# Testing of Safe Buildings Detection Technologies and Other Homeland Security Technologies in EPA's Environmental Technology Verification (ETV) Program

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## ABSTRACT
The U.S. EPA's Environmental Technology Verification (ETV) Program has conducted third-party performance testing on over 250 diverse environmental technologies. In the aftermath of the terrorist attacks of September 11, 2001, the ETV program has also undertaken verification of technologies relevant to homeland security. This paper summarizes ETV activities in six homeland security technology areas (detection of chemical or biological contamination in buildings; clean up of buildings after a contamination event; detection of chemical or biological contamination of drinking water; point-of-use treatment of drinking water against chemical and biological contaminants; treatment of wastewater produced by building decontamination efforts; and protection of building ventilation air from chemical and biological contamination), and focuses on activities in the first area. The procedures for testing of portable ion mobility spectrometers (IMS) as used by first responders are described, and test results are provided on the first portable IMS to undergo testing.

## INTRODUCTION
The events of September 11, 2001, placed homeland security at the forefront of the United States' priorities. As a result of this emphasis, the U.S. Environmental Protection Agency (EPA) is working with other agencies, including the Department of Homeland Security (DHS), to fill gaps in data and information related to environmental aspects of homeland security. EPA has established the National Homeland Security Research Center (NHSRC) in Cincinnati, Ohio, as the focus for this effort, with three key research areas:

- Safe Buildings
- Drinking Water Protection
- Rapid Risk Assessment

As one part of EPA's effort in these areas, the Environmental Technology Verification (ETV) Program is being used to verify the performance of several types of homeland security technologies: 1) devices to monitor indoor environments in public buildings and to detect chemical or biological contamination, 2) technologies to clean up buildings after a contamination event has occurred, 3) detectors of chemical or biological contamination of the nation's drinking water supply, 4) technologies for point-of-use treatment of drinking water against chemical and biological contaminants, 5) treatment technologies for wastewater produced by building decontamination efforts, and 6) technologies to protect building ventilation air from chemical and biological contamination. This paper focuses on ETV activities addressing the first technology area, and briefly summarizes activities taking place in the other areas.

EPA established the ETV Program in 1995 to verify the performance of environmental technologies that can solve problems affecting human health or the environment. ETV's mission is to accelerate the use of new environmental technologies in the domestic and international marketplace. ETV is a voluntary program in which technology vendors are invited to participate. ETV does not approve, certify, or rank technologies, but provides third-party, quality-assured performance data so buyers and users of environmental technologies can make informed purchase and application decisions. Those actively involved in the ETV Program include stakeholders, buyers and users, vendors, permitters, technology experts, and engineers. To date, ETV testing has verified the performance of over 250 environmental technologies, and produced over 70 protocols for technology testing. Additional information and all ETV verification reports, test protocols, and fact sheets are available at: http:// www.epa.gov/etv. EPA's application of the ETV approach to homeland security technologies is a result of the effectiveness of ETV in expanding the information available on environmental technologies.

Testing of monitoring and detection technologies within ETV is the responsibility of Battelle, EPA's partner and a not-for-profit technology research and development organization with headquarters in Columbus, Ohio. To date, Battelle's Advanced Monitoring Systems (AMS) Center has completed verification tests of over 60 environmental monitoring technologies, including mercury continuous emission monitors, open-path optical sensors, portable water analyzers, and ambient fine particulate monitors. Nearly 50 additional technologies are in the verification testing process. The AMS Center publishes a monthly newsletter, *The Monitor*, to provide information on air and water environmental technology verifications. Battelle also tests homeland security technologies intended to ensure building safety, under a separate program, the Safe Buildings Monitoring and Detection Technologies Verification Program. A second newsletter—*The Detector*—is published by Battelle to provide information about these homeland security detector verifications. (For more information or to receive these newsletters, contact Helen Latham at Battelle, (614) 424-4062, lathamh@battelle.org.)

# HOMELAND SECURITY TECHNOLOGY TESTING

## Safe Buildings Detection Technologies

In late 2002, Battelle was assigned the responsibility for testing monitoring and detection technologies to protect public buildings. To meet this responsibility, activities have focused on identification of candidate technologies, and testing of a first type of detector. A basic choice made early in the effort was to address detection technologies for chemical and biological contaminants, rather than radiological contamination, because of the already well-advanced state of radiological monitoring.

