DOUGLAS PRODUCTS

FUMIGATION FACTS

GENERAL INFORMATION ON VIKANE® FUMIGANT

VIKANE®

INTRODUCTION

Drywood termites and other wood-destroying insects can cause significant damage as they feed on materials containing cellulose found in structures, such as wood, paper, textiles, furnishings, and works of art. Because these insects live most of their life cycle within their food source, the exact distribution and extent of infestation is often difficult to determine. Therefore, localized treatments using physical methods or conventional insecticides may not eradicate all wood-destroying insects infesting a structure. To solve this problem, sulfuryl fluoride, the active ingredient of Vikane® fumigant, was developed to be used exclusively by professional fumigators for structural fumigation. Vikane is also used to control bed bugs, cockroaches, clothes moths, rodents, spiders, carpet beetles and other structure-infesting pests.

Research conducted during the development of sulfuryl fluoride, the active ingredient of Vikane, demonstrated that this fumigant possesses highly desirable characteristics for the eradication of structure-damaging and structure-infesting pests (Derrick et al. 1990). Sulfuryl fluoride gas is nonflammable, noncorrosive and does not cause undesirable odors. It quickly penetrates structural materials, is effective against a variety of structure-infesting pests and dissipates rapidly during aeration (Kenaga 1957; Stewart 1957). Since first marketed as Vikane in 1961, sulfuryl fluoride has been used to fumigate more than 3 million buildings, including dwellings, hotels, churches, museums, historical landmarks, rare book libraries, government archives, scientific and medical research laboratories, ships, transportation vehicles, and food-handling facilities (see Table1).

MODE OF ACTION AND EFFICACY

Vikane has been demonstrated to reduce oxygen uptake in insect eggs (Outram 1970). Vikane also prevents insects from metabolizing the stored fats they need to maintain a sufficient source of energy for survival by disrupting the glycolysis cycle (Meikle et al. 1963). For this reason, insects receiving a lethal exposure to Vikane may still be alive immediately following fumigation. Vikane eliminates target pest infestations present in the structure at the time of the fumigation. It does not provide residual control.

The required dosage of Vikane is determined by the temperature at the site of the pest, the length of the exposure period and the susceptibility of the pest to be controlled (Thoms and Scheffrahn 1994). Therefore, the dosage of Vikane required for control of a target pest at a given temperature is calculated in "ounce-hours," ounces of Vikane multiplied by hours of exposure. The ounce-hours required to control target insect pests have been determined from laboratory and field testing.

Insect eggs require a higher ounce-hour dosage of Vikane compared to later life stages. Control of the egg stage of social insects, such as termites and ants, is not necessary because newly hatched termites and ants cannot survive without adult care.

Higher dosages required to control eggs of insects, such as wood-boring beetles, can be obtained by increasing the exposure time, increasing the concentration of Vikane or a combination of both. Fumigators use the Fumiguide® calculator, which was developed specifically for Vikane, to determine the amount of Vikane required for specific pests and fumigation conditions.

Vikane has also been successfully used since 1961 to control a wide variety of pests, including bed bugs, cockroaches, clothes moths, rodents, spiders and carpet beetles. The eradication of eggs of carpet beetles requires very high dosages of Vikane (Su and Scheffrahn 1990) which exceed the maximum label doses of Vikane permitted for structural fumigation. Therefore, two fumigations using Vikane are required to eradicate carpet beetles. The second fumigation is conducted after all beetle larvae have hatched from eggs surviving the first fumigation.

FORMULATION AND PROPERTIES

Vikane is a gas at temperatures above -67°F. Vikane is packaged in white cylinders as a liquid under pressure, containing 99.8% sulfuryl fluoride (125 pounds per cylinder) with no other pesticides, solvents or additives. Vikane has a high vapor pressure; it evaporates 20,000 times more readily than mothballs and therefore disperses rapidly throughout structures during fumigation.

Vikane does not react with building furnishings or contents, including computers, electronics and manufacturing equipment. This is why fumigation with Vikane is an established method used to eradicate pests infesting delicate and rare preserved biological and historical museum artifacts (see Table 1). Vikane does not form toxic surface residues, so dishes, clothes, cooking utensils, equipment and other items do not need to be washed following fumigation with Vikane.

