ProFume® Fumigant (Sulfuryl Fluoride) Technical Bulletin

Australia

Overview

ProFume® fumigant (sulfuryl fluoride) is a broad-spectrum fumigant developed in collaboration with leading researchers in control of insect pests of wood, household items, and stored-products, and pest control professionals worldwide. Fumigation is usually the preferred method of eradication of cryptic pests because ProFume, with its excellent penetration properties, can control pests anywhere they occur within the commodities, household items, and structures. ProFume, because of its unique mode of action, can also be used as a viable rotation tool to manage and help prevent resistance issues with other fumigants and insecticides. Food tolerances have been established for ProFume which enable its use on a wide variety of commodities for global trade and in mills, food processing facilities, warehouses, storage containers, chambers and transportation vehicles.

Noteworthy Features

ProFume is:

- A broad-spectrum fumigant effective on all life stages of insects, other arthropods and rodent pests
- Flexible for use in long- or short-exposure fumigations
- Non-flammable, odourless, colourless gas that rapidly vaporizes and distributes quickly
- Non-corrosive gas for use in sensitive areas having equipment and electronic devices; very low reactivity as a gas and does not react with materials to form unpleasant odours or flavours
- Able to rapidly penetrate porous materials, rapidly aerate from materials and commodities, and has low sorption on fumigated materials
- An inorganic gas that does not leave surface residues on inert surfaces such as stainless steel, glass and ceramic, after fumigation
- Not an ozone depleter and does not interact or cause local ozone formation
- A new mode of action which can be utilized for resistance management strategies

The Sulfuryl Fluoride Story

History

The Dow Chemical Company developed sulfuryl fluoride as a structural fumigant and marketed it as Vikane® gas fumigant since 1961. Vikane has been successfully used to fumigate more than 3 million structures, including homes, museums, cathedrals, historical landmarks, rare-book libraries, and scientific and medical research laboratories to eradicate termites, wood-boring beetles, cockroaches, rodents, bed bugs and other structure-infesting pests.

Postharvest insect pests that infest grains and dried fruits and tree nuts in mills, warehouses and food storage facilities cause substantial economic and quality losses. Postharvest losses due to insects in the United States alone were estimated at $5 billion per year (Pimental 1991). With the adoption of the Montreal Protocol, the search for replacements for methyl bromide began in the early 1990s. Beginning in 1995, Dow AgroSciences formed partnerships with leading stored product researchers, fumigators and food industries around the world to evaluate and develop sulfuryl fluoride as a postharvest fumigant.

Pest Control Studies

Many leading researchers in industry, universities and government laboratories (Thoms and Scheffrahn 1994) conducted research to develop and validate sulfuryl fluoride (Vikane) as an effective structural fumigant for control of household pests. These pests include termites (Osbrink et al. 1987), wood-destroying beetles (Sprenkel and Williams 1988) and bed bugs (Phillips et al. 2014).

Researchers at six world-recognized stored-product research laboratories in the United States (USDA-ARS and Dried Fruit and Tree Nut Association [DFA] in Fresno, California) and Europe (Food and Environmental Research Agency in the UK, Julius Kuehn Institute in Germany, the University of Milan in Italy and Laboratoire National des Denrées Stockées in France) defined the dosages required to control all the life stages of target stored-product insect pests under a range of fumigation conditions (Baltaci et al. 2008, 2009; Baraket et al. 2009; Bell 2006; Bell et al. 1999, 2003; Bell and Savvidou 1999; Ducom et al. 2003; Schneider and Hartsell 1999; Zettler et al. 1999; Zettler and Gill 1999). These studies, conducted in laboratory and field trials, confirmed the effectiveness of ProFume® fumigant on all life stages, including diapausing stages and eggs, of a wide range of post-harvest insect pests, including the important pest species of Coleoptera and Lepidoptera.

Researchers also evaluated the efficacy of commercial applications of ProFume through trapping of in-situ insects and/or control of confined bioassay insects placed in flour mills and food processing plants (Drinkall et al. 2003, Hartzer et al. 2010, Reichmuth et al. 2003, Small 2007, Subramanyam 2006, Suss and Savoldelli 2008, Thoms et al. 2008, Tsai et al. 2006) and in commodities such as dates (Williams and Thoms 2008, Williams 2009) and cocoa beans (Bookout and Milyo 2006). Fumigations were prepared and conducted by commercial applicators. Researchers concluded ProFume is an effective fumigant for disinfestation of structures and commodities.

equipment and protocols approved by the American Association of Cereal Chemists (AACC 2000).