The identification of safe buildings detection technologies began with a consideration of the various applications in which such technologies might be needed. The three main applications are:

- Detect-to-warn
- Detect-to-respond
- Detect-to-restore.

Detect-to-warn refers to the continual monitoring of the entire building environment to detect a contamination event as it happens. This application requires large, permanent, multi-sensor systems installed in the building. Detect-to-respond refers to the initial response and diagnosis of a contamination event, as carried out by emergency crews and first response agencies. For this application portable, rugged, rapid, multi-component detection devices are needed. Detect-to-restore means the determination of residual levels of contamination left after cleanup, to guide decisions about return of the building to normal use. In this application high sensitivity and accuracy are the most important requirements, and sample collection with subsequent analysis is the conventional approach.

The detect-to-respond application was chosen as the initial focus of this effort, primarily because of the great emphasis on this application after September 11, and the consequent large expenditures made by first responders for largely unproven detection equipment. In addition, there are many commercially available small, portable detection devices that may be applicable to this application. The technologies applicable to this category were surveyed and reviewed, so that the technologies could be prioritized. Initially, the technology survey drew from published guidance such as the National Institutes of Justice surveys.[1,2] Subsequently, the survey was updated, in part through direct contacts with technology vendors. The category of portable ion mobility spectrometers (IMS) was chosen as the first type of technology for testing, a test/QA plan was developed,[3] and the first testing was conducted. In parallel, the survey of detection technologies continued, to identify the next categories for testing.

**IMS Verification.** The overall objective of the test described in the IMS test/QA plan[3] is to verify the performance of the portable IMS technologies with selected toxic industrial chemicals (TICs) and chemical warfare (CW) agents, under a realistically broad range of indoor conditions and procedures of use. The TICs are of interest because they are likely to be much more accessible than CW agents for use by a terrorist. Testing is conducted over a range of 5 to 35 °C and 20 to 80 percent relative humidity (RH), to represent conditions that might be encountered in an emergency response situation in a building. The rigorous nature of actual use by first responders is also simulated by testing with insufficient warmup after storage at room temperature and at hot and cold temperatures; battery life; and the effect of likely indoor interferences. Two units of each IMS instrument are tested simultaneously, to assure complete coverage of all test procedures in the event of a failure of one unit. The test data sets from the two units are compiled and reported as independent measures of the IMS performance.

Table 1 lists the quantitative performance parameters on which the portable IMS instruments are evaluated under this plan,[3] along with a summary of the objective of each

**Table 1. Summary of Evaluations Conducted in Portable IMS Verification Test**

| Performance Parameter | Objective | Comparison Based On |
|---|---|---|
| Response Time | Determine rise time of IMS response | IMS readings with step rise in analyte concentration |
| Response Threshold | Estimate minimum concentration that produces IMS response | Reference method results |
| Repeatability | Characterize consistency of IMS readings with constant analyte concentration | IMS readings with constant input |
| Accuracy | Characterize agreement of IMS with reference results | Reference method results |
| Recovery Time | Determine fall time of IMS response | IMS readings with step decrease in analyte concentration |
| T and RH Effects | Evaluate effect of T and RH on IMS performance | Repeat above evaluations with different T and RH |
| Interferent Effects | Evaluate effect of building contaminates that may interfere on with IMS performance | Sample interferents and TICs/CW agents together (and interferents alone[a]) |
| Cold Start | Characterize startup performance of IMS | Repeat tests with no warmup[a] |
| Hot Start | Characterize performance after hot storage | Repeat tests with no warmup[a] |
| Battery Operation | Characterize battery life and performance | Compare IMS results on battery *vs* AC power[a] |

a: Indicates this part of the test not performed with CW agents.

performance test, and the type of comparisons on which the test is based. In addition, qualitative information is compiled during testing on operational factors such as ease of use, clarity and variety of data displays and alarms, consumables use, maintenance and repair needs, and cost.

These tests are carried out with a set of TICs consisting of:

- Hydrogen cyanide (designated AC)
- Cyanogen chloride (CK),
- Phosgene (CG),
- Chlorine ($C1_2$), and
- Arsine (SA).

