

Deaths from asphyxiation and poisoning at work in the United States 1984-6

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ABSTRACT A review of 4756 deaths investigated by the Occupational Safety and Health Administration (OSHA) in 1984-6 found 233 deaths from asphyxiation and poisoning, excluding asphyxiations from trench cave-ins. The highest rates were in the oil and gas industry and in utilities. Toxic gases were the largest group (65) followed by simple asphyxiants (48), mechanical causes (42), and solvents (35). Deaths from solvents were significantly more likely in young workers. Nine deaths were caused by improper air supply to respirators and five by recreational inhalation of gas or vapours. Of the 146 deaths in confined spaces, only 12% were in rescuers, fewer than previously reported.

Air unsuitable for breathing has long been recognised as an occupational health hazard. The Roman emperor Trajan punished certain offenders by appointing them to clean sewers, a job considered one of the worst.¹ Fifty years ago, gas poisoning was considered a "frequent hazard of industrial life."² Although asphyxiation in specific industries such as steel was examined early in this century,³ there have been few population based studies of deaths due to this problem.

In the United States the Bureau of Labor Statistics (BLS) Annual Survey of Occupational Injuries and Illnesses reports deaths from 14 different causes. For 1984, of the 3740 work related deaths in the private sector reported by the BLS, 3% were due to gas inhalation and 4% from "all other causes" other than heart attacks and trauma.⁴ For 1985, the National Center for Health Statistics (NCHS) reported 700 deaths in the United States from poisoning by gases and vapours, mostly carbon monoxide,⁵ but did not indicate the proportion of these which were work related. An unpublished internal study by the Occupational Safety and Health Administration (OSHA) of all deaths investigated over a 44 month period from May 1974 to December 1977 reported that of the 5793 deaths investigated, 561 were due to asphyxiation or poisoning, or 9.7% of all deaths that were investigated during this period; these included both mechanical and chemical asphyxiations (printout provided by W Cloe, OSHA, 1978).

In Sweden of the 767 deaths classified as

"occupational accidents" in 1979-83, only 10 were reportedly due to contact with a chemical agent.⁶ There were 25 deaths listed from "miscellaneous causes" and the remaining 732 were from trauma. The Swedish report did not list a separate category for asphyxiation.

In Malaysia 485 work related deaths were reported to the workers compensation and social security system for 1983. Forty three (8.8%) were due to asphyxiation or poisoning.⁷

A study of fatal injuries in Britain during maintenance activities in manufacturing and service industries in 1980-2 reported that 24 (7.4%) of the 326 deaths in this category were due to asphyxiation or gas inhalation.⁸ Maintenance deaths made up 21% of all deaths reported to the Health and Safety Executive during this period. Other British studies have examined injury from specific substances. Bakinson and Jones reviewed 118 cases, including four deaths, of gassing due to methylene chloride, xylene, toluene, and styrene reported to the Factory Inspectorate, the predecessor of the Health and Safety Executive, from 1961 to 1980.⁹ When the cases were stratified by whether or not the victim had lost consciousness, younger workers appeared to be more severely affected.

Also in Britain McCarthy and Jones made a similar analysis of 384 cases in 1961-80, of which 17 were fatal, caused by trichloroethylene, perchloroethylene, and 1-1-1 trichloroethane.¹⁰ Younger workers were again found to be more vulnerable and in nine cases deliberate inhalation of solvents was suspected. Toxicity was attributed to the effects of these solvents on the central nervous system.

In the present study the OSHA Integrated Management Information System (IMIS) database was searched for all deaths in 1984-6 investigated by OSHA and in which asphyxiation or poisoning was implicated in an attempt to discover the extent of these deaths in the United States and the chemical substances and other factors involved.

OSHA offices investigate all reported work related deaths for which OSHA has jurisdiction. Mining, transportation, maritime, federal employees, and certain other groups are regulated by other agencies. Farms with fewer than 11 employees are exempt from OSHA regulation.

OSHA obtains death reports from employers, the media, and local health officials. A study in Pennsylvania in 1983-4 found that only 50-60% of all occupational traumatic deaths were within OSHA jurisdiction.¹¹ In Colorado the State Department of Health found that OSHA learnt of only 65% of the work related deaths in 1982-4 for which OSHA had jurisdiction.¹² OSHA offices do not investigate homicides, suicides, or motor vehicle accident deaths.