The solubility of sulfuryl fluoride in water is very low, 0.075% by weight at 77°F (Meikle and Stewart 1962). Therefore, watering soil around exterior perimeter building foundations prior to fumigation is recommended to reduce both the loss of fumigant through the soil and exposure of plant roots to Vikane during fumigation.

Vikane is nonflammable and stable at normal temperatures. In the presence of extremely high temperatures exceeding 752°F, such as an open flame or glowing heat element, sulfuryl fluoride will degrade to form hydrogen fluoride (HF). HF dissolves in water to form hydrofluoric acid, which can etch glass, metal, and ceramic surfaces near the heat source. Thus, prior to structural fumigation, all open flames and glowing heat filaments are turned off or disconnected.

Vikane® fumigant is odorless at concentrations used to fumigate structures and is not irritating as a gas to the eyes or skin. For these reasons, a tiny amount of the warning agent, chloropicrin, is introduced in the structure prior to fumigant introduction. Chloropicrin acts as a warning agent by causing irritation of the eyes, tears and discomfort, and having a noticeable, disagreeable and pungent odor at very low concentrations, less than 1 part per million (ppm).

Chloropicrin diffuses from structures more slowly than Vikane. Thus, on rare occasions, occupants may experience some slight eye irritation after all of the Vikane has aerated from the structure. The fumigator should be contacted to take remedial measures if this occurs. A fumigator will use an approved clearance device, such as an Interscan or SF-ExplorIR, to determine that the concentration of Vikane within the structure is 1 ppm or less prior to allowing anyone to reoccupy the structure (see AERATION).

FUMIGATION PREPARATION

Prior to the fumigation, the fumigator will provide occupants of the building to be fumigated with a list of preparations to be conducted. The list will include the following items, which the label for Vikane requires be completed prior to releasing the fumigant into the structure.

1. All domestic animals, pets and desirable growing plants must be removed from the structure to be fumigated.
2. Mattresses and pillows completely enveloped in waterproof covers (not including waterbeds) must be removed from the area to be fumigated if the covers cannot be removed or opened.
3. All flames such as pilot lights and electrical heating elements must be turned off for reasons previously described. Follow procedures required by the local gas company when shutting off natural gas or propane service.
4. The following should be opened prior to fumigation: operable internal doors, internal openings to attics and sub-areas, storage chests, cabinets, drawers, closets, and appliances such as washers, dryers and ovens. In tarpaulin fumigations, operable windows are opened. These procedures assist in rapid dispersion of Vikane during fumigation and aeration.
5. Food, feed, drugs (including tobacco products) and medicinals, including those items in refrigerators and freezers, that are not in plastic, glass or metal bottles, cans or jars with the original manufacturer's airtight seal intact need to be removed from the fumigation site or double bagged in nylon (Nylofume®) bags. Exposure of food commodities protected in two nylon bags to 10x the drywood termite dosage for Vikane resulted in no detectable sulfuryl fluoride or added fluoride residues (Scheffrahn et al. 1990).

RELEASING VIKANE

After the building is inspected and determined to be cleared of all people, domestic animals and pets, the fumigator will apply the warning agent, chloropicrin, in the structure. Chloropicrin is introduced 5 to 10 minutes prior to introducing Vikane. Warning signs are posted on all entrances and sides of the building. After building entrances are secured, the fumigator will introduce Vikane into the structure.

Fumigators transport the cylinders of Vikane on their vehicles to the fumigation site. The fumigator introduces Vikane from outside the structure through tubing into the airstream of one or more fans inside the fumigated structure. The fans help rapidly disperse Vikane throughout the structure.

FUMIGATION PERIOD

The Fumiguide® calculates dosages of Vikane for exposure periods of 2 to 72 hours. To balance customer needs and economics, the fumigator typically plans exposure periods for Vikane of 16 to 30 hours. When the fumigation exposure period is complete, the fumigator will return to the structure to conduct the aeration procedure.