For all quality trials, grain was fumigated with a dosage of ProFume that exceeded the current maximum label dosage by 33%. Fumigation with ProFume did not affect wheat kernel quality, based on test weight; thousand-kernel weight; and moisture, protein, lipid, dietary fibre and thiamine content. Milling quality of fumigated grain, as determined by falling number, was not affected. Properties of dough and baked goods from flour milled from fumigated and non-fumigated red wheat were equivalent. This determination was based on dough peak mixing time, stability (ability of flour to adjust to overmixing and undermixing), and absorption rate of water measured using a farinograph, dough viscosity measured using a viscoanalyzer, and dough tenacity,

High-value commodities (dried fruit, tree nuts and cocoa) as well as grains milled for dough have all been expertly tested for sensory and quality impacts. ProFume showed no impact on these commodities, even when applied at 33% above labeled dosage.

Food Quality

Extensive studies have been conducted to verify fumigation with ProFume does not affect the quality of commodities when compared to the same non-fumigated commodities. These trials were not required for registration but have been important for acceptance of ProFume by the food processing industry.

Grain kernels of three wheat varieties (durum, hard red winter and soft red winter wheat) tested in residue trials were also tested in a battery of quality trials conducted by the Department of Grain Science and Industry, Kansas State University, using state-of-the-art

extensibility, strength and volume as measured using an alveograph. Baking tests showed bread volume, cookie height, and width and spread of dough were not affected by grain fumigation. Properties of dough and spaghetti of semolina flour milled from fumigated and non-fumigated durum wheat were equivalent. This was based on visual and handling characteristics of raw dough and spaghetti, colour of raw and dried spaghetti, cooking time and cooking yield of spaghetti, and tensile strength of cooked spaghetti.

Taste testing trials for high-value commodities (dried fruit, tree nuts and cocoa) were conducted. Single and repeated fumigations were conducted at a dosage of ProFume® fumigant that exceeded the current maximum label dosage by 33% for dried fruits and tree nuts. Walnuts were also vacuum fumigated. Tests were conducted by experts trained in sensory evaluation using two methods of taste testing. No significant differences in taste quality of fumigated and non-fumigated dried fruit and tree nuts were observed in these trials.

For cocoa sensory trials, cocoa beans from Sulawesi and Ivory Coast were fumigated at three dosages. Fumigated and non-fumigated cocoa beans were roasted, cracked, winnowed and milled into liquor for testing. Taste testing was conducted by the nine member companies of the Chocolate Manufacturers Association (CMA, now part of the National Confectioner's Association), using their in-house experts and protocols. The consensus of this testing is that there are no sensory issues with ProFume, and the CMA members approved ProFume as a suitable fumigant.

Food Residues

Research by Meikle (1964) identified the two types of residue found in food commodities that were fumigated with sulfuryl fluoride: the parent sulfuryl fluoride and the degradation products fluoride anion (F-) and sulfate ($SO4^{2-}$). Sulfate as a terminal residue of sulfuryl fluoride is not of any toxicological concern due to its natural abundance in living systems. Research by Meikle and Stewart (1962) and Scheffrahn et al. (1989) investigated these residues in a variety of food commodities. Their research demonstrated that sulfuryl fluoride residues are transient in food commodities and rapidly decrease to very low (ppb) or non-detectable levels. Fluoride and sulfate can form permanent residues in commodities containing proteinaceous material, particularly when fat (oil) is present. In oil alone, there were essentially no detectable residues of fluoride or sulfate.

Extensive residue trials fumigating a wide variety of commodities with the maximum label dosage rates of ProFume® fumigant have been conducted following Good Laboratory Practice (GLP). Representative types for each commodity were selected for the residue trials. For example, three of six classes of wheat milled in the United States (durum, hard red winter and soft red winter wheat) were tested in the GLP residue trials. These classes represent common wheat varieties milled and have a wide range in protein content (available amino functional groups for reaction) that could affect F anion residue formation. In addition to the whole commodity, any processed fractions that would be fumigated were tested. Therefore, processed fractions of cereal grains, such as flour, germ and meal for wheat, were evaluated in the GLP residue trials.

