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PRACTICE/CASE HISTORY

Acute Illness Associated with Exposure to a New Soil Fumigant Containing Dimethyl Disulfide—Hillsborough County, Florida, 2014

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ABSTRACT

Dimethyl disulfide (DMDS) is a new soil fumigant that is considered a replacement for methyl bromide. In 2014, the Florida Department of Health (FDOH) received several complaints of illness following a strong DMDS odor in Hillsborough County. Public health investigation of DMDS-related illness was conducted to assess illness and identify areas to target for prevention activities. This investigation included surveillance, interviews, review of medical records, review of supporting documentation, and determination of pesticide-related illness and injury case status. FDOH interviewed 66 people complaining of illness related to DMDS. Thirty-two were classified as possible and 11 as suspicious cases of DMDS-related illness. Among cases, the mean age was 48 years (range: 3–71 years). The majority were non-Hispanic (n = 43, 100%), white (n = 40, 93%), and female (n = 23, 53.5%). The most common signs and symptoms reported by exposed people included eye pain, throat irritation, nausea, dizziness, headache, and fatigue. There were 88% of cases classified as having low severity of illness and 12% classified as having moderate severity. The average distance from an application site among individuals who reported being exposed at or near their home was 0.74 miles for those classified as cases (n = 36) and 2.84 miles for those not classified as cases (n = 21, P < .05). This is the first known comprehensive report of DMDS-related illness in humans. Even though illnesses associated with DMDS in this investigation were generally of low severity, it is important to identify better ways to prevent off-target movement of DMDS and to improve notification to communities when nearby DMDS applications are planned.

KEYWORDS

Acute poisonings; dimethyl disulfide; Paladin; pesticides; soil fumigant; surveillance

Introduction

Dimethyl disulfide (DMDS) is a relatively new soil fumigant that is considered a replacement for methyl bromide, the highly toxic fumigant that the US Environmental Protection Agency (EPA) has proposed phasing out.[1] DMDS is a pale yellow liquid with vapor pressure of 29 mm Hg at 25°C and water solubility of 1–10 g/L at 20°C.[2] It is used to control preemergent weeds, soil-borne plant pathogens, and nematodes in soils used to grow vegetables (tomatoes, peppers, eggplants), cucurbit crops (cucumber, squash, and melons), strawberries, blueberries, field-grown ornamentals, and forest nursery stock.[3] It is also approved as a food additive in the United States[4] and is used in oil refineries as a sulfiding agent.[5] DMDS has a sulfurous or garlic-like odor similar to sulfur compounds added to gas and propane products to warn people of a leak. DMDS soil fumigant is either injected beneath the soil surface with specialized application equipment or applied to the soil surface through a drip irrigation line. All treated areas must be covered with a plastic tarp to retain the fumigant in the soil to improve efficacy and minimize odor. The duration that the tarps are kept in place can vary from 12 to 21 days. Buffer zone distances for DMDS range from 25 to 690 feet, depending on application rate, application method, and acres treated. Additionally, DMDS cannot be applied within at least ⅛ mile (and up to ¼ mile for certain injection applications with higher application rates and acres treated) of difficult-to-evacuate sites (e.g., nursing homes, hospitals, licensed schools, licensed day care facilities, licensed assisted living facilities, and prisons) that will be occupied during the application and the 36 hours after the

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application is complete.[3] Exposure to the odor of DMDS may result in nausea, headache, or dizziness in individuals. DMDS products generally have a low to moderate toxicity.[3] DMDS may also cause irritation of the upper respiratory tract, eyes, and skin. Upper respiratory tract irritation may result in sneezing, coughing, sore throat, dyspnea, chest tightness, and a feeling of suffocation. DMDS has not been shown to cause allergic sensitization, birth defects, reproductive toxicity, or mutagenicity.[3,6] There is no laboratory test available to determine DMDS levels in biological samples (e.g., blood and urine). Poisonings are treated symptomatically and with supportive care. DMDS does not persist or accumulate in the air, water, or soil. DMDS evaporates readily from soil and water. When released into the atmosphere, DMDS degrades rapidly with a half-life of about 1 hour. In surface water and in the presence of sunlight, the half-life of DMDS is 1.3 days.[7]

Two products containing DMDS are registered for use in 26 states, including Florida. These products are Paladin (Arkema, Inc., King of Prussia, PA; EPA registration number 55050-4; EPA toxicity category II; active ingredient = 98.8% DMDS) and Paladin EC (Arkema, Inc.; EPA registration number 55050-5; EPA toxicity category II; active ingredient = 93.8% DMDS). The toxicity of a pesticide is determined by EPA under guidance available from the Code of Federal Regulations 40 CFR 156.208(c)(1). Pesticides in category I are the most acutely toxic, and pesticides in category IV are the least. Chloropicrin, another fumigant, is applied frequently with DMDS. The product name is ASHTA Gold (ASHTA Chemicals, Ashtabula, OH; EPA registration number 62531-2; EPA toxicity category I; active ingredient = 99% chloropicrin).

