FEATURE

Chemical suicides: Hazards and how to manage them

Emergency response to chemical suicides has become more common place in recent years. In order to address the operational implications of these events, it is first important to understand the methodologies which are commonly used, the locations where the events often occur, the concentrations of material generated, and how those concentration relates to exposure standards and flammability. Using hydrogen sulfide, carbon monoxide, hydrogen cyanide, and phosphine as examples, guidance is offered about risk control measures including personal protective equipment and decontamination strategies to effectively and safely mitigate the incidents.

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INTRODUCTION

Q2 The use of chemicals to commit suicide has occurred since antiquity.[1,2] In more recent times, industrial and agricultural chemicals, especially organophosphate pesticides, gained favour[3–9] and have been especially prevalent in third world countries[3,10,11] where the number of deaths reported has been significant. The rise of the internet in recent years has aided rapid information sharing about newly developed methods using chemicals. These new approaches have attracted much interest[12–16] within Japan, United States, Europe, and Australia despite the relatively low number of events because of the threat to safety of emergency responders and bystanders.

These methods[17–24] often use readily available chemicals that when mixed generate toxic and sometimes flammable gases, such as hydrogen sulfide, carbon monoxide, and hydrogen cyanide. These acts are carried out in a range of settings[23–25] from motor vehicles, bathrooms within residences, to even hotel rooms. The lack of knowledge about the situation has led to bystanders and emergency responders[15,16] (such as paramedics, firefighters and police officers) also being affected by the toxic gases generated. In many cases,[15,16,26] these affected persons required emergency decontamination and hospital treatment.

This paper will focus on describing locations where these events occur, the most popular methods where chemicals are mixed to generate toxic gases, and how much is likely to be generated within common settings where these acts occur. The hazards and resultant actions that can be taken to minimize the risks to emergency responders, health professionals, occupational hygienists and others will also be described.

In order to understand the scope of the problem, one must understand the volume of space involved in these types of events. The typical hotel room floor area[27] in the United States is around 325 ft^2 including bathroom and assuming a ceiling height of 8 feet the volume is 2,600 ft^3 (73.62 m^3). Bathroom sizes vary significantly within residences[28,29] depending on residence age and location. Typically, a single bath floor area is about 20 ft^2 and the largest double vanity bathroom floor area is about 110 ft^2. They correspond to volumes of 160 ft^3 (4.53 m^3) to 880 ft^3 (24.92 m^3) respectively. The internal volumes of motor vehicles[30,31] vary from ca. 85 ft^3 (2.4 m^3) to almost 600 ft^3 (17 m^3). These values are summarised in Table 1.

THE METHODS OF INTEREST

A wide variety of methods using chemicals to commit suicide have been previously reported in the literature[3,32] and typically pesticides, industrial chemicals and pharmaceuticals were used. More recently, methods where toxic gases are generated have become more popular and they include:

- Carbon monoxide generated from formic acid;
- Hydrogen cyanide generated from sodium cyanide;
- Hydrogen sulfide generated from metal polysulfides; and
- Phosphine generated from aluminium phosphide.

Carbon Monoxide

The formic acid route to generate carbon monoxide has been reported in the literature and suicide books such as the "Peaceful Pill Handbook".[17,18,20,46] Typically, concentrated sulfuric acid is mixed with formic acid to generate carbon monoxide. The reaction is as follows: Q3

$$HCOOH + H_2SO_4 \rightarrow CO + H_2O + 2\,H^+ + SO_4^{-2}$$

There is little, if any, information regarding formic acid volumes reported in the literature. If it is assumed the formic acid concentration is 90% and the reaction proceeds to completion then 500 mL of formic acid will generate approximately 281 L of carbon monoxide at 25 °C. The resultant

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Table 1.

Enclosed Space Classification	Internal Volume (m^3)	CO (ppm)	HCN (ppm)	PH_3 (ppm)	H_2S (ppm)
Hotel room	73.62	3,817	1.3	32.6	166
Bathroom–small	4.53	62,150	22	530	2,693
Bathroom–large	24.92	11,295	4	96	490
Car–full size	2.83	99,450	35	848	4,311
Car–medium size	2.69	104,645	37	892	4,535
Car–small size	2.41	116,800	42	996	5,062
SUV–full size large	5.97	47,150	16.7	402	2,044
SUV–full size	5.08	55,415	20	472	2,402
SUV–mid size	4.34	64,860	23	553	2,811
Minivan	5.56	50,625	18	432	2,194
Van–very large	16.91	16,645	6.0	142	721
Van–large	12.97	21,705	8.0	185	941
Van–medium	9.18	30,610	10	261	1,329

steady state carbon monoxide concentrations in the specified enclosed spaces are shown in Table 1.