AERATION

Aeration and clearance testing are the final steps of fumigation. Aeration involves proper ventilation and clearance of Vikane and the warning agent, chloropicrin, from a structure.

One (1) ppm is the Permissible Exposure Limit (PEL) for Vikane established by the United States Environmental Protection Agency (USEPA). This PEL is the Time Weighted Average (TWA) exposure to which members of a population, including infants, children and the elderly, can be exposed to Vikane. This 1 ppm PEL is substantially lower than the level that may affect people and pets following even long-term exposure. The fumigator must aerate a structure so that the concentration of Vikane in the air is 1 ppm or less prior to allowing re-entry.

Unlike liquid and solid insecticides, Vikane is a gas possessing a very high vapor pressure (potential to escape from an area) and low boiling point (it is a gas above -67°F). During aeration of the fumigated structure, Vikane will quickly diffuse from high concentrations within a structure to the outside air where it rapidly dissipates to nondetectable levels.

Degassing is the process of fumigant diffusing out of materials when the concentration of gas is less around the object than within the object. Required aeration procedures allow the fumigant time to diffuse from structural voids and building contents and to ventilate out of the structure. The fumigator will use fans and open cabinets and windows to speed the process of aeration.

Many structures have been tested to validate the current aeration procedures. The aeration procedures have been vigorously tested to ensure that concentrations of Vikane® fumingant will not increase after occupants return, even when occupants close all windows and use no internal air circulation. Aeration procedures for Vikane have been thoroughly reviewed and approved for use by state and federal (USEPA) regulatory authorities.

Specially trained professionals conduct the clearance testing to determine that a structure can be reoccupied. Specialized detection equipment, such as the Interscan, Miran SapphIRe, or SF-ExplorIR, must be used to test the concentrations of Vikane within structures. This equipment is designed and calibrated to detect very low concentrations (1 ppm) of Vikane. Frequently, after the aeration procedures are completed, concentrations of Vikane are nondetectable (less than 1 ppm).

VIKANE AND THE ENVIRONMENT

When Vikane is aerated from a structure it rapidly dissipates into the atmosphere because of its high vapor pressure. The relatively small amounts of Vikane released are calculated to have virtually no impact on the global atmosphere and environment. Sulfuryl fluoride is fully oxidized, and thus is not expected to interact or contribute to local ozone formation, such as smog, because of its low reactivity in the atmosphere. The relative contribution of sulfuryl fluoride to acid rain is infinitesimally small compared to the massive amount of sulfur released into the atmosphere from industry. Sulfuryl fluoride contains no chlorine or bromine and thus cannot react to deplete stratospheric ozone by the known mechanisms (Bailey 1992). Sulfuryl fluoride is not listed as a greenhouse gas under the Kyoto Protocol, which is the international treaty regulating greenhouse gases. Recently published information suggests that compared to other sources of greenhouse gases, the potential contribution of sulfuryl fluoride is about one one-hundredth of 1 percent (0.01%) of total contributions to global warming (Papadimitriou et al. 2008).

TOXICOLOGY OF VIKANE

Metabolism

Inhalation is the primary route of exposure to Vikane. Metabolism studies in laboratory animals indicate that sulfuryl fluoride is rapidly hydrolyzed in respiratory tissues to fluorosulfate, with release of fluoride, followed by further hydrolysis to sulfate and release of additional fluoride. This rapid metabolism results in dose-dependent increases in fluoride in the blood, tissues and urine following inhalation exposure to sulfuryl fluoride. On the other hand, parent sulfuryl fluoride is not present in blood, tissues or urine. Sulfate is a normal constituent of the body, is generally regarded as safe and thus is unlikely to contribute to the systemic toxicity of sulfuryl fluoride. Fluorosulfate and fluoride are rapidly eliminated from the plasma and tissues, and excreted in the urine. Fluoride is cleared rapidly from plasma by the kidney as well as through uptake into bone. A comprehensive review of the pharmacokinetics of fluoride is provided by Whitford (1996).

