Plastic Polymers and the Changing Nature of Fires

By Robb Zurek and Draeger’s Engineering Team

Research shows that over the past 50 years there has been rapid growth in the use of plastic-based products in building structures and their contents. This has drastically changed the nature of fires and the combustion byproducts as plastic materials burn. There is growing evidence that, along with the well-known threat of carbon monoxide (CO), life-threatening concentrations of hydrogen cyanide (HCN) gas can be present in combustion byproducts. Sometimes airborne concentrations of HCN may be high enough that they cause immediate symptoms in responders not wearing their self-contained breathing apparatus (SCBA). In other cases, lower concentrations of HCN breathed in for a long enough time may cause symptoms later, including fatal heart attacks.

There is heavy use of plastics in today’s building structures and their contents, including carpeting, furniture, cabinetry, etc. It has been observed that when plastics catch fire, they burn hotter and produce higher quantities of toxic combustion byproducts than were seen in fires of a few decades ago. In addition to anecdotal evidence, research findings support these conclusions.

For the past four years, Rick Rochford, a captain with the Jacksonville, Florida, Fire and Rescue Department, has been conducting atmospheric monitoring studies for hydrogen cyanide (HCN) gas and carbon monoxide (CO) accumulations at various fire situations. The CO threat has been known for years, but Rochford’s studies showed that HCN was present at every fire he investigated. Furthermore, his findings support the conclusion that the combustion creating HCN and CO has also changed the way fires burn when plastics and other synthetics have replaced ordinary combustible materials throughout society.

An examination of today’s building designs, construction materials, and structure contents reveals many synthetic polymers. These synthetics, which produce HCN when they burn, include nylon, polyurethane, synthetic rubber, melamine, resins for molding, and various laminates. Among this list of synthetics, insulation materials produce some of the highest levels of HCN and other toxicants during combustion. This includes both rolled insulation and spray foam insulations.

These synthetics are making fires burn 2 to 3 times hotter, creating faster flashovers, and producing larger amounts of turbulent smoke during combustion. The flashovers from synthetic polymer combustion can create temperatures as high as 1,000 to 1,500 degrees Fahrenheit. Because synthetics burn hotter than natural materials and produce quicker flashovers, they also speed up the release of HCN.

Rochford’s findings suggest that fire responders may frequently be exposed unknowingly to dangerous toxicants, including HCN. He cites the production of HCN at fires as being caused by the incomplete combustion of nitrogen- and carbon-containing substances. The hydrocarbon nature of plastic polymers is the source of all the elements needed to
form HCN during combustion. This results in much higher concentrations of poisonous HCN than combustion of natural fibers such as wool, silk, cotton, and paper.

**Quantitative Decomposition**

Combustion byproducts fall into three hazard categories: irritants, asphyxiates and toxicants. These can exist in both gaseous and particulate forms. During the quantitative decomposition period, gas is emitted without the presence of any flames. It’s caused by the thermal decomposition of the molecular materials in the object. Although there are a multitude of chemical byproducts in the smoke from a structure fire, asphyxiates and toxicants are the ones we tend to focus on due to their potential effect on workers’ health. CO affects oxygen-carrying capabilities within a person’s bloodstream. HCN affects the tissues of internal organs, with the most serious negative effects being on the heart and brain, to the point where damaged tissue is not regenerated.

**Secondary HCN Exposure**

Secondary exposure is also a concern. Soft body tissue acts like a sponge; therefore, fire victims absorb combustion byproducts. When a victim is removed from a contaminated environment and is brought into clear air, their body tissue begins to outgas some of the contaminants. Therefore, emergency responders working on the victim get exposed to the same contaminants, including HCN and a host of other chemicals.