Methods

A printout was obtained of all deaths for the years 1984-6 from the OSHA IMIS database. This database contains information on all accidents investigated by OSHA in 47 states. These states comprise 83% of the United States workforce.¹³ California, Washington State, and Michigan have state OSHA plans that maintain datafiles not compatible with the federal system. The OSHA IMIS database contains descrip-

tive information about the employer and injured employee and a written abstract concerning the circumstances of injury.

OSHA death investigations are coded according to "nature of injury," for which a list of 22 items is available for the investigating officer to choose from. All deaths coded "asphyxiation" or "poisoning" were selected for this study. In addition, the abstract of every death in the database for 1984-6 was reviewed to detect coding errors.

One death coded as an asphyxiation was excluded from this series. This was in a worker who was struck in the chest by a 3000 lb steel beam and crushed. Mechanical asphyxiations due to being buried in materials such as in grain elevators or sand bins were included.

Results

For the period 1984-6, 4756 deaths were reported in the OSHA IMIS database for 47 states. Of these, 423 (8.9%) were due to asphyxiation or poisoning. The 190 asphyxiations that occurred in trench cave-ins have been described elsewhere and will not be discussed further.¹⁴ For the remaining 233 cases, a list of the agents which caused death is shown in table 1. There were 42 deaths from mechanical causes such as being buried alive in a grain bin, seven in which the report was incomplete and the code for the agent causing the death was missing, 48 were due to simple asphyxiants such as argon or nitrogen, and 27 from oxygen deficient air in which a specific substance was not reported. Of the remaining 109 deaths, 65 were due to

Table 1 Causes of asphyxiation and poisoning in death investigations in the OSHA IMIS database, 1984-6

<i>Simple asphyxiants</i>	<i>Solvents</i>	<i>Mechanical</i>
1 Propane	1 Chlorodifluoromethane	42 Total
10 Methane	1 Coal tar pitch volatiles	
7 Argon	2 Dichlorodifluoromethane	
18 Nitrogen	1 Diesel fuel	<i>Other</i>
12 Carbon dioxide	3 Gasoline	1 Dimethyl sulphate
48 Total	1 Isopropanol	1 Maleic anhydride
	1 Methyl chloride	1 Sulphuryl fluoride
	4 Methyl chloroform	1 Cyanide
	8 Methylene chloride	4 Hydrogen fluoride
	3 Naphtha	1 Phosphorus (yellow)
	1 Perchloroethylene	9 Total
	2 Toluene	
	4 Trichlorotrifluoroethane (F-113)	
	2 Trichloroethylene	
	1 Trichloroethane	
	35 Total	
<i>Toxic gases</i>		
3 Ammonia		
25 Carbon monoxide		
3 Chlorine		
30 Hydrogen sulphide		
4 Nitrous oxide		
65 Total		
<i>Oxygen deficient atmosphere</i> (substance not reported)	<i>Unidentified or report incomplete</i>	<i>Table total</i>
27 Total	7 Total	233

This table does not include the 190 asphyxiations due to trench cave-ins

toxic gases, 35 to solvents, and nine to other poisonous agents. Air sampling data related to the incident was not available from the database, nor were details of first aid or emergency medical treatment.

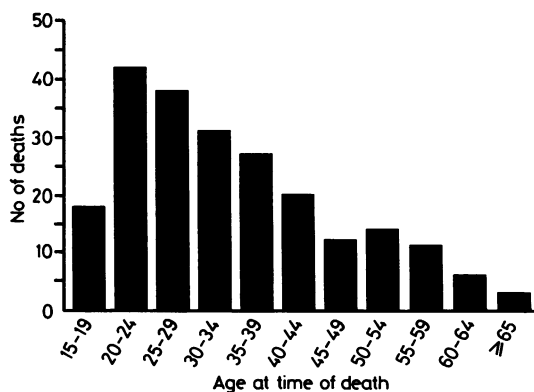
These 233 deaths occurred in 198 separate events. There were 78 deaths in 1984, 76 in 1985, and 79 in 1986. Fifty three (23%) were in firms covered by a collective bargaining agreement with a union.

