CASE REPORT

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Suicide by Exposure to Sulfuryl Fluoride

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ABSTRACT: The insecticide fumigant, sulfuryl fluoride, was used as an instrument of self destruction in at least two of the three fatal exposures detailed in this report. The autopsy findings, while nonspecific, have a confirmatory value. Toxicologic analysis should include a plasma and a urine fluoride level, since the toxic effects of exposure are probably related to this ion. Concentrations of fluoride in our cases were: 50.42 mg/L (Case 1) and 20 mg/L (Case 3). However, the values must be interpreted in light of all known information as a result of the paucity of reported cases of fatal sulfuryl fluoride exposures. The cases described provide a model for the investigation of tent fumigation deaths. Proper investigation of fumigant deaths requires knowledge of the insecticide, the fumigation procedure, and the implementation of warning devices. Guidelines are offered along with a procedural checklist for the investigation of tent fumigation deaths.

KEYWORDS: pathology and biology, sulfuryl fluoride, suicide

Tent fumigation of buildings is one method of insect extermination utilized in various parts of the United States, including Florida. Sulfuryl fluoride (Vikane®—Dow Chemical Company) is currently a popular tent fumigant with potentially lethal ramifications for humans. Three fatal cases of sulfuryl fluoride poisoning are described along with recommendations for investigating fumigation deaths.

Materials and Methods

The recent investigation of a fatal case of sulfuryl fluoride exposure by this office prompted a search for similar cases. No other cases were found in the records of the Dade County (Florida) Medical Examiner's Office. A search of the literature disclosed only one other death as a result of sulfuryl fluoride exposure, which was reported by Hayes in 1976. However, details were sketchy and fluoride levels were not reported. Telephone interviews with the manufacturer of sulfuryl fluoride revealed they knew of two cases. Details of one incident were obtained from the Broward County (Florida) Medical Examiner's Office (Case 2 of this report). The manufacturer provided the information about the second incident (Case 3 of this report).

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In Case 1, the urine was tested for drugs utilizing both an enzyme multiple immunoassay technique (Emit)® and a colorimetric spot test. The blood fluoride concentration was determined by a modification of the Sunshine and Finkle procedure [*1*].

Case 1

A 29-year-old white male was found dead in his apartment. The previous day, the apartment complex was tented for fumigation and charged with 22.5 kg (50 lbs) of sulfuryl fluoride, the procedure being completed by noon. About 6 h later, the decedent checked out of a nearby hotel (where he had been temporarily lodged with other tenants by his landlord) and he reentered the tented structure by removing several seam clamps adjacent to a warning sign. Entry into the apartment was gained through the front door, which also had a posted warning sign.

When found at approximately 10 a.m. the following morning, the apartment windows were closed, a circulating fan was turned off, and the air-conditioner was running. He was supine on the living room floor in front of a television, clad only in a T-shirt and covered by a lightweight cloth blanket. Drying, bloody froth was in both nares and mouth. His socks and shoes were arranged neatly beside a nearby opened sofa bed. The bedspread had a large fecal stain.

Background information included a history of depression, ethanol abuse, and heroin addiction. He had previously attempted suicide by inhaling natural gas. The day before the tent fumigation, he had questioned the exterminator concerning the lethality of the agent. He was warned, in the presence of the apartment manager, that the chemical was extremely deadly.

A postmortem examination revealed the serosal surfaces and conjunctivae were free of petechiae. The mucosa of the larynx, trachea, and bronchi were congested and covered with pink-tinged froth. The 850-g right lung and 720-g left lung were intensely congested and edematous. A urine drug screen was positive for benzodiazepines and propoxyphene. The blood contained 1.2 mg/L of propoxyphene, 8.7 mg/L of norpropoxyphene, 2.9 mg/L of diazepam, 2.1 mg/L of nordiazepam, and a fluoride concentration of 50.42 mg/L (obtained 24 to 36 h postmortem). No alcohol was detected.