After gaining approval for use in Florida in 2011, small amounts of DMDS were applied to farmland in 2012, and widespread use of DMDS commenced in 2013. In Hillsborough County, DMDS applications generally occur in the months of August and September. In August and September 2014, the Florida Department of Health (FDOH) received several complaints of illness following reports of a strong chemical odor in Hillsborough County. The odor was later confirmed to be associated with DMDS. This report summarizes FDOH's investigation of these complaints.

Methods

Public health investigation for DMDS-related illness included surveillance, interviews, review of medical records, review of supporting documentation (e.g., partner agency investigation reports), and determination of pesticide-related illness and injury case status. FDOH received reports of potential pesticide-related illness directly from affected people, the Florida Poison Information Center Network, the Florida Department of Agriculture and Consumer Services (FDACS), and the Environmental Protection Commission of Hillsborough County. Many reports were received after a community meeting to address DMDS concerns held in Hillsborough County on September 22, 2014. Investigators collected information on demographic characteristics of people reporting illness, pesticide exposure scenario, site of exposure, signs and symptoms, medical care sought, illness severity, and work-relatedness. In December 2014, FDOH staff visited clinics and farmworker communities in the area surrounding where the complaints originated to identify any farmworkers who may have experienced illness from the DMDS applications.

Medical records were requested for all people who reported seeking medical care. FDACS investigation reports were reviewed for information about the pesticides used, dates and locations of DMDS application, violations of pesticide use, and environmental sampling.

Case definition

FDOH has adopted guidelines from the National Institute of Occupational Safety and Health's (NIOSH) Sentinel Event Notification System for Occupational Risk (SENSOR)—Pesticides program to classify cases.[8] A brief description of the case classification can be found in Table 1. All interviewed individuals were classified based on information regarding their exposure, health effects, and the causal relationship between reported symptoms and the specific pesticide exposure. Possible cases are based on subjective data about exposure and illnesses, and a suspicious case classification was assigned when there was not enough toxicological information available to determine

Table 1. Case classification matrix for pesticide-related illness and injury following DMDS applications.

	Classification category				
Classification criterion*	Confirmed	Probable		Possible	Suspicious
Exposure[a]	1	1	2	2	1 or 2
Health effects[b]	1	2	1	2	1 or 2
Causal relationship[c]	1	1	1	1	2

Note. Other classification categories:

Unlikely: Evidence of exposure–health effect relationship is not present or a temporal relationship does not exist.

Insufficient information available: Insufficient data available about the exposure or the health effects (e.g., having only one new postexposure abnormal sign/symptom).

Unrelated: Illness determined to be unrelated to DMDS exposure based on no history of DMDS exposure or evidence of nonpesticide causal agent.

*Cases are placed in a classification category based on scores received on available evidence for exposure, health effects, and causal relationship.

[a]Scores relating to criteria for exposure: 1 = clinical, laboratory, or environmental evidence for exposure; 2 = evidence of exposure based solely on written or oral report.

[b]Scores relating to criteria for health effects: 1 = two or more new postexposure signs or laboratory findings reported by a licensed health care professional; 2 = two or more postexposure symptoms reported by the patient.

[c]Scores relating to criteria for a causal relationship: 1 = the observed health effects are consistent with known toxicology of DMDS; 2 = insufficient toxicological information available to determine if there is a causal relationship between DMDS and the health effects.

the causal relationship between DMDS exposure and the reported illness(es) (e.g., when an illness has been shown to be associated with other sulfur products, but not shown to be associated with DMDS). Confirmed and probable categories require objective verification and solid toxicological support and for no cases were these two criteria present together.

