Sampling for Chemical, Biological, Radiological, Nuclear, and Explosive Agents during Emergency Response to Mass Destructive Attacks, Terrorism, and Chemical Disasters

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CONTENTS

1. INTRODUCTION

This review of air sampling equipment for detecting materials that can cause mass destruction or casualties is a hard copy that cannot reflect the constant changes in the field. The many websites cited are designed to provide exactly that function, and readers are encouraged to use the Internet with all its power. There is no end to the information that can be found and, of course, there is never enough money to buy the best of everything, once you have found it.

The purpose of this chapter is to present basic information in an organized manner, to help those interested in first response begin the searching and evaluating process to obtain air sampling equipment that will suit their specific needs for emergency response to the potential use of "weapons of mass destruction (WMD)." To medical and health professionals, these are more appropriately called "weapons of mass casualty," however, for clarity and consistency, the commonly used term "WMD" will be used in this chapter. This collection of background information and sources for additional reference has important implications for those involved in emergency services, law enforcement, and counterterrorism teams, as well as for others involved in prevention, such as border patrols, transportation, and customs agents. It is further intended for occupational health and safety professionals, scientific researchers, and public health managers involved in design and implementation of prevention or first response programs. Readers are asked to keep in mind that air sampling alone cannot provide all the information needed by first responders. There are numerous other texts and websites covering personal protective equipment, incident response, and facility preparation, that are not discussed here.

Opinions provided in this document not attributed to referenced researchers are those of the author, and are based on his experience as a naval officer with responsibilities in this area. Any expressed opinions do not reflect the opinion or policy of ACGIH® or any other official organization or government agency. The absence of any manufactured equipment or subject matter website is not to be considered as a lack of endorsement.

2. BACKGROUND

The current threat from terrorist activities, and the effect of such actions on modern life, has completely captured public attention, and is of concern worldwide.[1,2] Terrible images quickly intrude into our lives, thanks to camera phones and satellite communication, enabling us all to see, hear and bear witness to events as they happen in real time. Now weapons of mass destruction (WMD), which were once considered solely in the armamentarium of governments that could afford to create and maintain them, have unfortunately become more readily available, to groups or even individuals. Their use is no longer restricted to war.[3] The threat of the use of WMD has changed the concept of first response. What was once training for fire fighting and response to natural disasters, has become more technical in nature for accurate detection of chemicals, biologics, and forms of radiation. Specialized technology is now needed to protect citizens quickly and effectively by identifying where contamination may be present.

The past 30 years have seen increased regulations, improved training and technology in detecting and cleaning up spills of dangerous chemicals and toxic substances around the world. However, the new threats from WMD present a more complicated and difficult plan for response. Using chemical and biological weapons or readily available industrial materials to intentionally expose unsuspecting populations to death or serious harm poses a new set of problems to all governmental and public health agencies dedicated to public safety.

"Chemical, Biological, Radiological, Nuclear, and Explosive" provides the acronym "CBRNE", used to describe the sources of the WMD threat. In each of these five identified areas (C, B, R, N, and E), there is an established and growing body of literature concerning:

- The source and types of substances;
- Their effects on the human body;
- Methods to measure the presence and levels of these substances;
- Medical treatment of people exposed to different levels of these substances; and
- Decontamination, cleanup and removal of these substances to return the environment to a state suitable for people to return.

A comprehensive response to WMD will address all areas, and advance planning is required. A chemical plant response team will by design have a different plan and different needs than a fire department in a rural community. The planning needs of an emergency medical team for a major city hospital must take into consideration large numbers of casualties, and the urban environment.[4,5]

The goal of this chapter is to help identify appropriate equipment for air sampling to measure the presence and levels of toxic substances. Information on the types of substances that may be encountered, the health effects, and post-event remediation after an incident is becoming more readily available, and several sources are provided in the website resources section. Planning for post-disaster response will help incident commanders make the best use of available resources.

A. Chemical Threats

Chemical exposures are typically characterized by the rapid onset of medical symptoms from minutes to hours.[6] There are often direct observations such as colored residues, dead foliage, pungent odors, and dead insects and animals to indicate a chemical agent may have been used. Even a single, sudden "acute" exposure may result in delayed or chronic effects. An example of this type of exposure may occur from ionizing radiation.

The Centers for Disease Control website (www.cdc.gov) indicates that a chemical emergency occurs when a hazardous chemical has been released and the release has the potential for harming people's health. Chemical releases can be unintentional, as in the case of an industrial accident, or intentional, as in the case of a terrorist attack.

Certain chemicals have been developed by military organizations specifically for use in warfare. These include nerve agents such as Sarin and VX, sulfur and nitrogen mustards, and choking agents such as phosgene. A major concern is that terrorists could somehow obtain or manufacture these chemical warfare agents and use them to harm people. Many hazardous chemicals used in industry such as chlorine, ammonia, and benzene could also be obtained and used for harm, or they could be accidentally released.

Categories of hazardous substances listed by the Centers for Disease Control and Prevention are provided in Table 1, with some modification. The CDC website provides fact sheets on protection, evacuation, sheltering in place, and personal cleaning and disposal of contaminated clothing. Basic chemical emergency information designed for the public can be found in the general and chemical-specific fact sheets and in the toxicology FAQs on the CDC website.

B. Biological Threats

In the case of a biological incident involving exposure to viable microorganisms, the onset of symptoms typically requires days to weeks, and will have no characteristic signatures. Because of the delayed onset of symptoms in a biological incident, the area affected may be greater due to the migration of infected individuals.

TABLE 1. Hazardous Chemical Categories

Category	Description	Examples
Blister agents	Chemicals that severely blister the eyes, respiratory tract, and skin on contact	Sulfur and nitrogen mustards, Lewisite, and phosgene oxime
Blood agents	Poisons that affect the body by being absorbed into the blood	Hydrogen cyanide, hydrocyanic acid and cyanogen chloride
Caustics and corrosives	Chemicals that burn or corrode the lining of the nose, mouth, throat, and lungs on contact	Hydrochloric, sulfuric, phosphoric, and nitric acids
Choking, lung or pulmonary agents	Chemicals that cause severe irritation or swelling of the respiratory tract	Organohalides, oxides of nitrogen, phosgene, perfluoroisobutylene
Incapacitating agents	Drugs that cause an altered state of consciousness (possibly unconsciousness)	Anticholinergic compounds atropine, scopolamine, hyoscyamine, and hyoscine
Long-acting anticoagulants	Poisons that prevent blood from clotting, which can lead to uncontrolled bleeding	Heparin, coumarin, and warfarin (Coumadin®)
Metals	Agents that consist of metallic poisons	Lead, mercury, antimony, cadmium, and beryllium
Nerve agents	Extreme poisons that prevent the nervous system from working properly	Tabun, Sarin, Soman, and VX
Organic solvents	Agents that damage the tissues of living things by dissolving fats and oils	Toluene, perchloroethylene, trichloroethylene, and naphthalene
Riot control agents and tear gas	Highly irritating agents used by law enforcement for crowd control	Tear gas and Mace, which are alkylating agents
Toxic alcohols	Poisonous alcohols that can damage the heart, kidneys, and nervous system	Pure ethyl alcohol, methanol, and butyl alcohol
Vomiting agents*	Chemicals that cause nausea and vomiting	Diphenylaminearsine or Adamsite, diphenylchlorarsine, and diphenylcyanoarsine

* These types of compounds create such discomfort that personnel are forced to abandon their personal protective equipment, making them more vulnerable to other more lethal compounds. Additionally, any compound that is disabling causes a greater burden of care and response than one that is immediately fatal.

Biological toxins are poisons produced by living organisms, or congeners, that are synthesized in a laboratory. It is the poison, not the organism, that produces harmful effects in humans. A toxin typically develops naturally in a host organism (for example, saxitoxin is produced by marine algae); however, genetically altered or synthetically manufactured toxins have been produced in the laboratory. Biological toxins are most similar to chemical agents in their dissemination and effectiveness.(7,8) Table 2 provides some examples.

C. Radiological Threats

The onset of symptoms from a radiological incident requires days to weeks, and there typically will be no characteristic signatures. Radiological materials are not recognizable by the senses, and are colorless and odorless. Detection of radiation and radioactive materials can be done accurately and with great sensitivity due to the nature of the source of energy, and the current state of technology for detection equipment. The interaction of ionizing energy with the tissues of the human body may produce "Acute Radiation Syndrome (ARS)," which consists of three levels of effects: hematopoietic (blood cells; most sensitive); gastrointestinal (GI cells; very sensitive); and central nervous system (brain/muscle cells; insensitive). The initial signs and symptoms are nausea, vomiting, fatigue, and loss of appetite. Below about 200 rems (2 Sv), these symptoms may be the only indication of radiation exposure.(6) Some sources and types of radiation that could be involved in a disaster scenario are provided in Table 3.

D. Explosive Threats

In general, explosives can be broken into three groups based on their vapor pressures. The high vapor pressure explosives include ethylene glycol dinitrate, nitroglycerin, and 2,4-dinitrotoluene. These explosives have saturated vapor concentrations in air greater than one part per million (1 ppm), thus at equilibrium there will be roughly one molecule of explosive vapor per every million air molecules. The medium vapor pressure explosives have saturated vapor concentrations in air near one part per billion (1 ppb), a factor of about 1,000 lower than the high-vapor-pressure explosives. The medium-vapor-pressure group includes trinitrotoluene and ammonium nitrate. Finally, the low-vapor-pressure explosives have saturated vapor concentrations in air near or below the one part per trillion (1 ppt) level, an additional factor of 1,000 lower than the medium-vapor-pressure explosives. The low-vapor pressure group includes cyclotrimethylene-trinitramine or cyclonite, and pentaerythritol tetranitrate. These vapor pressures are for pure materials. Vapor pressures for mixtures containing these explosives may be even lower. Vapor pressure is a major factor affecting the trace detection of explosives.(9)

3. PLANNING FOR FIRST RESPONSE

References and websites provided in this chapter not only offer information on sampling equipment, but also on preparing for a WMD or chemical release incident. Air sampling and detection equipment should not be considered without evaluating all other aspects of first response. Planners must identify the needs of their facility or area, and understand what type of hazard they may face. The National Response Team, Hazardous Materials Emergency Planning Guide, NRT-1(10,11) provides a planning checklist based on the structure of the NRT's Technical Guidance for Hazards Analysis (http://www.nrt.org). This checklist includes details involving Hazard Identification (combining facility, transportation route, and chemical data); Vulnerability Analysis (modeling of releases); Risk Analysis (ranking of hazards); and Emergency Response Planning (combining the previous three concepts). This guide is highly recommended prior to considering what air sampling equipment to purchase.

TABLE 2. Hazardous Biological Categories

Category	Description	Examples
Biotoxins	(Actually a misnomer as "toxins" are all of biological origin as specifically addressed in federal legislation) – Poisons that come from plants or animals	Botulinim toxins, clostridium toxins, ricin, saxitoxin, staphylococcal enterotoxin, tetrodototoxin, trichothecene mycotoxins
Bacteria	Single-celled organisms that can be grown on solid or in liquid culture media	Anthrax, brucellosis, tularemia, cholera
Viruses	Simplest type of micro-organism, consisting of a nucleocapsid protein coat containing genetic material, either RNA or DNA	Marburg, Rift Valley Fever, smallpox, Yellow Fever, Dengue, Ebola
Rickettsiae	Obligate intracellular organisms intermediate in size between most bacteria and viruses	Endemic typhus, Q fever, Rocky Mountain Spotted Fever

TABLE 3. Hazardous Radiological Categories

Category	Description
Alpha particles	Short range in air; low ability to penetrate other materials, strong ability to ionize. Alpha particles are unable to penetrate human skin, and are not an external radiation hazard. Alpha-emitting nuclides inside the body pose a considerable internal hazard.
Beta particles	High-energy electrons emitted from the nucleus of an atom during radioactive decay. Normally can be stopped by the skin or a very thin sheet of metal.
Cesium-137 (Cs-137)	Strong gamma ray source that can contaminate property, entailing extensive clean-up. Commonly used in industrial measurement gauges and for irradiation of material. Half-life is 30.2 years.
Cobalt-60 (Co-60)	Strong gamma ray source, used as a radiotherapeutic for treating cancer, food and material irradiation, gamma radiography, and industrial measurement. Half-life is 5.27 years.
Gamma Rays	High-energy photons emitted from the nucleus of atoms; similar in action to x-rays. Can penetrate deeply into body tissue. Shielding against gamma radiation requires thick layers of dense materials.
Highly enriched uranium	Uranium enriched to above 20%. Weapons-grade HEU is enriched to above 90% in U-235.
Iridium-192	A gamma-ray emitting radioisotope used for gamma-radiography. Half-life is 20.2 years.
Plutonium-239 (Pu-239)	Metallic element used for nuclear weapons. Half-life is 24,110 years.
Radioactive waste	Disposable radioactive materials from nuclear operations. Generally classified into two categories, high-level and low-level waste.
Special Nuclear Material	Plutonium and uranium enriched in the isotope Plutonium-239, Uranium-233 or Uranium 235.
Uranium 235	U-235 is used as a reactor fuel or for weapons. Weapons typically use U-235 enriched to 90%. Half-life is 7.04 × 108 years.
X-Ray	Invisible, highly penetrating electromagnetic radiation of much shorter wavelength than visible light. Very similar to gamma-rays.