The cause of death was reported as inhalation of sulfuryl fluoride and the manner of death was certified as suicide.

Case 2

A 22-year-old white male was found dead next to an open sulfuryl fluoride gas container in the warehouse of the pest control company where he was employed. The safety cap was off and the tank, which normally holds 31.5 kg (70 lbs) of material, was empty. He had been a driver for the company and had access to the keys of the warehouse which was normally locked. He was allegedly a homosexual. No history of despondency could be elicited. No suicide note was found at the scene.

The postmortem examination revealed blood-tinged froth covered the mouth. Fecal matter surrounded the anus. The viscera were congested and petechiae dotted the serosa. The brain was edematous. The respiratory mucosa was congested, as were the lungs. Blood or urine fluoride levels were not obtained. The cause of death was reported as sulfuryl fluoride poisoning and the manner of death as suicide.

Case 3

A 19-year-old Arabic female died approximately 12 h after exposure to sulfuryl fluoride which was being used to fumigate her residence. Investigation revealed she was enrolled in a

language school and lived with an American female to practice her English. The owner of the residence read and signed an instruction/warning sheet from the exterminator company. This indicated when the residence was to be vacated, how the residence should be prepared, and that reentry would not be allowed until the day following the fumigation. The instructions, reportedly, were read and explained to the decedent in English and Arabic. She was reminded of the instructions several times during the week before the fumigation. On the afternoon of the fumigation, she nonetheless entered the house to collect some personal items. She was subsequently found unconscious by friends and removed by firemen.

The friends who found her related they were unaware of any warning signs on the residence. The responding firemen did notice a warning sign on the front of the residence, but thought it referred to another tented structure and entered the building without using oxygen apparatus. The adjacent portion of the duplex was sealed around the door with masking tape. Masking tape was also found on a porch railing in front of the decedent's half of the duplex.

Upon arrival at the hospital, the victim was alert, responsive, coughing, and complaining of chest discomfort. Scattered rales were in the anterior and posterior portions of the chest. She became hypotensive shortly after arriving in the emergency department. Approximately 6 h after exposure, she became hyperexcitable, hyperventilated, and developed a supraventricular tachycardia. A few hours later, she developed a productive cough and began drooling. Her condition worsened with the development of severe pulmonary edema, carpal/pedal tetany, cardiac dysrhythmias, and death.

The only significant autopsy findings were marked pulmonary edema with congestion, and petechiae of the visceral pleurae. The antemortem serum fluoride concentration was 20 mg/L (no postmortem concentration was reported).

Discussion

Sulfuryl fluoride (SO_2F_2), also known as sulfuric oxyfluoride, was first introduced in 1957 and has been widely used as a fumigant over the past 10 to 15 years. It is a colorless, odorless nonflammable compound with a boiling point of $-52°C$ and a molecular weight of 102.07. [*2–4*]. Sulfuryl fluoride is shipped and stored as a compressed gas. It is nonirritating but, when heated, gives off toxic and corrosive fumes such as hydrofluoric acid [*2,5*].

An understanding of acute exposure in humans is primarily based on animal experiments because of the scarcity of human case reports. In animals, high-dose exposure results in rapid incapacitation, seizures, and death as a result of respiratory arrest with or without *status epilepticus*. Animals exposed to low doses of sulfuryl fluoride first have parasympathetic stimulation with vomiting, diarrhea, lacrimation, salivation, and abdominal colic. This is followed by cardiovascular collapse and pulmonary edema. Necropsy reveals visceral congestion, cardiac (atrial) dilatation, and overdistension of pulmonary alveoli. At higher levels of sulfuryl fluoride exposure, the animals also have focal pulmonary hemorrhages. Similar to the low-dose experimental animals, our cases had visceral congestion and pulmonary edema upon gross and microscopic examination. Two had fecal soiling suggestive of parasympathetic stimulation. These effects are theorized to be secondary to the release of free fluoride ion [*6*] which binds calcium, thus leading to tetany, seizures, and cardiac rhythm disturbances. Similar inactivation of potassium and magnesium ions may also aggravate these physiological derangements [*7*]. In high concentrations, sulfuryl fluoride may have narcotic properties [*5*]. Also, it is a direct cellular poison which may lead to cardiovascular collapse by interferring with vascular and neuromuscular tone [*6*].

