Hydrogen Cyanide:New Generation Concerns Resulting in Firefighting Tactics and Medicine

Residential structure fire with the possibility of one inside for Engines 10, 17, 4, Ladders 10 and 4, R-17, F-5, and Safety 2 came across the Data Dispatch system and the crews headed towards the location anticipating of what lies ahead. Rounding the corner Engine 10 arrives on scene and transmits over the radio" 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 making entry into structure with confirmation from neighbors that someone is inside. Next engine coming in lay a supply line.

Fire 5 arrives on scene and assumes command and hears that Engine 10 while performing the primary search has found the victim in the back of the house near the fire and is bringing him outside to an awaiting Rescue unit. The victim is unresponsive with shallow gasping breath sounds and heavy carboneous soot buildup around their mouth and nose. Rescue crews receive the victim and goes directly to work with advanced life support measures to revive the patient and transport to the nearest medical facility for further medical treatment. The patient unfortunately succumbed to the event and family members were notified.

Events like the one mentioned above happen every day around the world and much warning has been given on the dangers of carbon monoxide poisoning resulting from fires. But there is another danger to firefighters and victims in structural fires which is less recognized, and that is acute cyanide poisoning.

Fire service personnel often think of carbon monoxide as the silent killer. More and more, however, research is pointing to hydrogen cyanide, as a second and equally hazardous threat that deadly HCN gas in fire smoke threatens responders.

On February 20, 2003 a fire in a West Warwick Nightclub took the lives of 100 occupants when pyrotechnics were set off when the band Great White was performing. The pyrotechnics ignited substandard sound suppressing foam to sheets of flame and created HCN and CO levels to a range making exiting out of the building difficult.

In early 2006 firefighters in Providence R.I. (Milkovits,Amanda,Providence Journal,2006) were tested for HCN levels after three separate structures fire. Eight of the 27 had elevated levels of HCN and required treatment. One firefighter collapsed at the scene and was treated for HCN that required an antidote and in February 2008 was released on medical disability.

Most firefighters can probably recall incidents during which they experience dizziness, weakness, rapid heart rate just to name a few and not realize that they may have been exposed to cyanide poisoning. As more firefighters become ill or die as a result of an unknown, researchers expect the finger will be pointed to HCN.

By now, those in the fire service should know that HCN is extremely toxic and has serious effects on the body to prove that here are some interesting facts about hydrogen cyanide (Riley, Carlin, Young, Steve 2007-2008):

- ✓ HCN is 35 time 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 often incapacitates the victim within a short period of time.
- ✓ HCN has a half life in blood of one hour.

- ✓ HCN is highly flammable and most will burn away during combustion.

Where Does Hydrogen Cyanide Come From?

Hydrogen Cyanide is a bi-product of combustions from ordinary materials of everyday life (insulation, carpets, clothing, and synthetics) which can release cyanide if they catch fire. The culprit is nitrogen which makes up the combustible material. Even the nitrogen gas which makes up the major part of the air can contribute under the right circumstances to form a minute amount of cyanide during burning of combustibles. 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 from the combustion of man-made plastic and resins containing nitrogen, especially if the fire is hot and in an enclosed space. Common man-made materials which generate cyanide gas during combustion include nylon, polyurethane, melamine, and acrylonitrile. These materials are present everywhere in building furnishings and our vehicles, foam insulations, furniture, carpets, draperies, appliances, many plastics, and articles of clothing's.

Despite burning away during combustion, the heated objects within the fire continue to produce more products as long as their temperature remains elevated. Given that HCN is 35 times more toxic than CO, considerations of this deadly gas should be front and center in firefighter minds. HCN exist, and has for years, in the smoke that firefighters are exposed to everyday. Scientists are just figuring out what long-term effects will be with repeated exposures. Until research is definitive, how do firefighters protect against the effects of HCN? Many would suggest that the answer lies on the back and that SCBA is a firefighter's best friend when it

comes to protecting against HCN. For years, wearing an SCBA was an optional: however, today it is mandatory. The question now is when do we remove the SCBA, after the flames are out?

Surprisingly enough the HCN may still be present in the atmosphere still in high concentrations to affect the firefighters. Until it can be diagnosed using atmospheric air monitors the SCBA should be worn until the atmosphere is completely free of HCN.

How much Hydrogen Cyanide Gas Can Kill?

The Occupational Safety and Health Administration (OSHA) website (www.osha.gov) lists the threshold odor concentration for detection of HCN as 0.58 parts per million by the most sensitive individuals, but firefighters and others exposed to smoke from burning materials will not be able to smell the gas. Also possibly 40% of the human population are unable to smell HCN because of genetic and other factors and even if they could smell HCN it may be masked by other chemicals. Hydrogen cyanide causes rapid death by metabolic asphyxiation. The lethal concentration in air (LC_{50}, concentration estimated to kill 50% of test population) require to kill humans depends upon the duration of exposure.

In the table listed below details the LC_{50} in air estimated for humans (source: Hathaway et al. 1991. Proctor and Hughs' Chemical hazards of the Workplace. 3rd ed Van Nostrand Reinold, N.Y. N.Y.)