Severity of illness was also determined by using SENSOR guidelines and was based on the reported symptoms, number of days hospitalized, and the number of days absent from work or normal activities.[9] Severity of illness was categorized as low severity, moderate severity, high severity, or death. Low-severity cases usually resolve without treatment and cause minimal time lost from work (<3 days). Moderate-severity cases require medical treatment but are not life-threatening and result in <6 days lost from work or normal activities. High-severity cases are considered life-threatening and commonly require hospitalization for >3 days or result in ≥6 days lost from work or from normal activities.

Data analysis

Information obtained from interviews and medical records were entered into Florida's reportable disease surveillance database, classified, and reviewed. Descriptive statistics were calculated using data from all interviewed individuals. Results are presented as means or proportions. SAS software version 9.3 (SAS Institute, Cary, NC) was used for all analyses. Locations of the DMDS application sites and the residence of all people with residential exposures were mapped using Google Earth. The distance from the residence to the closest border of an application site was calculated, and proportions of individuals within 0.25, 0.5, or 1 mile of an application site were determined. The chi-square test was used to compare cases by distance from application site. Statistical significance was defined as $P < .05$.

Results

In September and October 2014, FDOH received complaints of DMDS-related illness from 40 households in Hillsborough County. Among the 33 households contacted, FDOH interviewed 66 people complaining of illness related to DMDS application. Another seven households that had reported illness could not be reached after repeated contact attempts. Among the 66 people interviewed, 43 (65%) were considered to have acute DMDS-related illness, among whom 32 (74%) were classified as possible and 11 (26%) as suspicious (Table 2). The other 23 (35%) interviewed individuals did not meet the case definition (e.g., signs and symptoms preceded exposure or insufficient information was available on exposure or illness), including one who died (see Subject 1 below).

Among the 43 cases, the mean age was 48 years (range: 3–71 years). Eleven people had at least one preexisting condition of concern, which included asthma ($n = 4$), allergies ($n = 5$), both asthma and allergies ($n = 1$), or multiple chemical sensitivity ($n = 1$). Among the cases, 38 (88%) were classified as having a low severity of illness and 5 (12%) a moderate severity of illness. None of the cases were farmworkers, and none resulted from work-related exposure.

Table 2. Demographic and clinical characteristics of individuals with reported acute pesticide-related illness and injury following DMDS applications—Hillsborough County, Florida, 2014 (N = 43).

Characteristics	n (%)
Age group, years*	
<20	6 (14.3)
20–44	6 (14.3)
45–64	24 (57.1)
≥65	6 (14.3)
Gender	
Female	23 (53.5)
Male	20 (46.5)
Race	
Native American	1 (2.3)
Black	2 (4.7)
White	40 (93)
Ethnicity	
Non-Hispanic	43 (100)
Signs/Symptoms** (self-reported)	
Neurological	35 (81.4)
Headache	28 (65.1)
Weakness	4 (9.3)
Dizziness	11 (25.6)
Respiratory	30 (69.8)
Throat irritation	10 (23.3)
Dyspnea	9 (20.9)
Cough	8 (18.6)
Ocular	20 (46.5)
Eye pain	19 (44.2)
Gastrointestinal	15 (34.9)
Nausea	12 (27.9)
Vomiting	7 (16.3)
Cardiac	6 (14)
Chest pain	4 (9.3)
Fatigue	10 (23.3)
Medical care sought	
Physician's office only	15 (34.9)
Hospital	3 (7)
None	25 (58.1)
Case classification	
Possible	32 (74.4)
Suspicious	11 (25.6)
Illness severity	
Low	38 (88.4)
Moderate	5 (11.6)

*One adult had unknown age. Only one child (aged 3 years) was identified.

**Some patients reported multiple signs/symptoms. Ocular: also includes eye irritation (n = 1), lacrimation (n = 2), and blurred vision (n = 2); Respiratory: also includes wheezing due to asthma exacerbation (n = 1); Gastrointestinal: also includes abdominal pain (n = 2); Neurological: also includes confusion (n = 1); Cardiac: also includes high blood pressure (n = 2) and irregular heart beat (n = 1).

Fifty-seven individuals (36 cases and 21 noncases) from 28 households indicated that their exposure was at or near their home (the other nine individuals indicated that exposure was at a location other than their home). The average distance from an application site was 0.74 miles (range = 0.3–3.16 miles; mode and median = 0.43 miles) among individuals classified as a case (n = 36) and 2.84 miles (range = 0.43–59.59 miles; mode = 7.34 miles; median = 2.12 miles) among individuals who reported being exposed at or near their home but who were not classified as a case (n = 21, P < .05). Individuals classified as a case and whose exposure occurred at or near their home were more likely to live within 0.25 miles and less likely to live more than 1 mile away from an application site compared with individuals not classified as a case (P = .001).

