CHAPTER 12

Future Trends in CWA and TIC Detection

We have discussed various technologies employed for detection of CWA and TIC vapors. Each of those technologies offers unique desirable as well as undesirable features. There is considerable room for improvement. Increasing detection reliability and reducing the frequency of false responses continue to be major challenges. The recent emphasis on TIC detection capability in addition to that of CWAs has also created substantial challenges for researchers and developers. Such requirements limit the number of technologies that can be effectively used.

For example, current IMS detectors, in theory, could be made to detect diverse TIC compounds in addition to their CWA detection capability. IMS detectors attempt to identify compounds based on compound characteristics to form peaks in the mobility spectrum. Each of the targeted compounds can then be assigned a "window" or "electronic gate" to identify the substance when the instrument detects a peak in that region. Drift time varies with respect to temperature or pressure variations. Therefore, an excessively narrow drift-time "window" for a given compound would prevent the instrument from detecting it at temperature extremes.

Length of the drift region is also a limiting factor. The number of segments available for window assignments determines the number of species that can be identified. As discussed previously, many substances have a similar drift time. If these fall into respective gates in sufficient quantity, the alarm is triggered. Therefore, the larger the number of species to be detected, the higher the frequency of false alarms for many substances. IMS detectors would need to contain libraries geared to detecting more specific groups of compounds in diverse operational scenarios. Perhaps with the current advances in microelectronics and software engineering, a single IMS detector could contain several resident detection libraries, and each of them could be searched to identify and list suspected compound(s) correlated to the detected peak(s) prior to sounding the alarm.

Besides the use of IMS technology, researchers are concentrating on the use of polymer coatings on microscaled sensors so that many of these sensors could be arranged in an array to detect diverse compounds. Other techniques, such as chemical resistance, surface acoustic waves, light emission, semiconductor cells, and fiber optics, are being used to harvest responses from microsensor arrays. Polymer coatings can be made quite specific. Each coating could be made to carry out a reversible chemical reaction for a specific family of compounds. Detection results from combining inputs from sensor arrays and developing pattern recognition algorithms. These approaches are still in their infancy, however. Much improvement is required to harden polymers to withstand temperature extremes and vibration stress, increase longevity, and make possible fast reversibility without residual effects.

Many researchers are attempting to integrate currently available detection technologies. It was hoped that the CWA or TIC detection capabilities of multiple sensors could be integrated, data analyzed through computer programming, before deciding whether a detected substance is indeed the targeted CWA or TIC, and not interference from nontoxic components of the sample. These approaches are aimed at minimizing the potential for false alarms and producing more reliable detection when the sample indeed contains toxic compounds.

The Challenges for the Chemical Sciences in the 21st Century Workshop on National Security and Homeland Defense brought together chemical scientists and engineers from academia, government, national laboratories, and industrial research laboratories to provide a broad range of experiences and perspectives needed to fight the war against terrorism. Their presentations and discussions showed that chemists and chemical engineers have the skills to develop solutions for national security and homeland defense problems. The conference showed that advances in science and technology would be much more promising when chemists and engineers and related disciplines collaborate. The organizing committee derived two multifaceted findings from workshop discussions.

1. Extensive research opportunities exist throughout the many facets of chemistry and chemical engineering that can assist national security and homeland defense efforts.
2. Cooperative research in systems analysis is required to apply the new knowledge to developing tools and products required for national security and homeland defense.

Three major needs identified at the workshop follow:

1. Detectors with the broadest possible range for chemical and biological agents. New sensing and sampling technologies are needed to yield improved threat detection and identification.
2. More specific detectors that can provide speed, high sensitivity, and reliability.
3. Detection and identification equipment miniaturization for field use. This is the most urgent feature required by soldiers, first responders, and other users. Miniaturized devices will lighten the loads that these users must carry during an incident.

Proper post-incident management is most critical to minimize casualty. Sensors with significantly improved specificity and sensitivity beyond currently available devices can assist authorities in assessing the extent of contamination for effective evacuation and determining when a site is safe for return to normal functions.

