Fire Engineering

HYDROGEN CYANIDE: NEW CONCERNS FOR FIREFIGHTING AND MEDICAL TACTICS

06/29/2009

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From the PBI Performance Products, Inc. e-Newsletter, sponsored by

A report of a residential structure fire with the possibility that someone was inside comes across the data dispatch system. Engines 10, 17, and 4; Ladders 10 and 4;, Rescue-17, Fire 5;, and Safety 2 respond. Engine 10 arrives on-scene and transmits this report: "Engine 10 on-scene. W-3 single-story residential with heavy fire and smoke coming from the back of the house.Engine 10 has command and is making entry into structure with confirmation from neighbors that someone is inside. Next engine coming in will lay a supply line."

Fire 5 arrives on-scene and assumes command. He learns that Engine 10 found a female victim in the back of the house near the fire while performing the primary search, and is bringing her outside to the waiting rescue unit. The victim is unresponsive, is taking shallow gasping breaths, and has heavy carbonaceous soot buildup around the mouth and nose. Rescue crews receive the victim and go directly to work with advanced life support measures. The patient is transported to the nearest medical facility for further medical treatment. Unfortunately, she succumbs, and family members are notified.

Events like this happen every day. We have been given much warning about the dangers of carbon monoxide (CO) poisoning associated with fires. But, there is another danger to firefighters and victims in structural fires that is not as well recognized: That is hydrogen cyanide (HCN). Increasingly, research is pointing to hydrogen cyanide as a substance that is as much as a threat to responders and victims encountering fire smoke as carbon monoxide.

HYDROGEN CYANIDE

On February 20, 2003, a fire in The Station nightclub in West Warwick, Rhode Island, took the lives of 100 occupants when pyrotechnics were ignited during a Great White band performance. The pyrotechnics ignited substandard sound-suppressing foam, which created HCN and CO levels incompatible with life in less than 90 seconds[1].

In early 2006, firefighters in Providence, Rhode Island, were tested for HCN after three separate structure fires. Eight of the 27 had elevated levels and required treatment. One firefighter collapsed on-scene and was treated for HCN poisoning.[2]

Most firefighters can probably recall incidents during which they experienced dizziness, weakness, and rapid heart rate (just to name a few symptoms), and did not realize that they may have been exposed to cyanide. As more firefighters become ill or die, researchers expect that HCN will be involved.

HCN is extremely toxic and seriously affects the body. Following are some facts about hydrogen cyanide[3]:

- HCN is 35 times more toxic than CO.
- HCN is produced when products such as wool, silk, cotton, nylon, plastic, and polymers, foam, melamine, polyacrylonitriles, and synthetic rubber burn.
- HCN can enter the body by absorption, inhalation, or ingestion and targets the heart and brain.
- HCN can incapacitate a victim within a short time.
- HCN has a half-life of one hour in the blood.
- HCN is highly flammable, and most of it will burn away during combustion.

Where Does Hydrogen Cyanide Come From?

Hydrogen cyanide is a by-product of the combustion of materials used in products used in everyday life (insulation, carpets, clothing, and synthetics). The culprit is nitrogen. Nitrogen gas in atmospheric air can contribute (under the right circumstances) to the formation of minute amounts of cyanide during combustion. High temperatures and low-oxygen concentrations favor the formation of cyanide gas. Smoke from the combustion of grass clippings, green wood, tobacco, cotton, paper, wool, silk, weeds, and animal carcasses will likely contain some hydrogen cyanide gas. But the real offender is the combustion of manmade plastic and resins containing nitrogen, especially if the fire is hot and in an enclosed space. Common manmade materials that generate cyanide gas during combustion include nylon, polyurethane, melamine, and acrylonitrile. These materials are ubiquitous in building furnishings, vehicles, foam insulation, carpets, draperies, appliances, many plastics, and articles of clothing.

Despite burning away during combustion, objects within a fire continue to produce cyanide as long as their temperature remains elevated. Given that HCN is 35 times more toxic than CO, firefighters should give serious consideration to this deadly gas. Scientists are just figuring out what long-term effects repeated exposures will cause. Until research is definitive, firefighters must protect themselves against the effects of HCN. Many would suggest that the answer lies with SCBA. For years, wearing an SCBA was optional. Today, it is mandatory. The question is: When dp firefighters remove their SCBAs? HCN may still be present in the atmosphere in high concentrations during overhaul. Firefighters must wear their SCBAs until HCN levels have been assessed with atmospheric air monitoring.

How Much Hydrogen Cyanide Gas Can Kill?

The Occupational Safety and Health Administration (OSHA) lists the threshold odor concentration for detection of HCN as 0.58 parts per million (ppm) by the most sensitive individuals, [4] but firefighters and others exposed to smoke from burning materials will not likely be able to smell the gas. Also, up to 40 percent of the population lacks the genetic ability to smell HCN. Hydrogen cyanide causes rapid death by metabolic asphyxiation. The lethal concentration in air (LC50 concentration estimated to kill 50 percent of the test population) depends on the duration of the exposure. The table below details the LC50 in

air estimated for humans[5].