Non-industrial public areas present a challenge to plan for the unforeseen and unpredictable in all aspects. Past intentional releases of toxic compounds exposing unprotected civilian populations include the use of the chemical weapon "Sarin" in the Tokyo subway system, and the deaths in the United States resulting from the insertion of anthrax into the postal system. Recent discussion in the media of "dirty bombs" and "liquid bombs" provide additional examples of the threats from WMD that have increased awareness of society's vulnerability to these types of weapons.

A first-response group will be expected to support authorities at WMD incident sites by identifying potentially hazardous substances, determining possible consequences, suggesting additional action, and identifying where additional support may be needed. They must react quickly, provide medical and technical advice, and help if further assets are requested. All roles are discussed in the Incident Command System training series, along with a suggested common language for groups to use under field conditions (http://training.fema.gov).

First responders must help ensure that staging areas, food, water, and local sanitation will not impact on field assets. Table 4 provides examples of core equipment that could be used by a first responder group. More information on these items can be found later in this chapter. Research into and identification of equipment that can be used by first responders is a continuous process. The references and website resources discussed are to keep first responders and planners up-to-date with many types of equipment research, not just air sampling equipment. Appendix A provides a checklist for helping to determine air sampling needs and what equipment may best fit those needs. Appendix B is a partial list of manufacturers, air sampling equipment, and websites.

The National Institute of Standards and Technology, Office of Law Enforcement Standards (NIST/OLES) is the executive agent for the Standards Coordination Committee. NIST/OLES implements and administers the CBRNE Equipment Standards Suite repository. NIST/OLES, on behalf of the SCC, has published and administers a first responder equipment set of guides to assist first responder agencies in making informed procurement decisions. These guides are available on the website at www.ncjrs.gov, and are partially reproduced, with permission, in this chapter. For chemical detection equipment,[12] biological detection equipment,[8] and explosive detection equipment,[9] the information provided is essential. The Office of State and

TABLE 4. Core Equipment for First Responders

Category	Description
Commercial multi-gas monitor with Photo-Ionization Detector (PID)	PID provides low ppm to high ppb non-specific detection for volatile chemicals ionized by ultraviolet radiation. Rapid qualitative assessment of most liquid and solids, and for soil or water when using an extraction kit. Limited sensitivity.
Improved Chemical Agent Monitor (ICAM)	Source detection of nerve and blister agents. Prone to false positives. Detection limit low enough to be below the incapacitation level for just about all agents except the nerve agent VX. Widely used.
M-22 Chemical Agent Detector and Alarm	Remote detection of nerve and blister agents.
M-8 Paper; M-9 Paper	Detects nerve and blister agents in liquid.
M-256 Kit	Wet chemistry method for simple categorization of nerve, blister, and blood agents. Increased sensitivity over the ICAM unit.
Portable Gas Chromatograph/Mass Spectrometer, with headspace sampler	Identification of over 150,000 volatile organic compounds. Requires significant training.
Colorimetric tubes	Provides semi-quantitative analyses for selected chemicals. Highly prone to error.
Polymerase Chain Reaction (PCR) analysis	DNA identification of biological organisms.
Handheld immunoassay "tickets"	Identification of biological warfare agents.
Fourier Transform Infrared (FTIR) Spectrometer	Rapid analysis of chemical makeup of substances.
Military Radiation, Detection, Identification, and Computation Sets	Detection and measurement of radiation sources. Many portable devices available.

Local Government Coordination and Preparedness (SLGCP) Systems Support Division has reissued and updated some of the guides. The updates are available online under the System Assessment and Validation for Emergency Responders (SAVER) Program, described below.

A common suite of first responder equipment standards is needed to establish minimum performance, and interoperability requirements for CBRNE equipment used by local, state, and federal first responders. Such standards serve multiple purposes, including establishing equipment baseline capabilities, guiding production by manufacturers, and guiding procurement decisions by the public safety communities. The Interagency Board for Equipment Standardization and Interoperability (IAB) coordinates such standards.

The Standardized Equipment List (SEL) is provided to the responder community by the IAB. The SEL contains a list of generic equipment recommended by the IAB to government organizations in responding to Weapons of Mass Destruction (WMD) events. The SEL is a voluntary guideline and promotes standardization across the response community by offering a standard reference and a common set of terminology. It can be found online at the Responder's Knowledge Base.

The Responder's Knowledge Base (RKB), online at http://www.rkb.mipt.org, provides emergency responders with a first stop for integrated information on standards, training, grants, and current equipment. It provides knowledge links, user opinions, and hints authored by subject matter experts. By integrating this information into one location, the RKB has become a go-to site for the responder community. Once registered for access to this site, at the top of the page go to "Search the RKB". Click on "Browse all Products". On the left under "Results by Category," click on "Detection." Chemical, biological, radiological, and explosive detection equipment are provided, with the number of entries listed.

4. GOVERNMENT AGENCIES AND PROGRAMS

After the events in the United States of September 11, 2001, the President of the United States issued Executive Order 13228 on October 8, 2001, and thus established the Office of Homeland Security (OHS) and the Homeland Security Council (HSC). Section 3 of the Executive Order states that "...the OHS shall work with federal, state, and local agencies, and private entities, as appropriate, to coordinate national efforts to ensure public health preparedness for a terrorist attack." On November 25, 2002, in the largest change to the government in more than 50 years, the OHS became the Department of Homeland Security (DoHS), established by the Homeland Security Act of 2002.

Since 2002, the Office of State and Local Government Coordination and Preparedness (SLGCP) has been established under DoHS. SLGCP develops preparedness programs to enhance the capability of federal, state, and local governments, and the private sector to respond to terrorist incidents involving CBRNE devices. SLGCP administers programs and grant support for training, equipment acquisition, and technical assistance to prepare for CBRNE acts of terrorism. The SLGCP Systems Support Division (SSD) conducts commercial technology assessments, and transfers equipment directly to emergency responders. As part of Congressional funding during 2003, SSD was tasked with developing CBRNE technology guides and standards for the emergency responder community.

The Interagency Board for Equipment Standardization and Interoperability (IAB) is sanctioned by the Attorney General of the United States, and was founded by the Department of Defense's (DoD) Consequence Management Program Integration Office and the Department of Justice's (DoJ) Federal Bureau of Investigation (FBI) WMD Countermeasures on October 13, 1998. With the participation of various local, state, and federal government organizations, the IAB formulated its mission statement, organized the board into four subgroups and two committees, developed a charter, and identified the IAB Process and Strategic Objectives. The IAB link is found at http://www.iab.gov, and includes links to most of the other sites referenced here. The IAB is designed to establish and coordinate local, state, and federal standardization, interoperability, compatibility, and responder health and safety to prepare for, train and respond to, mitigate, and recover from any incident by identifying requirements for an all-hazards incident response with a special emphasis on CBRNE issues.

In creating a strategic plan for developing a suite of CBRNE protective equipment standards, the IAB is also responsible for identifying, adopting, modifying, and developing such CBRNE equipment standards. The IAB Standards Coordination Committee (SCC) has established a prioritized order for developing and adopting standards, and will periodically review and revise the prioritization as requirements change or as standards are implemented.

The DoHS Office of Grants & Training (OG&T) established the SAVER Program as a national resource to assist emergency responders in performing their duties. The SAVER Program provides high quality, impartial, operationally relevant evaluations and validations of critical emergency responder equipment and systems, and provides these results in an operationally useful format. It can be found online at https://saver.fema.gov.

Both the SAVER Program and the RKB are highly recommended as additional first steps in a search for information on air sampling equipment suitable for CBRNE response.

Every first responder must be trained in the Incident Command System (ICS). The procedures are an essential part of first response, but are not addressed here. The Federal Emergency Management Agency (FEMA) website (at www.fema.gov) provides access to online training in the ICS, providing a common language and common understanding for response. Part of the ICS is to identify different levels of response.

First level responders must identify exactly what the hazard is, and begin to restrict the area. This includes police, firefighting and emergency medical personnel. The best equipment for such first level responders would have an alarm at the presence of hazardous material, be lightweight and portable, and provide fast response for the safety of the responders. Some equipment is best for detecting materials on surfaces, some for airborne material.

Second level responders set up safety zones, observe movement of equipment and personnel in and out of the area, and limit further contamination. These are activities that would begin after the initial crisis has been addressed, but before the site has been secured. Suitable equipment would be able to detect very low levels of material, and help determine the needed level of personal protection equipment. Equipment that can log measurements over time can help estimate total exposures for personnel assigned to the area for extended periods of time for damage control, crime scene investigation, etc.

Third level responders are generally hazardous material technicians who carry out investigations, perform clean-up, and spend more time in the area. Equipment for these responders may not have to meet the same requirements for portability as for first level responders, yet may need to detect very low levels of material, and also maintain a log of total measurements.

One highly recommended site for planning purposes is found at the RAND Corporation site(http://www.rand.org). Listed under publications is a four-volume set titled "Protecting Emergency Responders," which is provided free in PDF format as a public service. It includes help with decisions as to what sampling equipment would be best. Many concerns expressed by persons who have already acted as first responders are provided.

5. REGULATORY REQUIREMENTS

In addition to set standards for CBRNE equipment performance, there are governing regulations for disasters that may involve exposures to hazardous substances. The Occupational Safety and Health Administration (OSHA) has standards for training and responding to hazardous and toxic materials for any employees who are exposed or potentially exposed to hazardous substances.[13]

The term emergency response is defined as a response effort by employees from outside the immediate release area or by other designated responders – (i.e., mutual-aid groups, local fire departments, etc.) to an occurrence that results in an uncontrolled release of a hazardous substance. Responses to incidental releases of hazardous substances where the substance can be controlled by employees in the immediate release area are not considered to be emergency responses. Responses to releases of hazardous substances where there is no potential safety or health hazard are not considered to be emergency responses.

First responders and those planning for first response should be familiar with the following regulations written by the Environmental Protection Agency, found at the EPA website (www.epa.gov).

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) commonly known as the Superfund Act, (P.L. 96-510) enables federal authorities to respond to hazardous materials pollution incidents that threaten either the environment or public health. This regulation would be used to fund a federal response to a terrorist attack. The Superfund Amendments and Reauthorization Act (SARA) amended the CERCLA on October 17, 1986.

The Emergency Planning and Community Right-To-Know Act (EPCRA), also known as Title III of SARA, was enacted by Congress as the national legislation on community safety. This law was designated to help local communities protect public health, safety, and the environment from chemical hazards. Congress required each state to appoint a State Emergency Response Commission (SERC). The SERCs were required to divide their states into Emergency Planning Districts and to name a Local Emergency Planning Committee (LEPC) for each district. Broad representation by firefighters, health officials, government and media representatives, community groups, industrial facilities, and emergency managers ensures that all necessary elements of the planning process are represented. These are the people who would be involved in planning for first response, and to whom this chapter is directed.

6. CHEMICAL DETECTION INSTRUMENTATION

Chemical weapons are effective for terrorism activities because they are highly lethal, difficult to detect at low levels, and highly persistent. Unless contamination is identified and contained, it can be unintentionally spread to areas such as hospitals, emergency rooms and other medical treatment areas.

Chemical agents can be detected by several means that incorporate various technologies, grouped into three major categories: point detection, stand-off detection, and analytical instruments.

There can be difficulty in identifying a small amount of chemical agent in a background of non-hazardous environmental chemicals. For example, a chemical vapor detector may readily detect trace levels of material in an open field, but may not detect the same level of substance in a crowded subway, or on a busy street. Chemicals produced by everyday activities may affect the reliability of the instrument, as well as its sensitivity. More effective and accurate methods of detection that are less affected by environmental chemicals are expected to become commercially available in the near future.

A. Point Detection Technologies

Point detection technology refers to detection at the source or emission point. Point detectors can be used as warning devices to alert personnel to the presence of a toxic vapor cloud. In this scenario, the detector is placed upwind of the first responder location. When the toxic chemical is carried downwind toward this location, it first encounters the detector, thus sounding an alarm allowing the first responders to don the necessary protective clothing. However, if the concentration of chemical agent or TIM is high enough to be immediately life threatening, point detectors may not allow sufficient time to take protective measures. Another use of a point detector would be to monitor the vapor concentration originating from a decontamination site. Point detectors can also be used to determine contamination triage, i.e., highly contaminated personnel, lightly contaminated personnel, and uncontaminated personnel with the idea that all contaminated people need rapid decontamination but not for those non-contaminated, thereby saving resources.