Three members of one family reported illnesses following a DMDS application in another county (i.e., Miami-Dade County, which is 300 miles away from Hillsborough County) in September 2014; however, the FDOH investigation determined that these individuals' signs and symptoms were not related to DMDS exposure. No DMDS exposure complaints were received from any other Florida county.

Case/subject reports

The following descriptions of individuals show different scenarios related to DMDS exposure.

Subject 1

In November 2014, a 45-year-old woman who was interviewed during the investigation died from a pulmonary embolus (PE). She did not make reference to a strong odor during her interview with FDOH, suggesting a low or nonexistent exposure to DMDS and chloropicrin. Neither DMDS nor chloropicrin is known to be associated with the coagulation disorders leading to PE. As such, it was concluded that pesticide exposure was unlikely to have contributed to this death.

Case 1

In early September 2014, a 70-year-old man experienced fainting, cough, trouble sleeping at night, and chest congestion. He reported a continuous odor of dead animals while taking walks in the morning and evening. Medical records documented preexisting conditions of chronic obstructive pulmonary disease and chronic rhinitis. He had difficulty breathing for a month following exposure. He was classified as a suspicious case with moderate severity.

Case 2

In August 2014, a 54-year-old man developed headache, sore throat, and chest pain after experiencing a strong smell coming from fields around his residence (distance from closest application site was 0.3 miles). He reported detecting the smell for several days. He did not seek any medical care, as his symptoms resolved quickly. He had no preexisting condition. He was classified as a possible case with moderate severity.

Case 3

In August 2014, a 60-year-old woman experienced itching of eyes, throat irritation, and pain after noticing an unpleasant odor coming from nearby fields (distance from closest application site was 0.08 miles). Her symptoms persisted for 2–3 weeks until the odor disappeared. She did not seek any medical care and was classified as a possible case with low severity.

Case 4

In August 2014, a 10-year-old girl experienced dizziness, headache, fatigue, rash, nausea, abdominal pain, and eye irritation/pain. She mentioned the odor made her sick while waiting for the school bus close to her house (distance from closest application site was 0.43 miles). She was evaluated by a physician and classified as a possible case with low severity.

Case 5

In August 2014, a 50-year-old man experienced headache and irritation of the nose and throat after smelling a strong garlic-like/dead-animal-like odor. He experienced the odor when driving close to treated fields with his windows down. He did not seek any medical care and classified as a possible case with low severity.

FDACS farm investigations

Separate from the FDOH investigations, during 2014 FDACS conducted investigations of four strawberry farms involving DMDS applications. Of the four investigations conducted by FDACS, only one found a violation involving DMDS, although the violation was unlikely to have precipitated the reported odor. It was a technical violation whereby during the DMDS application chisel spacing was set at 14 inches. The Paladin, Paladin EC, and ASHTA Gold soil fumigant labels require that chisel spacing should not exceed 12 inches.

Discussion

Because methyl bromide depletes the stratospheric ozone layer and is being phased out, DMDS is proposed as an alternative. EPA has established a level of concern for DMDS of 55 ppb to mitigate the potential for human health effects based on a no observed adverse effects level (NOAEL) of 9,000 ppb and a lowest observed adverse effects level (LOAEL) of 12,500 ppb in rat study. The observed adverse effect at LOAEL was nasal irritation.[2] In contrast, the American Conference of Governmental Industrial Hygienists established a 500 ppb time-weighted-average exposure limit for DMDS for industrial workers.[10] DMDS has a sulfurous odor similar to that of garlic and decaying fish with an odor threshold of approximately 7–12 parts per billion (ppb), which is much less than EPA's level of concern (55 ppb). As a result, unpleasant odors might occur near the application area at concentrations not considered toxic. Under certain environmental conditions (e.g., temperature inversion, air stagnation, light winds), off-target movement of DMDS may cause unpleasant odors in and around use areas for short periods of time despite buffer zones established to protect bystanders. Thus, it is possible that some of the symptoms reported by residents in the area surrounding application sites might have resulted only from aversion to the odor, assuming air concentrations were <55 ppb. Among the more than 500 air monitoring readings performed by the manufacturer of DMDS-containing products at the borders of farm fields in Hillsborough County during August and September 2014, all reported DMDS concentrations of 0–1 ppb,[7] which is below the odor threshold; however, additional information about these test results, including the timing of collection and the distance from nearest application, was not reported.