Only two of the deaths were in women, in similar incidents at different plants. Both occurred when the employee fell into a degreasing tank while attempting to retrieve a printed circuit board.

The age was known for 222 of 233 deaths. The mean age was 34.2 years, with a standard deviation of 12.5 (figure). Workers killed by solvents were significantly younger than the others ($p < 0.01$), with a mean age of 29.0 years.

INDUSTRY

The largest number of deaths was in manufacturing



Age at death for 222 victims of asphyxiation and poisoning, 1984-6. (Age was unknown for one victim.)

(38%), followed by trade (14%), construction (12%), and the oil and gas industry (11%) (table 2). The highest rates for asphyxiation and poisoning were seen in the oil and gas industry and in utilities. In these industries the primary substances were hydrogen sulphide, present in sewers, manholes, and oil field fracturing tanks, and gaseous hydrocarbons such as methane.

MECHANICAL ASPHYXIATIONS

These 42 deaths occurred in grain elevators or grain bins (12), storage bins (8), railroad cars (5), sand hoppers (4), dump trucks (2), and other (11). Grain bins and elevators, sand hoppers, and storage bins were implicated in 24 (57%) deaths. In 13 the employee was standing in a bin on top of sand or grain in which a void or cavity existed that had been "bridged." When the bridge collapsed the employee fell into the material and was suffocated. Ten other deaths occurred when an employee fell into a bin and was buried in loose material.

CONFINED SPACES

Of the remaining 184 deaths, excluding the 42 mechanical asphyxiations and the seven cases with incomplete information, 146 (79%) occurred in confined spaces. According to OSHA, a confined space is "an enclosed or partially enclosed work space that has limited means of entry and exit, which may be subject to accumulations of toxic or flammable contaminants, or where an oxygen deficiency may develop."¹⁵

Of the 146 deaths in confined spaces, 17 (12%) were in coworkers or emergency personnel attempting to rescue a worker who had become unconscious. In 16 of these the rescue was attempted without the use of self contained breathing apparatus, and in one the SCBA ran out of air. Two of the 17 deaths were police officers who responded to a distress call in an incident at a sewage treatment plant.

Table 2 Cause of asphyxiation by industry group

	Mechanical	Simple asphyxiants	Toxic gases	Oxygen deficiency substance not reported	Solvents	Other	Report incomplete	Total	1984 employment (thousands)	Rate/ million workers
Agriculture	3	0	0	0	0	1	0	4	933.8	1.68
Construction	3	6	4	8	6	0	0	27	434.5	2.44
Oil/gas	1	8	11	4	2	0	0	26	612.7	16.64
Manufacturing	20	26	13	7	11	6	5	88	1941.2	1.78
Services	1	2	7	2	5	1	1	19	2076.1	0.36
Retail, wholesale and	10	1	12	4	5	0	1	33	2213.4	0.58
Transport	3	1	3	1	5	1	0	14	2673.1	2.05
Utilities	1	4	7	0	0	0	0	12	898.9	5.24
Other	0	0	8	1	1	0	0	10	7213.3	0.54
Total	42	48	65	27	35	9	7	233	78983.8	1.16

Employment data taken from the 1984 Bureau of Labor Statistics Survey of Occupational Injuries and Illnesses. (Rates are adjusted for data from 47 states.)

The types of confined spaces were varied and included vats, tanks, reactor vessels, ship holds, and other unventilated areas. The largest single group was sewers and manholes, with 31 deaths (21%). In this group, with the exception of a single incident involving a chlorine leak that killed three workers, these deaths had similar circumstances—namely, the entry of an unprepared worker into an unventilated space below ground level.

The OSHA IMIS database contains coding for only one chemical or physical substance per death report; the coding for the deaths in sewers and manholes was: oxygen deficiency, no specific substance noted (14), hydrogen sulphide (8), carbon monoxide (3), chlorine (3), methane (2), and other (1).

