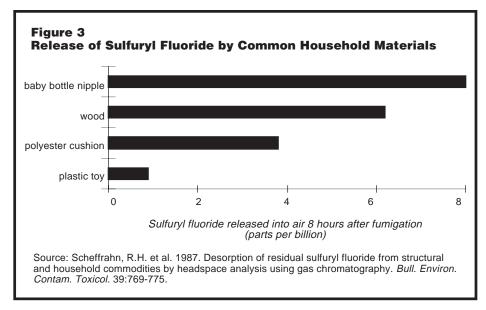
sulation, latex baby bottle nipples, wood, and polyester cushion fibers. (See Figure 3.) Four materials (wool fabric, polyester cushion fiber, plastic toy soldiers, and polystyrene insulation) released sulfuryl fluoride for 40 days post fumigation.²¹ This indicates that exposure under certain conditions might be higher than expected. In fact, when DowElanco monitored air levels of sulfuryl fluoride in houses following fumigation, in one house (out of a total of 32 houses monitored) there was an increase in sulfuryl fluoride levels after the post-treatment ventilation was completed.²

Exposure to Potentially Neurotoxic Concentrations: When sulfuryl fluoride fumigations are carried out according to label directions, EPA believes that "residents and workers reentering treated houses may be at risk for acute neurotoxic effects." EPA calculated that the exposure of a resident to sulfuryl fluoride during the first day following fumigation could be as much as 6 mg/kg. EPA calculated that exposures of this magnitude are not adequately protective of residents' health.²

So far, EPA's response to this concern has been limited. In 1993, EPA suggested that the acceptable concentration for allowing residents to reenter their homes after fumigation should be lowered to 1 ppm from the current 5 ppm.² EPA set a deadline of October, 1994, for making this decision,² but it has not yet been made ²²

Since EPA has calculated that children are about 5 times more susceptible to sulfuryl fluoride than adults, children are at significantly greater risk for neurotoxic effects after fumigation. If EPA were to make the label changes they suggested in the RED, calculations of children's exposure would be just within the range that EPA considers acceptable.²

In addition to children, "individuals with a history of chronic respiratory disease are at increased risk from exposure to sulfuryl fluoride," according to Cooperative Extension's Pesticide Information Project. Both children and the chronically ill remain at special risk while EPA



Sulfuryl fluoride is absorbed during treatment by household materials, and later released back into the air.

delays in making its decision.

Ecological Effects and Environmental Fate

Because sulfuryl fluoride is used only indoors, all tests for effects on nontarget animals and plants, as well as all environmental fate tests were waived during the reregistration process.² It is, however, clearly toxic to nontarget animals and plants. The Vikane label, for example, requires that all domestic animals, pets, and desirable growing plants be removed from buildings before they are fumigated.⁹

Associated Chemicals

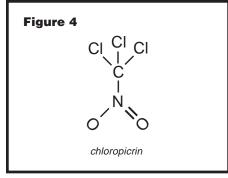
Most pesticide products contain socalled "inert" ingredients. These are ingredients that are added to the pesticide to make it more potent or easier to use; they are routinely called trade secrets by pesticide manufacturers. Vikane has no intentionally added "inerts." When sulfuryl fluoride completed the reregistration process in 1993, however, it contained 1 percent "inert impurities which are a result of the manufacturing process." Recently (1996), DowElanco has reduced these impurities to 0.2 percent. There is no publicly available information about the identity of the impurities.

In addition, the fumigant chloropicrin

(see Figure 4) must be used as a warning agent 5 to 10 minutes before sulfuryl fluoride fumigation is carried out.9 Chloropicrin "causes smarting of the eyes ... and has a very disagreeable odor." It is used to warn anyone that might inadvertently be in the building because sulfuryl fluoride itself is odorless and colorless. 1 Chlorpicrin causes intense tearing of the eyes, headaches, nausea, diarrhea, coughing, and skin irritation. Repeated exposure can damage the lungs, causing bronchitis and also may damage the liver and kidney.²³ It is a restricted use pesticide which, like sulfuryl fluoride, it is labeled with the most toxic "Category 1" or "Danger" signal word. It is toxic to fish, with concentrations of just over 0.1 ppm being toxic to trout and bluegill.²⁴

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