The CW agents selected for use in IMS testing are:

- Sarin (GB) and
- Sulfur mustard (HD).

IMS testing involves primarily challenging the IMS instruments with concentrations of these chemicals that were at or near Immediately Dangerous to Life and Health (IDLH) levels, consistent with the detect-to-respond application targeted. Table 2 summarizes these concentrations for each TIC and CW agent used in testing. Lower concentrations were also used, for example, to determine the response threshold of the IMS instruments.

**Table 2. Target Challenge Concentrations used in Portable IMS Verification Tests**

| Chemical | Concentration | Type of Level |
|---|---|---|
| Hydrogen cyanide (AC) | 50 ppm (50 mg/$m^3$) | IDLH[a] |
| Cyanogen chloride (CK) | 20 ppm (50 mg/$m^3$) | Estimated IDLH |
| Phosgene (CG) | 2 ppm (8 mg/$m^3$) | IDLH |
| Chlorine ($Cl_2$) | 10 ppm (30 mg/$m^3$) | IDLH |
| Arsine (SA) | 3 ppm (10 mg/$m^3$) | IDLH |
| GB | 0.014 ppm (0.08 mg/$m^3$) | 0.4 of IDLH |
| HD | 0.063 ppm (0.42 mg/$m^3$) | 0.7 of AEGL-2[c] |

a: IDLH = Immediately dangerous to life and health.
b: Value for CK estimated based on IDLH for AC.
c: AEGL = Acute Exposure Guideline Level; AEGL-2 levels are those expected to produce a serious hindrance to efforts to escape in the general population.[(2)] The values shown assume a 10-minute exposure.

The interferences used in IMS verification testing were chosen because they are likely to be present in a building, and because of their potential capability to affect IMS response. Table 3 lists the interferents and their challenge concentrations used in the IMS tests. The concentrations shown are in parts-per-million carbon in air (ppmC), and are based on published indoor measurements, or on estimates based on outdoor measurements. The interferent DEAE is an anti-corrosion additive that can be found in indoor air when boiler water supply is used for humidification of building air. In testing, the IMS instruments are challenged with the interferents both without and with each target TIC or CW agent present, to test for false positive and false negative responses, respectively.

**Table 3. Interferents Used in Portable IMS Verification Test**

| Interferent | Test Concentration (ppmC) |
|---|---|
| Latex paint fumes | 10 |
| Ammonia-based floor cleaner | 10 |
| Air freshener vapors | 1 |
| Gasoline exhaust hydrocarbons | 2.5 |
| Diethylaminoethanol (DEAE) | 0.02 |

**IMS Test Results.** To date the IMS verification procedure outlined above has been completed on one commercial IMS instrument, the Bruker RAID-M, which is shown in Figure 1. Two units of this instrument were tested side-by-side in most tests, using a flow dilution and environmental control system enclosed in an appropriate laboratory or chemical agent surety hood. A photograph of the two units in the test apparatus during TIC testing is shown in Figure 2.