**Proactive Measures**

As a whole, responders need to be proactive in the areas that will be most beneficial to fire victims and themselves. The most important areas are:

- Monitoring the environment around a fire for HCN, CO, and possibly other chemicals
- Monitoring team members for possible exposure to these chemicals
- Monitoring use of SCBAs
- Taking personal responsibility for SCBA usage
- Decontaminating personal protective gear after returning to the station
- Educating the medical community on the probability of HCN exposure by victims and firefighters

For atmospheric monitoring to be effective in protecting the lives of responders, the instrumentation must be on the first unit to arrive at a fire, and it must be used consistently to let the responders know exactly what they are facing in terms of toxic environments. Put simply, HCN detection equipment needs to be deployed in the field and used at all fires.

The possibility of HCN exposure must be communicated to doctors and nurses when a victim or firefighter is presented at the hospital. While symptoms may point to a heart attack, the underlying cause may be more than overexertion.

At the fire scene and afterward, everyone needs to be on the alert for HCN poisoning in fellow firefighters. HCN is a cellular asphyxiant that interferes with aerobic respirations. The outward signs of HCN poisoning are lethargy, weakness, shortness of breath, chest tightening, headache, drowsiness, disorientation, possibly bizarre behavior, and cardiac
issues. In addition, look for bright red discoloration on the skin of those who have experienced prolonged exposure inside a contaminated environment.

Particularly close attention should be paid to anyone who has soot or burns around the mouth and nose and is coughing up carbonaceous sputum. Another classic symptom is a smell of almond extract on the breath. Even then, this particular odor may not be detected due to other chemicals outgassing from the person’s body. If there is sufficient indication of HCN toxicity in any of these individuals, then administration of HCN antidotes can be utilized to help speed up the person’s recovery.

Enhanced compliance includes adherence to the NFPA 1404 Respiratory Standards for 2007. Since NFPA 1404 is fairly new, some departments may not be aware of its Rule of Air Management, commonly known as ROAM.

ROAM intends to make responders aware of how much air they have in their bottle. When fire responders report for duty at the station each day, the first thing they should do is make sure they have a full bottle of air. This should be checked again before going into the contaminated atmosphere of a working fire.

**Decontaminate After the Fire**

Companies also need to be concerned about post-fire decontamination. They need to make sure that responders shower and change their clothes soon after they finish a response. It is also essential for turnout gear, including Nomex® hoods, to be washed frequently. Regular cleaning of equipment is crucial because contaminant molecules can build up on personal protection materials. Even better is availability of a second set of gear, which allows rotation of the two sets.

**Chronic Effects of Contaminant Exposure**

Repeated and prolonged exposure to HCN and other contaminants can have long-lasting effects on the body, including breathing problems, respiratory arrest, chest pains, cardiac arrhythmias, cardiovascular collapse, vision dimming, headaches, depression, loss of appetite, extreme weakness in the extremities, and paralysis. Another fairly common problem is an enlarged thyroid gland. In the absence of a rigorous physical, responders should regularly get a thorough physical exam by a personal doctor.

In the end, each individual must perform his or her duties in a safe manner to protect themselves as well as victims.

**Conclusions**

1. HCN is present in the combustion byproducts of virtually every fire today. It comes from the thermal breakdown of plastics and other synthetic polymers. These materials burn two- to three-times hotter than natural materials, causing quicker flashovers and creating more toxic vapors.

2. Responders need to watch for the effects of HCN exposure, such as disorientation, weakness, shortness of breath, headache, drowsiness, and cardiac issues. Repeated and prolonged exposure can lead to chronic and debilitating health problems, and early death.
3. The most important form of protection from HCN, CO, and other contaminants is diligent use of SCBAs and monitoring of the air supply in those devices until the responder is well away from a burning structure.

4. Atmospheric monitoring is by far the most reliable way of determining whether the environment around a fire scene is contaminated.

5. Post-fire decontamination should be followed rigorously to prevent exposure afterward.

6. Company-wide education and training are key elements in improving safety and the use of SCBAs, but company officers must also lead by example.

Robb Zurek is Communication Program manager for North America at Draeger Safety, Inc. Draeger manufactures gas detection, respiratory and safety products for the oil and gas, chemical, fire, and mining industries.