In addition to laboratory residue trials, GLP residue trials were conducted in flour mills and commercial food processing facilities to determine F anion residues in fumigated commodities following processing. Residue data from all trials were used to develop risk assessments for adults and children based on percentage of commodity treated annually with ProFume, contribution of commodity to diet and other factors.

Residue Tolerances

The United States Environmental Protection Agency (EPA) used the residue trials described above to develop residue tolerances for the parent compound, sulfuryl fluoride and F anion in commodities fumigated with

ProFume® fumigant. These residue tolerances are published in the Federal Register: 40 CFR 180.575 for sulfuryl fluoride and 40 CFR 180.145 for fluorine compounds. Other countries/regions where ProFume is registered for application, including Australia, Canada, Mexico and the European Union, have also used the above residue trials to establish residue tolerances for ProFume.

For international trade, maximum residue tolerances (MRLs) for sulfuryl fluoride are established in CODEX for tree nuts, dried fruits, and cereal grains and their processed fractions (Codex Alimentarius/FAO, see: http:// www.fao.org/fao-who-codexalimentarius/standards/pestres/en/). Not all countries use CODEX, such as Japan and the EU, and instead have their own listing of MRLs for sulfuryl fluoride. Since ProFume was first registered in the United States in 2004, a wide variety of commodities fumigated with ProFume have been traded globally. A global MRL database is available through Bryant Christie Inc. (www.globalmrl.com). Global MRL databases may be available through other service providers and regulatory authorities.

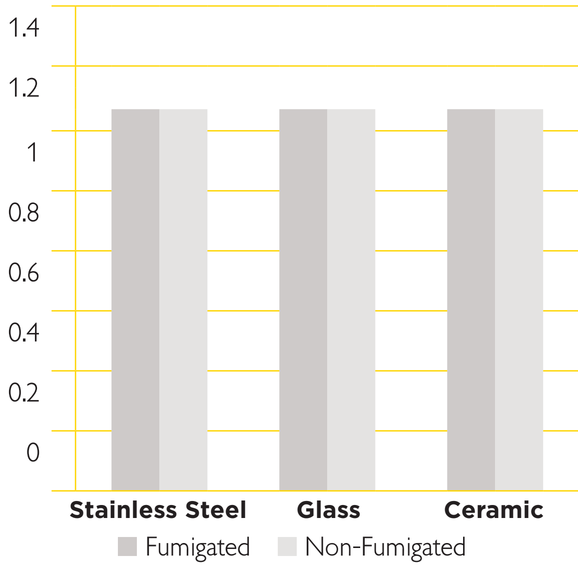
Commodities

In many countries where ProFume is registered, it is labeled for fumigation of a variety of raw agricultural commodities. Depending upon the country, these commodities may include cereal grains (whole kernels and processed fractions) such as wheat (soft red, hard red, durum and white) rice, corn (field and popcorn), barley and oats; dried fruits such as raisins, prunes, figs, apples, apricots and dates; tree nuts such as walnuts, almonds, hazelnuts and pecans; and dried herbs, ginger, cocoa and coffee beans, cottonseed, dried legumes, ham, cheese and peanuts. Seeds of commodities can also be fumigated with ProFume. A complete listing of commodities can be found on the labeling for the country in which ProFume is registered.

Lack of Reactivity with Inert Materials

ProFume does not react with commodity packaging or building components and contents, including computers, electronics and manufacturing equipment. Testing of computers conducted at 122ºF (50ºC) and up to tenfold the maximum permissible label dosage of ProFume (15,000 oz-h/1000 ft^3 [= $g\text{-}h/m^3$]) showed no adverse effects during fumigation (Bell et al. 2003). Additional testing was conducted with copper tubing exposed to threefold the maximum label dosage at temperatures up to 104ºF (40ºC) and relative humidity up to 70%. The copper tubing showed no discoloration immediately after fumigation and for the two month observation period following fumigation (Bell et al. 2003).

