



HDIAC

Homeland Defense & Security
Information Analysis Center



2018 State of the Art Report: Identifying Chem/Bio Weapons Use

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HDIAC Overview

What is the Homeland Defense & Security Information Analysis Center (HDIAC)?

One of three Department of Defense Information Analysis Centers

Responsible for acquiring, analyzing, and disseminating relevant scientific and technical information, in each of its eight focus areas, in support of the DoD and U.S. government R&D activities

HDIAC's Mission

Our mission is to be the go-to R&D/S&T and RDT&E leader within the homeland defense and security (HDS) community, by providing timely and relevant information, superior technical solutions, and quality products to the DoD and HDS Communities of Interest/Communities of Practice.

State of the Art Reports

- The Homeland Defense & Security Information Analysis Center (HDIAC) develops annual State of the Art Reports (SOARs) on scientific and technical topics that are highly relevant to the Department of Defense (DoD)
- Methodology: we paired original research conducted at the HDIAC Basic Center of Operations with expert elicitation from outside Subject Matter Experts (SMEs) to choose individual chapter topics
- Authors include researchers from academia, national laboratories, and federal agencies

Why Chem/Bio Weapons?

- **2001 anthrax attacks**
- **Use of chemical weapons in Syrian conflict**
- **Fentanyl and fentanyl derivatives concerns**
- **UK chemical weapon attack**
- **Kim Jong-nam assassination**

Themes in the Report

This report highlights areas of technology likely to have an outsized effect on the current state and future practice of chem/bio identification:

- Smaller
- Faster
- Universal detection
- Increased mobility
- Decreased cost

Outline/Areas Covered

This report addresses 4 areas in which scientific and technical (S&T) research and development (R&D) are most likely to intersect with improving chem/bio identification relevant to DoD and defending the homeland:

- Detection for chemical and biological agents
- Biologically-based toxicity sensors for detection of chemicals in drinking water
- Inventory and supply chain management technologies for situational awareness
- Forensic considerations in the investigation of biological weapons use

Identification and Detection Technologies for Chem/Bio Agents – Trends

Overview

- New advances in computational power, communication capabilities, and microfluidics accelerating development
- Emerging trend to develop more sophisticated point of care testing
- Challenges: accuracy and size

Recent Advances Driven By:

- Increasing computer processing power
- Decreasing chip size
- Improved functionality of cell phones
- Microfluidic device production methods

Detection Technologies for Chem/Bio Agents – Chemical Detection

Matrix Complexity and Sample Preparation

- Minimize environmental contamination
- Reduce dilution effects or sample losses
- Prevent future chemical alteration of the sample

Mass Spectrometry

- **Equipment**
 - Inficon Hapsite ER GC-MS
 - Smiths Detection GUARDION GC-MS platform
 - FLIR G510
- **Ionization techniques**
 - Direct analysis in real time (DART)
 - Electrospray ionization (ESI) method
 - Continuity platform

Detection Technologies for Chem/Bio Agents – Chemical Detection

Optical Spectroscopy and Colorimetric Arrays

- Raman and IR-based techniques

Fieldability

- Number of samples per battery
- Size, weight, and power (SWaP)
- Systems limited to one samples type – vapor, liquid, or solid

Detection Technologies for Chem/Bio Agents – Biological Detection

Environmental Detection

- **Matrix Complexity and Sample Preparation**
 - No universal sampling method
 - Matrix effects
 - Soil – humic acid, particle size
- **Immunological Detection (Antibody-based)**
 - Later Flow Immunoassays/assays (LFIs or LFAs)
 - Enzyme-linked Immunosorbent Assays (ELISAs)
 - MULTI-SPOT plates
 - Surface Plasmon Resonance (SPR)
- **Molecular Detection (Nucleic Acid-based)**
 - Polymerase Chain Reaction (PCR), Real-time, End-point
 - Isothermal Amplification
 - Genome sequencing (Illumina sequencing and nanopore sequencing)
- **Alternative Technologies**
 - Raman spectroscopy/Surface-enhanced Raman Spectroscopy (SERS)
 - μ PADs/ePADs

