Occupationally Related Hydrogen Sulfide Deaths in the United States From 1984 to 1994

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Alice Hamilton described fatal work injuries from acute hydrogen sulfide poisonings in 1925 in her book Industrial Poisons in the United States. *There is no unique code for H_2S poisoning in the* International Classification of Diseases, 9th Revision*; therefore, these deaths cannot be identified easily from vital records. We reviewed US Occupational Safety and Health Administration (OSHA) investigation records for the period 1984 to 1994 for mention of hazardous substance 1480 (hydrogen sulfide). There were 80 fatalities from hydrogen sulfide in 57 incidents, with 19 fatalities and 36 injuries among coworkers attempting to rescue fallen workers. Only 17% of the deaths were at workplaces covered by collective bargaining agreements. OSHA issued citations for violation of respiratory protection and confined space standards in 60% of the fatalities. The use of hydrogen sulfide detection equipment, air-supplied respirators, and confined space safety training would have prevented most of the fatalities.* (J Occup Environ Med. *2000;42:939–942*)

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In 1925, Alice Hamilton described the lethal effects of hydrogen sulfide (H_2S) gas: "Death may come on like a stroke of lightening, as in HCN [hydrogen cyanide] poisoning, but usually there are first symptoms of irritation of the nervous system, which occur even earlier than the formation of H_2S—hemoglobin."[1]

H_2S gas is toxic and can be rapidly fatal when inhaled at concentrations greater than 700 ppm.[2] H_2S inhibits mitochondrial electron transport, and the site of inhibition is similar to that of cyanide in that H_2S involves a selective reaction with cytochrome aa_3. H_2S is a more potent inhibitor of cytochrome oxidase than is cyanide, which gives it a lethal effect.[3] In addition, H_2S gas is heavier than air. When generated in confined spaces, H_2S can displace air and allow high concentrations of the gas to build up, creating a toxic environment that is asphyxiating and possibly explosive, depending on the concentration.[4]

Death is obviously the most serious toxic effect of H_2S on the body, but it also can damage areas of the body, including the eyes, lungs, olfactory parts, nervous system, heart, blood, brain, gastrointestinal system, and liver. Table 1 describes some of the toxic effects of H_2S gas at different concentrations. In the 18th century, Bernardino Ramazzini described the irritating effects of H_2S to the eyes as "these foul exhalations wage ruthless war, and they attack them so cruelly with their piercing stings that they rob them of life, that is to say of light."[5]

H_2S is a by-product of decayed organic material and is found in

TABLE 1
Effects of Hydrogen Sulfide Gas on Humans*

Effect	Concentration (ppm)
Detectable odor	0.2
Maximum allowable concentration for daily 8-hr exposure	20
Eye and respiratory irritation	50
Olfactory nerve paralysis	150
Exposure may cause pulmonary edema	250
Systemic symptoms occur in ½ hour	500
Quickly unconscious; death without rescue	750
Rapid collapse; respiratory paralysis	1,000
Immediate death	5,000

* Assembled from information in References 2, 3, 6, and 10.

swamps, sewers, marshes, oil and natural gas–producing wells, sulfur springs, and geothermal wells.[6] Crude oil is often saturated with H_2S, and natural gas may have levels of H_2S as high as 90% (900,000 ppm). It has been a serious threat to workers in the petroleum and natural gas industries.[7] H_2S is one of the principle compounds involved in the natural recycling of sulfur.

H_2S is found ubiquitously in industry as a reagent in manufacturing or as an undesirable by-product of manufacturing or industrial processing. Such operations include tanneries, wastewater treatment facilities, manure[8] and sewage facilities, rayon manufacturers, sulfur production, coke oven plants, kraft paper mills, iron smelters, food processing plants, tar and asphalt manufacturing plants, and natural gas and petrochemical plants. In the paper milling industry, for example, H_2S is involved in each step of the kraft process and must be recovered or scrubbed from these processes to reduce emissions into the environment.[9]

In 1977, the National Institute for Occupational Safety and Health estimated that there were 125,000 employees who were potentially exposed to H_2S in the United States. The Institute published a partial list of 73 occupations in which exposures varied from high and frequent to low and rare.[10] The number of potential H_2S exposures has probably increased with commercialization of the farming industry and growth of manufacturing industries that use H_2S.

In her book *Industrial Poisons in the United States*, Dr Hamilton describes several cases of H_2S poisoning that have characteristics in common with the cases we see at present. She tells of accidental fatal H_2S poisonings: (1) in a German tannery vat where the sludge was being manually removed; (2) in a fat rendering plant where a young workman was sent through a manhole to clean a kettle and fell dead; a second man died after trying to rescue the workman, and the foreman was rendered unconscious but he recovered; (3) at a large glue and lubricant factory where three men were overcome with H_2S gas and two died within minutes; the third put on a helmet and tried to rescue the other men and felt faint and dizzy but was revived in the open air; and (4) in a sump hole at a sewage plant where two men were overcome by sewer gas; the first man died and the second was overcome but was rescued by a third man, who was also overcome by gas during the rescue but survived.[11]

In the 75 years since Dr Hamilton wrote about the dangers involved in working around H_2S gas, there has been little change in the types of deaths that occur with exposure to the gas.