Consequently, various subsystems will be needed to support the development of these more sensitive instruments. Systems for reliable sample collection, sample processing, and presentation of chemicals to sensors are essential. Standardized methodologies are needed. Systematic quality assurance on sensor evaluation can only be achieved through standardized methodologies that have proven successful. Toward this end, the National Institute of Standard Technologies is in the process of generating standard testing protocols under which all future detection devices shall be tested for certification.

The U.S. government has drastically increased financial support of research of these sensors, mainly through the Homeland Defense program, DoD, National Science Foundation, and Department of Energy. Private industry is also heavily involved in developing sensors. New sensors or technology improvements are surfacing in the market fairly rapidly. However, as of this writing, none of the current technologies has had any significant impact on emergency preparedness. For sensors to be effectively implemented, they must be highly reliable, fairly inexpensive, widely deployable, and have networking capability.

Development of sensors that can detect and identify the release of toxic materials under various environmental conditions must continue. Effective response to a given agent involved in a chemical attack can only be achieved through the right choice of sensors for the occasion. Effective postrelease management is defined in terms of orderly evacuation to minimize casualties.

As mentioned in Chapter 7, the handheld Fast GC-PFPD may prove to be one of the more reliable detection devices for identifying CWAs and the most toxic TICs. The instrument combines features of concentrating the sample, thermal desorption, gas chromatographic separation, and subsequent pulsed flame photometric detection. The system has been tested, demonstrated, and documented in reports by the inventor using CWA simulants, but has not been tested with actual CWAs because, unfortunately, it has not been commercially available. According to the information obtained from the inventor's web page (www.tau.ac.il/chemistry/amirav), the system is ready for laboratory demonstrations with some external electronics because the prototype unit has not been made and the system has not been commercialized. No CWA test results are available until funding support is available. Therefore, a program with sustained funding to focus and coordinate research and development on promising sensors and sensor networks with an emphasis on fielding the system is needed. Emphasis on finding commercial off-the-shelf (COTS) should be expanded to prototyping highly promising devices as well.

Sensors and detectors require different technologies for different applications. To develop robust sensors, a multidisciplinary systems approach must be taken. Experimentalists, statisticians, engineers, and data analysts must become involved from concept development to fielding of the sensor. Well-designed experiments incorporating appropriate statistics must be used in developing field-worthy sensors to minimize testing costs. Actual and potential interference must be identified and dealt with either through hardware design, use of multiple sensor types, application of multivariate techniques, or better software development. Sensor calibration and drift compensation need to be verified through reliable testing methodologies that can provide reproducible results so that compensation can be correlated and corrected, either mathematically or through hardware improvements.

Once developed, detectors and sensors need to be tested according to strict criteria. Test standards, including LODs and identification of potential problem areas, must be revealed. The U.S. government periodically offers the opportunity for realistic field testing. Wind tunnel testing is available at several sites. Developers should take advantage of these resources for technology validation. It would be useful to develop new, integrated multisource databases to create chemical and biological agent reference libraries. There is a need for consolidation, as various libraries exist among many individual agencies.

It is extremely important to note that false negatives, for whatever reason, from a detector could prove to be fatal if the device cannot detect targeted toxic substances. Therefore, research emphasis should not only focus on reducing the false positive alarm rate. The potential for false negatives is more important and must be addressed. While false positives are nuisance factors, false negatives could lead to fatalities.

In summary, the world has changed considerably since the September 11, 2001, incidents. The term "weapons of mass destruction" or WMD has become a household word. Among WMDs, nuclear, biological, and/or chemical weapons are among the highest-ranked possibilities for terrorist groups to deploy besides those used in the 2001 incidents. We have limited this book to the discussion of topics related to chemical weapons.

This book was not intended to cover everything about chemical weapons. There are many related articles, books, publications, and government reports that discuss and summarize various detection technologies, as well as describing CWAs and TICs. The book is a condensation of years of hands-on experience with CWA substances and various detection technologies. Our goal has been to present the subject matter in as simple a form as possible so that the information can reach a large spectrum of readers. We believe that should an incident occur, if people have general knowledge about CWAs and TICs, the panicky response — which typically leads to a much larger number of casualties than would occur without panic — will be minimized. We also hope that this book will provide decision makers with information on the various detection technologies and devices that will help them make decisions on selecting, evaluating, and improving devices for their specific needs.