Odor is an environmental stressor that can trigger nonspecific symptoms such as nausea, headache, and dizziness.[11] As such, aversion to DMDS odor alone might have produced some of the observed symptoms. However, DMDS is also reported to cause irritation of the upper respiratory tract, eyes, and skin.[3,6] Chloropicrin is also applied frequently with DMDS. Inhalation of chloropicrin, the active agent in tear gas, can produce many of the same signs and symptoms as DMDS, including throat irritation, coughing, dyspnea, dizziness, nausea, and vomiting.[12] Chloropicrin is also a powerful lachrymator.

EPA reported two incidents in 2009 where community members became symptomatic in the presence of an odor that was alleged to arise from nearby DMDS applications.[2] One involved "several residents" of a Georgia community who complained of headaches, and the other was in Florida where "several residents became ill." However, these reports do not meet the SENSOR—Pesticides case definition of acute pesticide-related illness because of insufficient documentation of health effects.

FDOH first received reports of acute DMDS-related illness in 2013 (n = 9). In that year, FDACS first referred six people to FDOH, but FDOH determined that these individuals' signs and symptoms were not related to DMDS exposure. Subsequently in 2013, FDOH investigated three additional people in Hillsborough County with illnesses consistent with DMDS exposure. Their symptoms included dizziness (n = 3), fatigue (n = 1), headache (n = 1), nausea (n = 2), and abdominal pain (n = 1). All three were classified as possible cases of DMDS-related illness with low severity.

Until 2013, all DMDS-treated areas were required to be covered with a plastic tarp to retain the fumigant in the soil, thereby improving efficacy and mitigating odor. As a result of the odor reports received in 2013, in the 2014 application season FDACS required that treated areas be covered by totally impermeable film (TIF) tarps, which contain a layer of ethylene vinyl alcohol. Despite this change, complaints related to DMDS continued during 2014.

DMDS-containing products are registered for use in 26 states; however, according to the manufacturer of Paladin, Florida uses the largest volume (personal communication, Andrew Horvath [Arkema, Inc.], January 5, 2015). Other states with large volume sales are Georgia, North Carolina, South Carolina, and Mississippi. Hillsborough County accounted for 90% of the odor complaints received by the company, although the county accounts for only 20% of the company's "commercial acres in Florida."

NIOSH conducts surveillance for acute occupational pesticide-related illness and injury in 12 states, including Florida, through the SENSOR—Pesticides program. Of the 12 SENSOR states (California, Florida, Iowa, Louisiana, Michigan, North Carolina, New Mexico, New York, Nebraska, Oregon, Texas, and Washington), only Florida has ever reported any acute DMDS-related illnesses.

Limitations

The findings in this report are subject to at least three limitations. First, the number of people with acute DMDS-related illness might be underreported. Because symptoms might persist for only a few hours and usually resolve without medical treatment, many people might never associate these symptoms with DMDS exposure/odor and might not seek medical care. It is also possible that some people with illness were excluded because sufficient information to meet the case classification was not provided. Second, some people might have been incorrectly classified as having acute DMDS-related illness because signs and symptoms for these acute illnesses are often nonspecific and laboratory diagnostic tests are not available. In addition, chloropicrin exposure alone or in combination with DMDS may have caused some illnesses; however, only two individuals reported the lacrimation often associated with chloropicrin exposure. Additionally, all of the cases were classified using subjective data, without objective verification of illness and exposure. Therefore, false positives might have been included as cases. Lastly, environmental measurements were not taken at the time of the odor complaint and evidence of DMDS exposure was based on self-reported odor only. Therefore, the actual DMDS exposure levels experienced by the 43 cases are not known.

Conclusion

This is the first known report with systematic documentation of illnesses associated with DMDS exposure in humans. In contrast to methyl bromide, which depletes stratospheric ozone and is acutely toxic to human health and which has the potential to produce severe illness and death, illnesses associated with DMDS were generally of low severity. However, measures should be taken to reduce exposure and consequent illness. This investigation highlights the importance of reducing odor following DMDS application on farms with residents nearby. Improved methods of preventing off-target movement of DMDS to neighboring communities are needed, and prevention measures found to be effective should be adopted by growers. Communities should also be notified when nearby DMDS applications are planned and should be advised on appropriate actions if they detect DMDS odor.

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