Dr Christina Baxter, of EmergencyResponseTIPS.com and Hazard3.com, offers helpful advice for first responders

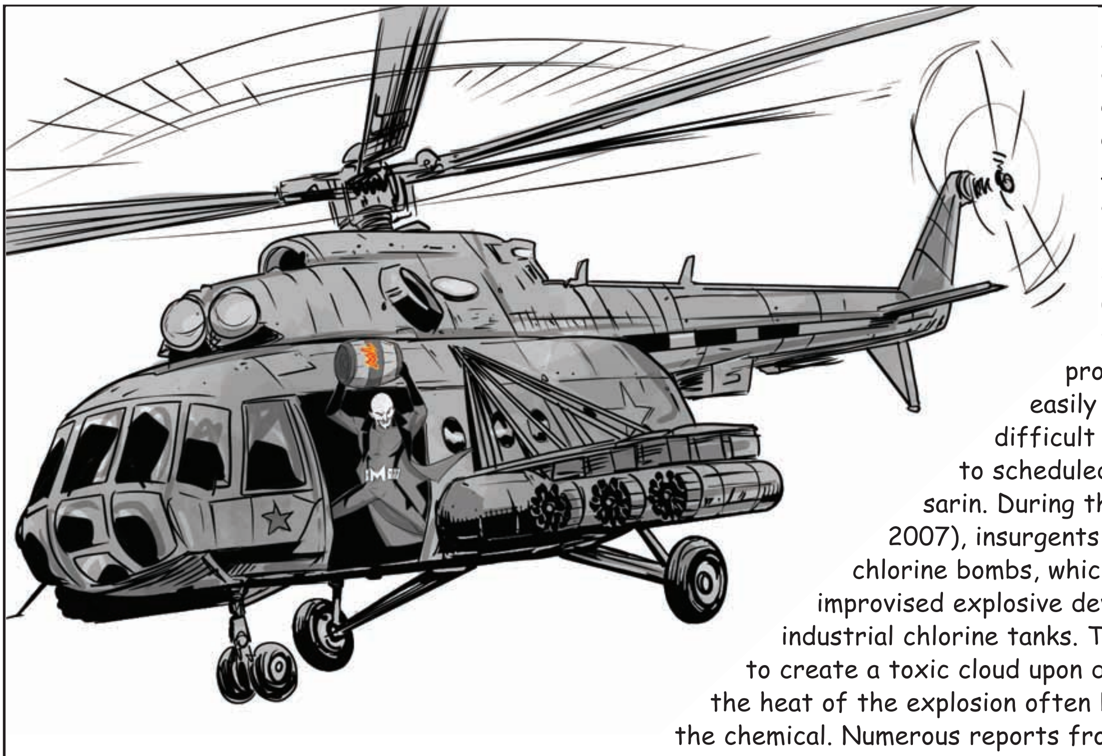
Keeping you safe!

This column aims to provide operational guidance to the hazmat/CBRNE community on the selection and performance of equipment and tactics. In this edition the focus is on responding to events involving chlorine, as it remains a threat as an offensive weapon.

History

Classified as a toxic gas, chlorine is an oxidising agent and powerful irritant that attacks the respiratory system. In the civilian context, incidents involving chlorine are often the result of leaks from stored chlorine or a reaction where it is generated.

The use of chlorine gas as a weapon marked a sombre turning point in the history of modern warfare. On 22 April 1915, during the second battle of Ypres, the German army deployed approximately 168tonnes of the gas from thousands of pressurised cylinders. It caused immediate panic as it entered the trenches and the soldiers, having no protection, suffered from severe asphyxiation. Thousands of troops were affected.



More recently, chlorine has re-emerged as a weapon of choice for non-state actors and in certain civil conflicts, because it has massive industrial utility (water purification, bleach production, etc), is easily acquired and difficult to regulate compared to scheduled nerve agents like sarin. During the Iraq war (2006-2007), insurgents began rigging chlorine bombs, which comprised standard improvised explosive devices attached to industrial chlorine tanks. These were designed to create a toxic cloud upon detonation, though the heat of the explosion often burnt off much of the chemical. Numerous reports from the Organisation for the Prohibition of Chemical Weapons identified the use of chlorine gas in barrel bombs dropped from helicopters during the Syrian civil war (2014-2018). These attacks often targeted urban areas for maximum psychological terror. In recent years, chlorine has been used as a binary device (See *CBRNE World* February 2022) to target law enforcement personnel.

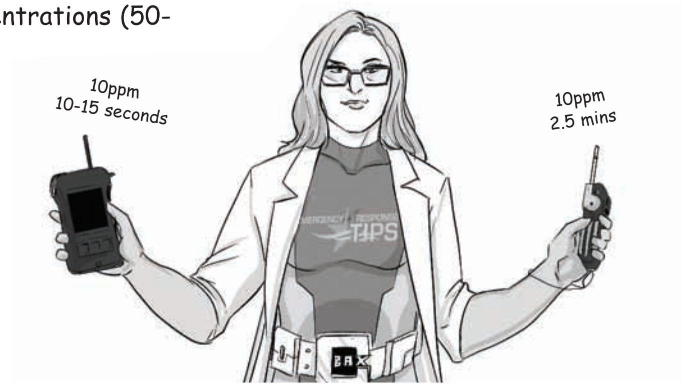
Toxicology
Chlorine is a yellow-green gas at room temperature (500-1000ppm). At lower concentrations, it may appear as a faint haze or even be invisible to the naked eye. As it is nearly 2.5 times heavier than air, chlorine will sink and 'pool in low-lying areas. Most people can smell 'bleach' long before they see chlorine as the odour threshold is between 0.2 and 3.5 ppm. The typical occupational exposure limit is 1ppm and the immediately dangerous to life or health (IDLH) limit is 10ppm.