LC50 PPM	Exposure Duration
3,404 PPM	1 minute
270 PPM	6 to 8 minutes
181 PPM	10 minutes
135 PPM	30 minutes

The American Conference of Governmental Hygienists reported that workers exposed to hydrogen cyanide concentrations ranging from 4 to 12 ppm for seven years reported increased headaches, weakness, changes in taste and smell, throat irritation, precordial pain, and nervous instability. Workers exposed to low concentrations developed enlarged thyroid glands. The following permissible limits have been established:

- OSHA's permissible HCN exposure is 10 ppm on an 8-hour time-weighted average (TWA).
- The National Institute for Occupational Safety and Health (NIOSH) lists a short-term exposure lower limit of 4.7 ppm for workers. The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned 4.7 ppm as a worker ceiling limit.
- The word "SKIN" in the NIOSH and OSHA listings means that hydrogen cyanide is absorbed through the skin and eyes.

SYMPTOMS OF EXPOSURE

Firefighter and victims inhaling hydrogen cyanide associated with smoke often experience cognitive dysfunction and drowsiness that can impair the ability to escape or to perform rescue operations.[6] Exposure to low concentrations (or initial exposure to higher concentrations) may result in stupor, confusion, flushing, anxiety, perspiration, headache, drowsiness, tachypnea. Exposures to higher concentrations of HCN result in prostration, tremors, cardiac arrhythmia (which can be delayed two to three weeks after the fire exposure), coma, respiratory depression, respiratory arrest, and cardiovascular collapse.

PREHOSPITAL MANAGEMENT

The prehospital treatment of acute cyanide poisoning entails removing the patient from the source of cyanide, implementing supportive modalities including 100 percent oxygen and providing cardiopulmonary resuscitation, if necessary. There is some concern about providing antidotal treatment to victims exposed to HCN from smoke inhalation.

Antidotal treatment of smoke-inhalation victims on the basis of presumptive diagnosis of HCN poisoning in the prehospital setting is discouraged because nitrate-based kits is the only form of antidote available in the United States. These kits can pose dangers for smoke inhalation victims with concomitant carbon monoxide poisoning. Carbon monoxide displaces oxygen from hemoglobin to form carboxyhemoglobin, whereas nitrates in cyanide antidote kits displace oxygen from hemoglobin to form methemoglobin. The cumulative oxygen-depriving effects of nitrates and carbon monoxide can be fatal.

A new antidote called "hydroxocobalamin" has been effectively used in France for the past 10 years. It is designed specifically for use on-scene or at the hospital for acute HCN poisoning from any source. Hydroxocobalamin neutralizes cyanide by fixing it to form cyanocobalamin (vitamin B12), which is excreted in the urine. It does not reduce the blood's capacity to carry oxygen.

Cyanide exposure is an expected outcome of smoke inhalation in closed-space fires. Research has established that cyanide poisoning can be an important cause of incapacitation and death as well as a potential source of chronic health complications for firefighters. It also suggests that cyanide can act independently of, and perhaps synergistically with, carbon monoxide to cause morbidity and mortality. Because cyanide gas in smoke caused by fires can be rapidly lethal, early management of smoke inhalation-associated cyanide poisoning in the prehospital setting is critical for saving lives. Furthermore, the International Association of Fire Fighters Local 799 (Rhode Island Local 799, 2006) recommends that the following training formats be followed[7]:

- Training and equipment. Develop and institute a training program that focuses on making members aware of the hazards of hydrogen cyanide at fires. Include the following:

a.) the reason cyanide is more significant today than ever before.
b.) The chemistry, identification, and toxicology of cyanide.
c.) The medical concerns associated with cyanide for fire, EMS, and hospitals.
d.) The reasons firefighters cannot merely rely on their past experiences to determine whether a particular atmosphere is safe.

- Compliance. Develop enhanced compliance with mandatory mask regulations. Company officers must focus on protecting their members while ensuring that SCBAs are used. I tell my members: "Your SCBA bottle contains 4,500 psi. From 500 to -4,500 psi belongs to your department for the work that you perform; from 0 to 500 psi belongs to your family."
- SCBA training for difficult operations such as climbing ladders, working on roofs and communicating while on air.
- Post-fire decontamination. Wash/rinse off your turnout gear after every fire. Be sure to shower and change your uniform upon returning to the station.
- Medical community. It needs to be made aware of the presence of cyanide in modern-day smoke and should keep the possibility of cyanide poisoning in mind when presented with a smoke inhalation victim.
- Public education (general public, media, and legislators). Alert the public to the dangers of smoldering and burning plastic and other cyanide-containing fuels. They should also understand that the dangers associated with cyanide may be present before flame is present and that it can incapacitate during the incipient stage of fire and prevent escape.

Do not let the benefit of having this information stop here. Share it with emergency responders and the public. Be sure to wear your personal protective equipment and use caution and common sense.

References

1. Providence Journal.
2. Milkovits, Amanda, "Details of Cyanide Poisoning of Rhode Island Firefighters," April 2006.
3. Riley, Carlin, Steven Young, "Firefighting in Canada," C*anadian Firefighter & EMS*, 2007-2008.

4. Occupational Safety and Health Administration, www.osha.gov.
5.. Hathaway, et al 1991. P*roctor and Hughs' Chemical Hazards of the Workplace*,. 3rd ed (New York, N.Y.: Van Nostrand Reinold, 1991).
6. *Health Hazard Manual for Firefighters*. (New Jersey: Brown, 1990., 21-22.
7. International Association of Firefighters Local 799, "Recommendations to be learned to prevent exposures to cyanide," 2006.

Additional Resources

Eckstein, Marc, MD, & Paul Maniscalco, M MPA, - "Focus on Smoke Inhalation--The Most Common Causes of Acute Cyanide Poisoning," April 2006.

First Responder, "Fires: What's in that smoke?" 2003.

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Subjects: Hydrogen cyanide poisoning, fire-based EMS

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