Dr Michael Logan, research and scientific branch, Queensland Fire and Emergency Services and Dr Christina Baxter, CBRNE programme manager, Combating Terrorism Technical Support Office, United States Department of Defense on making chemical agent detectors relevant to hazmat incident response

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Since the terrorist attacks on the World Trade Center and the Pentagon, emergency response organisations worldwide have been inundated with new detection equipment, most of which has targeted capabilities for the detection and identification of chemical warfare agents. Unfortunately, the training necessary to operate and maintain the detection equipment was not coordinated, and in many cases, was not provided at all. While the global threat has changed, it has not diminished, as evidenced by the recent deliberate releases of chemical warfare agents in Syria. Therefore, the need for chemical agent detectors within the detection portfolios of emergency response agencies remains.

Many chemical detectors have a military usage legacy ©CBRNe World

Many of the chemical warfare agent detectors that were deployed to and with emergency response assets are intended to detect and quantify traditional warfare agents and therefore have limited use beyond CBRNE incidents. Their suitability for use at hazmat incidents in general was not often considered. The most commonly available detectors across military and civilian emergency response organisations that have application within the CBRNE operational environment include photoionisation detectors (PID), ion mobility spectrometers (IMS) and flame photometric detectors (FPD). This article will highlight the application of chemical agent detectors beyond CBRN into the broader realm of hazmat incident response using examples to illustrate the successes and limitations. Detection has an essential role at all incidents including:

– Identifying and quantifying the chemicals agents of interest.
– Characterising the nature of the incident.
– Determining the extent of the hazardous areas.
– Informing selection of risk control measures.
– Decontamination assessment.
– Clearance monitoring so the site can be safely reoccupied.

The PID detects volatile organic compounds and some inorganic

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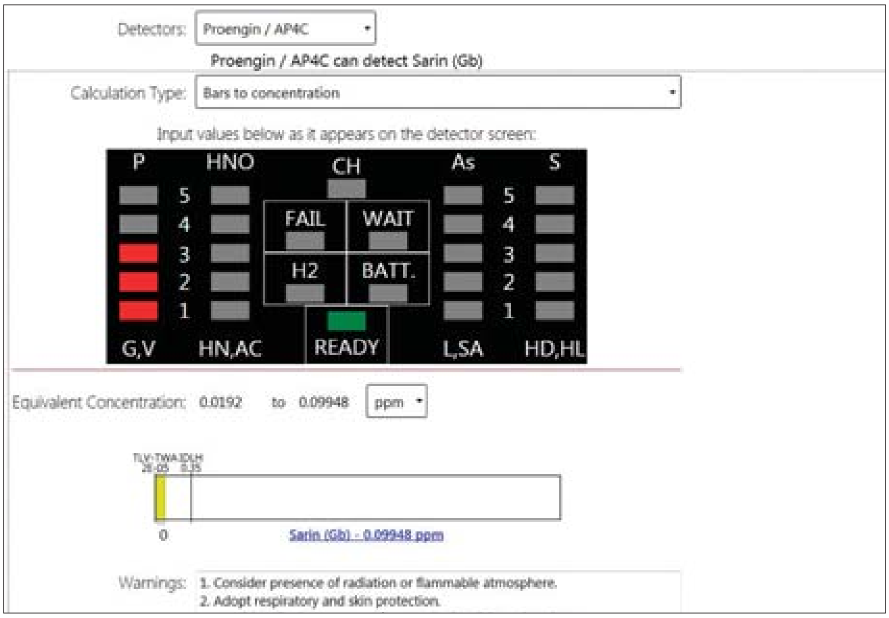
compounds. When the ionisation energy of the airborne contaminants of interest is less than that of the UV lamp energy utilised, they are ionised by the UV light. Ions so generated are then counted producing a signal strength relative to a calibration chemical. The measurement is usually in parts per million relative to isobutylene. The instrument is not selective but has a wide detection range. Commercial instruments are available from Drager, Ion Sciences, Rae Systems and others.