Chlorine acts as a pulmonary agent, reacting with moisture in the mucosal membranes in the lungs to produce hydrochloric acid and hypochlorous acid. This causes the lungs to fill with liquid, preventing oxygen exchange, and resulting in pulmonary oedema, also known as dry drowning. The timing of the chlorine-induced pulmonary oedema is highly dependent upon the concentration and duration of chlorine exposure. Concentrations upwards of 400-1000ppm are often fatal in minutes while lower concentrations may take 6 to 15 hours. It also readily attacks the eyes and at high concentrations can irritate the skin. Liquified chlorine causes immediate corrosion on direct skin contact.

Detection
There are many ways to detect chlorine gas ranging from papers and colorimetric tubes to electronic detectors, but some are not yet available, like gas phase Raman. If the chlorine gas is visible (500-1000ppm), it is likely to be 50-100 times higher than the IDLH. But visibility is an unreliable safety metric as chlorine may be lethal well below the visibility threshold. Similarly, odour should not be used to indicate the absence of chlorine.

Indicating papers like pH paper and potassium iodide paper can be used to estimate the concentration of chlorine in the air. Use moistened pH paper as the reaction to dry paper can be inconsistent. At around 1-10ppm, wetted pH paper will turn red within seconds. At high concentrations (50-100 ppm), the paper is readily bleached losing its colour and value. At 1-10ppm, potassium iodide paper will turn a deep blue-black and it will also readily 'bleach' back to white at high concentrations (50-100ppm).

Colorimetric indicator tubes are available for both qualitative and quantitative chlorine detection. They commonly use oxidation and other strong oxidisers (bromine, fluorine, nitrogen dioxide, etc) to produce similar results. Note that the reaction time is dependent on temperature and humidity. The response time for colorimetric tubes for 10ppm is around 2.5 minutes.



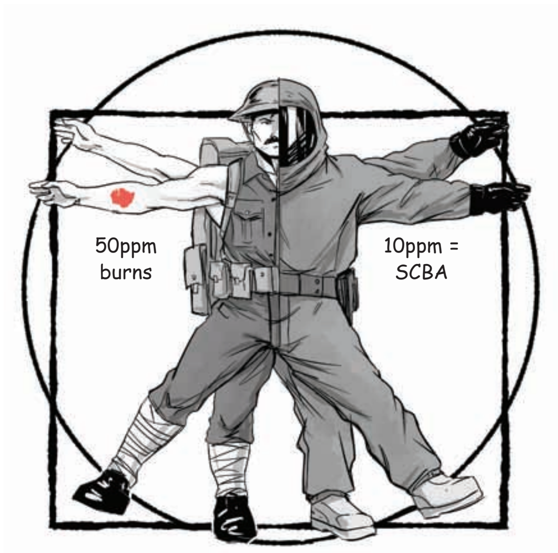
Electrochemical cells are used to detect chlorine quantitatively. In this case, chlorine gas reacts and the current generated relates to the chlorine concentration. Most standard electrochemical cells measure 0-50ppm with a 0.1ppm resolution and a 30 second response time. Industrial sensors are sold with broader detection ranges (up to 100-200ppm) albeit with a lower resolution. It is important to understand the cross-sensitivities to the specific electrochemical cell as they are dependent upon the chemistry within.

Ion Mobility Spectrometers (IMS) may also detect chlorine, which is ionised and the time to reach the detector is used to determine its identity. The current generated is related to its concentration. The ChemProX alarms for chlorine at 10ppm with a response time of 10-15 seconds but can 'trend' at lower levels.

Keeping you safe!

Protection

While chlorine is primarily a respiratory threat, it is also a powerful corrosive and skin irritant. At concentrations below 10ppm, most people will not experience immediate skin damage. Significant irritation begins at around 10ppm and burns begin at around 50ppm following prolonged exposure. Protective clothing should meet suitable standards, such as NFPA 1990 in the US, and should be selected considering the task, its duration, location, situation, hazard and potential for contact.



The minimum required respiratory protection for chlorine concentrations exceeding 1ppm is an air purifying respirator with a suitable cartridge. Some agencies recommend lower values, eg NIOSH (0.5ppm) and ACGIH (0.1ppm), for donning respiratory protection due to the potential long-term respiratory impacts of chlorine. Once the concentration exceeds 10ppm, self-contained breathing apparatus is required

In the absence of PPE, first responders should apply the time, distance and shielding rules to protect themselves and the public until specialist resources arrive.

Decontamination

Research has shown that short exposures to chlorine of under 30 minutes, in the range 30-500ppm required the removal of outer layers of clothing followed by natural ventilation for most people. Those with localised dermatitis-like reactions should be spot washed with water. This greatly minimises the assets required for decon following a chorine release. For exposures greater than 30 minutes in this concentration range or higher, immediate removal of clothing and skin washing is recommended. Remember to always follow up decontamination with monitoring to ensure that levels have been reduced as low as reasonably achievable.

Summary/Preplanning

Chlorine is a common industrial threat as well as a known terrorist threat. To enhance your readiness to manage incidents involving chlorine it is essential to engage with your security, public health, and police agencies to identify the sites in your response area that manufacture, store, use and transport chlorine as well as vulnerable sites where it could be deployed. You should also review the resources available, exercise and test your arrangements with your partner agencies to ensure they are effective.

Stay safe!

Images are courtesy of Phil Buckenham *https://philbuckenhamart.wixsite.com/philbuckenham*