The chemical properties of sulfuryl fluoride do not result in fluoride deposition on inert surfaces. Research conducted by DFA showed no detectable increase in fluoride residues on stainless steel, glass and ceramic surfaces following fumigation with ProFume at the maximum label dosage at 95ºF (35ºC) for 24 hours (Nead-Nylander and Thoms 2013).



Stewardship

Douglas Products has a rigorous stewardship policy for all its sulfuryl fluoride products. Fumigators using ProFume® fumigant are required to participate in training programs, adhere to a written stewardship policy and allow Douglas Products or a distributor representative for ProFume® fumigant to observe their initial ProFume fumigation.

Registration

The first registration received for ProFume was in Switzerland in 2003. ProFume was first registered in the United States in 2004. As of 2017, ProFume is registered in 21 countries, including Australia, Canada, Mexico and many countries in Europe. Douglas Products continues to work on registering ProFume for use in additional countries.

Targeted Pests

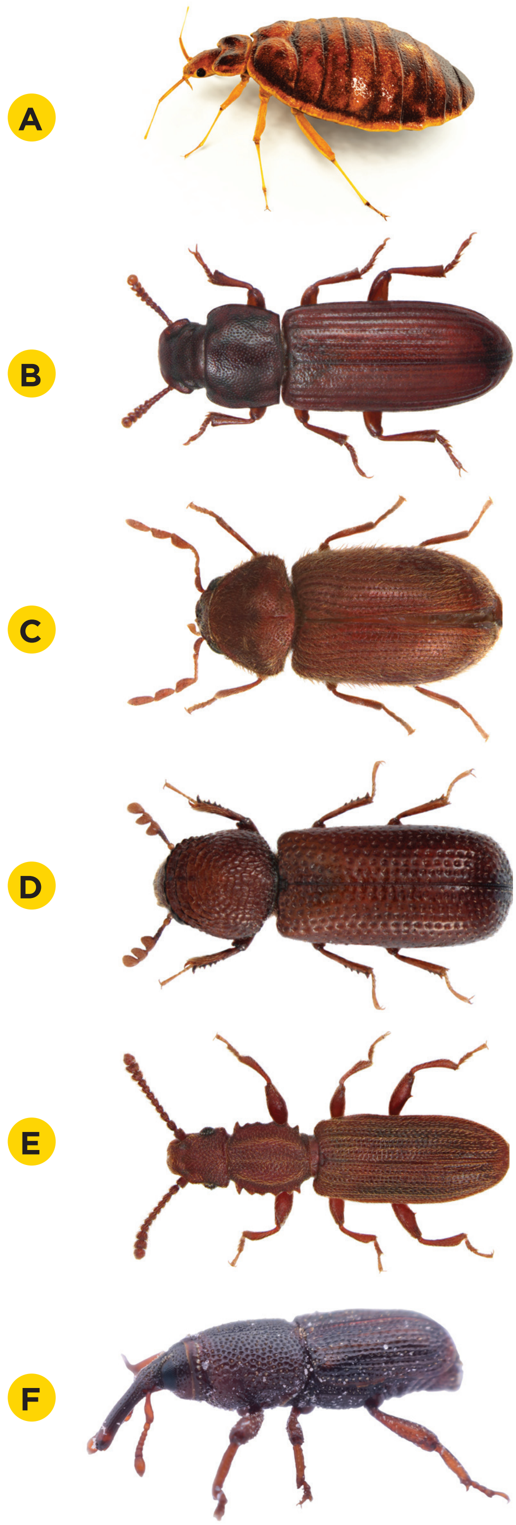
PESTS

Existing infestations of insects such as borers, bedbugs, cockroaches, clothes moths, carpet beetles and drywood termites.