Methods

Surveillance of fatal events or related injuries from H_2S is not possible by using vital statistics because deaths from H_2S are not assigned a unique code in the *International Classification of Diseases, 9th Revision.* We chose to examine fatal injuries involving H_2S by reviewing records from US Occupational Safety and Health Administration (OSHA) investigations.

Fatality reports from the OSHA Integrated Management Information System (IMIS) were searched for all deaths from 1984 to 1994 that were coded as hazardous substance 1480 (H_2S). In addition, all records for which the narrative abstract contained the term hydrogen sulfide were reviewed for fatalities. California, Michigan, and Washington have state OSHA plans for which data systems and files were incompatible with the federal system from 1984 to 1989, but data from 1990 to 1994 from these states were included. The OSHA IMIS database contains descriptive information about the employer and the injured employee, including a written abstract of the events surrounding the injury.

OSHA investigates all reported occupationally related deaths over which it has jurisdiction. It obtains death reports from employers, the media, and local health officials. Other agencies regulate mining, transportation, maritime, and federal employees and certain other groups. Farms with fewer than 11 employees are exempt from OSHA regulation. OSHA does not investigate homicides, suicides, or deaths from motor vehicle accidents.[12]

Results

For this 11-year period, there were 18,559 occupationally related deaths reported to the OSHA IMIS database. Of these, 80 (0.43%) fatalities were due to H_2S poisoning. They occurred in 57 incidents throughout the United States ($n = 79$) and American Samoa ($n = 1$). States

TABLE 2
Number of Hydrogen Sulfide Deaths by State From 1984 to 1994

	Deaths	
State	*n*	%
Alaska	1	1.25
Am. Somoa	1	1.25
Kansas	1	1.25
Missouri	1	1.25
New Jersey	1	1.25
North Carolina	1	1.25
North Dakota	1	1.25
Tennessee	1	1.25
Virginia	1	1.25
West Virginia	1	1.25
Indiana	2	2.5
Ohio	2	2.5
Georgia	3	3.75
Illinois	3	3.75
Louisiana	3	3.75
Montana	3	3.75
Oklahoma	3	3.75
Pennsylvania	3	3.75
New Mexico	4	5.0
Wyoming	4	5.0
Mississippi	5	6.25
Florida	7	8.75
Iowa	8	10.0
Kentucky	9	11.25
Texas	11	13.75
Total	80	100

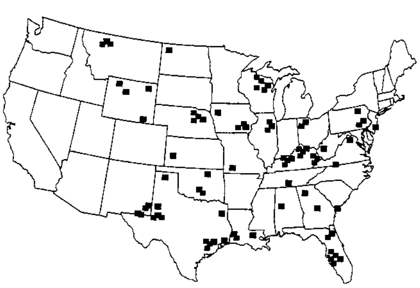

Fig. 1. US occupationally related H_2S deaths from 1984 to 1994 (■; $n = 79$).

with H_2S fatalities during the study period are listed in Table 2. The distribution of H_2S fatalities is shown in Fig. 1 (except for the fatality in American Samoa). H_2S fatalities related to the petroleum industry ($n = 22$) are shown in Fig. 2. These fatalities demonstrate a distribution consistent with sour gas (H_2S-contaminated) petroleum production in the Rocky Mountain region (except for one death in Alabama).

Victims were predominantly male (97.5%), with a mean age of 35.7 years (range, 15 to 65 years). One case was excluded because no age was listed in the IMIS data. Sixty-six (82.5%) of the workers were non-union; therefore, only 14 (17.5%) of the deaths were at workplaces covered by collective bargaining agreements. Only 18 (22.5%) fatalities were at companies with fewer than 11 employees, which are not subject to routine OSHA inspections (Table 3). OSHA cited the employers for safety violations in 60 (75.0%) of the fatalities; 48 (80.0%) of those citations were issued for violations of the respiratory protection standard or the confined space standard.[13] Under the OSHA definition of confined spaces, 69 (86.25%) of the deaths were in such situations.[14] Of the 80 fatalities, 19 (23.8%) workers died while trying to rescue coworkers. Information about non-fatal injuries was included in the reports of the 57 incidents, and 36 workers survived and required hospital treatment from H_2S exposures sustained during rescue attempts. Only one coworker (1.3%) who was wearing a self-contained breathing apparatus was killed when his air supply was depleted during the rescue process. One (1.3%) police officer died when he failed to use respiratory protection before entering a confined space in a rescue attempt.