Typical initial fumigation concentrations of Vikane in single-family homes are 1440-3850 ppm, but the concentration must be reduced to 1 ppm or less before humans can enter dwellings without respiratory protection. Pharmacokinetic modeling studies of potential human exposure scenarios at 1 ppm sulfuryl fluoride show that blood levels of fluoride from sulfuryl fluoride will be minimal (Poet et al. 2012). The results show that peak plasma fluoride derived from sulfuryl fluoride will be lower in adults and children re-entering a recently fumigated home than would be expected from drinking water. The predicted fluoride levels in plasma also are lower in workers exposed during a typical work year of fumigating structures than from fluoride exposures from water or several dietary sources of fluoride. Research has shown that daily contact to low levels of fluoride, such as by water fluoridation, reduces tooth decay by about 25% over a person’s lifetime (CDC 2012).

Repeated Exposure Toxicity Studies

Sulfuryl fluoride has been studied extensively in a variety of toxicological studies in laboratory animals, including repeated exposure studies. These studies varied from 2 weeks to 2 years in duration and evaluated sulfuryl fluoride concentrations above those permitted for human exposure (Eisenbrandt and Hotchkiss 2010). The toxicity of sulfuryl fluoride is species, dose and time dependent. Repeated inhalation exposure (6 hr/day, 5 or 7 days/week) of laboratory animals to sulfuryl fluoride results in inflammation of the upper and lower respiratory tissues (portal of entry irritant). Repeated exposure to sulfuryl fluoride at higher concentrations results in target organ effects in the kidney, thyroid and brain. Inhalation exposure to sulfuryl fluoride does not result in developmental effects and does not have effects on reproduction. Lifetime studies in which rats and mice were exposed to sulfuryl fluoride to assess whether or not the chemical has potential to cause cancer also were negative. Therefore, sulfuryl fluoride is not teratogenic or carcinogenic.

Remarkably little difference in effects was observed among the species of laboratory animals in the sulfuryl fluoride repeated exposure toxicological studies (Eisenbrandt and Hotchkiss 2010). The no-observable-effect level (NOEL) for studies that were 2 to 13 weeks in duration (6 hr/day, 5 days/week exposures) were in the range of 30 to 100 ppm sulfuryl fluoride. The NOELs for specialized neurotoxicity studies were the same or higher than the NOELs for general toxicity. Importantly, an acute neurotoxicity study demonstrated that rats exposed for 6 hr/day for 2 days to 100 ppm or 300 ppm did not have signs of neurotoxicity.

Other Routes of Exposure to Vikane® Fumigant

Ingestion is highly unlikely since the material is a gas at temperatures higher than -67°F. Laboratory animals maintained for 66 days on feed directly fumigated at 2 lb/1000 cubic ft (7700 ppm) showed no adverse effects. Typical structural fumigation concentrations are 1 lb/1000 cubic ft (3850 ppm) or less. The gas is not absorbed through the skin in acutely toxic amounts; rats exposed dermally for 4 hours to concentrations of 9599 ppm did not show evidence of toxicity.

Effects of Overexposure

The potential adverse effects of sulfuryl fluoride in humans and laboratory animals exposed to high concentrations are attributed to fluoride toxicity (Schneir et al. 2008; Eisenbrandt and Hotchkiss 2010). Significantly overexposed humans have elevated fluoride levels in blood and urine. The severity of sulfuryl fluoride toxicological effects is dependent on the exposure concentration and exposure duration. In general, the effects of overexposure to high concentrations are central nervous system depression and respiratory irritation followed by pulmonary edema, which is the accumulation of fluids in the lungs and can result in death. Humans exposed to high concentrations of sulfuryl fluoride may expect to experience symptoms similar to drunkenness. Speech and movements may be slowed, and fingers, hands and toes may become numb.