CARBON MONOXIDE

Of the 25 deaths through carbon monoxide, six were due to faulty pumps and compressors and five to vehicles operated indoors in areas with insufficient ventilation. Faulty space heaters caused four deaths and gases from industrial furnaces two. Six deaths were from other sources and two had no descriptive information of the source of CO.

HYDROGEN SULPHIDE

There were 30 deaths involving H₂S. Eight were in sewers or manholes and nine in fracturing tanks or pits containing crude oil. These oil and gas industry deaths were in small firms in Texas, Oklahoma, and Rocky Mountain states. Thirteen deaths were in a variety of other circumstances.

SOLVENTS

Of the 35 deaths that could be attributed to solvents, 24 were from chlorinated hydrocarbons and 11 from naphtha, toluene, gasoline, diesel fuel, isopropanol, and coal tar pitch volatiles. Nine of the 35 deaths occurred in degreasing apparatus, eight in basements or pits below floor level in a plant area where solvents were used, and six in storage tanks. Five deaths were in employees who entered a tanker truck to clean it after transporting solvents and seven in other circumstances.

HYDROFLUORIC ACID

Three of the four deaths due to hydrofluoric acid involved maintenance operations in which the employee was sprayed with acid while unclogging a line or pump. In the fourth case an employee stepped on a five gallon bucket of hydrofluoric acid, his foot went through the cover, and he was splashed on the legs and abdomen. Three deaths occurred from cardiac arrest, two of them within minutes of exposure. In the fourth case the time and manner of death were not noted in the report.

SUBSTANCE ABUSE

Five deaths were definitely related to substance abuse, and a sixth case was questionable. Four occurred from recreational inhalation of nitrous oxide at work. Two of these were restaurant workers who inhaled gas ordinarily used to power whipped cream dispensers. One worker sniffing a can of methyl chloroform (1-1-1 trichloroethane) used for cleaning was found dead with his face over the open can. He had been recently hired and, unknown to the employer, had a history of drug abuse. The sixth case was a truck driver who was found dead in his cab, with the windows closed, with an empty can of Freon beside him. The death was presumed to be from inhalation but it is unknown whether this was intentional.

RESPIRATOR DEATHS

There were 14 deaths in which respirators were a factor: two in confined spaces, one in a rescuer, occurred when a self contained breathing apparatus ran out of air. Two other deaths involved the use of half face respirators with organic vapour absorbing cartridges in an oxygen deficient atmosphere, instead of self contained breathing apparatus. One worker using an air supplied respirator while sandblasting the inside of a tank died when the air supply hose came loose.

Nine deaths were due to improper air supply. Four involved hooking up a respirator to a nitrogen line instead of to air. In one case the nitrogen line was painted the same colour as a nearby air line. In two other deaths the lines were not marked and in the fourth case the type of marking was not noted in the report. A fifth death occurred when a worker attached the air line of his respirator to an unmarked argon line. In all of these cases the same size fitting was used for air, nitrogen, and argon lines. Four deaths were from carbon monoxide in which respirators were supplied with air contaminated with carbon monoxide from the exhaust of a compressor motor.

Discussion

The number of deaths found in this study from asphyxiation and poisoning (423) was selected from only those incidents that were investigated by OSHA in 47 states in a three year period. The average number of deaths for this period in the OSHA database was 1585 a year. The actual number of work related deaths in the United States in these years is not clear, with the BLS reporting 3740 for 1984,⁴ and NIOSH reporting 6258 based on death certificate data.¹⁶ In any case, OSHA investigated half or less of all work related deaths. Probably, therefore, the number due to asphyxiation or poisoning during this period was greater than 423.

The proportion of all work related deaths found in this study to be due to asphyxiation or poisoning (8.9%) is similar to the findings of most previous reports.^{7,8} One exception is the Swedish death data which are not comparably coded. For industry groups, 37% of the deaths were in manufacturing, the same as reported in the NIOSH criteria document on confined spaces.¹⁷ The number found in oil/gas (11%) and utilities (5%) were higher than in the NIOSH report. Previous studies have not reported high rates of asphyxiation in these two industries.

Almost all of the victims were men. The same trend was seen by McCarthy and Jones for deaths from gassing and was attributed to differences in exposure by sex in the occupations at risk.¹⁰ There may also be differences in the degree of risk that is considered acceptable by men.