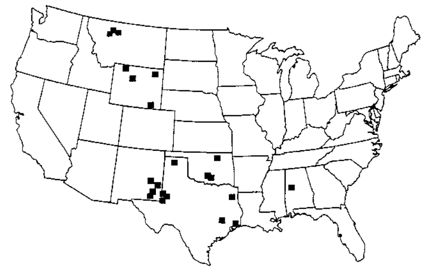

Fig. 2. Oil and gas worker–related H_2S deaths from 1984 to 1994 (■; $n = 22$).

TABLE 3
Hydrogen Sulfide Fatalities and Company Size

No. of Employees	No. of Fatalities	%
1–10	18	22.5
11–20	9	11.25
21–50	17	21.25
51–99	7	8.75
100–249	11	13.75
250 or more	18	22.50
Total	80	100

Discussion

Fortunately, the number of deaths from H_2S has decreased over the years (Fig. 3), but there are still clusters of deaths and injuries from workers trying to rescue other workers without the proper life support equipment. The 36 H_2S-related injuries seen in these incidents were reported only because there were associated fatalities. The number of H_2S-related injuries without an associated fatality is unknown.

Because the majority (86.3%) of H_2S-related fatalities occur in confined spaces, employers must develop comprehensive policies and procedures to protect employees who enter those areas. Before entering a confined space, employees should document that the space has adequate oxygen supply and ventilation and is free of toxic chemicals and gases. The employee must have adequate knowledge of the type of respirator to wear in toxic and/or oxygen-deficient atmospheres. There must also be site-specific work procedures and egress planning available to employees working at the site. The site should also be supported with emergency rescue equipment and trained emergency personnel.[15]

Many workers have died without knowing that they were working in a potentially life-threatening hazardous area. Most of the fatalities occurred in companies that were subject to OSHA inspections. OSHA requires that the employees be adequately trained before working in any confined space areas. The number of deaths occurring from ignorance or disregard of the hazards of confined spaces shows that renewed efforts are needed to educate both employers and employees about these hazards.

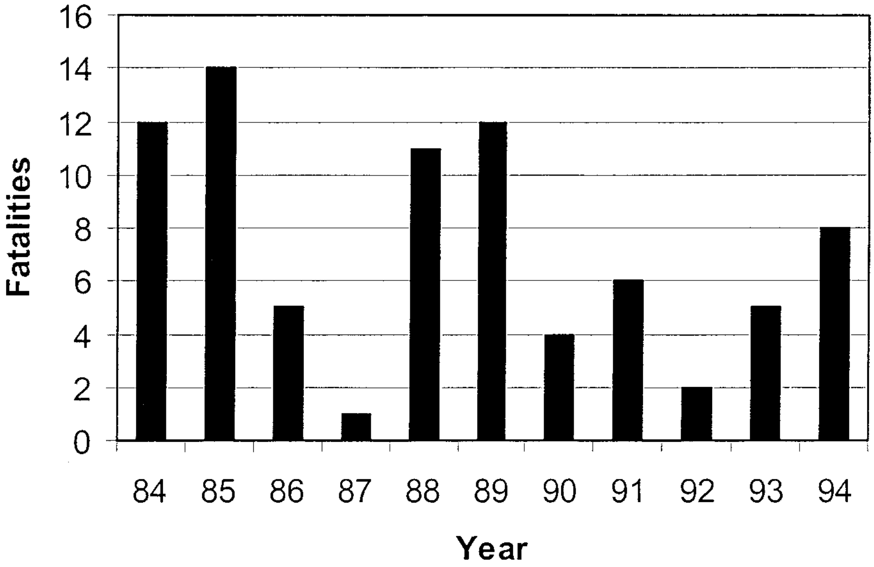

Fig. 3. Number of yearly H_2S deaths from 1984 to 1994.

Given that the majority of the deaths occurred in the absence of trained or professional rescuers, efforts could begin by having well-trained firefighters, rescue personnel, and police officers train local employers, employees, rescuers, and police officers about the dangers of confined spaces. This training could then be extended to all employees through in-house training.

Another area of concern is the lack of monitoring systems for hazardous gases in industrial, petroleum, and sewer worksites. Evaluation of the 80 cases revealed that 77 (96.3% of the fatalities might have been prevented by an H_2S alarm or portable gas meter. The mandatory use of portable H_2S meters with alarms in areas where employees come in contact with contaminated petroleum products; enter confined spaces associated with sulfur, sewage, or sewage treatment; and work with sulfur compounds could reduce the loss of life associated with H_2S poisoning.

In summary, the use of H_2S detection equipment, air-supplied respirators in toxic or oxygen-deficient atmospheres, and confined space safety training could help to prevent most H_2S-related fatalities.

Acknowledgments

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