All life stages of stored product pests including:

- Confused flour beetle (*Tribolium confusum*)
- Dried fruit moth (*Ephestia cautella*)
- Drugstore beetle (*Stegobium paniceum*)
- Grain weevil (*Sitophilius granarius*)
- Hide beetle (*Dermestes maculatus*)
- Indian meal moth (*Plodia interpunctella*)
- Lesser grain borer (*Rhyzopertha dominica*)
- Mediterranean flour moth (*Ephestia kuehniella*)
- Rice weevil (*Sitophilius oryzae*)
- Rust red grain beetle (*Cryptolestes ferrugineus*)
- Red flour beetle (*Tribolium castaneum*)
- Saw-toothed grain beetle (*Oryzaephilus surinamensis*)
- Tobacco beetle (*Lasioderma serricorne*)
- Warehouse beetle (*Trogoderma variabile*)

Note: Not all seed varieties have been tested for viability following fumigation. Refer to Douglas Products for specific advice (Customer@DouglasProducts.com).



A – Bedbug; **B** – Confused flour beetle; **C** – Drugstore beetle; **D** – Lesser grain borer; **E** – Saw-toothed grain beetle; **F** – Rice weevil

Dosage

Fumigation dosage is measured as a product of both concentration (C) and exposure time (T) per unit area (C x T). Because of variables in structures, the environment, pest species to be controlled and other fumigation factors, each fumigation is different, and therefore the amount of ProFume® fumigant needed per unit area is variable. The Fumiguide™ program and calculator dosages are based on input of a wide range of fumigation variables. The data used to produce the Fumiguide are the result of 10 years of research by six stored-product research laboratories in the United States and Europe (see **"Pest Control Studies"** on page 3) and nearly 1,200 bioassays of the key stored product insects evaluated during 51 commercial fumigations.

Precision Fumigation™

Precision Fumigation™ tools and techniques have been researched, developed and promoted for ProFume. Precision Fumigation can be defined as optimizing fumigant use to maximize efficiency and minimize risk. Precision Fumigation is achieved by integrating all the factors affecting control, such as pest biology, temperature, exposure time and improved sealing techniques into the fumigation management plan.

Mode of Action

Once sulfuryl fluoride enters an insect or other arthropod through the spiracles in postembryonic life stages, or diffusion through openings in the egg shell, the compound is broken down to the insecticidally active fluoride anion. The fluoride anion disrupts the glycolysis and fatty acid cycles, depriving the insect of necessary cellular energy. Insecticidal activity results from fluoride inhibition of enzyme systems utilizing magnesium within the glycolysis (Meikle et al. 1963). After inhibition of glycolysis and the citric acid cycle, insects attempt to utilize protein and amino acids to maintain a viable energy level. However, these alternative energy-producing processes are insufficient to maintain a proper metabolic rate for survival.

Resistance Management

Laboratory trials (Jagadeesan et al. 2015, Jagadeesan and Nayak 2017, Nayak et al. 2016) and field trials in bulk grain storages (Nayak et al. 2016, Opit et al. 2016) have verified that label dosage rates of ProFume provide effective control of all life stages of key phosphine-resistant insect pests, including the lesser grain borer (*R. dominica*), red flour beetle (*T. castaneum*), rice weevil, (*S. oryzae*) and rusty grain beetle (*C. ferrugineus*). These trials verified no cross-resistance between phosphine and sulfuryl fluoride.

Modelling studies conducted for Indian meal moth (*P. interpunctella*) and red flour beetle (*T. castaneum*) indicated that there is a very low probability for resistance development because of high rates of insect immigration, low selection pressure, no known cross-resistance and overlapping generations (Prabhakaran et al. 2001).

Due to its efficacy for controlling phosphine-resistant insect pests, ProFume is used as a rotational treatment to prevent/ delay development of insecticide resistance or as a tool to control phosphine-resistant insect populations.

Description of Chemistry

ACTIVE SUBSTANCE NAME	
IUPAC Name	sulfuryl fluoride
CAS Name	sulfuryl fluoride
CAS Registry Name	2699-79-8
Common Name	Sulfuryl fluoride, sulphuryl fluoride
Structure and Empirical Formula	SO2F2

Thermal Degradation

In the presence of extremely high temperatures exceeding 752°F (400°C), 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 fumigation, all open flames and glowing heat filaments are turned off or disconnected within the fumigated space.

Mammalian Toxicity

Introduction: Sulfuryl fluoride is an odourless, colourless gas and at low concentrations, nonirritating to mucous membranes and gives no warning of its presence. ProFume® fumigant is toxic and must be handled carefully in regard to the potential hazards it presents. Therefore, ProFume is labelled for use only by certified fumigators who are trained in proper fumigation techniques as part of the Douglas Products stewardship program.