The following technologies are available for point detection:

(1) Ionization/Ion Mobility Spectrometry (IMS)
(2) Flame Photometric Detection (FPD)
(3) Infrared Spectroscopy (IRS)
(4) Electrochemical Detectors (ECD)
(4) Electrochemistry
(5) Colorimetric or Color Change Detection (CCD)
(6) Surface Acoustic Wave (SAW)
(7) Photo-Ionization Detection (PID)
(8) Sensor Array Technology (SAT)
(9) Thermal and Electrical Conductivity Detection (T&ECD)
(10) Flame Ionization Detection (FID)

(1) Ionization/Ion Mobility Spectrometry (IMS)

A detector using IMS technology dynamically samples the environment using an air pump. Contaminants in the sampled air are ionized and passed through a weak electric field toward an ion detector. The time it takes the species to traverse the distance is proportional to the mass of the ionized chemical species and is used as a means of identification. Most IMS portable detectors use radioactive Beta emitters to ionize the sample. IMS requires a vapor or gas sample for analysis; therefore, liquid samples must first be volatilized. An example of a handheld detector using this technology is the Advanced Portable Detector, APD 2000, manufactured by Smiths Detection.

The U.S. Army M8A1 Automatic Chemical Agent Alarm[14] is another example of a chemical agent detection and warning system based on IMS technology. The system incorporates the M43A1 ionization product detector to detect the presence of nerve agent vapors or inhalable aerosols.

The U.S. Army Chemical Agent Monitor (CAM) is used to detect only nerve and blister agent vapors. It uses a 10-mCi nickel-63 beta-particle radiation source to ionize airborne agent molecules that have been drawn into the unit by a pump. A liquid crystal display presents data as a series of concentration-dependent bars in one mode for nerve agents and a different mode for blister agents. A low vapor hazard has 1 to 3 bars visible, and a very high vapor hazard has 7 to 8 bars visible.

IMS equipment is widely used not only for chemical detection in an emergency response situation, but also to detect for explosives and explosive residue. Because of the wide utility of this technology, and the established track record of the many different types of manufactured equipment that use it, the SAVER website (http://saver.tamu.edu) has a section devoted solely to IMS technology, equipment, and improvements.

(2) Flame Photometric Detection (FPD)

Flame photometry is based upon burning ambient air with hydrogen gas. Since the classical nerve agents all contain phosphorus and sulfur and mustard contains sulfur, these agents are readily detected by flame photometry. The flame decomposes any chemical agents or TIMs present in the air. At the elevated flame temperature, the phosphorus and sulfur emit light of specific wavelengths. A set of filters is used to transmit only the light emitted from phosphorus and sulfur to a photomultiplier tube, which produces an analog signal related to the concentration of the compounds in the air. Flame photometry is sensitive and allows ambient air to be sampled directly. However, it is also prone to false alarms from interfering chemicals that contain phosphorus and sulfur. Using a flame photometric detector (FPD) with a gas chromatograph will reduce the likelihood of false alarms. There are a number of gas chromatographs that use FPDs for detection purposes. An example of a handheld detector using this technology is the APACC Chemical Control Alarm Portable Apparatus, manufactured by Proengin SA.

(3) Infrared Spectroscopy (IRS)

Infrared spectroscopy is the measurement of the wavelength and intensity of the absorption of mid-infrared light by a sample. The wavelengths of IR absorption bands are characteristic of specific types of chemical bonds and every molecule has a unique IR spectrum (fingerprint). IR spectroscopy finds its greatest utility for identification of organic and organometallic molecules. There are two IR spectroscopy technologies employed in point detectors: photoacoustic infrared spectroscopy (PIRS) and filter based infrared spectroscopy.

Photoacoustic detectors use the photoacoustic effect to identify and detect chemical vapors. When a gas absorbs infrared radiation, its temperature rises and causes the gas to expand. If the intensity of the IR is modulated in an audible frequency, a microphone can be used to detect the resulting sound. Photoacoustic gas detectors use filters to transmit specific wavelengths of light absorbed by the chemical agent being monitored. When a chemical agent is present in the sample, an audible signal at the frequency of modulation is produced. One mobile laboratory unit that utilizes the photoacoustic IR spectroscopy technology is the Innova Type 1312 Multigas Monitor, from California Analytical Instruments.

The filter-based infrared spectrometry technology is based upon a series of lenses and mirrors that direct a narrow band past an infrared beam in a preselected path through the sample. The amount of energy absorbed by the sample is measured and stored in memory. The data management and control software (DMCS) retains data for longer term storage, retrieval, and further analysis. Thermo Environmental Products produces a portable ambient air analyzer, the MIRAN SapphIRe Portable Ambient Air Analyzer.

(4) Electrochemical Detection (ECD)

Electrochemical detectors monitor the resistance of a thin film that changes as the film absorbs chemicals from the air, or they monitor a change in the electrical potential of an electrode when chemicals in solution or in air are absorbed.

An example of one type of reaction is the inhibition of cholinesterase by nerve agents. A solution containing a known amount of cholinesterase is exposed to an air sample. If nerve agent is present, a percentage of the cholinesterase will be inhibited from reaction in the next step. The next step involves adding a solution containing a compound that will react with uninhibited cholinesterase to produce an electrochemically active product. The resulting cell potential is related to the concentration of uninhibited cholinesterase, which is related to the concentration of nerve agent present in the sampled air. Another type of electrochemical detector monitors the resistance of a thin film that increases as the film absorbs chemical agents from the air. Electrochemical detectors are selective, however, they are not as sensitive as technologies such as IMS and flame photometry. Several of the field electrochemical detectors encounter problems when exposed to environmental extremes. Hot and cold temperatures change the rates of reactions and shift the equilibrium point of the various reactions, which affects sensitivity and selectivity. An example of a detector using this technology is the Model 800 B Series manufactured by I.J. Cambria Scientific, Ltd.

(5) Colorimetric or Color Change Chemical Detection (CCD)

Detector kits are wet chemistry techniques formulated to indicate the presence of a chemical agent by a color change. These kits are used to verify the presence of a chemical agent after an alarm is received from another monitor. The kits are also used to test drinking water for contamination. A similar detection method using this technology is detection paper, which contains a dye that is colorless when crystalline and colored when dissolved in a chemical agent. Detector papers are generally used for testing suspect droplets or liquids on a surface; common materials can cause a false positive reaction. For gaseous or vaporous chemical agents, colorimetric tubes are also available. These consist of a glass tube that has the reacting compound sealed inside.

M8 and M9 paper is a standard device issued for all military first responders, and is commercially available.(14) The paper changes color when exposed to different liquid chemicals. It is useful as a screening device, but is prone to false positives as common materials such as hydraulic fluid can react to cause a color change.

The M256A1 detector kit is also a standard device issued to military first responders, and is commercially available as well. Designed to detect both liquid and vapor, it provides M8 paper which is used to identify chemical agents in liquid form. It also contains 12 detector tickets containing animal enzymes used to help detect very low concentrations of various chemical vapors. These include hydrogen cyanide, cyanogen chloride, blister and nerve agents. By following the directions provided with the kit, the first responder can combine the use of the paper and the enzymes to obtain a result in 20 to 25 minutes.

(6) Surface Acoustic Wave (SAW)

Surface acoustic wave detection consists of from 2 to 6 piezoelectric crystals, each coated with a film designed to absorb chemical agents from the air. Each film absorbs a particular class of volatile compound. For example, one polymeric film will be designed to preferentially absorb water, while other films absorb trichloroethylene, toluene, ethyl benzene, or formaldehyde. The piezoelectric crystal detects the mass of the chemical vapors absorbed into the different polymeric coatings. The change in mass of the polymeric coatings causes the resonant frequency of the piezoelectric crystal to change. By monitoring the resonant frequency, a response pattern for a particular vapor is generated and stored in a microprocessor. The system constantly compares each new response pattern to the stored response pattern for the target vapor. When the response pattern for the target vapor matches the stored pattern, the system alarm is activated. The selectivity and sensitivity of SAW detectors depend on the ability of the film to absorb only the suspect chemical agents from the sample air. Many SAW devices use pre-concentration tubes to reduce environmental interferences and increase detection sensitivity. A detector manufactured by Microsensor Systems, Inc. based upon the SAW technology is the SAW MiniAD mk II.

(7) Photo Ionization Detection (PID)

Photo ionization detectors operate by exposing a gas stream to a UV light of a wavelength with energy sufficient to ionize an agent molecule. An ion detector registers a voltage proportional to the number of ions produced in the gas sample, and thus the concentration of the agent. Specificity of these detectors is a function of how narrow the spectral range of the exciting radiation is and on how unique that energy is to ionizing only the molecule of interest. Rae Systems produces the MINIRAE Plus, a handheld detector that utilizes the PID technology. Another handheld PID detector is the Photovac 2020 manufactured by Perkin-Elmer.

(8) Sensor Array Technology (SAT)

Sensor array technology (SAT) devices use an array of several different chemical sensors such as conductive polymer, metal oxide, bulk acoustic wave (BAW) and SAW devices used simultaneously for real time monitoring. The various sensors must respond rapidly and reversibly to the chemical vapors they are exposed to. This technology is used in instruments commonly known as electronic noses. One mobile laboratory detector that is based upon SAT is the EEV eNose 5000 Electronic Nose.

(9) Thermal and Electrical Conductivity

Thermal and electrical conductivity detectors use metal oxide thermal conductivity semiconductors to measure the change in heat conductivity that occurs as a result of gas adsorption on the metal oxide surface. Also, the change in resistance and electrical conductivity across a metal foil in the system is measured when a gas adsorbs onto the surface of the metal film. Contaminants in the atmosphere being sampled will result in measurable electrical differences from the “clean” or background atmosphere.

Additionally, different contaminants will have different thermal conductivities and, therefore, different electrical responses from thermal and electrical conductivity detectors. An example of a handheld detector using this technology is the Portable Odor Monitor, manufactured by Sensidyne, Inc.

(10) Flame Ionization Detection (FID)

A flame ionization detector (FID) is a general-purpose detector used to determine the presence of volatile carbon-based compounds that are incinerated in a hydrogen-oxygen flame. When carbon compounds burn, an increase in the flame's baseline ion current takes place and detection of a compound occurs. FIDs are not specific and require separation technology for specificity, such as a gas chromatograph. Identification of compounds is generally determined by comparison of a compound's chromatographic retention time to that of a known standard, or to chromatographic retention indices for a series of known compounds using a standard set of chromatographic conditions. Perkin-Elmer manufactures a handheld FID, the MicroFID, for the non-specific determination of flammable and potentially hazardous compounds in the concentration range of 0.1 to 50,000 ppm.

B. Standoff Detectors

Standoff detectors are used to give advance warning of a chemical agent cloud. Standoff detectors typically use infrared spectroscopy and can detect chemical agents at distances as great as 5 kilometers. Spectra of clean, uncontaminated air must be used as a baseline to compare with freshly measured spectra of a sample that may contain a chemical agent. Standoff detectors are generally difficult to operate and usually require the operator to have some knowledge of spectroscopy in order to interpret results. Available standoff detectors use IR spectroscopy with either passive or active sensing, and more recently UV spectroscopy.

(1) Passive (Forward Looking Infrared (FLIR), Fourier Transform Infrared (FTIR)

Passive standoff detectors collect the IR radiation emitted from the chemical agent and TIM vapor clouds and compare it to the IR radiation absorbed from the background. Passive standoff detectors employ either (1) forward looking infrared (FLIR) imaging; or (2) Fourier Transform IR (FTIR) spectroscopy in order to collect the IR radiation. FLIR spectroscopy uses optical filters, and FTIR spectroscopy uses an interferometer. An example of a portable detector using this technology is the HazMatID from SensIR Technologies.

(2) Active (Differential Absorption LIDAR)

Light detection and ranging (LIDAR) is the laser analog to radar. In LIDAR, a pulsed laser beam is sent out to a target object. Some of the light incident on the target is reflected back to the sender, and the rest is scattered, reflected, transmitted or absorbed by the air. The time it takes for the light to travel from the sender to the target and back to the sender is used to calculate the distance to the target. In differential absorption LIDAR, two laser beams of slightly different frequencies are used to analyze the cloud. One of the frequencies is tuned to the molecular absorption of one of the molecules in the cloud. The intensity of the reflected beam is a function of the amount of laser light absorbed by the cloud. The cloud does not absorb the second frequency. The difference in the intensity of the two reflected beams will be due to absorption of the first laser beam by the cloud. The intensity of the return signal from the second laser beam is used as a baseline for calculating concentrations in the cloud. The time it takes for the two lasers to reflect back to the sender is used to calculate the range of the cloud. LIDAR is useful for tracking a chemical agent cloud once it has been identified, but it cannot identify a chemical agent. Scientific Solutions, Inc., and NP Photonics, Inc., are among several companies that produce equipment based on this technology for environmental monitoring.