PIDs have been extremely useful in hazmat incident management where often the identity of the chemical of interest is known. Its application has been extended into the realm of chemical agent detection as shown in the photo (an AreaRAE system being used as an area monitor during the destruction of munitions storing mustard agent in Queensland). The instrument manufacturers provide correction factors for the lamp of interest against a wide range of chemical threats. While the instrument is not capable of uniquely identifying a chemical, it is able to quantify chemicals within the manufacturer's provided library or correction factor tables.

PID performance is affected by selectivity, ionisation potential efficiency and matrix effects. Most instruments use a 10.6eV lamp and cannot detect chemicals such as hydrogen cyanide and there is often limited information about correction factors for chemical agents which restricts their usefulness in a CBRNE context.

Ion mobility spectrometers (IMS) detect chemical agents such as sarin and mustard. The agent of interest in air is ionised when it passes a radioactive source. Ions separate based upon their drift velocity when they drift down a tube in a weak electric field and are then counted at the detector, where the measurement is often displayed as bars. The instrument is not selective but is sensitive and has a wide detection range. Instruments are available from Smiths, Bruker Daltronics and others. IMS instruments have traditionally been used in CBRNE incident management. Their performance is affected by selectivity, matrix effects and often



Emergency Response Decision Support System output for 3 bars on phosphorous channel of AP4C relative to Sarin ©QFES

instrument recovery. There is often limited information about hazardous materials other than chemical agents in the instrument libraries' toxic industrial materials. For IMS instruments to become more applicable to mainstream hazmat operations, the libraries provided by the instrument manufacturers need to be expanded.

The flame photometric detector (FPD) detects chemical agents such as mustard. The agent of interest is combusted in a flame. When it burns it emits light and the light spectrum is analysed. Elements like sulphur have a specific spectrum and the unique features are used to identify their presence and quantify the amount present in air. The most common instrument is the Proengin AP4C and it has four detection channels focusing on arsenic, nitrogen, phosphorous and sulphur. They are not selective instruments and performance can be affected by matrix effects.

Each instrument technique described above has both operational advantages and disadvantages across CBRN and hazmat incident response. So can we extend the applicability of IMS and FPD beyond CBRNE, and specifically chemical agent detection, to make it an indispensable tool for everyday hazmat responses?

Over the past few years the Queensland Fire and Emergency Services (QFES) has developed and operationalised approaches to extend the utility of these instruments and, in particular the AP4C, into everyday hazmat operations. This has included testing, training, development of operational approaches and integration of all into decision support software tools. The approach adopted has several advantages: the instrument is routinely used; operators maintain their proficiency and confidence with the instrument; and the instrument utility is expanded into both CBRNE and hazmat operations. We have taken advantage of the operating principles of the AP4C to extend the range of sulphur, phosphorous, arsenic and nitrogen containing chemicals that can be measured. For example, hydrogen sulphide (since it contains sulphur) can be measured and quantified.

Examples where the instruments have been applied to a wide range of hazmat incidents across Queensland, Australia over the past several years are described below:

– Community air monitoring during and after fires, particularly those involving organophosphate pesticides (sarin is an organophosphate) or where decomposition of sulphur based

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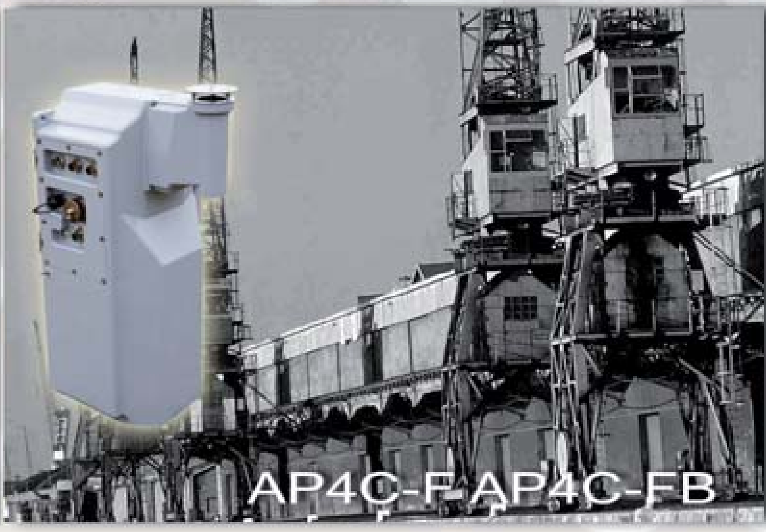
Chemical and biological detection