The toxicology of sulfuryl fluoride has been extensively studied; a review of this research is summarized by Eisenbrandt and Hotchkiss (2010). Governmental fluoride standards have been set after extensive review of toxicological, medical and epidemiological data that included consideration of women and children. Reviews were completed by the World Health Organization (WHO) in 1984; the U.S. Public Health Service, Department of Health and Human Services in 1991 and 2015; and the National Research Council in 1993 and 2006.

Metabolism: Inhalation is the primary route of exposure to ProFume. 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).

Acute Toxicity: Oral ingestion of sulfuryl fluoride is unlikely because of its physical properties. Sulfuryl fluoride is not toxic dermally; the gas is not absorbed through the skin in acutely toxic amounts. Rats exposed dermally for four hours to concentrations of 9599 ppm did not show evidence of toxicity. The main route of exposure is through inhalation. Like other fumigants, sulfuryl fluoride can cause adverse effects after acute inhalation exposure, depending on the exposure concentration and duration. A summary of acute toxicology data is provided below:

STUDY TYPE	ANIMAL	SEX	RESULTS
Acute Oral	Rat and Guinea Pig	n/a	LD_{50} 100 mg/kg
Acute Dermal	Rat, F-344	Male and Female	4-Hr LC_{50} 1122 ppm males 4-Hr LC_{50} 991 ppm females
Acute Inhalation	Rat, F-344	Male and Female	1-Hr LC_{50} 3730 ppm males 4-Hr LC_{50} 3021 ppm females
Acute Inhalation	Mice, B6C3F1	Male and Female	4-Hr LC_{50} 400-600 ppm
Acute Inhalation	Mice, CD1	Male and Female	4-Hr LC_{50} 400-600 ppm

Sub-chronic Toxicity Studies: A summary of sub chronic toxicology data is provided below:

STUDY TYPE	ANIMAL	SEX	NOEL
Dietary Study	Rat	Male and Female	19 ppm
13 wk Inhalation	Rat, F-344	Male and Female	30 ppm
13 wk Inhalation	Rabbit, NZW	Male and Female	30 ppm
13 wk Inhalation	Mice, CD-1	Male and Female	30 ppm
13 wk Inhalation	Dog, Beagles	Male and Female	100 ppm

Chronic Toxicity and 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 two weeks to two 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 (six hours/day, five or seven 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 if 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 levels (NOELs) for studies that were two to 13 weeks in duration (six hours/day, five 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 six hours a day for two days to 100 ppm or 300 ppm did not have signs of neurotoxicity.

Ecotoxicology and Environmental Fate

Ecotoxicology

Because ProFume® fumigant is a gas and applied in closed spaces, the likelihood of exposure to nontarget terrestrial and aquatic wildlife species is low. Ecotoxicology studies required for labeling and classification purposes have been conducted, and summaries of data are below:

STUDY TYPE	SPECIES AND STRAIN	VALUE
Acute Toxicity	Rainbow Trout	96h LC_{50} 0.89 mg/L
Acute Toxicity	*Daphnia Magna*	48h EC_{50} 0.62 mg/L
Algal Growth Inhibition	*Selenastrum capricornutum*	72h EC^{50} 0.59 mg/L

Environmental Fate

Dow AgroSciences was awarded the Stratospheric Ozone Protection Award by the EPA in 2002 for the development of ProFume® fumigant, and both the United Nations Montreal Protocol Innovators Award and the EPA's "Best of the Best" Ozone Protection Award in 2007. These awards were given to recognize the innovation required to develop ProFume for global use to protect the stratospheric ozone layer.