(3) Ultraviolet Spectroscopy

Certain compounds have the ability to absorb ultraviolet (UV) light. UV spectroscopy passes a monochromatic UV light through a dilute solution of the sample in a non-absorbing solvent. The UV spectrum is taken by placing a dilute solution of the analyte in a silica cell and preparing a matching cell of pure solvent. The cells are placed in the spectrometer, and each cell is scanned with UV radiation. UV spectra usually show only one broad peak indicating absorption. The intensity of the absorption is measured by the percent of the incident light passing through the sample. UV absorptions can be useful in identifying species or assisting in determining structure. Advantages include direct fast response to changes in gas concentrations, capability of large area surveillance, good cost effectiveness, and ability to remain unaffected by environmental conditions such as heat, humidity, snow, or rain. Disadvantages include the inability to indicate the precise concentration at a given point, and dependence on an unobstructed line of sight between beam emitter and detector. An example of UV spectroscopy equipment is the Safeye 400 Gas Detection System by Spectrex, Inc.

C. Analytical Instruments

The analytical instruments described in this section can be used to analyze sample amounts as small as a few microliters or milligrams. They accurately measure different molecules based upon their unique chemical properties. The instruments are quite sophisticated in order to detect and differentiate subtle differences between trace amounts. Accuracy and reliability require that only very pure reagents are used and that very rigid protocol and operating procedures are followed. This typically precludes their use outside of a laboratory environment that is staffed by technically trained people. Still, some analytical instruments have been developed for field applications. Interpretation of the measured data typically requires a technical background and extensive formal training. Analytical techniques include:

(1) Mass Spectrometry (MS);

(2) Gas Chromatography (GC);

(3) High Performance Liquid Chromatography (HPLC);

(4) Ion Chromatography (IC); and

(5) Capillary Zone Electrophoresis (CZE).

(1) Mass Spectrometry (MS)

Mass spectrometry can positively identify a chemical agent at a very low concentration. A volatilized sample is ionized, typically by an electron beam, which also causes the molecule to fragment into smaller ionized pieces. The ionized molecules and fragments are then passed into a mass analyzer that uses electric fields to separate the ions according to the ratio of their mass divided by their electric charge. The analyzer allows only ions with the same mass over charge ratio to impinge upon the detector. By scanning the electric potentials in the mass analyzer, all the different mass/charge ions can be detected. The result is a mass spectrum that shows the relative amount and the mass of each fragment, and the unfragmented parent molecule. Since each molecule forms a unique set of fragments, MS provides positive identification. To simplify interpretation of the mass spectrum, it is best to introduce only one compound at a time. This is often achieved by using a gas chromatograph to separate the components in the sample. The end of the gas chromatography column is connected directly to the inlet of the mass spectrometer. Two instruments that use mass spectrometry are the Inficon Hapsite Field Portable System and the Agilent 6890-5973 GC/MSD from Agilent Technologies. The Inficon Hapsite has been extensively field tested by the U.S. Navy and U.S. Air Force. A joint effort sponsored by all four services has led to a number of improvements, eliminating some elements prone to damage in the field. Improved software has made the unit more user-friendly, but extensive training and a significant level of operator skill are needed to use such equipment accurately.

(2) Gas Chromatography (GC)

Gas chromatography uses an inert gas to transport a sample of air through a long chromatographic column. Each molecule sticks to the column with a different amount of force and does not travel down the column at the same speed as the carrier gas.

The chemical agents come out of the end of the column at different times, referred to as the retention times. Since the retention times are known for the chemical agents, the signal from the detector is only observed for a short period starting before and ending just after the retention time of the chemical agent. This eliminates false alarms from similar compounds that have different retention times.

The use of a pre-concentrator specific to the analyte can also reduce false alarms caused by interferences. The pre-concentrator passes air through an absorbent filter that traps agent molecules. The filter is isolated from air and heated to release any chemical agent that may have been trapped. The released chemical agent is pumped through the column and detector. Two instruments that use gas chromatography are the Voyager Portable Gas Chromatograph from Photovac, Inc., and the Scentograph Plus II manufactured by Sentex Systems, Inc. Various types of detectors (such as Flame Ionization) are commonly used together with the GC.

(3) High Performance Liquid Chromatography (HPLC)

HPLC is most useful in the detection and identification of higher molecular weight chemical agents, and in the detection and identification of biological agents. With HPLC, those chemically stable compounds that do not easily volatilize can be analyzed without undergoing chemical derivatization. As with GCs, HPLC instruments can be equipped with a variety of detectors such as UV-visible spectrometers, mass spectrometers, fluorescence spectrometers, and electrochemical detectors. Two limitations to the use of HPLCs and their detectors in the field are the requirements for 120-volt AC power and high purity solvents. There are no portable HPLC units currently available. HPLC instrumentation is available from a variety of vendors, such as Hewlett Packard, Perkin-Elmer, Varian, the HP1000 HPLC System from Agilent Technologies, and the LC-10 HPLC System from Shimadzu Scientific Instruments.

(4) Ion Chromatography (IC)

Closely related to HPLC is ion chromatography (IC) where ionic species can be separated, detected and identified. IC instruments are available from Dionex and Brinkmann. IC has been successfully used in the U.S. Army Materiel Command's Treaty Verification Laboratory in the analysis of several chemical nerve agents and their degradation products. As with HPLC, IC instruments require 120-volt AC, high purity water, and high purity chemical reagents for the preparation of buffering solutions. Like HPLC, IC instruments can use UV-Vis spectrometers, mass spectrometers, and electrochemical detectors. The Metrohm Model 761 Compact IC System from Metrohm-Peak, Inc., uses this technology.

(5) Capillary Zone Electrophoresis (CZE)

Capillary zone electrophoresis (CZE or CE) can be thought of as a hybridization of GC, LC, and IC. Rather than using a temperature gradient or a solvent gradient (as in GC or HPLC, respectively), a mobile phase containing an ionic buffer is used (as in IC). A high voltage electric field (either fixed potential or a gradient) is applied across a fused silica column similar to the capillary columns used in GC. CZE instruments are typically configured with either a UV-Vis spectrometer or an electrochemical detector, but can be interfaced to a mass spectrometer. CZE instrumentation shares the same electrical requirements as HPLC and IC instruments, but need much smaller quantities of high purity water and chemical reagents. The BioFocus 2000 CZE System is based on this technology.

7. BIOLOGICAL DETECTION INSTRUMENTATION

Recent breakthroughs in molecular biology and DNA analysis, and the improvements in computerized circuitry that have revolutionized chemical instrumentation, have caused major changes in biological detection instrumentation as well. Sampling to identify biological organisms that may have been used as weapons poses extremely difficult technological challenges. Attempting to quantify exposures to estimate potential health risk is also difficult. Table 2 lists the major categories of biological agents of concern that have been known to be produced in weapon form. As with chemical compounds, planners and first responders must identify the threats they intend to protect against, review available equipment, and then match equipment needs to the threat.

The current methodology used by the U.S. military for the identification of biological warfare agents calls for a layered or tiered approach. It begins with presumptive testing using hand-held assays (HHA), followed by confirmatory testing using polymerase chain reaction (PCR), enzyme-linked immunosorbent assay (ELISA), or direct culture of bio-organisms. Last is a definitive, full scale analytical study of the collected material by experts in the field. For first responders, accuracy and minimization of either a false positive or false negative is balanced against a quick answer. In-depth analysis takes longer, but provides a definitive answer.[15]

The primary infection route from exposure to biological agents is through inhalation, and it is likely that most of the initial aerosol would have settled by the time emergency first responders arrive on the scene of an incident. This does not lessen the possibility of infection of the first responders by re-aerosolization of the agent, but requires that the emergency first responders take more than just air samples for analysis. It may be critical for the emergency first responders to conduct environmental (soil/water) sampling and air and swipe tests to corroborate the occurrence of a biological attack, and to determine if the biological agent is still present. Emergency first responders may only be involved in post-incident activities, and may not have any need for early warning capabilities.[8]

Since sampling is a key issue for all analytical devices, the way a sample is taken and how it is handled will affect the outcome of the analysis. In a point collection detection scenario, sampling for biological agent particulate matter (PM) in the air is especially difficult due to the low effective doses of these agents. To sample biological agents effectively, large volumes of air must be passed through the sampler, dispersing the small amount of organism into a small volume of water, forming a concentrated mixture.

Biological detection systems are currently in the research and development stages. Caution is necessary when considering a purchase of any commercially available device that claims to detect BW agents. This is a very different situation when compared to chemical detection equipment. One reason for the lack of available biological detection equipment is that detection requires extremely high sensitivity (because of the very low effective dose needed to cause infection and spread the disease) and an unusually high degree of selectivity (because of the large and diverse biological background in the environment).

Another reason for the lack of equipment is that biological agents – compared to chemical agents – are very complex systems of molecules and more difficult to identify. Ion Mobility Spectrometry (IMS), for example, cannot detect or discriminate biological agents. The need for high-efficiency collection and concentration of the sample, high sensitivities, and high selectivities make all chemical detectors in their current form unusable for biological agent detection.

Biological agent detection systems generally consist of four components: the trigger/cue, the collector, the detector, and the identifier.[8]

A. Trigger/Cue

Trigger technology is the first level of detection determining a change in the background at the sensor, indicating possible biological agents. Detection of an increase in the PM concentration by the trigger causes the remaining components of the detection system to begin operation. To reduce false positives (an alarm with no biological agent) and false negatives (no alarm with an agent), many detection systems combine trigger technology with a second detector technology such as fluorescence, into a single technology known as cueing. If the PM are found to be biological, the cue device activates the collector for sample collection. In addition to fluorescence, another type of trigger/cue technology uses particle sizing and counting techniques for nonspecific detection in specific size ranges (typically 0.5

μm to 30 μm).

The Fluorescent Aerodynamic Particle Sizer (FLAPS) is an aerodynamic particle sizing (APS) device modified to include an additional laser (blue or UV wavelength) that provides for aerosol particle fluorescence. A variation of the FLAPS particle sizer is the UV Aerodynamic Particle Sizer (UVAPS) that uses time-of-flight particle sizing, light scattering, and UV fluorescence intensity to nonspecifically detect biological agents in air samples. Both systems are commercially available from TSI Inc.

B. Collector

The infectious dose for some agents is extremely small; therefore, highly efficient collection devices must be employed. One type of collector pumps large volumes of air through a chamber where the air mixes with water. The water scrubs all of the PM from the air, and once collected in the water, the sample is further concentrated by evaporation of a portion of the water. After concentration, the sample moves into the analytical section of the biological agent detection system.

The principal difference between collection for biological agents and other types of PM sampling is that biological agent sampling is normally targeted at living organisms, so the sampling techniques must preserve and not harm the agents in the collected sample; most biological detection and identification technologies require a liquid sample, so the collection must be from PM in a liquid, and the liquid sample must be highly concentrated and available for rapid analysis since response time is critical.

Collectors can be broadly divided into two groups. One group of collectors are large and consume much power, with a high collection and concentration efficiency. They work with detection systems that operate well away from point of agent release. The next group of collectors consumes little power, are hand-portable, and have relatively low collection and concentration efficiencies. These collectors would work well in high agent concentrations, near the point of release, or perhaps indoors. They would not provide an adequate sample to downstream and remote instruments. Collectors significantly contribute to the overall weight, size, and power requirements of a detection system. Examples of collector technologies include viable and nonviable particle size samplers (impactors), virtual impactors, and cyclones.

The viable sampler collection plate is typically a Petri dish with selective agar (selective to a specific organism). The plates are incubated (typically 24 to 48 hours) and then the number of colonies on each plate are counted. Nonviable impactors direct the stream onto various filtration media. Andersen Instruments manufactures both types of impactors.

A virtual impactor is similar to a conventional impactor but uses a different impaction surface. The flat plate of the conventional impactor is replaced by a collection probe, and the larger particles penetrate the collection probe instead of striking a flat plate. By properly controlling the airflow in the impactor, it is possible to collect particles in a specific size range. The final stage directs the particle stream onto a liquid, resulting in a highly concentrated liquid sample. The Liquid Sampler (PEM-0020) with carousel is manufactured by Power Engineering and Manufacturing, Inc. The device uses virtual impaction to collect and concentrate airborne PM onto liquid film. The BioVIC™ Aerosol Collector, developed by MesoSystems Technology, Inc., serves as a front-end air sampler for biological detection systems. It pre-concentrates the air stream, capturing large numbers of particles either into a small volume of liquid, and then into a small air stream, or onto a solid surface for delivery into the sensor.

The Interim Biological Agent Detector System (IBADS) was initially developed for the U.S. Navy. It uses a wetted-wall cyclone to collect the PM into an aqueous sample. Variants of this device are used in the Portal Shield Biological Detection System and in the current version of the Joint Biological Point Detection System (JBPDS). The Smart Air Sampler System (SASS 2000) is a device that has been independently developed by Research International. It also uses wetted-wall cyclone technology. This hand-held device can operate on battery power.