LC_{50} PPM	Exposure Duration
3404 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. Also workers exposed to low concentrations developed enlarge thyroid glands however, some interesting governmental facts on the toxilogical aspects of HCN reveal:

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

Symptoms of exposure to Smoke Inhalation-Associated Cyanide Poisoning

Firefighter and victims inhaling hydrogen cyanide associated with smoke as in the burning of plastic materials often experience cognitive dysfunction and drowsiness that can impair the ability to escape or to perform rescue operations (Brown, Nellie J 1990). Exposure to low concentrations (or initial exposure to higher concentrations) may result in stupor, confusion, flushing, anxiety, perspiration, headache, drowsiness, tachypnea (greater than 100 beats per minute in an adult).Exposures to higher concentrations of HCN result in prostration, tremors, cardiac arrhythmia (in which can be delayed 2-3 weeks post fire exposure), coma, respiratory

depression, respiratory arrest, and cardiovascular collapse.

Other harmful effects may be in that smoke including carbon monoxide. Breathing the hot gas and smoke may cause thermal injury in the upper airway. There may be blistering and soot deposits in the nose and mouth. There may be adsorption of other toxins and upper airway edema usually becomes apparent within 24 hours of injury and usually resolves itself within 3-5 days.

Prehospital Management of Smoke Inhalation Associated Cyanide Poisoning

The prehospital treatment of acute cyanide poisoning entails: removing the patient from the source of cyanide, implementing supportive modalities of 100% oxygen and providing cardiopulmonary resuscitation if necessary. The provision of antidotal treatment is associated with unique concerns in victims exposed to HCN from smoke inhalation. The typical practice of administration of antidotal treatment on the basis of presumptive diagnosis of HCN poisoning is the prehospital setting is discouraged in smoke-inhalation victims because the only antidote available in the United States are nitrates such as the Lily Kit, Taylor Kit, and the Pasadena Kit. These kits can be proven dangerous for smoke inhalation victim's concomitant carbon monoxide poisoning. In other words carbon monoxide displaces oxygen from hemoglobin to form carboxyhemoglobin, whereas nitrates in the Cyanide Antidote Kit displace oxygen from hemoglobin to form methemoglobin. This additive oxygen-depriving effects of nitrates and carbon monoxide can be fatal. However, there is a new antidote called hydroxocobalamin which has been effectively used in France for the past 10 years. It is designed specifically to be used on the scene or at the hospital for acute CN poisoning from any source. The hydroxocobalamin neutralizes cyanide by fixing it to form cyanocobalamin (vitamin B12) which is excreted in the urine. It does not have the problem of reducing the blood's capacity to carry oxygen as in the case of nitrate administration.

Conclusions

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 to victims as well as chronic health complications to firefighters. It also suggests that cyanide can act both independently of, and perhaps synergistically with carbon monoxide to cause morbidity and mortality. Because cyanide gas in smoke caused by fires can turn lethal rapidly, early and management of smoke inhalation-associated cyanide poisoning in the prehospital setting are critical for saving lives. **(Marc Eckstein, MD, FACEP, Paul Maniscalco, MPA, DrBA(c)**

Furthermore, in closing the IAFF Local 799 (Rhode Island Local 799, 2006) recommends that the following training formats be followed:

- ✓ Training and equipment- develop and institute a training program that Focuses on making members aware of the hazards of hydrogen cyanide at fires such as:
    - a.) explanation about why cyanide is more significant today than ever before.
    - b.) chemistry, identification, and toxicology of cyanide
    - c.) medical concerns of cyanide for both fire, ems, and hospitals.
    - d.) why firefighters cannot merely rely on their past experiences to determine whether or not a particular atmosphere is safe.
- ✓ Compliance- develop enhanced compliance with mandatory mask regulations and company officers must focus on the protection of their members while ensuring that SCBA's are utilized. My analogy that I use frequently is that your SCBA bottle

contains 4500 psi. From 500-4500 psi belongs to you department for the work that you perform and from 0-500 psi belongs to your family. This statement needs to be instituted to every firefighter mind to help reduce the risks involved that firefighters are exposed to everyday.

- ✓ 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 needs education on the presence of cyanide in modern day smoke and should keep in mind upon presentation of a smoke inhalation victim that cyanide poisoning should until it is ruled out.
- ✓ Public Education needs to be administered to the general public, media, and legislatures about the dangers of smoldering and burning plastic and other cyanide containing fuels. They should also understand the dangers associated with cyanide that it may be present before any presence of flame and it is possible that incapacitation is very possible during the incipient stage of fire which could prevent them escaping.

The main mission of this article is to educate our responders by providing them with new technological information based on the principle of fire behavior. My hope is that this beneficial

information does not stop here, but distributed to all emergency responders who tackle this toxic chemical everyday of their career. I implore everyone to utilize their personal protection equipment to the best of their ability, utilize common sense and keep on working towards that happy and healthy retirement.

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2nd Battallion

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