Diagnostics

- **ASSURED Criteria**

Detection Technologies for Chem/Bio Agents – Future Outlook

- **Portable novel scan types**
- **Prepress sampling techniques**
- **Fieldable high-resolution detectors for chemical platforms**
- **Miniaturization of vacuum hardware**
- **Isothermal amplification to reduce SWaP**
- **Genomic sequencing technologies**
- **Reducing cost and improving sustainability**

Biologically-Based Sensors for Detecting Chemicals in Drinking Water – Overview

DoD has gap for rapid detection of toxic chemicals in drinking water

Developed Environmental Sentinel Biomonitor system (ESB)

- **Complement to Army-fielded chemical detectors (e.g., WQAS-PM)**
- **Two components**
 - Electric cell-substrate impedance sensing device
 - Pesticide sensor
- **Rapid (< 1 hour)**
- **Qualitative**



Figure 1. ECIS (instrument on the left) and ACE™ (instrument on the right) sensors with reusable supplies packaged in the ESB carrying case.

Biologically-Based Sensors for Detecting Chemicals in Drinking Water – Future Direction

Cell Line Selection

- Challenges with cells and cell lines
- Temperature requirements
- Limitations in detecting AChE-inhibiting insecticides
- Yielding high enough impedance

Omics Evaluations for ECIS Biomarker Toxicity

ESB/ECIS Field Testing

Inventory and Supply Chain Management Technologies for Situational Awareness – Overview

Situational Awareness - “The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future”

Before an incident, situational awareness methods and tools seek to:

- Collect data about what/where chemicals and biological assets are being used
- Integrate that data into a bigger picture of normal activities
- Enable the identification of atypical activities that may warrant further investigation

Prevent	Interdict	Warn	Rescue	Diagnose/Treat	Attribute	Remediate
Surveillance			Equipment/Sensors		Forensic Detection	Environmental Sampling
Situational Awareness		Satellite	Medical Diagnostics			

Inventory and Supply Chain Management Technologies for Situational Awareness – Framework

		Asset Types	
		Agents/Precursors	Equipment/Resources
Location Tracking	Laboratories/ Facilities (node)	Agents/Precursors + Laboratories/Facilities (node)	Equipment/Resources + Laboratories/Facilities (node)
	Supply Chains (system)	Agents/Precursors + Supply Chains (system)	Equipment/Resources + Supply Chains (system)

Framework for discussing situational awareness capabilities

Inventory and Supply Chain Management Technologies for Situational Awareness – Gaps/Opportunities

Advances needed in 3 key areas:

- Clarifying *who* owns the system-level view
- Identifying *what* assets are highest risk and therefore a high priority
- Advancing *how* data is gathered, integrated, and analyzed