The BioCapture™ BT-500 Air Sampler was developed by MesoSystems Technology, Inc., and incorporates the BioVIC™ Aerosol Collector, also developed by MesoSystems Technology, Inc. The BT-500 is a hand-held, battery-powered air sampler that collects airborne samples for quantifying concentration levels. The microbes are captured and concentrated into an aqueous sample for analysis by whole cell rapid detection, nucleic acid, or other liquid-based sensor systems. The removable single-use cartridge can also be archived for keeping evidence of a biological incident.

C. Detectors

Detectors are used to determine if the PM is biological or chemical in origin, and if further analyses of the sample are needed. Some detectors require additional processing of a sample, while others can inject a sample directly from the environment. If the sample exhibits characteristics of biological PM, it is passed through to the next level of analysis.

Detection has traditionally taken place after the trigger function. For example, an aerosol particle sizer triggers, then a detector examines the aerosol for biological content. Many of the newer detection technologies combine the trigger and detection functionalities into a single instrument, creating a cueing instrument. If the sample is biological, the collector gathers a PM sample and passes it directly to the identifier, which is discussed in the next section. Detectors are broadly divided into two groups, wet detection (flow cytometry) and dry detection (mass spectrometry).

Cytometry is the measurement of physical and chemical characteristics of cells. Flow cytometry uses the same technique as cytometry, but makes the measurements of cells or other particles present in a moving fluid stream. It measures particle sizes and counts particles in liquid suspensions through the use of laser light scattering. Flow cytometers involve sophisticated laser optics and computers to provide an automated method for bio-chemical analysis, and to process thousands of cells in a few seconds. Typically, the sample will also be treated by addition of a fluorescent dye that reacts with biological material.

Flow cytometers have been commercially available since the early 1970s, and have been used increasingly since then. The Los Alamos National Laboratory Flow Cytometer (LANL) and the Becton Dickenson Flow Cytometer (FACSCaliber) both use this technology.

Dry detection using mass spectrometry (MS) requires only a few nanograms of analyte to obtain characteristic information on the structure and molecular weight of the analyte. The technique ionizes molecules and breaks them apart into characteristic fragments for chemical identification. The mass spectrometer requires that samples be introduced in the gaseous state. Sample introduction into the MS can be made by direct air/gas sampling, a direct insertion probe, membrane inlets, effluent from a gas chromatograph (GC), effluent from a high-performance liquid chromatograph (HPLC), capillary electrophoresis, and effluent from pyrolysis devices. Bruker manufactures a Chemical Biological Mass Spectrometer (CBMS) that uses a multistage process to analyze aerosols for biological content and categorize any biological constituents. The instrument first concentrates the aerosol, combusts or pyrolyzes it, then introduces the sample into an MS for analysis.

D. Identifier

Identifiers are instruments that identify the suspect biological agent to the species level and toxin type, by relying on the detection of a biomarker unique for that agent. Antibody-based identifiers are used for systems where timely analysis and automation are required. Where time and manpower are available, gene-based systems start to take the lead. Because the identifier performs the final and highest level of agent detection, it is the most critical component of the detection architecture and has the widest variety of technologies and equipment available.

Immunoassay technologies detect and measure highly specific binding of antigens with their corresponding antibodies. The presence of an agent is detected and identified by the specificity of the antigen-antibody binding. The immunoassays are grouped into three categories: disposable matrix devices, biosensors that use tag reagents to indirectly measure binding, and biosensors that do not require a tag (direct affinity assays).

Disposable matrix devices usually involve dry reagents, which are reconstituted when a sample is added. Typical technologies include the Hand-Held Immunochromatographic Assays (HHAs), BTA™ Test Strips, and the Sensitive Membrane Antigen Rapid Test (SMART) system. HHAs are currently being used in virtually all field military biological detection systems, and are being used by consequence management units in first response. BTA™ Test Strips are detection strips manufactured by Tetracore LLC and distributed by Alexeter Technologies, LLC. The SMART detects and identifies multiple analytes. An example is the NDI Smart Ticket manufactured by New Horizons Diagnostics Corporation in Columbia, Maryland.

Reagent tag biosensor methods include fluorescent evanescent wave biosensor surface, and an example is the Fiber Optic Wave-Guide (FOWG). The FOWG uses antibody-coated fiber optic probes and a fluorescent "reporter" antibody to determine the presence of a suspect agent. If an agent is present in the aqueous solution circulating through the instrument, it will bind to the antibody on the probe. The instrument then circulates a second solution containing a fluorescent labeled antibody, which will also bind to the agent. The device then looks for the presence of the fluorescent tag on one of the probes.

A "No-tag" reagent biosensor method uses antigen-antibody binding for direct detection (i.e., direct affinity or homogeneous assays). Advantages to this type of assay include fewer steps and fewer components, no tag reagent solutions, reuse of sensors after a negative test, and a smaller, lightweight instrument that consumes less power. A device that uses no-tag reagent biosensor technology is the Bi-Diffractive Grating Coupler (BDG), an optical transducer being developed by Battelle Memorial Institute and Hoffman-LaRoche.

Nucleic acid amplification may be used to help detect the presence of DNA or RNA of bacterial and viral biological agents. It cannot detect the presence of the toxins. Samples for nucleic acid analysis can be obtained from field samples, from laboratory cultures, or from tissues of infected animals or humans. Polymerase chain reaction (PCR) is the most widely used method to amplify small quantities of DNA for analysis.

The Mini-PCR (Ten Chamber PCR) is an instrument developed by Lawrence Livermore National Laboratory (LLNL) and represents one of the first attempts to get gene-based identification technologies in a field-useable format. The LightCycler™, developed by Idaho Technology, is a thermal cycler that uses a unique built-in fluorimetric detection system with specially developed fluorescent dyes for on-line quantitation and amplification products. It is being manufactured under license by Roche Diagnostics. The Ruggedized Advanced Pathogen Identification Device (RAPID), from Idaho Technology, is a rugged, portable field instrument that integrates the LightCycler™ technology. The RAPID can run a reaction and automatically analyze the results in less than 30 minutes. Special software allows push button use of the RAPID, for quick, safe, and accurate field identification of possibly dangerous pathogens. It is currently available for military field hospitals and law enforcement use.

It is important to identify the laboratory services available for analysis. It is recommended to use only the analytical laboratories proficient in the Environmental Microbiology Proficiency Analytical Testing (EMPAT) program administered by the American Industrial Hygiene Association (AIHA). The AIHA website at http://www.aiha.org provides the most current proficiency testing results and accreditation category.

8. RADIOLOGICAL DETECTION INSTRUMENTATION

Detection equipment for the ionizing energies of radioactive materials has been well-established for many years. All first responders should have training to understand the health hazards of radiation, how to use basic detection equipment, and how to avoid contamination. Radiological detection equipment should have an alarm, be lightweight and portable, and provide fast response for the safety of the responders.

Radiation may be the most feared of materials used as a WMD, not the least because of the persistence of most types of radiation. Once an area has been contaminated, it may not be habitable for many years. The complete invisibility of radiation, the well-known health effects, and the ability of the material to be inadvertently spread unless it can be quickly detected all contribute to the concern. Modern threats include small or tactical nuclear weapons, improvised nuclear devices (INDs), or radiological dispersal devices (RDDs or dirty bombs). Radiation will be spread over surfaces from explosions involving radioactive material, and can settle on objects and people in the area. A large enough explosion, or radioactive material dropped from an aircraft, will suspend material in a large volume of air, distributed over a wide area. PM spread over a surface in these ways may be inhaled or ingested, causing internal injuries.

Another type of threat is radioactive sources appearing without warning in places such as junkyards or other locations, where the public can be exposed without knowledge or immediate signs or symptoms. The risk to public health and the public response could be enormous from a highly radioactive source placed in a commonly occupied area. A highly radioactive source will produce ionizing radiation that must be measured to determine the extent of the hazard and the safe distance for personnel.

Equipment useful for the detection and collection of radiological material includes:

A. Electronic Personal Dosemeter Radiological Detector (EPD);
B. AN/PDR-75;
C. AN/PDR-77;
D. AN/VDR-2 ;
E. ADM-300;
F. Thermo Electron RadEye PRD;
G. E-600 Digital Survey Meter
H. identiFINDER;
I. Ludlum 2241-3RK Response Kit.

The Staplex high-volume air sampler can be used with the above instruments for indoor and outdoor sampling. The Staplex Company manufactures the Model TFIA series of High-Volume air sampler that can be used with a radiation detection device to determine the presence of radioactive material.

A. Electronic Personal Dosemeter (EPD) Radiological Detector

An EPD is a radiation detection and monitoring instrument issued to individuals to alert for the presence of radiation. This device is designed for deployment in areas where low-level radiation hazards may be present making it useful in setting up radiological areas or response zones. It can detect different types of ionizing radiation (gamma, beta, and x-ray radiation), and can measure a wide range of radiation intensities from background to the high levels that may be produced by a weapon or bomb. Certain models allow data to be downloaded to centralized information systems, thus making the EPD useful at the responder level to monitor for total dose accumulation.

The EPD Mk2 electronic personal dosemeter, manufactured by PTW, is one type of digital monitor for personal radiation protection measurements. This dosemeter provides direct readout of dose equivalents displayed in Sievert (Sv) or rem. The display shows dose and dose rate values, and alarm thresholds for the dose and dose rate measuring modes can be set. The small size makes it possible to keep the dosemeter in a pocket.

B. AN/PDR-75

The AN/PDR-75 meter or RADIAC has been a standard radiation survey meter issued to the U.S. military for the past 45 years. “RADIAC” is an acronym for “radiation, detection, identification, and computation." The AN/PDR-75 is often used for medical triage, and will monitor and record gamma and neutron radiation.

This equipment will provide the capability to monitor and record the exposure of individual personnel to gamma and neutron radiation, and includes a personal dosimeter. This device, worn on the wrist, contains a neutron diode and a phosphate glass gamma detector. The dosimeter is inserted into a reader, which then displays the cumulative neutron and gamma dose for that person. The AN/PDR-75 is rugged and portable. The dosimeters used in the system are designed to provide an individual's permanent dose record.

C. AN/PDR-77

The AN/PDR-77 is the primary device used when responding to nuclear accidents. In addition, it is used to maintain equipment containing radioactive materials. It detects and measures alpha, x-ray, beta, and gamma radiation. It is able to switch measurement range automatically, and has adjustable audio and visual alarm thresholds.

D. AN/VDR-2

The AN/VDR-2 is an instrument issued to the military used to perform surface radiological surveys. It can provide a quantitative measure of radiation to decontaminate personnel, equipment and supplies, and includes an audible and visual alarm that is compatible with nuclear, biological and chemical protection systems in armored vehicles. It can also be used as a hand-held instrument for providing a quantitative measure of radiation. It will detect, measure and display the gamma dose rate as well as beta particle radiation.

E. ADM-300

While the ADM-300 is primarily used for radiological detection in walk-through surveys, it can also be used for air monitoring when operated with a high volume air sampler, such as a Staplex®. The ADM-300 will detect the presence of alpha, beta, gamma or x-ray radiation. Being able to detect only one type of radiation at a time is a limitation of the ADM-300.

An evaluation of Nuclear Research Corporation's ADM-300 RADIAC survey meter was performed in accordance with the criteria specified in ANSI N42.17A-1989 and MIL-STD-810D (1983). Two configurations of the ADM-300 were tested: with beta/gamma detectors along the side, and with beta/gamma detectors along the bottom. The unit passed most of the ANSI N42.17A criteria. The angular dependence of the ADM-300 with the beta/gamma detectors along the bottom is less severe than with the beta/gamma detectors along the side. External probes are available should be subjected to similar testing prior to purchase.

F. Thermo Electron RadEye PRD

The Thermo Electron RadEye PRD can be used as a personal radiation detector sensitive to small amounts of radiation. It is a lightweight and very rugged instrument designed for the real-time measurement of the gamma dose rate. The device is a low-level gamma detector but not a dosimeter, and hence will not accumulate total dose. Based on a patented Natural Background Rejection (NBR) technology, it can be used for radiation detection, gamma dose rate measurements and area monitoring. The RadEye G – Wide Range Gamma Survey Meter incorporates a large energy compensated GM-tube for the precise dose rate measurement for gamma and x-ray.

G. E-600 Digital Survey Meter

Thermo Electron Corporation produces the Model E-600 Digital Survey Meter as a portable radiation-detecting meter, with a data logging capability that can store up to 500 data points. Each data point includes the location, date, time, detector channel, operating mode, displayed value, unit of measurement, instrument and probe serial numbers, and the instrument status. Location data may be read directly by the E-600's serial port via a laser scanner, alphanumeric keypad, Global Positioning System, or other device able to use computerized data.

The instrument display provides the user with a view of the full range of capabilities, blending analog information with digital data. The display lights up in the dark and is operational through a wide temperature range.