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Table 1: Types of diverse structures and contents fumigated with Vikane® fumigant

Category	Structure (reference citation number)
Ships/Boats	**Full-size replicas of historic tall mast ships – Spirit of Dana Point and Brig Pilgrim**, Ocean Institute, Dana Point, CA (1) **Hokule'a full-scale replica of ancient voyaging canoe**, HI (2) **Full-size replica of La Nina**, Corpus Christi, TX (3)
Large Buildings	**Miami International Airport**, 8 MM ft^3, tape-and-seal, Miami, FL (4) **Fort Homer Hesterly Armory**, 1.9 MM ft^3, tarped, Tampa, FL (5) **Pinellas County Administrative Center**, 10-story, tarped, St. Petersburg, FL (6) **Palm Beach County Convention Center**, 7 MM ft^3, FL (7)
Hotel	**Hotel**, 4.5 MM ft^3, tarped, bed bug treatment, Kona, HI (8)
Multi-unit Dwellings	**The Landings condo**, 3.4 MM ft^3, tarped, Coronado, CA (9) **Historic Dormitory, University of Florida**, Gainesville, FL, 2.1 MM ft^3 , tarped (10) **Mariners Bay**, 9.7 MM ft^3, tarped, Marina Del Ray, CA (11) **NJ Apartment**, tape-and-sealed, bed bug treatment (12)
Churches	**St. Stephen Church**, Oberpindhart, Germany (13) **St. John's Lutheran Church**, Orange, CA (14) **St. Andrew's Episcopal Church**, Saratoga, CA (15) **Historic Mokuaikaua Church**, Kailua-Kona, HI (16)
Historic Buildings and Museums	**Balboa Park Performing Arts Theater**, San Diego, CA (17) **Bishop Museum**, Honolulu, HI (18) **Bonnet House**, Ft. Lauderdale, FL (19) **Boy Scout C. J. Daily Ranch House**, Camarillo, CA (20) **Charles Blucher home**, Corpus Christi, TX (21) **230-year-old Mission San Juan Capistrano**, CA (22) **Flagler Mansion**, Palm Beach, FL (23) **Fowler Museum**, University of California, Los Angeles, CA (17) **1920s Getty house - LA mayor's residence**, Los Angeles, CA (24) **Hearst Castle**, San Simeon, CA (25) **Immigration Station**, Angel Island, CA (26) **Kalaupapa Settlement** [former leper colony], Molokai, HI (27) **Japanese American Museum**, Los Angeles, CA (17) **Japanese screens LA County Museum of Art**, Los Angeles, CA (28) **1909 Masonic Lodge**, Redlands, CA (29) **McGuire Center for Lepidoptera and Biodiversity**, Gainesville, FL (30) **Peterson Automobile Museum**, Los Angeles, CA (17) **Pioneer Village Museum**, Bakersfield, CA (31) **San Bernardino Asistencia**, Redlands, CA (17) **Sante Fe railroad water tower home**, Seal Beach, CA (32) **Santa Monica Pier**, CA (33) **Tuttle Mansion**, Watsonville, CA (34) **Waikiki Shell**, Honolulu, HI (2) **Waipahu Cultural Garden Park**, Inari Shrine, Oahu, HI (35)
Government and Business Buildings	**Cameron Co. Courthouse**, Brownsville, TX (36) **City Hall**, Corona, CA (17) **City Hall**, Santa Monica, CA (17) **Hillsborough Co. Courthouse**, Tampa, FL (37) **1915 Lee Co. Courthouse**, Ft. Myers, FL (38) **Navy Brig Ford Island**, Pearl Harbor, HI (18) **Pacific Navy Command Center**, Pearl Harbor, HI (18) **Schofield Barracks**, HI (18) **Toyota National Headquarters**, Torrance, CA (17)
Medical and Research Facilities	**City of Hope Cancer Center**, Duarte, CA (17) **Valley Community Clinic**, San Fernando Valley, CA (39) **Leigh Hall, Chemistry Building**, University of Florida, Gainesville, FL (30)
University Buildings	**Hamilton Library** – University of Hawaii, HI (18) **Loma Linda University**, Loma Linda, CA (17) **University of Redlands**, Redlands, CA (17) **University of Southern California**, Los Angeles, CA (17) **University of Florida, Historic dormitories**, Gainesville FL (40)
Transportation Vehicles	**Transit Buses**, Houston, TX (41)

MM = million when referring to structure volume in Table 1

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