Smoke from structural fires produces many toxic gases that put firefighters at risk, including carbon monoxide (CO) and hydrogen cyanide (HCN). Dangerous individually, significantly more harmful together: What you should know about the “toxic twins”.

Understanding the Toxic Twins: HCN and CO
Together, CO and HCN – known in the fire industry as the “toxic twins” – create a deadly chemical asphyxiant that can put the firefighter or fire victim into cardiac arrest at the time of the fire and cause cancer decades later.

Because the combination of CO and HCN is exponentially more harmful than exposure to these agents individually, measuring each gas against its single alarm threshold is insufficient for overhaul operations.

This paper describes the nature of fires today, examines the progressive effects of CO and HCN on the body, and describes best practices for firefighter safety – including a new gas monitoring technology that can provide early warning of danger by simultaneously measuring the presence of both gases.

**Background**

In the 1970s, the fire service began to recognize the danger of inhaled toxic gases from smoke. Soon after, investigators became aware of the dangers of toxic gases found during overhaul. Now, the industry is learning of the long-term health dangers such as cancer from toxic gases.

Historically, home furnishings were made of natural products such as cotton, wool, and wood. But in the 1960s, they began to be made of synthetic materials. Today, the vast majority of furniture, carpeting, bedding, clothing, appliances, electronics, and building materials inside the average home or office is made of synthetic materials. Insulation – both rolled and spray foam – is the single product known to produce some of the highest levels of HCN and other toxicants during combustion.

Because synthetics burn hotter than natural materials and produce quicker flashovers, they also speed up the release of HCN. Radiant heat from the fire source quickly heats all of the materials around it. The materials incur what is called quantitative decomposition – where they spread toxic gas through the structure before they ignite.

One of the most tragic examples of quantitative decomposition occurred in 2003 at the Station Nightclub in West Warwick, Rhode Island. Two pyrotechnic devices were set off during a band performance, creating an exothermic reaction that threw sparks over a distance of 15 feet for about 15 seconds. These sparks ignited a substandard sound suppression foam board that was wrapped around the stage to project sound into the audience. As temperatures soared from the initial flames, thermal decomposition of the foam board began to produce high quantities of smoke filled with HCN.

Subsequent investigations and a simulation of this event by NIST concluded that with an inadequate sprinkler system in the building, the performance area was uninhabitable within 90 seconds. Many of the 462 people in the room were overcome by the HCN/CO in the smoke before they could get out of the structure. 100 people lost their lives and more than 200 were severely burned or injured as a result of this event.
Where there is smoke, there are toxic gases
In residential fires today, the leading cause of death is from smoke inhalation – not burn injuries. A 2011 study by the NFPA shows an 8-to-1 ratio of smoke inhalation to burns for deaths in home fires. During a fire, oxygen levels decrease and the environment is likely to contain high levels of carbon monoxide and many other toxins.

Moreover, smoke produces toxins regardless of its thickness, color or movement. It is impossible to tell from looking at smoke how much toxic gas is coming out of the structure. It’s pretty obvious that there are toxins in heavy, turbulent smoke – but they can also be present in light colored smoke or even haze.

While firefighters are exposed to harmful substances both through their lungs and their skin, lungs are 300 times as efficient in getting toxins into the body.

HCN: the silent killer
While the threat of CO has been known for years, Firefighters are trained to watch for symptoms of carbon monoxide poisoning – including headaches, nausea, and drowsiness.

Exposure to high levels of carbon monoxide can be fatal, but what is often overlooked is the presence of cyanide. While many associate cyanide with chemical weapons and hazardous material (hazmat) scenarios, research has shown that cyanide is a significant contributor to the thousands of fire-related deaths each year.

Studies have shown that in fire smoke, hydrogen cyanide can be up to 35 times more toxic than carbon monoxide.