H. identiFINDER Digital Spectrometer

Thermo Electron Corporation also produces the identiFINDER Digital Spectrometer. The unit is lightweight, and can be used for locating and identifying man-made and natural radionuclides. It combines high sensitivity with a wide dose rate range, and locates the source via gamma spectrometry and subsequent nuclide identification. The unit integrates a multi-channel analyzer, amplifier, high voltage power supply, and memory with an integral scintillation and GM detector. It is designed and marketed for homeland security, industrial, medical, nuclear power generation and nuclear fuel cycle applications.

I. Ludlum 2241-3RK Response Kit

Another unit useful for radiation detection is the Ludlum 2241-3RK Response Kit that includes a digital survey meter and a pancake detector. The dose-rate meter will detect a wide range of levels, and an audio alert produces a sound to indicate the extent of radioactive contamination. It will give a good indication and range concerning rates of exposure.

9. EXPLOSIVE VAPOR DETECTION INSTRUMENTATION

Explosive detection techniques can be divided into two categories: bulk detection and trace detection.[9] In bulk detection, a mass of explosive material is detected directly, usually by viewing images made by x-ray scanners or similar equipment. In trace detection, the explosive is detected by chemical identification of trace residues of the explosive compound as vapor or PM. Explosives can be categorized into three groups based on their vapor pressures, high, medium, and low.

High vapor pressure explosives include ethylene glycol dinitrate, nitroglycerin, and 2,4-dinitrotoluene, which exhibit saturated vapor concentrations in air close to 1 ppm. Medium vapor pressure explosives have saturated vapor concentrations in air near one part per billion (1 ppb), and include trinitrotoluene and ammonium nitrate. Low-vapor-pressure explosives have saturated vapor concentrations in air near or below the one part per trillion (1 ppt) level, and this group includes cyclotrimethylenetrinitramine or cyclonite, and pentaerythritol tetranitrate. These vapor pressures are cited for pure materials, mixtures may be lower.

The relative values of the vapor pressures have important implications for trace detection. High vapor pressure explosives are easy to detect using ion mobility spectrometers or electron capture detectors. Detecting compounds by swiping surfaces for particle contamination is possible, but may be less effective than with lower vapor pressure explosives. In the case of PM sampling, the evidence may not be present long enough to make a detection.

Medium vapor pressure explosives can sometimes be detected from their vapor, but in many cases this will test the limits of sensitivity for gas phase detection, and PM detection based on surface swiping is usually preferred. Ammonium nitrate is a somewhat special case because it is almost always used in quantities of hundreds or even thousands of pounds in devices such as car bombs, and not in small bombs that could be carried on a person or shipped through the mail. Thus, when ammonium nitrate is used, there is likely to be lots of contamination present to make a swipe-based detection, and various bulk detection techniques should also be effective.

Low vapor pressure explosives do not produce enough vapor to be detected from their vapor in any but the most exceptional circumstances, and efforts to detect these compounds using trace technology must focus on swipe collection of PM. This makes swiping the preferred collection technique when dealing with plastic explosives.

The presence of oils and plasticizing agents that give the plastic explosive its form and consistency also give it a very low vapor pressure. When these explosives are manufactured, they are often spiked with a high vapor pressure nitro-compound called a taggant, making vapor detection possible. Relying on vapor detection with plastic explosives is still very risky, because old or homemade samples of plastic explosives will not contain the taggant.

A. Trace Detection Technologies

Technologies for explosive detection include:

(1) Ion mobility spectrometry (IMS);
(2) Chemiluminescence;
(3) Electron Capture Detectors (ECD);
(4) Surface Acoustic Wave (SAW)Sensors;
(5) Thermo-Redox Detectors (TRD);
(6) Field Ion Spectrometry (FIS);
(7) Color Change of Test Paper;
(8) X-ray Explosives Detection.

(1) Ion Mobility Spectrometry (IMS)

Ion Mobility spectrometry (IMS) is one of the most widely used techniques for the trace detection of explosives and other hidden materials such as weapons or drugs. A number of companies market IMS systems, including Barringer, Graseby, and Ion Track Instruments. Most IMS systems are small and portable enough to be moved around in the trunk of a car, and can be operated by a person with only a few hours of training. These instruments have response times of only a few seconds, detect a number of key explosives down to subparts per billion in some cases, and have audio and visual alarms that tell the operator when and which type of explosive has been detected. The most effective means for collecting a sample for presentation to one of these systems is surface swiping, but vacuum collection of samples is also possible with many systems.

(2) Chemiluminescence

Most explosive compounds contain either nitro or nitrate groups, and taggants in plastic explosives also contain nitro groups. Detectors based on chemiluminescence take advantage of this common property by detecting the light emitted from electronically excited nitro molecules. In a chemiluminescence system, explosive molecules are first pyrolyzed to produce nitric oxide. The nitric oxide molecules are then reacted with ozone, producing excited state molecules. A photomultiplier detects photons emitted when the molecules decay to form unexcited molecules. The signal output measured by the photomultiplier is directly proportional to the amount of nitro molecules present, and the explosive is detected.

Chemiluminescence alone cannot identify what type of explosive molecule is present. For this reason, chemiluminescence detectors are not used alone but are fitted with a front-end gas chromatograph (GC). The GC allows different molecules detected by chemiluminescence to be identified based on their GC retention times. The resulting system is referred to as a GC/chemiluminescence (GC/CL) detector. Systems of this type are marketed by Thermedics as Thermedics Egis. Because of its high sensitivity and excellent selectivity it is a popular system with laboratory researchers and forensic analysts. A drawback of GC/CL systems is their inability to detect explosives that are not nitro-based.

(3) Electron Capture Detectors (ECD)

An electron capture detector (ECD) detects explosives and other types of molecules having high electron affinities. In an ECD, a vapor sample is drawn into an inlet port, and this vapor mixes with a stream of inert carrier gas (usually helium or argon). The gas flow then travels through an ionization region to an exhaust line. In transit, the gas flow passes through a chamber with a radioactive material that acts as an electron source, usually nickel-63 or tritium. The emitted electrons become thermalized through collisions with the gas in the chamber, and eventually are collected at an anode. Under equilibrium conditions, there is thus a constant standing current at the anode. This standing current is the characteristic of the gas mixture being drawn into the system. If the initial gas mixture originally consists of helium and room air, the standing current will be reduced if the vapor of an explosive is added to the sample chamber. This happens because the explosive molecules have a high electron affinity and thus a tendency to capture free electrons and form stable negative ions, leaving fewer electrons to reach the anode. Thus, a reduction of the measured standing current is the evidence that an explosive or some similar species is present. As with a chemiluminescence detector, the ECD by itself cannot distinguish individual types of explosives from each other or certain interferants, so a gas chromatograph is placed on the front end to allow temporal identification of different explosives. Several companies market detectors of this type referred to as GC/ECD detectors. One commercially available GC/ECD detector is the Ion Track Instruments Model 97 ECD.

(4) Surface Acoustic Wave (SAW) Sensors

Surface acoustic wave (SAW) sensors are usually coupled with a front end GC, as is the case with ECD and chemiluminescence detectors. The principal component of a SAW sensor is a piezoelectric crystal that resonates at a specific, measurable frequency. When molecules condense on the surface of this crystal, the resonant frequency shifts in proportion to the mass of material condensed. The frequency shift depends upon the properties of the material being deposited, the surface temperature, and the chemical nature of the crystal surface. SAW sensors are marketed by Electronic Sensor Technology, Inc.

(5) Thermo-Redox Detectors

Thermo-redox technology is based on the thermal decomposition of explosive molecules and the subsequent reduction of nitro groups. Air containing the explosive sample is drawn into a system inlet at a rate of approximately 1.5 L/min. The air is next passed through a concentrator tube, which selectively adsorbs explosive vapor using a proprietary coating on the coils of the tube. The sample is then pyrolyzed to liberate nitrogen dioxide molecules, and these molecules are detected using proprietary technology. Intelligent Detection Systems markets the thermo-redox based equipment formerly marketed by Scintrex.

(6) Field Ion Spectrometry (FIS)

Field ion spectrometry (FIS) is a trace detection technology related to IMS, in that it involves separating and quantifying ions while they are carried in a gas at atmospheric pressure. Both systems use ionization methods that yield identifying spectra. In FIS, ions enter an analytical volume defined by a pair of parallel conducting plates. In response to the asymmetric field, the ions tend to migrate towards one of the plates where they will be neutralized. Only specific ions can pass completely through the analytical volume and into the collection area for detection. The device can be tuned to selectively pass only ions of interest. Scanning the field intensity produces a spectrum of ion current versus field intensity that is known as an ionogram. One manufacturer of FIS sensors is Mine Safety Appliances (MSA).

(7) Color Change of Test Paper

EXPRAY Field Test Kit is a unique, aerosol-based field test kit. Detection of explosive residue is made by observing a color change of the test paper. EXPRAY can be used in a variety of applications, and although in some aspects it does not perform as well as many of the other trace detectors discussed in this section, its very low cost, coupled with simplicity and ease of use, may make it of interest to many first response groups or planners. The EXPRAY field kit is comprised of three aerosol spray cans, for Group A, Group B, and nitrate-based explosives, and special test papers which prevent cross contamination.

A suspect surface is wiped with the special test paper, and then sprayed with EXPRAY-1. The appearance of a dark violet-brown, blue-green, or orange color indicates the presence of Group A explosives. If there is no reaction, the same piece of test paper is then sprayed with EXPRAY-2. The appearance of a pink color indicates the presence of Group B explosives, a group which includes most plastic explosives. If there is still no reaction, the same paper is then sprayed with EXPRAY-3. The appearance of pink then indicates the presence of nitrates, which could be part of an improvised explosive. If EXPRAY-2 is applied after a positive result with EXPRAY-1, a change to pink color indicates a double or triple base explosive. The chemistry associated with these color changes is proprietary. The order of spraying is critical, and all three sprays should be used in order to perform a complete test. It is marketed by Mistral Group.

B. X-ray Explosives Detection

X-ray technologies are most often used for screening luggage, packages, mail, and other small items. It involves irradiation of a target item with x-rays, followed by detection of an image created by x-rays that are either transmitted or backscattered by the item. The process of personnel screening is problematic because of privacy concerns and the perceived health problems associated with x-rays. There are currently two different x-ray based personnel scanners on the U.S. market. Vehicle screening systems are also available, though these are large, expensive, and require passengers to exit the vehicle before it is screened.

10. SAMPLING EQUIPMENT PLANNED FOR THE FUTURE

Devices suitable for CBRNE detection on individuals are currently under development, and would be of great value to a first responder. Designed as a micro-processor based identification badge, such devices would detect the exposure of individuals to a number of toxic industrial chemicals (TICs) and chemical agents. They are intended to measure individual exposure at unrecognizable, sub-clinical levels, and possibly serve as an indicator that additional medical care may be needed. Such low-cost devices would store and display the individual's exposure history, and provide health information for entry into medical records. They could also assist in the determination of the extent of contaminated areas, and would act as an alert for the operation of personnel and equipment decontamination stations. This would also enable a real time indication of dose or concentration, providing the fast reaction time needed by first responders. Although this is presently a cooperative effort between several government agencies and government contractors, there is no estimated time line for completion. It may be several years before such personalized monitors for CBRNE detection become available.

Because biological agents are easy to manufacture and obtain, and are potentially lethal, remote detection of a biological agent would be of great interest to the first responder. Standoff systems are designed to detect and identify biological agents at a distance, before the agents reach the location of the detector system. Such systems may use technology based on laser remote sensing or LIDAR, an acronym for light detection and ranging. Because LIDAR systems use light, which is composed of short wavelength energy, they are able to detect the small aerosol particles characteristic of biological agent attacks (predominantly less than 20 microns in diameter). IR based LIDAR systems have ranges of 30 km to 50 km, as the atmosphere is fairly transparent to this wavelength of light.

Sandia National Laboratories in New Mexico (http://www.sandia.gov) are a government owned, contractor operated facility. There are a number of projects underway to improve air sampling and materials identification technology. Sandia is working with the Massachusetts Institute of Technology to develop a method of quantum cascade laser spectroscopy with the potential for rapidly identifying chemical and biological agents, as well as for imaging applications.

Sandia and other labs have also developed and tested a chemical detection system that can be rapidly deployed at special events to protect people against toxic industrial chemical threats. A test conducted with the police department in Livermore, California, proved that the system could provide the information needed to understand and respond to an attack rapidly. This system is still under development.

Sandia is also currently exploring licensing opportunities for "Hound™", a hand-held portable sample collection and pre-concentration device that, when combined with chemical detectors, would enable the detection of trace amounts of explosives, drugs, and other chemicals. Recently, the Texas Department of Public Safety used "Hound™" to identify methamphetamines and nitrates during a routine traffic stop. This product is under development.

Sandia's MicroChemLab™ technology, when installed in miniature chemical and biological detection systems, can rapidly detect and identify a range of chemical and biological weapons. MicroChemLab units could help first responders quickly determine whether a chemical or biological attack has taken place, and respond accordingly. Sandia is searching for industry partners to manufacture and commercialize MicroChemLab.