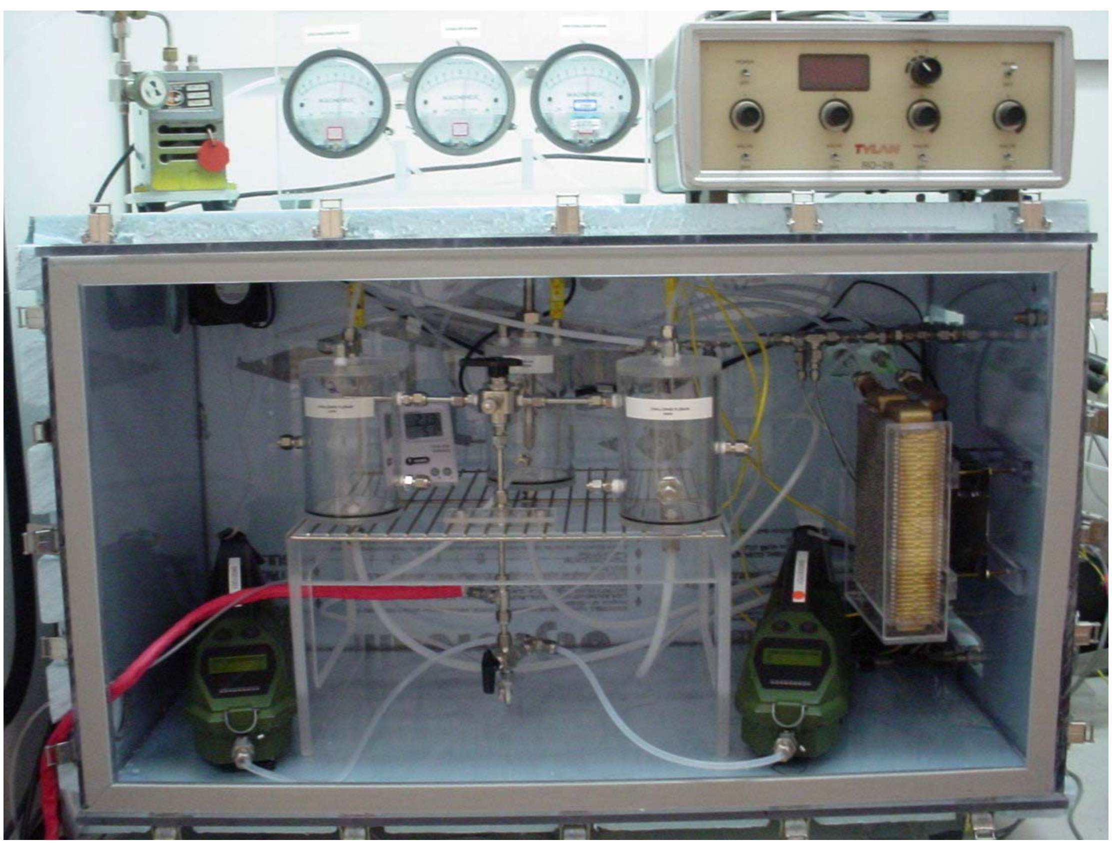
The verification report on the Bruker RAID-M portable IMS has recently been completed. The response times of the RAID-M for all the TICs and CW agents used were within the range of about 3 to 10 seconds, and audible and visual alarms were clear and prominent. Recovery times (time to return to a non-alarm state) were sometimes much longer (several minutes), especially when operating the IMS after insufficient warmup time. Response was very sensitive for AC and CK, such that full-scale response occurred even at concentrations far below the IDLH level. Response thresholds were: <0.06 ppm for AC, <0.6 ppm for CK, 0.08 to 0.33 ppm for CG, 0.25 to 0.5 ppm for $Cl_2$, 0.0035 to 0.007 ppm for GB, and 0.01 to 0.02 ppm for HD. The RAID-Ms were not programmed to respond to SA. Temperature and humidity had little effect on RAID-M response, and in almost all cases, the RAID-M units accurately identified the TIC or CW agent being sampled.

Substantial interferent effects were observed with the RAID-Ms. The presence of latex paint fumes and floor cleaner vapors strongly suppressed IMS response to $Cl_2$, whereas response to CK was increased by all of the interferents tested. Response to GB was sharply reduced by latex paint fumes, floor cleaner vapors, and air freshener vapors; response to HD was reduced by about half by all interferents except floor cleaner vapors, which had minimal effect. The interferents caused the RAID-Ms to indicate the presence of other CW agents, such as VX or GA. False positive readings were observed occasionally with floor cleaner vapors and with DEAE, but not with the other interferents. The false positive responses were in the form of an indication that VX was detected. Operation of the RAID-Ms with insufficient warmup time caused lower initial readings, relative to the fully warmed-up state, and lengthened recovery times, as noted above. Battery life from a fully charged starting state was about 6.5 hours, and nearly 8 hours, respectively, for the two RAID-M units. The verification report on the Bruker RAID-M is available on the ETV web site.