Fluoride may be found in every tissue of the body, but is concentrated in bone, teeth, blood, thyroid, and kidney. It is primarily eliminated from the body by urinary excretion [*6*]. Fluoride is most easily measured in the urine with a specific ion electrode and techniques (pH/mV meter) as used in testing drinking water [*8,9*]. Blood or plasma fluoride levels may

be more helpful in cases of acute intoxication or where death intervenes before significant amounts appear in the urine. The serum or plasma fluoride concentration is determined by a modification of the method described by Sunshine and Finkle [*1*] which utilizes a Conway diffusion cell and spectrophotometrically measures the fluoride as a sodium salt. Currently, insufficient data does not permit a valid opinion as to what constitutes a fatal fluoride concentration in any tissue. One source, however, gives the lethal concentration in the blood as greater than 3 mg/L [*6*], and another as up to 3 mg/L [1]. Blood fluoride concentrations were 50.42 mg/L (24 to 36 h postmortem), and 20 mg/L (antemortem) in Cases 1 and 3 respectively (and not measured in Case 2).

Tent fumigation consists of enclosing the structure to be treated in heavy-gauge opaque plastic. These are supplied as red or orange sheets which are held together with metal clips. The bottom is sealed against the ground with sandbags. All food in the building must be sealed in plastic to prevent contamination, and household plants must be removed. Windows are left open, and fans for circulating the agent are placed in each apartment or scattered throughout the structure. Air-conditioners are turned off. Warning signs are required on the doors beneath the tent and are spaced along the outside of the tent as well. Plastic hoses allow for placing the fumigant and for periodic testing of fumigant levels in the structure. Before filling the tent with pesticide, attempts are made to warn anyone possibly remaining in the building of the impending danger. The building is inspected, verbal warnings are given, and a chemical warning agent (usually chloropicrin, "tear gas") is released into the tent. Lastly, the tent is charged or filled with an appropriate weight of gas (usually 0.675 kg [1½ lbs] per 30 m^3 [1000 ft^3]) calculated to treat the volume of the structure to a peak of 16 to 24 ppm. This basic procedure is modified to treat single or multistory buildings, ships, and aircraft.

Understanding the fumigation procedure allows the formulation of pertinent questions when investigating toxic exposures (Table 1). Basic information includes when the structure was tented, the time the agent was introduced, and how much was used. It it necessary to find exactly where and how entry into the tented structure was accomplished, and this should be photographically documented. All warning devices and procedures should be ascertained and documented. The scene evaluation should determine the number, locations, and language(s) of the warning signs. Fumigation employees should be interviewed to establish which procedures were used. Inspection records concerning the times of measuring the concentrations in the structure should be collected. The completed scene investigation

TABLE 1—*Tent fumigation scene checklist.*

1. Agent used (trade and generic names)
2. Name/address of fumigation company
3. Name of supervisor at site for:
   a. Tent erection
   b. Fumigant charging
   c. Inspector monitoring gas concentration
   d. Tent removal
4. Other witnesses
5. Date/time tenting complete
6. Name/manufacturer of fumigant chemical
7. Time agent introduced
8. Amount of agent introduced
9. Warning devices/procedures used
   a. Verbal
   b. Written/posted
   c. Chemical
10. Where/how tent entry was accomplished
11. Date/time of incident discovery

should allow an understanding as to how, and perhaps why, the exposure occurred. This should lead to further improvement in the system to prevent additional exposures to this toxin.

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