These are examples of research that is going, and in the next few years there may be a greater number of instruments that will answer the needs of first responders for a rapid and accurate determination.

11. SUMMARY

Planning for a response to disasters of any kind saves lives. Finding and avoiding toxic materials that cannot be detected by the five human senses also saves lives, and that is the point. A good plan, good equipment, well-trained professional responders, and strong community support give people confidence, and that is the best defense against the consequences of disasters, whatever the source.

The increasing complexity of the available technology offers both advantages and disadvantages. The advantages, of course, are improved capability for detecting toxic or hazardous materials, perhaps even before they are accidentally or intentionally released into the environment.

The disadvantages of constantly improving and increasingly complex technology include the overwhelming choices available to a disaster planner, and the difficulty in matching resources to identified needs. Planners must depend on the judgment and research of others when the time comes to decide what type of equipment to purchase, and under what conditions it should be used. The consequences of choosing equipment poorly can be deadly.

Hopefully this chapter has offered some assistance in gathering many different sources of information in one place.

12. ACKNOWLEDGMENTS

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14. WEBSITE RESOURCES

Sites listed here were current at time of publication; no endorsement is implied or intended. These are to aid in searching for air sampling equipment for first responders.

U.S. Environmental Protection Agency: Integrated Risk Information System (IRIS) on Aniline. U.S. EPA, National Center for Environmental Assessment, Office of Research and Development, Washington, DC; online at http://www.epa.gov/iris/subst/0350.htm.

Aerobiology, Inc.: Indoor Air Quality Specialists. Aerobiology, Inc., Dulles, Virginia; online at http://www.aerobiology.net.

Aerotech P&K: Indoor Air Quality Testing. Aerotech P&K, Phoenix, Arizona; online at http://www.aerotechpk.com.

Chemical, Biological, Radiological, and Nuclear Defense Information Analysis Center (CBRNIAC). Battelle Memorial

Institute, Aberdeen Proving Ground, Edgewood, Maryland; online at http://www.cbrniac.apgea.army.mil.

Centers for Disease Control (CDC): Bioterrorism Preparedness and Response. Centers for Disease Control, Atlanta, Georgia; online at emergency.cdc.gov.

Central Intelligence Agency (CIA): Chemical, Biological, Radiological Incident Handbook. Central Intelligence Agency, Washington DC online at https://www.cia.gov/library.

James Martin Center for Non-Proliferation Studies: Chemical and Biological Weapons Resource Page. Monterey Institute of International Studies, Monterey, California; online at http://cns.miis.edu/research/cbw/index.htm.

National Library of Medicine (NLM), MedlinePlus: Emergency Response. National Library of Medicine (NLM), Bethesda, Maryland; online at http://medlineplus.gov.

National Library of Medicine: Wireless Information System for Emergency Responders (WISER). NLM, Bethesda, Maryland; online at http://wiser.nlm.nih.gov.

National Memorial Institute for the Prevention of Terrorism (MIPT): Lessons Learned Information Sharing. National Memorial Institute for the Prevention of Terrorism (MIPT), Oklahoma City, Oklahoma; online at http://www.llis.gov.

Occupational Safety and Health Administration (OSHA): Hazardous Waste Operations and Emergency Response Standard (HAZWOPER). Occupational Safety and Health Administration (OSHA), Washington, DC; online at www.osha.gov.

RAND Corporation: Protecting Emergency Responders. RAND Corporation, Santa Monica, California; online at http://www.rand.org/pubs.

U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID): Defense Against Toxin Weapons Manual. USAMRIID, Frederick, Maryland; online at www.usamriid.army.mil/education.

U.S. Department of Health and Human Services (HHS): Radiation Event Medical Management (REMM). Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response, Office of Planning and Emergency Operations, Radiation Event Medical Management (REMM); online at http://REMM.NLM.gov.

U.S. Department of Homeland Security, Federal Emergency Management Agency, Emergency Management Institute: ICS 100, Introduction to the Incident Command System. Emergency Management Institute, Emmitsburg, Maryland; online at http://training.fema.gov/EMIWeb/IS/is100.asp.

U.S. Department of Homeland Security, Federal Emergency Management Agency: Metropolitan Medical Response System (MMRS) Program. Metropolitan Medical Response System (MMRS) Program, Washington, DC; online at http://mmrs.fema.gov/.

U.S. Department of Homeland Security, Federal Emergency Management Agency: System Assessment and Validation for Emergency Responders (SAVER). DOHS, Washington, DC; online at http://tti.tamu.edu/projects.

U.S. Department of Homeland Security: Responder Knowledge Base. U.S. DHS and MIPT; online at https://www.rkb.mipt.org.

U.S. Department of Justice, National Institute of Justice, Publications: Guide. National Institute of Justice, Washington, DC; online at http://nij.ncjrs.gov/publications.

U.S. Department of Transportation: Pipeline and Hazardous Materials Safety Administration. DPT, PHMSA, Office of Hazardous Material Safety, Risk Management; online at http://hazmat.dot.gov/riskmgmt/risk.htm.

U.S. Environmental Protection Agency: Chemical Emergency Preparedness and Prevention. U.S. EPA; online at http://www.epa.gov/ebtpages/emergencies.html.

U.S. National Response Team: Guidance, Technical Assistance and Planning. U.S. NRT, Washington, DC; online at http://www.nrt.org.

15. ACRONYMS

AEL	Authorized Equipment List
APS	Aerodynamic particle sizing
CBRNE	Chemical, Biological, Radiological, Nuclear, and Explosive
CCD	Colorimetric or Color Change Detection
CDC	Centers for Disease Control
COC	Chain of Custody
Cue	Device used with trigger technology to limit false alarms
DoHS	Department of Homeland Security
DoJ	Department of Justice
ECD	Electron Capture Detection
EGDN	An explosive, ethylene glycol dinitrate
EMPAT	Environmental Microbiology Proficiency Analytical Testing
FID	Flame Ionization Detection
FIS	Field Ion Spectrometry
FLAPS	Fluorescent aerodynamic particle sizer
FPD	Flame Photometric Detection
HAZWOPER	Hazardous Waste Operations and Emergency Response Standard
IAB	Interagency Board for Equipment Standardization and Interoperability
IMS	Ionization/Ion Mobility Spectrometry
IND	Improvised Nuclear Device
IRS	Infrared Spectroscopy
LLIS	Lesson Learned Information Sharing
MMRS	Metropolitan Medical Response System
NIJ	National Institute of Justice
NIST/OLES	National Institute of Standards and Technology, Office of Law Enforcement Standards
NRT	National Response Team
OG&T	DoHS Preparedness Directorate's Office of Grants and Training
OHS	Office of Homeland Security
PETN	An explosive, pentaerythritol tetranitrate
PID	Photo-Ionization Detection
PM	Particulate Matter
RADIAC	Radiation, Detection, Identification, and Computation
RDD	Radiological Dispersal Device ("dirty bomb")
REMM	Radiation Event Medical Management

15. ACRONYMS (CONT.)

RKB	Responder's Knowledge Base
SAT	Sensor Array Technology
SAVER	System Assessment and Validation for Emergency Responders
SAW	Surface Acoustic Wave
SCC	Standards Coordination Committee
SEL	Standardized Equipment List
SLGCP	DoHS Office of State and Local Government Coordination and Preparedness
SSD	SLGCP Systems Support Division
T&ECD	Thermal and Electrical Conductivity Detection
TIC	Toxic Industrial Chemical
TIM	Toxic Industrial Material
TNT	An explosive, trinitrotoluene
TRD	Thermo-Redox Detection
Trigger	Device used to determine changes in PM background
USAMRICD	U.S. Army Medical Research Institute of Chemical Defense
USAMRIID	U.S. Army Medical Research Institute of Infectious Diseases
WISER	Wireless Information System for Emergency Responders
WMD	Weapons of Mass Destruction

16. KEYWORDS

Air sampling equipment, CBRNE equipment, Emergency Response, chemical detection equipment, CDE, chemical agent, CA, biological detection equipment, enzymatic detection, radiological detection equipment, portable first response equipment, hazardous material, HAZMAT, hazardous material emergency, HAZMAT emergency, First Responders, WMD response, chemical detection paper, ion mobility spectroscopy, IMS, infrared radiation, IR, photo ionization detection, PID, flame photometry, miniature automatic continuous agent monitoring system, MINICAMS, surface acoustic wave chemical detector, SAW.

APPENDIX A: GUIDANCE FOR SELECTING AIR SAMPLING EQUIPMENT

The following list of questions is highly recommended in helping first responders and emergency planners choose the best air sampling equipment for their use. The original set of questions from which these were adapted are included as an appendix in the NIJ Guide (Fatah et al., 2005) cited in the reference section. These were developed by the staff of the Center for Domestic Preparedness (Fort McClellan, AL), military Chemical and Biological Units, the NIJ, and members of the IAB, including representatives from the state and local law enforcement, medical, and fire communities.

A. Applicability

(a) How long has the company/manufacturer been involved with CBRNE and first responder industries? You may also ask for references.

(b) What capability does this equipment give me that I do not currently possess?

(c) What equipment can I do away with if I purchase this?

(d) Is the equipment designed only for use with military chemicals?

(e) Is the company currently supplying its product(s) to similar agencies? If so, who? Ask for names and phone numbers of departments currently using the company's equipment. Ask to follow-up on the phone any written reports.

(f) What agents has the equipment been tested against?

(g) Who conducted the tests?

(h) Have the test results been verified by an independent laboratory or only by the manufacturer?

(i) What were the results of those tests?

(j) Are the test data available? Where?

(k) What types of tests were conducted?

(l) Have any engineering changes or manufacturing process changes been implemented since the testing? If so, what were the changes?

B. Operation

(a) What is the theory of operation? Surface acoustic wave (SAW) photo ionization, flame ionization, etc.

(b) What common substances cause a 'false positive' reading or interference?

(c) Can the equipment detect both large and small agent concentrations?

(d) Does this equipment require any hazardous materials for cleaning? If yes, what are they?

(e) Taking weight and size into consideration, what procedures or processes are needed to employ down range?

(f) What procedures or processes are employed to decontaminate the equipment in order to remove it from the Hot Zone? How difficult are they?

(g) What are the environmental limitations – high temperature, low temperature, humidity, sand/dust?

(h) What are the storage requirements (i.e., refrigerators, cool room, or no special requirements)?

C. Specifics of Use

(a) How long does it take to put the equipment into operation? Can it be efficiently operated by someone in a Level A suit?

(b) Are there audible and visual alarms? What are their set points and how hard is it to change them?

(c) Are the alarm set points easily set to regulatory or physiologically significant values?

(d) How quickly does the detector respond to a spike in the agent concentration?

(e) How quickly does the detector clear when taken to a clean area?

(f) What is the response time of the detector to a spike in the agent?

(g) What is the return rate on the equipment under warranty?

(h) What are the top five reasons for failure?

(i) How often does the equipment require calibration?

(j) Does calibration require returning the equipment to the manufacturer?

(k) Does calibration involve hazardous materials?

(l) What special licenses, permits or registrations are required to own or operate the equipment?

(m) What is the shelf life of the equipment under the following conditions: left out of a sealed container, and stored in a sealed container; both before and after exposure to potential contaminants.

D. Costs

(a) What additional items are required to operate or maintain the equipment? At what cost?

(b) How long do the batteries last?

(c) How long does it take to replace batteries or recharge?

(d) What is the cost of new batteries?

(e) Are the expended batteries HAZMAT and what is the cost of disposal of batteries?

(f) What type of warranty and maintenance support is offered, at what cost?

(g) What are the required on-hand logistical support and costs?

(h) How often does the equipment need to be sent back to the manufacturer for maintenance?

(i) What training materials are provided – manuals, videotapes, CD ROMs?

(j) What is the cost of training materials?

(k) What training is required to use the equipment and interpret the results?

(l) Does the company provide this training, and what is the cost?

(m) How often is refresher training required?

APPENDIX B: MANUFACTURER AND PRODUCT WEBSITE LISTING

The following is a partial listing. Endorsement is not intended or implied.

