

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.

By Michael Logan,
Christina Baxter

INTRODUCTION

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 favor³⁻⁹ 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 interest¹²⁻¹⁶ 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 methods¹⁷⁻²⁴ 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 settings²³⁻²⁵ from motor vehicles, bathrooms within

Michael Logan is affiliated with Research and Scientific Branch, Queensland Fire and Emergency Services, GPO BOX 1425, Brisbane, Queensland 4001, Australia.

Christina Baxter is affiliated with Emergency Response TIPS, LLC, Woodbridge, Virginia 22191, USA.

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 area²⁷ in the United States is around 325 ft² including bathroom and assuming a ceiling height of 8 feet the volume is 2,600 ft³ (73.62 m³). Bathroom sizes vary significantly within residences^{28,29} depending on residence age and location. Typically, a single bath floor area is about 20 ft² and the largest double vanity bathroom floor area is about 110 ft². They correspond to volumes of 160 ft³ (4.53 m³) to 880 ft³ (24.92 m³) respectively. The internal volumes of motor vehicles^{30,31} vary from ca. 85 ft³ (2.4 m³) to almost 600 ft³ (17 m³). These values are summarised in Table 1.

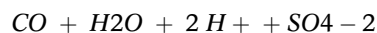
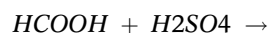
THE METHODS OF INTEREST

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:



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

Table 1. Steady state concentration of gases as a function of enclosed spaces.

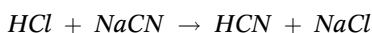
| Enclosed Space Classification | Internal Volume (m ³) | CO (ppm) | HCN (ppm) | PH ₃ (ppm) | H ₂ S (ppm) |
|-------------------------------|-----------------------------------|----------|-----------|-----------------------|------------------------|
| Hotel room | 73.62 | 3,817 | 1.3 | 32.6 | 166 |
| 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 |

resultant 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 range³⁴ 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:

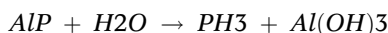


It has been reported in the literature¹⁹ that 200–300 mg of the cyanide salt is sufficient. However, Nitschke and Stewart²⁰ advocated using 1–2 g and preferably 2 g of sodium cyanide. They suggested the probability of death increases significantly if above 0.5 g. If it is assumed that if the reaction 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 gas³³ and has a PEL of 10 ppm, IDLH value of 50 ppm and LC-lo (5 min) value of 200 ppm.³⁴ The flammable range³⁴ 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:

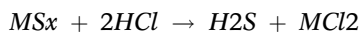


Aluminum phosphide tablets are typically^{35,36} 600–3,000 mg and contain 56% aluminum phosphide. While the amounts^{22,35,36} ingested varied from 1.5 to 10 g of the tablet, the average was 4.7 g. If it is assumed the reaction goes to completion, then 5.6 g of aluminium phosphide will generate approximately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

Phosphine is classified as a toxic and flammable gas³³ with a PEL of 0.3 ppm, IDLH value of 50 ppm and LC-lo (5 min) value of 1,000 ppm³⁴. It has a flammable range³⁴ 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:



The exact chemical composition of commercial calcium polysulfides is

often unknown^{39–41} but are typically quoted as CaS_x. Nitschke and Stewart²⁰ 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 range³⁴ 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.

Based on the reagent quantities suggested in the literature, hydrogen cyanide and phosphine exhibited the lowest concentration of toxic gases generated, and were significantly less than the Lower Flammability Limit (LFL). Thus, hydrogen cyanide, and phosphine only posed a toxic hazard to bystanders and emergency responders. Hydrogen sulfide also posed a toxic hazard, and in some locations the hydrogen sulfide concentrations also exceeded 10% of the LFL. Therefore, hydrogen sulfide poses a flammability hazard to bystanders and emergency responders. The estimated hydrogen sulfide volume generated is similar to that reported by Kobayashi et al.²⁴ where they estimated a 120 mL bottle of liquid bath would generate about 1,000 ppm of hydrogen sulfide in a 3.3 m³ internal volume. The carbon monoxide concentrations generated were the highest of all the gases generated and poses a toxic hazard to bystanders and emergency responders. The carbon monoxide concentration approached the LFL in small enclosed spaces such as cars, and also poses a flammability hazard.