TICs and CWAs remain the preferred WMD for terrorist attacks. Although these chemicals do not cause widespread casualties and destruction on the level of biological agents or nuclear weapons, they are relatively easy to obtain, conceal, and disseminate, and thus constitute a serious threat. This is especially true for urban areas where there are large aggregations of people in big buildings, subway systems, airports, and sport events. Release of toxic chemicals in a public place could easily occur by an individual or small group of terrorists who are willing to sacrifice their lives. The deployment of toxic chemicals may even permit the disseminator(s) the opportunity to escape, when compared to the use of explosives in suicide bomber incidents. Once the chemical is set for release, the terrorist has a better chance of exiting the area before the innocent victims as the concentration of toxic chemical vapor silently increases. A few hundred grams of nerve agent is sufficient to cause massive casualties and disruption. Nerve agents can easily be concealed, such as in a soda or water bottle.

Toxic chemicals, flammable materials, and explosive materials are readily available for terrorist groups to cause massive casualties with high visibility to create public panic. The 1995 release of sarin (GB) gas in the Tokyo subway system is a prime example of what, when, where, and how toxic chemicals could be deployed among civilians to gain worldwide attention.

Although CWAs have existed for many years, and instruments for detecting the more lethal agents have been developed over the years, the perfect detection device is still unavailable. To expect a single device to provide adequate detection of all lethal agents as well as TIC compounds would be naive. Each of the technologies has pros and cons. The Domestic Preparedness Detector Testing Program that tested many commercially available, off-the-shelf (COTS) devices has revealed many deficiencies of existing detection devices. We were fortunate to have been actively involved in many of these tests to gain firsthand knowledge of device characteristics.

The Domestic Preparedness Program has evaluated most of the modern COTS detectors that may have the capability to detect CWAs with reliability and sensitivity. The program solicited detector candidates from private sector manufacturers and did not receive many responses, which indicates the current limited potential of finding additional suitable CWA detectors in COTS scenarios at this time.

Since the September 11, 2001, incidents, the U.S. has formed the Homeland Defense Department to combat terrorism. Substantial funding is committed to various disciplines to research and develop better detection devices. Perhaps more reliable devices may be developed soon. The emphasis has been on developing inexpensive devices so that they could be widely deployed. Unfortunately, this emphasis has prevented or hindered further enhancement of highly promising technologies that are considered "too expensive" to produce and are thus not funded. The fragmented approach of seeking an ideal detector through the COTS route may not be fruitful. Individual researchers or manufacturers do not have the resources to develop complex systems that could detect various toxic materials and still be "inexpensive." It would be ideal, of course, if reliable detectors could be had cheaply. But, we must ask ourselves, is it possible? Until we reach that stage, it is hoped that decision makers in various government programs will expand their horizons to first fully develop promising devices that have the potential to become reliable detectors, in spite of higher price tags, while also continuing to seek better alternatives.

The recent trend for data fusion of more than one technology in a package is an excellent start. Data fusion of several technologies will, undoubtedly, result in an expensive system. For that to be successful, however, experts in each of the technology disciplines must come together with open minds to work cooperatively. Manufacturers must be willing and open-minded enough to share their proprietary knowledge and work toward the common goal. Reluctant to accept or incorporate each other's merits is a roadblock to success. It is our hope that the respective merits of various devices can be combined to achieve the ideal.

No matter how sensitive and reliable a detection system can be, it will detect nothing (and warn no one) until a target toxic chemical has been released. The best that a detection system can do is to provide rapid and advance warning at a distance from the release before the concentration reaches harmful levels so that people can escape the area before excessive exposure causes catastrophic consequences. Reliable detection devices are vital for the postincident management.

We hope this book will serve as a useful reference to those in the field of developing chemical detectors. Device testing is a vital process toward successful development. It is also hoped that this book will provide the general public with an overview of chemical warfare agents.