Carbon monoxide is classified as a toxic gas,[33] and has a OSHA Permissible Exposure Limit (PEL) Time Weighted Average (TWA) of 50 ppm, Immediately Dangerous to Life or Health (IDLH) value of 400 ppm and a Lethal Concentration Low (LC-lo) (5 min) value of 5,000 ppm.[34] Carbon monoxide is also flammable with a flammable range[34] of 12.5%–74%.

Hydrogen Cyanide

The metal cyanide salt route to generate hydrogen cyanide is widely known.[19,20] Typically, the person directly ingests the metal cyanide and reaction with the stomach acid generates hydrogen cyanide. The reaction is as follows:

$$HCl + NaCN \rightarrow HCN + NaCl$$

It has been reported in the literature[19] that 200–300 mg of the cyanide salt is sufficient. However, Nitschke and Stewart[20] advocated using 1–2 g and preferably 2 g of sodium cyanide. They suggested the probability of death increases significantly if above 0.5 g. If it is assumed that if the reaction goes to completion then 2 g of sodium cyanide will generate approximately 1 L of hydrogen cyanide.

Hydrogen cyanide is classified as a toxic and flammable gas[33] and has a PEL of 10 ppm, IDLH value of 50 ppm and LC-lo (5 min) value of 200 ppm.[34] The flammable range[34] is 5.6%–40%.

Phosphine

The metal phosphide route to generate phosphine is widely known and reported in the literature.[20,21,35–38] Typically, the person directly ingests the metal phosphide (such as aluminium phosphide) tablet and the reaction with water or the stomach acid generates phosphine gas. The reaction is as follows:

$$AlP + H_2O \rightarrow PH_3 + Al(OH)_3$$

Aluminum phosphide tablets are typically[35,36] 600–3,000 mg and contain 56% aluminum phosphide. While the amounts[22,35,36] ingested varied from 1.5 to 10 g of the tablet, the average was 4.7 g. If it is assumed the reaction goes to completion, then 5.6 g of aluminium phosphide will generate approximately 2.4 L of phosphine.

Phosphine is classified as a toxic and flammable gas[33] with a PEL of 0.3 ppm, IDLH value of 50 ppm and LC-lo (5 min) value of 1,000 ppm[34]. It has a flammable range[34] of 1.8%–98%.

Hydrogen Sulfide

The metal sulfide route to generate hydrogen sulfide has become more widely known after its reported use in Japan.[23–25] It is sometimes known as the detergent method. Typically, an acid such as hydrochloric acid is mixed with a metal polysulfide such as calcium sulfide to generate hydrogen sulfide. The reaction is as follows:

$$MS_x + HCl \rightarrow H_2S + MCl$$

The exact chemical composition of commercial calcium polysulfides is often unknown[39–41] but are typically quoted as CaS_x. Nitschke and Stewart[20] suggested a bottle is sufficient, and thus a 500 mL commercial solution[39–41] is considered. If it is assumed there is 1 mole of CaS per liter and the reaction goes to completion then approximately 12.2 L of hydrogen sulfide is generated.

Hydrogen sulfide is classified as a toxic and flammable gas,[33] with a PEL of 10 ppm, IDLH value of 100 ppm and LC-lo (5 min) value of 800 ppm.[34] The flammable range[34] is 4%–45%.

DISCUSSION

The reagent solutions necessary for these reactions are generally easily obtained and the reactions readily generate toxic gases. Table 1 shows the steady state concentration of the gases generated as a function of a variety of enclosed spaces. The steady state concentrations often readily exceeded the published IDLH values and LC-lo values of the respective gases, especially in small rooms and motor vehicles. These values have significant implications for the safety of bystanders and unprotected emergency responders. Furthermore, the gas concentration will likely be significantly higher immediately adjacent to any reaction apparatus, or the affected person, especially where the person has directly ingested the reactant. This is more likely if there is incomplete mixing within the room where the gas was generated.

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