Manufacturer	Instrument Name	Website
ABB Process Analytics	Automatic Continuous Air Monitoring System	www.abb.com
Agilent Technologies	Agilent 6890-5973, GC/MSD	www.home.agilent.com
AIM Safe-Air Products Limited	Logic 400 series (Model 450) Personal Air Monitor	www.aimsafeair.com
Anachemia Canada, Inc.	3-Way Paper, Chemical Agent Liquid Detectors	www.anachemia.com
Anachemia Canada, Inc.	Chemical Agent Detector Kit	www.anachemia.com
Anachemia Canada, Inc.	M256A1 Kit	www.anachemia.com
Anachemia Canada, Inc.	Nerve Agent Vapor Detector (NAVD)	www.anachemia.com
Analytical Technology	C16 PortaSens II Gas Detector	www.analyticaltechnology.com
Armstrong Monitoring Corp.	AMC Series 1100 Portable Gas Detector	www.armstrongmonitoring.com
Assay Technology, Inc.	Electronic Reader	www.assaytech.com
Barringer Instruments	Responder Raman Chemical Identifier	www.barringer.com
Barringer Instruments	HazMatID Infrared Chemical Identifier	www.barringer.com
Barringer Instruments	GasID Portable Gas and Vapor Identifier	www.barringer.com
Barringer Instruments	APD 200 Hand-held Chemical Agent Detector	www.barringer.com
Barringer Instruments	Sabre 4000 Hand-held Explosives & Chemical Agent Detector	www.barringer.com
Bear Instruments, Inc.	Kodiak 1200	www.bearinst.com
Beckman Coulter, Inc.	Beckman-Coulter P/ACE 5000 CZE System	www.beckmancoulter.com
Biorad, Digilab Division	Infrared Detector for Gas Chromatograph	www.bio-rad.com
Biorad, Digilab Division	Trace Ultra High Sensitivity	www.bio-rad.com
Biosystems	PhD2 Personal Gas Detector	www.biosystems.com
Biosystems	Toxi Gas Detector	www.biosystems.com
Biosystems	Toxi Plus Gas Detector	www.biosystems.com
Biosystems	Toxi Ultra Gas Detector	www.biosystems.com
Brinkmann Instruments, Inc.	Brinkmann Metrohm Model 1761 IC System	www.brinkmann.com
Bruker Daltonics	Chemical Biological Mass Spectrometer (CBMS)	www.bdal.com
Bruker Daltonics	EM-640 Mobile Mass Spectrometer	www.bdal.com
Bruker Daltonics	IMS 2000	www.bdal.com
Bruker Daltonics	MM-1 Mobile Mass Spectrometer	www.bdal.com
Bruker Daltonics	Rapid Alarm and Identification Device-1 (RAID-1)	www.bdal.com
Bruker Daltonics	Viking 573	www.bdal.com
Bruker Saxonia Analytik	GmbH RAPID I (Remote Infrared Detector)	www.bruker.com
BW Technologies	BW Defender	www.gasmonitors.com
BW Technologies	GasAlert	www.gasmonitors.com
BW Technologies	GasAlertMax	www.gasmonitors.com

California Analytical Instruments	Innova Gas Analyzer Type 1301	www.gasanalyzers.com
California Analytical Instruments	Innova Type 1312 Multigas Monitor	www.gasanalyzers.com
Calspan	Veridian ALAD System	www.calspan.com
Dionex Corporation	Dionex DX-500 IC System	www.dionex.com
Draeger Safety, Inc.	Draeger CDS Kit	www.draeger-safety.com
Draeger Safety, Inc.	MicroPac Personal Gas Alarm	www.draeger-safety.com
Draeger Safety, Inc.	MiniWarn Gas Detector	www.draeger-safety.com
Draeger Safety, Inc.	MultiWarn II Gas Detector	www.draeger-safety.com
Draeger Safety, Inc.	Pac III Single Gas Detector	www.draeger-safety.com
Dynatherm Analytical, Inc.	Continuous Environmental Monitor (ACEM) 900	www.dynatherm.com
Electronic Sensor Technology	4100 Vapor Detector	www.znose.com
Electronic Sensor Technology	7100 Vapor Detector	www.znose.com
Enmet Corporation	Omni-4000 Gas Detector	www.enmet.com
Enmet Corporation	Quadrant Portable Gas Detector	www.enmet.com
Enmet Corporation	Smart Logger Gas Detector	www.enmet.com
Enmet Corporation	Spectrum	www.enmet.com
Enmet Corporation	Target Gas Detector	www.enmet.com
Enmet Corporation	TX-2000 Toxic Gas Detector	www.enmet.com
Environics USA Inc.	M90-D1-C Chemical Warfare Agent Detector	www.environics.fi
Environmental Technologies Group	Advanced Portable Detector (APD) 2000	www.envtech.com
Environmental Technologies Group	Air Sentry-FTIR	www.envtech.com
Environmental Technologies Group	Chemical Agent Monitor (CAM)	www.envtech.com
Environmental Technologies Group	Improved Chemical Agent Monitor (ICAM)	www.envtech.com
Environmental Technologies Group	Fixed Site/Remote Chemical Agent Detector	www.envtech.com
Environmental Technologies Group	ICAM-Advanced Portable Detector (ICAM-APD)	www.envtech.com
Environmental Technologies Group	Individual Chemical Agent Detector (ICAD)	www.envtech.com
The Foxboro Company	FoxTox Personal Multi-Gas Monitor	www.foxboro.com
The Foxboro Company	Miran 981B Multipoint	www.foxboro.com
Gas Tech, Inc.	95 Series Single Gas Monitor	www.gastech.com
Gas Tech, Inc.	Genesis Portable Gas Monitor	www.gastech.com
Gas Tech, Inc.	GT Series Portable Gas Monitor	www.gastech.com
General Monitors	Model TS400 Toxic Gas Detector	www.generalmonitors.com
Giat Industries	AP2C CW Detector	www.nbc-sys.com
Giat Industries	DET INDIV Individual Nerve Agent Detector	www.nbc-sys.com
Giat Industries	KDTC	www.nbc-sys.com
Grace Industries	Haz-Alert Gas Detector	www.gracesales.com
Graseby Dynamics	Chemical Agent Monitor-2 (CAM-2)	www.grasebydynamics.com
Graseby Dynamics	GID-2A Chemical Detector	www.grasebydynamics.com
Graseby Dynamics	GID-3, Chemical Agent Detection System	www.grasebydynamics.com
Graseby Dynamics	Lightweight Chemical Detector (LCD-2)	www.grasebydynamics.com
Heinz Laboratories	5-Step Field ID Kit 8 Model 2000	www.heinztraining.com
Hewlett-Packard Co.	Hewlett Packard HP1000 HPLC System	www.agilent.com

Hewlett-Packard Co.	Hewlett-Packard HP3D CZE System	www.hp.com
Hewlett-Packard Co.	HP 2350 Atomic Emission Detector	www.hp.com
Hewlett-Packard Co.	HP 6890	www.hp.com
Hewlett-Packard Co.	HP 6890 Series II	www.hp.com
HNU Systems, Inc.	IS-101	www.hnu.com
I.J. Cambria Scientific, LTD	Model 800 B Series	www.ijcambria.com
Industrial Scientific Corporation	ATX 612 Multi-Gas Aspirated Monitor	www.indisci.com
Industrial Scientific Corporation	Gas Badge Personal Gas Alarm	www.indisci.com
Industrial Scientific Corporation	LTX312 Gas Monitor	www.indisci.com
Industrial Scientific Corporation	T80 Single Gas Monitor	www.indisci.com
Industrial Scientific Corporation	TMX412 Multi-Gas Monitor	www.indisci.com
Inficon	Hapsite Portable Gas Chromatograph	www.inficonvocmonitoring.com
Intelligent Detection Systems	EVD 3000 Portable Hand-held Explosives Detector	www.tracedetection.com
Intellitec	AN/KAS-1 Chemical Warfare Directional Detector	www.intellitecsolutions.com
Intellitec	M21 Automatic Chemical Agent Alarm	www.intellitecsolutions.com
Intellitec	M8A1 Automatic Chemical Agent Alarm	www.intellitecsolutions.com
International Sensor Technology	IQ-250 Single Gas Detector	www.intlsensor.com
International Sensor Technology	TLV Panther Gas Detector	www.intlsensor.com
Interscan Corporation	7000 Series Data Logging Portable Gas Detector	www.gasdetection.com
Ion Track Instruments	Model 97 Electron Capture Detector	www.iontrack.com
K & M Environmental	Chrom Air Badges	www.kandmenvironmental.com
Ludlum Measurements, Inc.	Ludlum 2241-3RK Response Kit	www.ludlums.com/product/2241
Lumidor Safety Products	MicroMax Multigas Monitor	www.lumidor.com
Lumidor Safety Products	Toxibee Personal Gas Alarm	www.lumidor.com
Lumidor Safety Products	Unimax Personal Single Gas Detector	www.lumidor.com
Marconi Applied Technologies	eNOSE 5000 Electronic Nose	www.neotronics.com
Matheson Safety Products	Kitagawa Gas Detector Tubes	www.mathesontrigas.com
Microsensor Systems, Inc.	CW Sentry	www.microsensorsystems.com
Microsensor Systems, Inc.	SAW Minicad II	www.microsensorsystems.com
Mil-Ram Technology, Inc.	Tox-Array 1000 Gas Detector	www.mil-ram.com
Mine Safety Appliances	Hazmatcad and Hazmatcad Plus for First Responders	www.msanet.com
Mistral Group	Expray Explosives Field Test Kits	www.mistralgroup.com
MSA Instrument Division	MSA Gas Detection Tubes	www.msanorthamerica.com
MSA Instrument Division	MSA Passport II PID Monitor	www.msanorthamerica.com
PE Sciex	API 365	las.perkinelmer.com
Perkin-Elmer Corporation	MicroFID Handheld Detector	las.perkinelmer.com
Perkin-Elmer Corporation	Perkin-Elmer Turbo LC Plus HPLC System	las.perkinelmer.com
Perkin-Elmer Corporation	Photovac 2020 PID Monitor 80 217	las.perkinelmer.com
Perkin-Elmer Corporation	Photovac Microtip Photoionization Detector	las.perkinelmer.com

Perkin-Elmer Corporation	Photovac Snapshot Hand Held Gas Chromatograph	las.perkinelmer.com
Perkin-Elmer Corporation	Voyager	las.perkinelmer.com
Proengin SA	ADLIF System	www.proengin.com
Proengin SA	APACC Chemical Control Alarm (Model M266 E)	www.proengin.com
PTW	EPD Mk2 electronic personal dosemeter	www.ptw.de
Quest Technologies, Inc.	MultiCheck 2000 Multi-Gas Monitor	www.quest-technologies.com
Quest Technologies, Inc.	MultiLog 2000 Multi-Gas Monitor	www.quest-technologies.com
RAE Systems, Inc.	ToxiRae Plus Personal Gas Monitor	www.raesystems.com
RAE Systems, Inc.	MiniRae 2000	www.raesystems.com
RAE Systems, Inc.	MultiRae Plus Gas Detector	www.raesystems.com
Rae Systems, Inc.	ppbRae	www.raesystems.com
RAE Systems, Inc.	VRAE Hand Held 5 Gas Surveyor (Model 7800)	www.raesystems.com
Scott/Bacharach, LLC	AutoStep Plus	www.scottinstruments.com
Scott/Bacharach, LLC	Bodyguard 4 Personal Monitor	www.scottinstruments.com
Scott/Bacharach, LLC	SureSpot Badges	www.scottinstruments.com
Sensidyne, Inc.	Portable Odor Monitor	www.sensidyne.com
Sensidyne, Inc.	Sensidyne Gas Detection Tubes	www.sensidyne.com
Sentex Systems, Inc.	Scentograph Plus II	www.inficonvocmonitoring.com
Sentex Systems, Inc.	Scentoscreen-GC with Argon Ionization Detector	www.inficonvocmonitoring.com
Shimadzu Scientific Instruments	Shimadzu LC-10 HPLC System	www.ssi.shimadzu.com
Spectral Sciences Incorporated	Gasman Portable Multiple Toxic Gas Monitor	www.spectral.com
Spectrex Corporation	SXC-20 VOC Monitor	www.spectrex.com
Spectrex Inc.	Safeye Model 400 Gas Detection System	www.spectrex-inc.com
SRI Instruments, Inc.	Dual-Flame Photometric Detector	www.sri-instruments.com
Staplex Company	STAPLEX Hi-Volume Air Sampler	www.staplex.com
Thermo Environmental Instruments	Model 680EZ Portable Photoionization Detector	www.thermoei.com
Thermo Environmental Instruments	Century TVA-1000 Toxic Vapor Analyzer	www.thermoei.com
Thermo Environmental Instruments	Miran SapphIRe Portable Ambient Air Analyzer	www.thermoei.com
Thermo Electron Corporation	E-600 Digital Survey Meter	www.thermo.com/rmp
Thermo Electron Corporation	identiFINDER Digital Spectrometer	www.thermo.com/rmp
TSI Incorporated	ProtectAir Multi-Gas Monitor Model 8570	www.tsi.com
Varian Chromatography Systems	Saturn 2000	www.varianinc.com
Varian, Inc.	Varian ProStar Analytical HPLC System	www.varianinc.com
Zellweger Analytics, Inc.	Chemkey TLD Toxic Gas Monitor	www.zelana.com
Zellweger Analytics, Inc.	CM4 Gas Monitor	www.zelana.com
Zellweger Analytics, Inc.	Gas Beacon/Gas Leader	www.zelana.com
Zellweger Analytics, Inc.	MiniGas-XL Multi-gas Monitor	www.zelana.com
Zellweger Analytics, Inc.	Model 7100 Gas Monitor	www.zelana.com
Zellweger Analytics, Inc.	Neotox-XL Single Gas Monitor	www.zelana.com