Keywords: confined space, exposure limits, gas detection, LEL, OEL, oil, petrochemical, PID, photo-ionisation, toxic gas, TWA, vapour, volatile organic compounds, VOC.

VOCs – a very real danger

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Abstract

As well as being combustible, many volatile organic compounds (VOCs) pose a significant toxic threat, a problem which has received increased attention over recent years. The nature of the threat makes it vital to monitor exposure of individuals to these compounds over time. The degree of hazard posed by each VOC is different, further increasing the complexity of the task of keeping people safe. The consequences of not doing so, however, can be long term, debilitating or even fatal illness.

Introduction

In many working environments, volatile organic compounds (VOCs) are virtually ubiquitous. These compounds are frequently hydrocarbons, and at room temperature, are liquids that give off highly flammable vapour. They also tend to be toxic and have low occupational exposure limits. In fact, long before a concentration sufficient to register on a combustible gas indicator is reached, the toxic exposure limit has usually been exceeded. Increased awareness of the toxicity of VOCs has led to lowered exposure limits and increased requirements for direct measurement.

VOCs – a common problem

Volatile organic compounds are characterised by their tendency to evaporate easily at room temperature[1]. Familiar substances containing VOCs include solvents, paint thinner and nail polish remover, as well as the vapours associated with fuels, including petrol, diesel, heating oil, kerosene and jet fuel. The category also includes specific toxic substances, such as benzene, butadiene, hexane, toluene, xylene, and many others.

A particularly toxic VOC is benzene. Well documented adverse health effects of chronic benzene exposure are anaemia and leukaemia[2]. It is especially hazardous because it is so common, being used in the manufacture of many man-made compounds, like some rubbers, dyes and detergents. It is also a precursor of other VOCs, such as toluene, phenol and aniline, as well as being found in diesel, petrol and jet fuel.

There are many industries in which VOCs pose a significant threat to health, particularly in industries working with oil and its derivatives. There are many VOCs derived from the oil refining and petrochemical industries. These are essential to the production of a lot of important materials, such as dyes, plastics, detergents, solvents, paints, synthetic rubber and pharmaceuticals. Exposure to these compounds can occur during their transportation, storage or use, or as a result of a spillage or leak.

Most of the work involved in inspecting and modifying fuel tanks and their associated systems must be done from inside the tanks. Despite being emptied, the tank will contain fuel residue, and workers will be exposed. Confined space entry check procedures and subsequent monitoring must include VOC detection.

Multiple threats of VOCs

Depending on the workplace environment, VOCs can pose multiple hazards. Often, VOC vapours are heavier than air. A manufacturing facility or depot may have many confined spaces where the build-up of VOCs could displace the air, posing a risk to workers. Confined space fatalities are too often caused through oxygen deficiency in this way.

Any flammable gas must reach a minimum concentration in air — its lower explosive limit (LEL) — before combustion is possible[3]. Vapours from VOCs also tend to have low LELs. To illustrate, methane, not a VOC but a well recognised explosion risk, is defined by ATEX to have LEL of 44,000 parts per million (ppm)[4] equal to 4.4% CH_4 volume in air. Benzene, by contrast, has an LEL of only 13,000ppm[2] (1.3%). Combined with a very low flash point of -11°C, the explosive hazard posed by benzene becomes easy to understand.

Toxic affects of VOCs

For the most part, VOCs are chronically rather than acutely toxic. This means that their effects are not apparent for some time after exposure. Although, this is not exclusively the case; benzene, again, being a good example (table 1). From around 50ppm, inhalation of benzene can result in headaches, lethargy, and a general feeling of weakness[5]. At around 500ppm, symptoms of illness become apparent after only an hour's exposure; above 1500ppm, serious symptoms can manifest themselves. Just half an hour at 7500ppm is considered "dangerous to life". Beyond 20,000ppm, depression of the central nervous system, cardiac arrhythmia, respiratory failure and death are an imminent risk[2].