Fate in Air: When ProFume is aerated from a structure or commodity, it rapidly dissipates into the atmosphere because of its high vapor pressure. The relatively small amounts of ProFume 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. Sulfuryl fluoride is broken down mainly through hydrolysis to release fluoride and sulfate. The relative contribution of sulfuryl fluoride to acid rain is infinitesimally small compared to the massive amount of sulphur 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, and more recent climate agreements such as the Paris Agreement. Compared to greenhouse gases, such as carbon dioxide, methane and nitrous oxide, listed in the Kyoto Protocol and other climate agreements, the amount of sulfuryl fluoride emitted into the atmosphere is extremely small. Based on published estimates of the global warming potential of sulfuryl fluoride (Papadimitriou et al. 2008, Carpenter et al. 2014, Rigby et al. 2014), the current and projected annual emissions of sulfuryl fluoride would be equivalent to only about 0.05% of the total anthropogenic global carbon dioxide emission. During their evaluation of sulfuryl fluoride in 2008 and 2009, European authorities concluded that emissions of sulfuryl fluoride represented a negligible share of global greenhouse gas emissions. As part of its stewardship program, Douglas Products supports efforts for ongoing monitoring of trace atmospheric levels of sulfuryl fluoride through the Advanced Global Atmospheric Gases Experiment (AGAGE) project. Monitoring results from AGAGE continues to confirm the extremely low atmospheric levels and negligible contributions of sulfuryl fluoride as a potential greenhouse gas.

The relatively small amounts of ProFume released are calculated to have virtually no impact on the global atmosphere and environment.

Fate in Soil: Predictive models using the physical properties of sulfuryl fluoride estimate that less than 0.1% of sulfuryl fluoride will be found in the soil at equilibrium. This is due to the high vapor pressure, which results in rapid dissipation into the atmosphere.

Fate in Water: Sulfuryl fluoride quickly hydrolyses in water to form fluorosulfate and fluoride. Degradation rates increase with increases in aqueous pH. The half-life for sulfuryl fluoride in water with pH of 5.9, 8.1 and 9.2 is three days, 18 minutes and 1.8 minutes, respectively.

Worker Exposure

ProFume® fumigant is labelled for use only by trained fumigators certified/licensed by their state or national regulatory authority because of the risk of adverse effects from possible acute exposure to the gas. The risk of any adverse effects depends upon the concentration of gas and/or the time a person may be exposed. Consequently, regulators in various countries have established Exposure Standards or Limits that guide safety. In some countries, they are known as Permissible Exposure Limits (PELs). Many countries use the Time Weighted Average (TWA – an exposure concentration that should not be exceeded over a period of time such as an eight-hour working day or a full 24 hour day) and the Short-Term Exposure Limit (STEL – an exposure concentration that should not be exceeded over a 15 minute period in any working day). PELs are highly protective of workers as they represent exposures that have absolutely no adverse effects.

Every country regulatory agency reviews and interprets the data from toxicological studies independently. As a result, the PEL for different countries varies. However, all represent a high standard of safety for use of the product.

Examples are given below:

- *Australia: The Australian Pesticide and Veterinary Medicines Authority (AVPMA) established a Re-Entry or Clearance Limit of 3 ppm specifically for fumigators, while Worksafe Australia set a TWA of 5 ppm and a STEL of 10 ppm as general Exposure Standards.*
- *Canada: The Pest Management Regulatory Agency (PMRA) established a 1 ppm PEL for workers.*
- *Europe: The European Food Safety Authority (EFSA) established a 3 ppm PEL for workers, which is followed in labeling for European countries where ProFume is registered for application, with the exception of France (1 ppm for biocidal use and 2 ppm for phytosanitary use).*
- *United States: Both the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) and Occupational Safety and Health Administration (OSHA) PEL are 5 ppm for workers. The EPA PEL for fumigation workers, specifically, is 1 ppm.*

A positive-pressure self-contained breathing apparatus (SCBA) is necessary when entering areas being fumigated where the concentration is unknown or is greater than the PEL or Re-Entry Level (1 to 3 ppm, depending upon country) as measured by a detection device with sufficient sensitivity. Country regulations may specify that a fumigator wear an SCBA when conducting specific fumigation tasks, such as during application of ProFume.

Pharmacokinetic modelling 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 structure than would be expected from fluoridated 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.

Eye protection requires wearing goggles or full-face shield during fumigant introduction. No special skin protection is required. Skin contact with the liquid may cause freeze damage where the liquid is confined to the skin.

Formulations: ProFume is packaged in steel cylinders as a liquid under pressure, containing 99.8% sulfuryl fluoride (125 pounds/57 kg per cylinder) with no other pesticides, solvents or additives.

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