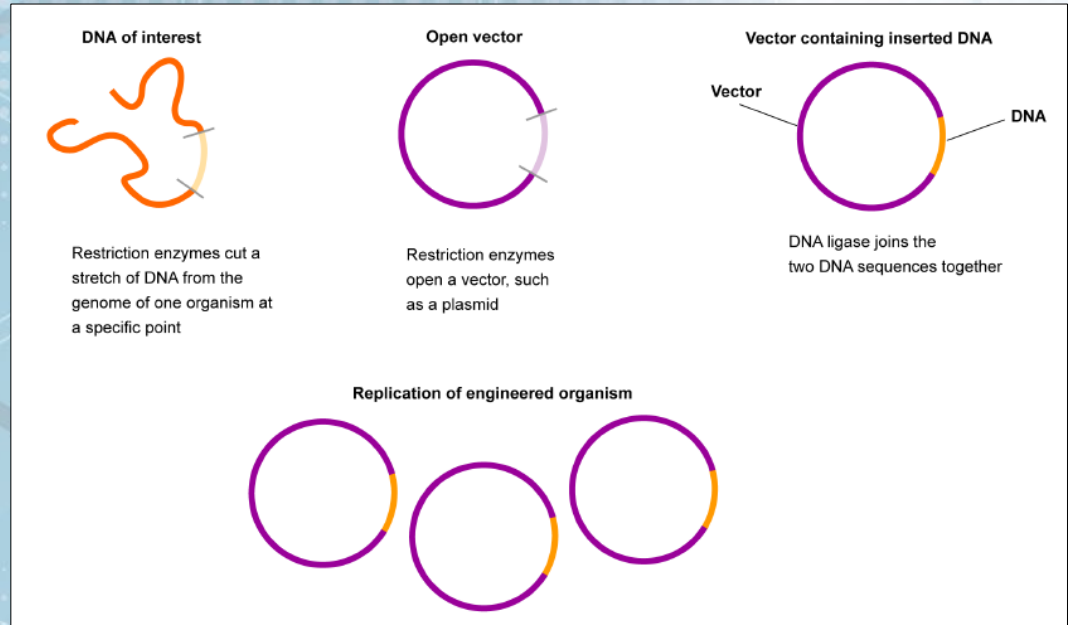
Intersecting domains of technology

Forensic Considerations in the Investigation of Biological Weapons Use – Overview

- **Bioforensics** – Scientific study of biological organisms and processes with the investigatory approach of establishing incident-related facts
- Forensic investigations are typically, but not always, directed toward legal or juridical ends
- The U.S. may seek to deploy its civilian or military bioforensics capabilities in any number of scenarios, such as a suspected biological weapons attack on U.S. soil or the soil of U.S. allies
- An accidental release of a bioweapons agent—or substantively equivalent non-dual-use agent—is also a distinct possibility

Forensic Considerations in the Investigation of Biological Weapons Use – Emerging Biothreats

- **Gene Editing**
- **Synthetic Biology**
- **Do-It-Yourself Biologists**



Genetic engineering with restriction enzymes

Forensic Considerations in the Investigation of Biological Weapons Use – Developments

CAPABILITY	TYPE OF ANALYSIS
Analytical chemistry	Identification, characterization of ricin, abrin, and other protein toxins (toxinology) using mass spectrometry, which also supports proteomics analyses
Bacteriology	Culture identification, phenotypic characterization of multiple organisms
Genomics	Whole genome genotyping, large-scale comparative analyses, incremental metagenomics capability, inferential analysis
Toxinology	Identification, characterization of ricin, abrin, and other protein toxins (toxinology) using mass spectrometry, which also supports proteomics analyses
Virology	Culture identification, phenotypic characterization of viruses

Agent-Based and Methods-Based Capabilities for Bioforensics Analyses

Looking Forward

Cellular mechanisms in individuals

- *Prometheus* – determine if person is contagious before symptoms appear
- *Rapid Threat Assessment (RTA)* – cellular-level understanding of chem/bio exposure

Population level monitoring

- BioWatch
- SIGMA+

Genomics

- EDGE Bioinformatics

Remote, non-invasive techniques

HDIAC Services

Technical Inquiry Service

- HDIAC provides up to 4 free hours of information services:
 - Literature searches
 - Document/bibliography requests
 - Analysis within our eight focus areas – Alternative Energy, Biometrics, CBRN Defense, Critical Infrastructure Protection, Cultural Studies, Homeland Defense and Security, Medical, Weapons of Mass Destruction

Core Analysis Task (CAT)

- Challenging technical problems requiring more than 4 hours of research can be solved by initiating a CAT:
 - Pre-competed and pre-awarded
 - Work can begin on a project approximately two months after the statement of work has been approved
 - Cap of \$500,000
 - Must be completed within 12 months

HDIAC Subject Matter Experts

HDIAC Subject Matter Expert (SME) Network

HDIAC SMEs are experts in their field(s), and, typically, have been published in technical journals and publications.

SMEs are involved in a variety of HDIAC activities

- Authoring HDIAC Journal articles
- Answering HDIAC Technical Inquiries
- Engaging in active discussions in the HDIAC community
- Assisting with HDIAC Core Analysis Tasks
- Presenting webinars

If you are interested in applying to become a SME, please visit HDIAC.org or email info@hdiac.org.

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