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materials occurs (AP4C, PID).
– Pesticide leaks from Insectigas gas cylinders that contain dichlorvos (an organophosphate or nerve agent) where the extent of the leak was determined, success of the mitigation approaches proved and when it was confirmed as safe to reoccupy the area (AP4C, PID).
– Toulene di-isocyanate spillage where the extent of the leak was determined, and success of the mitigation approaches proved, and when it was confirmed as safe to reoccupy the area (Bruker RAID M1, PID).
– Clearance monitoring and decontamination screening for persons who have been exposed to phosphine and other toxic gases (AP4C, PID, RAID M1).

In recent years, the QFES has responded to a large number of canisters containing aluminium phosphide that were washed up along Queensland beaches. Aluminium phosphide, when In contact with water, will generate phosphine gas, which is both toxic and flammable. Using the AP4C, a responder can quickly determine if phosphine is escaping from the canister, if phosphine is present when the canister is opened, and can monitor the extent of any hazardous area when the canister contents are reacted under controlled conditions. The PID will also respond to phosphine, but continued exposure affects the instrument's performance. IMS detectors cannot usually detect phosphine.

An important consideration for any operator is to have readily available information about what chemicals can be identified, what numerical values the bar measurements displayed equate to and their interpretation. The measured values can be compared with established criteria like permissible exposure limits (PEL), workplace exposure standards (WES) or immediately dangerous to life and health (IDLH). Operators then know immediately what danger the environment presents to themselves and the community. They can determine whether their measured values are appropriate to actions such as: isolation zones; respiratory/skin protection and decontamination strategies.

A software tool has been developed to enable operators to determine the chemicals that can be identified by a variety of PIDs, IMS and AP2C/4C instruments and the concentration of the chemical present. This tool can be found within the emergency response decision support systems (ERDSS) (see www.chemicalcompanion.org) and is available at no cost to emergency response organisations in the US, Australia and partner countries.

QFES scientific officer inspecting canister found to contain aluminium phosphide with AP4C. The instrument display is showing a strong response to phosphorous ©QFES

A sample output, using the AP4C for detecting sarin is shown on page 32. In this example, the user has chosen the AP4C as the detector, the chemical of interest to be measured as sarin, and the instrument reading as three bars. The instrument output provides the user with an equivalent concentration range for three bars (0.02 to 0.1 ppm). The ERDSS output also provides a chemical concentration bar where the highest potential concentration is shown in relation to the relevant exposure standards (PEL in the US and WES in Australia). The colour of the concentration bar changes based upon the measurement: green for less than exposure standard, yellow for between exposure standard and IDLH, and red for greater than IDLH. This is meant to be a constant reminder to the operator to meet the requirements for personal protective equipment when executing a detection scheme.

Using the ERDSS tool, the operator can choose a variety of chemicals, detectors, calculation types, and the interactive instrument panel display appears as it would on the instrument.

The QFES has shown chemical agent detectors such as the AP4C can be applied much more broadly than for CBRNE incidents alone, and especially across all areas of hazmat incident management. The QFES now operates more than 10 AP4C instruments as well as numerous PIDs across Queensland. They are considered an integral part of its hazmat incident detection portfolio and the chemical agent detection capability is retained across Queensland where operators are much more confident and proficient at using the instruments.

NOTE: The findings in this report are not to be construed as an official US government position unless so designated by other authorising documents.