Table 1: Affects of inhalation of benzene at increasing parts per million

Benzene (ppm)	Signs and symptoms
50 – 150	Headache, lethargy, weakness (5 hours)
500	Symptoms of illness (60 minutes)
1,500	Serious symptoms (60 minutes)
7,500	Dangerous to life (30 minutes)
20,000	Central nervous system depression, cardiac arrhythmia, respiratory failure and death (5 –10 minute exposure)

The effects of most low-level VOC exposure are frequently not felt for many months or years, however. Exposure can be through inhalation or through contact via the skin or eyes. Inhalation poses most risk, as the vapour is able to pass through the thin membrane of the lungs into the blood stream. The results can range from irritation of the respiratory tract to damage of the nervous system and cancer. Long-term neurological symptoms can include impaired memory, reaction times, balance and hand-eye coordination. Peripheral neurotoxic effects can include tremors and diminished motor movements. Mood disorders (presenting as depression, irritability, and fatigue) can be common. Volatile organic compounds have also been implicated in kidney damage, immunological problems and increased cancer rates.

Monitoring against toxic exposure

Occupational exposure limits (OELs) are designed to protect workers against the negative health effects of exposure to hazardous substances. The OEL is the maximum concentration of an airborne contaminant to which an unprotected worker may be exposed during the course of workplace activities. For example, in the United Kingdom, OELs are listed in EH40/2005 Workplace Exposure Limits[5]. This document currently lists enforceable exposure limits for about 500 substances. Unprotected workers may not be exposed to a concentration of any listed substance that exceeds the limit published. Responsibility for ensuring this falls to the employer.

A personal gas detector is the only sure way to monitor against the OEL being exceeded. In general, OELs, are defined in two ways:

- **Long Term Exposure Limit (LTEL)**
  calculated as an 8-hour time weighted average
- **Short Term Exposure Limit (STEL)**
  the maximum allowable concentration over a shorter time period, usually 10 or 15 minutes

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The time weighted average (TWA) is the permitted worker exposure averaged over an 8-hour day. It allows for periods above the TWA limit, but only as long as the STEL is not exceeded and there is equivalent under-exposure to compensate. If no STEL is mandated, a common approach is to set an STEL-equivalent limit of (depending on the jurisdiction) between two to five times the allowable 8-hour TWA averaged over a 10 to 15 minute period.

Most direct reading instruments include at least three separate alarms for each type of toxic gas measured. Typically, a toxic gas instrument will include an 8-hour TWA alarm, an STEL alarm, and an instantaneous "ceiling" alarm, (sometimes called the "peak" alarm), that is activated immediately whenever this concentration is exceeded.

Table 2: Comparison of explosive and toxic limits

VOC	UK OEL[5]		100% LEL* (vol. %)	5% LEL (as ppm)
Acetone	TWA STEL	500ppm 1500ppm	2.5	1250ppm
Benzene	TWA	1ppm	1.2	600ppm
Hexane	TWA	20ppm	1.0	500ppm
Hydrogen sulphide	TWA STEL	5ppm 7ppm	4.0	2000ppm
Isopropyl alcohol (also propan-2-ol)	TWA STEL	400ppm 500ppm	2.0	1000ppm
Styrene	TWA STEL	100ppm 250ppm	1.0	500ppm
Toluene	TWA STEL	50ppm 100ppm	1.0	500ppm

* LEL taken from IEC60079-20-1:2010.

Many VOCs pose an explosive hazard and a toxic hazard, and often at very different concentrations (table 2). Alarm levels set to monitor for exposure to TWA, STEL and ceiling concentrations are usually well below those set for the LEL. While pellistors (also know as catalytic hot-bead or wheatstone bridge) are the common sensor style for detecting combustible gases at LEL levels, this technology is not much use to protect against the toxic effects of VOCs.

Sensors based on photo-ionisation detection (or PID) technology are most favoured to ensure that workers are not being exposed to toxic levels of volatile organic compounds[3]. For many applications, this is incorporated into a compact multi-sensor instrument.

Summary

It is easy to be complacent about low-level, long-term exposure to volatile organic compounds, as the long-term effects may not be felt for many years. Indeed, realisation is still growing of what the full extent of these long-term effects can be. However, they can include seriously debilitating and life-threatening diseases, including kidney damage, neurological harm, anaemia and leukaemia. The best solution to protect against this kind of exposure is personal gas detection based around photo-ionisation detection.

For information about Crowcon gas detection solutions for the oil & gas and petrochemical industries, visit www.crowcon.com/industries-and-applications/oil-and-gas-exploration-and-production.html

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