The NIOSH short-term exposure limit (TLV-STEL) for HCN is 4.7, above which concentration a worker should not be exposed (averaged over 15 minutes). Exposures cannot be repeated more than 4 times per day. The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned 4.7 ppm as a worker ceiling limit (TLV-C), above which concentration a worker should never be exposed.

Studies showed HCN levels of 200 ppm common in normal structural fires: That is lethal in 30 to 60 minutes.
The prevailing thought had been that if you get a person out of the smoke and into fresh air, the toxins will be replaced by the fresh air. It is now known that the toxins are stored in the body and can be difficult to displace. Cancer has now become the #1 long-term cause of firefighter death.

Because of the extreme toxicity of HCN, firefighters who experience dizziness, weakness, and rapid heart rate after a fire may actually be feeling the effects of HCN. It is theorized that many firefighter heart attacks and cardiac arrest during or following fire operation may be HCN-related.

HCN also has a narcotic-like effect and can result in irrational and bizarre actions, causing the firefighter or victim to make life threatening decisions.

### FACTS ABOUT HCN

- HCN is 35 times more toxic than CO
- HCN can enter the body by absorption, inhalation, or ingestion and targets the heart and brain
- HCN can cause heart attacks and cardiac arrest, then hamper resuscitation
- HCN can cause bizarre and irrational behavior, hamper ability to perform role or to self-rescue, and can hinder or prevent rescue by others
- HCN can incapacitate a victim within a short time

<table>
<thead>
<tr>
<th>HCN CONCENTRATION IN THE AIR</th>
<th>VOL.%</th>
<th>VERGIFTUNGSSYMPOTOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 ppm</td>
<td>0.00021</td>
<td>Max workplace concentration for 8-hour work – Europe</td>
</tr>
<tr>
<td>2 – 4 ppm</td>
<td>0.0004</td>
<td>Perception threshold</td>
</tr>
<tr>
<td>4.7 ppm</td>
<td>0.00047</td>
<td>NIOSH REL: STEL</td>
</tr>
<tr>
<td>10 ppm</td>
<td>0.001</td>
<td>OSHA PEL: TWA</td>
</tr>
<tr>
<td>20 – 40 ppm</td>
<td>0.004</td>
<td>Slight symptoms after several hours</td>
</tr>
<tr>
<td>45 – 54 ppm</td>
<td>0.0054</td>
<td>Immediate and subsequent damage within one hour</td>
</tr>
<tr>
<td>100 – 200 ppm</td>
<td>0.02</td>
<td>Deadly after 30 – 60 minutes</td>
</tr>
<tr>
<td>300 ppm</td>
<td>0.03</td>
<td>Immediate death</td>
</tr>
</tbody>
</table>
How HCN affects the body

HCN is a cellular asphyxiant that interferes with aerobic respirations. During normal respiration, the body provides nutrients to key enzymes that allow our bodies to function properly. However, when HCN is inhaled, it has a high affinity for a key enzyme called cytochrome C oxidase – which basically shuts down the aerobic respiratory path. The result is anaerobic respirations, resulting in lactic acidosis and other toxic substances that are created in the tissues and organs.

Individuals inhaling hydrogen cyanide associated with smoke often experience cognitive dysfunction and drowsiness that can impair their ability to escape or to perform rescue operations. Exposure to low concentrations (or initial exposure to higher concentrations) may result in stupor, confusion, flushing, anxiety, perspiration, headache, drowsiness, and rapid breathing. Exposure 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.

Unfortunately, there is no quick test that be administered to individuals at the site of a fire to check for HCN toxicity. As a result, all firefighters need to be on the alert for HCN poisoning in fellow firefighters – both at the fire scene and afterward at the station.

If a firefighter or victim shows significant signs of HCN toxicity, HCN antidotes can be administered to help speed the person’s recovery.