It is clear the emergency responder needs to be aware that the concentrations of any generated gas may readily exceed established thresholds for toxicity and in some circumstances pose a flammability hazard.

While it has been reported that information has been provided at the scene to warn others,²⁶ it cannot be certain bystanders or emergency responders will have prior information about the reagents, reaction and the gas generated. Therefore, bystanders and emergency responders need to isolate the affected area and not enter any space without first considering the hazards and consequent risk to their safety. They also need to characterise the environment using portable gas detection equipment to ascertain the identity and concentration of the gases over a range spanning from below the PEL up to the LFL and including the IDLH and LC-10.

All these gases are toxic by the respiratory route and the gas concentrations readily exceeded the PEL and,

in the majority of situations, the IDLH. Thus, self-contained breathing apparatus (SCBA) is required to be adopted to protect all emergency responders entering these spaces. The gas concentrations also readily explain the reported injuries^{15,26} to exposed bystanders and unprotected emergency responders who attempt to rescue or provide aid to the affected person.

While exposure to carbon monoxide gas does not present a skin hazard,⁴² it has been widely assumed and accepted that these other gases also present a skin hazard.⁴³⁻⁴⁵ Consequently, emergency responders and hospital emergency departments have decontaminated using water all exposed persons at these incidents. Moreover, this assumption about the gases leads emergency responders to often select the highest level of skin protection available, i.e., vapor tight chemical protective clothing. However, is this approach to decontamination and skin protection supported by the science that describes gas-skin interactions?

Gaskin et al.⁴³⁻⁴⁵ recently reported investigations concerning the interaction between common toxic gases and the skin at concentrations that are of relevance during emergency response situations. They found for phosphine, hydrogen cyanide, and hydrogen sulfide there was no evidence that these gases presented a skin hazard at concentrations up to the accepted lethal concentrations. Consequently, it is clear these gases are primarily respiratory hazards and therefore it is imperative to prevent respiratory exposure of bystanders or unprotected emergency responders. The results and this behavior shows firefighter protective clothing will offer suitable skin protection at these events.

Gaskin et al.⁴³⁻⁴⁵ also reported that fresh air was an expedient and timely method to remove any gas trapped within the clothing of affected persons. Their findings challenge the prevailing decontamination approach adopted at the incidents and also hospitals to deal with exposed persons. Instead, decontamination of exposed persons and emergency responders using air either through natural ventilation or forced ventilation, will be effective. This

decontamination approach should also include appropriate criteria to prove no residual gases remain within their clothing. The concern is not contact with the gas generated, but the toxic or corrosive reagents. Applying a wet decontamination approach where the area of interest is decontaminated remains appropriate where there is evidence of contact on the affected person with the toxic or corrosive material, for example, the person has vomited the toxic reagents. These considerations have significant implications for the subsequent medical management of the affected persons during transit, hospital, or mortuary.

SUMMARY

Mixing these readily available chemicals will generate toxic gases at concentrations that readily exceed established occupational values, and in some cases approach or exceed the LFL in spaces where these suicide events commonly occur. Consequently, it is essential that bystanders and emergency responders assess the risk these incidents pose to their safety and isolate the affected area to prevent any harm to others. Moreover, emergency responders should characterise the environment and adopt SCBA to protect their respiratory system. Their firefighter protective clothing will provide suitable skin protection at these events.

It is also clear that using fresh air, either forced or natural ventilation, is an effective decontamination approach for persons exposed only to the toxic gases. Wet decontamination of the area on a person contacted by the toxic or corrosive reagents remains an appropriate decontamination approach. The same approaches can be applied to industrial incidents involving these materials, such as laboratory accidents in the university environment, as the context of production of the resultant gases does drive the response.

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