**Other Detection Technology Categories**. Verification tests are also being planned for other portable IMS instruments, using the same test/QA plan and procedures used for the Bruker RAID-M. In addition, the test/QA plan used for the IMS verification is applicable

**Figure 1. Bruker RAID-M Portable Ion Mobility Spectrometer**

**Figure 2. Two RAID-M Units in the Test Apparatus**



to other types of portable chemical detectors as well. Other technology categories to be tested include portable flame spectrometry, surface acoustic wave (SAW) devices, and portable photoionization detectors (PIDs). At the time of this symposium, testing is under way on two units of the HAZMATCAD Plus, a portable hybrid electrochemical/ SAW detector manufactured by Microsensor Systems, Inc. At the conclusion of TIC testing with the HAZMATCAD Plus, testing will also begin on the ACADA system, a portable IMS instrument sold by Markland Technologies, Inc.

## Safe Buildings Decontamination Technologies

Verification of technologies that can decontaminate indoor surfaces in buildings and other structures contaminated with chemical or biological agents is the focus of the ETV Building Decontamination Technology Center, which is managed by Battelle. Technologies in this area can be tested for their efficacy in decontaminating either chemical or biological contaminants, or both. Verification testing uses actual CW and biological agents and surrogates, applied to common indoor materials and then exposed to the decontamination process, to verify the ability of the decontaminant technology to kill or destroy those agents. Indoor materials used for testing include carpet, wood, glass, painted wallboard, painted concrete, decorative laminate, and galvanized steel ductwork.

The chemical agents used in decontaminant testing include the CW agents VX, GD, and HD. The primary biological agent used in testing is anthrax spores (*Bacillus anthracis* ), along with the surrogate organisms *Bacillus stearothermophilus* and *Bacillus subtilis*. In addition, commercial spore strips are included in all test procedures, to assess how well these strips correlate with the actual efficacy of the decontaminant against anthrax.

Three commercial decontaminant technologies have undergone testing as of January 2004 in the Building Decontamination Technology Center:

- Bioquell Inc., hydrogen peroxide vapor technology - biological decontamination only
- Certek Inc., formaldehyde vapor technology - biological decontamination only
- CDG, Inc., gaseous chlorine dioxide ($ClO_2$) technology – both biological and chemical decontamination.

Reports on these technologies are in preparation and will be available in the spring to summer of 2004. Additional technologies of interest include foams and liquid decontaminants, hot air treatment, and UV light.

## Drinking Water Contaminant Detection

The verification of detection devices for chemical and biological contaminants in drinking water is conducted by Battelle under the AMS Center. Technologies tested as of the time of this symposium include five portable detectors for cyanide in water (based on colorimetric detection or ion selective electrodes), and eight rapid toxicity monitors, which use living organisms or other biologically-based approaches to serve as real-time indicators of water toxicity. The detection mechanisms of the rapid toxicity monitors range from bacterial luminescence, to fluorescence, to oxygen consumption by the living organisms. These monitors can quickly indicate early signs of biological or chemical contamination (usually within an hour). They do not identify a specific toxic substance or biological agent but can, to some extent, measure the amount of toxicity in the sample. All verification reports on the cyanide and rapid toxicity monitors are available from the ETV web site (**http://www.epa.gov/etv**). Verification tests of immunoassay test kits and rapid polymerase chain reaction (PCR) technologies are currently underway.

## Drinking Water Treatment Technologies

Point-of-use water treatment technologies are being verified by the National Sanitation Foundation (NSF) of Ann Arbor, Michigan, as part of the ETV Drinking Water Systems Center.

## Decontamination Wastewater Treatment

Technologies for treatment of wastewater that is produced from building decontamination activities are also being verified by NSF, as part of the ETV Water Quality Protection Center.

## Building Air Protection Technologies

Technologies for protecting building ventilation air from chemical and biological contamination are being tested by Research Triangle Institute, as part of the ETV Air Pollution Control Technology Center. Initial verifications have focused on testing air filters for their ability to remove biological aerosols. Verification reports on ten such technologies are available at http://www.epa.gov/etv/verifications/vcenter10-1.html.

## REFERENCES


1. *Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders*, NIJ Guide 100-00, Vols. I and II, National Institute of Justice, Washington, D.C., June 2000.
2. *An Introduction to Biological Agent Detection Equipment for Emergency First Responders*, NIJ Guide 101-00, National Institute of Justice, Washington, D.C., December 2001.
3. *Test/QA Plan for Verification of Portable Ion Mobility Spectrometers for Detection of Chemicals and Chemical Agents in Buildings*, Battelle, Columbus, Ohio, July 2003.