**SYMPTOMS OF HCN POISONING**

- Coughing up carbonaceous sputum
- Soot or burns around the mouth and nose
- Shortness of breath, chest tightening, headache
- Smell of almond extract on the breath (anecdotal)
- Cardiac issues
- Disorientation, possibly bizarre behavior
- Drowsiness
- Possibly bright red skin discoloration (for prolonged exposure)
- Lethargy
- Weakness

**Treatment of a possible HCN patient**

Because cyanide gas in fire smoke can quickly become lethal, early attention to possible cyanide poisoning is critical for saving lives.

The prehospital treatment of acute cyanide poisoning entails removing the person from the source of cyanide, administering 100% oxygen, and providing cardiopulmonary resuscitation, if necessary.

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.
Beware of secondary HCN Exposure

Firefighters also need to realize that because soft body tissue acts like a sponge, fire victims absorb a lot of the combustion byproducts. When a victim is removed from a contaminated environment and brought out into clear air, their body tissue begins to outgas some of the contaminants. Therefore, emergency responders working on the victim become exposed to the same contaminants, including HCN and many other chemicals.

After the victim has been delivered to the hospital and the firefighters go back to their station, the rescuers may start to experience headaches, nausea, vomiting, and things of that nature. While these symptoms may be a result of work stress, it’s just as likely caused by exposure to contaminants such as HCN and CO.

New technology provides early warning of toxic twin danger

Research shows that the combination of CO and HCN is actually more harmful than exposure to either one individually. If both gases are inhaled together, they have a toxic synergistic effect: CO prevents oxygen from reaching vital organs, HCN attacks the central nervous system and the cardiovascular system, causing people to become disoriented and confused. Thus measuring each single gas against its single alarm threshold is not ideal for overhaul operations.

Dräger, a leading provider of high quality safety equipment to firefighters worldwide for more than 125 years, has introduced new “toxic twin” signal processing technology that provides protection against the combination of CO and HCN. The standard settings for the alarm threshold are for CO 30 – 35 ppm (A1) and 50 – 60 ppm (A2); for HCN 1.9 – 2.5 ppm (A1) and 3.8 – 4.5 ppm (A2).

The previous state of the art was to treat and measure CO and HCN separately – no adjustment was made for the presence of both gases. Each alarm threshold was analyzed separately and not enough attention was paid to the toxic synergistic effect.

With the toxic twins signal processing, the gas values are measured together and are added. An alarm is triggered by scaling the concentration of both substances.

How can firefighters protect themselves?

While firefighters cannot avoid exposure to toxic substances such as HCN and CO in the line of duty, they can protect themselves by adhering to the following guidelines.

– Wear PPE: This requires energy and an ongoing commitment on the part of the firefighter
– Monitor toxic gases: Make gas monitoring a standard procedure
– Use SCBA: Keep SCBA on until it has been determined that air is safe to breathe and make SCBA available for drivers/operators
– Shower in an hour: By showering within an hour, firefighters can reduce exposure to toxins by 90%. If they wait until they go home that night, they have received 100% exposure – so the shower does nothing to reduce their risk of cancer.
– Decon: Decontaminate PPE according to Fire & Emergency Training Institute (FETI) guidelines
– Watch out for each other: Be alert to symptoms in fellow firefighters, both at the fire scene and back at the station
– Education and training: Institute a training program that focuses on making firefighters aware of the hazards of hydrogen cyanide.
Dräger has incorporated “toxic twins” function into the Dräger X-am® 5000 and 5600 gas monitors with firmware 7.0 or later. The technology is patented in the USA by Dräger (Pub. No. US2014/0284222 A1) for the toxic substances CO and HCN.

**SUMMARY**

This new gas monitoring innovation increases firefighter safety during overhaul based on scientific research conducted in the U.S. With this new technology, Dräger provides the best possible safety against the toxic synergistic effect of hydrogen cyanide and carbon monoxide.

Discover our full range of portable gas detection technologies and find the right solutions for the challenges you face every day:

www.draeger.com/portable-gas-detection
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