Although the mean age of the total group was relatively young (34.2 years), those who died from inhaling solvents were significantly younger than those who died from other causes. In the two reports of solvent toxicity cases in Britain there was a relative excess of younger cases and these were more severely affected. Perhaps certain tasks with heavy exposure to solvents, such as tank cleaning or operating a degreaser, involve more younger workers. Whether the increased number of deaths from solvents in younger workers are due to differences in exposure, susceptibility, or other factors deserves further investigation.

The 42 mechanical asphyxiations illustrate the danger of standing or working above stored grain, sand, or other loose materials. Although this hazard has been described before,¹⁸ the magnitude of the problem has not been noted. Since much of agricultural work is exempt from OSHA investigation, the number of asphyxiations involving grain could be much higher.

The NIOSH criteria document on confined spaces also studied the OSHA database and found 143 deaths, or 71.5 a year, for 1976-7.¹⁸ In the present study, for 1984-6, there were 146 deaths in confined spaces, or 48.7 a year, a decline of 32%. This decline may be real or may be due to inclusion of deaths from causes such as electrocution or fire in the earlier figure. Another NIOSH report found 60% of deaths to be in rescuers.¹⁹ As six of the eight incidents discussed were multiple death accidents, these may reflect a tendency of NIOSH to investigate notorious events that would tend to have a high proportion of injured rescuers. A more recent NIOSH guide gave a figure of 50%.²⁰ Both are higher than the 12% found in the present study.

The high death rates in the oil and gas industry reflect exposure to the long recognized hazard of hydrogen sulphide released from high sulphur content crude oil.²⁰ Deposits of "sour crude" are concentrated

in the western United States and Canada where oil field workers are exposed in pits, fracturing tanks, and pumping operations. A review of H₂S poisoning in Alberta, Canada, found a 6% death rate in workers who had become ill as a result of exposure to H₂S.²¹ Hydrogen sulphide has a foul odour, but at levels over 150 ppm causes olfactory paralysis, with no warning to the worker of the hazardous atmosphere.²²

Death from H₂S poisoning has also been observed, as it was in this study, among those who work in sewers.^{23,24} Manholes and sewers are classic examples of confined spaces where gas from sewage decomposition can accumulate in high concentrations. As in oil field workers immediate olfactory paralysis eliminates warning and is followed rapidly by loss of consciousness.

Hydrofluoric acid burns have been reported to be frequent, with rare deaths.²⁵ The four cases investigated by OSHA all had exposures of large areas of the body. In the three cases involving work unclogging pumps and lines inadequate waterproof protective clothing was worn to protect the employee when a spray of liquid struck him full force. For any skin contact with hydrofluoric acid, immediate treatment with calcium gluconate, as a topical gel or by injection, is necessary,²⁶ which was not done or was delayed in these cases.

Previous studies have emphasised that a proper type of air supply respirator should be used in oxygen deficient atmospheres and not cartridge type respirators. From the data presented here it appears that improper air supplies, such as pure nitrogen, or air contaminated by carbon monoxide, are as lethal as the choice of the wrong respirator. Special attention should be paid to avoiding the use of compatible fittings on lines supplying air for breathing and those with other gases. Intakes of compressors for air supply should be isolated from any motor exhaust.

This study has reported deaths from asphyxiation in the United States workforce for a three year period. The OSHA investigations cover less than half the work related deaths in the United States and certain groups such as agricultural workers are underrepresented. Nevertheless, the OSHA database is population based (47 states) and allows us to make some inferences about work groups at risk. Utility workers entering manholes and oil field workers in fracturing tanks appear to have the highest risk of asphyxiation. The previously reported finding that young workers are disproportionately affected by solvents has been confirmed in this study but is still unexplained. A study of morbidity data may provide sufficient cases to see if the excess in young workers appears more in those solvents favoured for drug abuse.

Although the OSHA IMIS database contains little information on the level of exposure to chemicals in

these fatal accidents, or on the treatment of victims after exposure, the information available has provided a useful picture of the circumstances of fatal asphyxiation and poisoning.

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