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An Introduction to Biological Agent Detection Equipment for Emergency First Responders

NIJ Guide 101–00

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An Introduction to Biological Agent Detection Equipment for Emergency First Responders

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FOREWORD

The Office of Law Enforcement Standards (OLES) of the National Institute of Standards and Technology (NIST) furnishes technical support to the National Institute of Justice (NIJ) program to support law enforcement and criminal justice in the United States. OLES's function is to develop standards and conduct research that will assist law enforcement and criminal justice agencies.

OLES is: (1) subjecting existing equipment to laboratory testing and evaluation, and (2) conducting research leading to the development of several series of documents, including national standards, user guides, and technical reports.

This document covers research conducted by OLES under the sponsorship of NIJ. Additional reports as well as other documents are being issued under the OLES program in the areas of protective clothing and equipment, communications systems, emergency equipment, investigative aids, security systems, vehicles, weapons, and analytical techniques and standard reference materials used by the forensic community.

Technical comments and suggestions concerning this guide are invited from all interested parties. They may be addressed to the Office of Law Enforcement Standards, National Institute of Standards and Technology, 100 Bureau Drive, Stop 8102, Gaithersburg, MD 20899–8102.

Sarah V. Hart, Director
National Institute of Justice

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COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	hf	high frequency	o.d.	outside diameter
ac	alternating current	Hz	hertz	Ω	ohm
AM	amplitude modulation	i.d.	inside diameter	p.	page
cd	candela	in	inch	Pa	pascal
cm	centimeter	IR	infrared	pe	probable error
CP	chemically pure	J	joule	pp.	pages
c/s	cycle per second	L	lambert	ppm	parts per million
d	day	L	liter	qt	quart
dB	decibel	lb	pound	rad	radian
dc	direct current	lbf	pound-force	rf	radio frequency
°C	degree Celsius	lbf·in	pound-force inch	rh	relative humidity
°F	degree Fahrenheit	lm	lumen	s	second
dia	diameter	ln	logarithm (base e)	SD	standard deviation
emf	electromotive force	log	logarithm (base 10)	sec.	Section
eq	equation	M	molar	SWR	standing wave ratio
F	farad	m	meter	uhf	ultrahigh frequency
fc	footcandle	μ	micron	UV	ultraviolet
fig.	Figure	min	minute	V	volt
FM	frequency modulation	mm	millimeter	vhf	very high frequency
ft	foot	mph	miles per hour	W	watt
ft/s	foot per second	m/s	meter per second	λ	wavelength
g	acceleration	mo	month	wk	week
g	gram	N	newton	wt	weight
gr	grain	N·m	newton meter	yr	year
H	henry	nm	nanometer		
h	hour	No.	number		

area=unit^2 (e.g., ft^2, in^2, etc.); volume=unit^3 (e.g., ft^3, m^3, etc.)

ACRONYMS SPECIFIC TO THIS DOCUMENT

APS	Aerosol Particle Sizer	IND	Investigational New Drug
BA	Biological Agent	IR	Infrared
BAWS	Biological Aerosol Warning System	JSLSCAD	Joint Service Lightweight Standoff Chemical Agent Detector
BDG	Bi-Diffractive Grating	LANL	Los Alamos National Laboratory
BW	Biological Warfare	LD_{50}	Lethal Dose for 50% of Population
CA	Chemical Agent	LIDAR	Light Detection and Ranging
CBMS	Chemical Biological Mass Spectrometer	LLNL	Lawrence Livermore National Laboratory
CIBADS	Canadian Integrated Biological Agent Detection System	MALDI-TOF	Matrix Assisted Laser Desorption Ionization-Time of Flight
CW	Chemical Warfare	mg	Milligram
DARPA	Defense Advanced Research Projects Agency	NASA	National Aeronautical Space Administration
DNA	Deoxyribonucleic Acid	PCR	Polymerase Chain Reaction
DoD BSK	Department of Defense Biological Sampling Kit	PHTLAAS	Portable High-Throughput Liquid Aerosol Air Sampler System
DOE	Department of Energy	PY-GC-IMS	Pyrolysis-Gas Chromatography-Ion Mobility Specrometer
ECBC	Edgewood Chemical and Biological Command	RNA	Ribonucleic Acid
EOO	Electro Optics Organization, Inc.	RSCAAL	Remote Sensing Chemical Agent Alarm
FLAPS	Fluorescent Aerodynamic Particle Sizer	SBCCOM	Soldier and Biological Chemical Command
FTIR	Fourier Transform Infrared	SESI	Science and Engineering Services, Inc.
HHA	Hand-Held Immunochromatographic Assay	SRI	Stanford Research Institute
HeNe	Helium-Neon	TE	Transverse Electric
HUS	Hemolytic uremic syndrome	TIMs	Toxic Industrial Materials
HVAPS	High Volume Aerodynamic Particle Sizer	TM	Transverse Magnetic
IAB	Interagency Board	TTP	Thrombocytopenic purpura
IBADS	Interim Biological Agent Detector System	UAV	Unmanned Aerial Vehicle
IMS	Ionization/Ion Mobility Spectrometry	WMD	Weapons of Mass Destruction

PREFIXES (See ASTM E380)

d	deci (10^{-1})	da	deka (10)
c	centi (10^{-2})	h	hecto (10^{2})
m	milli (10^{-3})	k	kilo (10^{3})
µ	micro (10^{-6})	M	mega (10^{6})
n	nano (10^{-9})	G	giga (10^{9})
p	pico (10^{-12})	T	tera (10^{12})

COMMON CONVERSIONS

0.30480 m =1 ft	4.448222 N = 1 lbf
25.4 mm = 1 in	1.355818 J = 1 ft·lbf
0.4535924 kg = 1 lb	0.1129848 N m = 1 lbf·in
0.06479891g = 1gr	14.59390 N/m = 1 lbf/ft
0.9463529 L = 1 qt	6894.757 Pa = 1 lbf/in^2
3600000 J = 1 kW·hr	1.609344 km/h = 1 mph

psi = mm of Hg x (1.9339×10^{-2})

mm of Hg = psi x 51.71

Temperature: $T\,{}^{\circ}_{C} = (T\,{}^{\circ}_{F} - 32) \times 5/9$

Temperature: $T\,{}^{\circ}_{F} = (T\,{}^{\circ}_{C} \times 9/5) + 32$

ABOUT THIS GUIDE

The National Institute of Justice (NIJ) is the focal point for providing support to State and local law enforcement agencies in the development of counterterrorism technology and standards, including technological needs for chemical and biological defense. In recognizing the needs of State and local emergency first responders, the Office of Law Enforcement Standards (OLES) at the National Institute of Standards and Technology (NIST), working with NIJ, the Technical Support Working Group (TSWG), the U.S. Army Soldier and Biological Chemical Command (SBCCOM), and the Interagency Board for Equipment Standardization and Interoperability (IAB), is developing chemical and biological defense equipment guides. The guides will focus on chemical and biological equipment in areas of detection, personal protection, decontamination, and communication. This document focuses specifically on assisting the emergency first responder community in the understanding of biological agent detection equipment.

The long range plans are to: (1) subject existing biological agent detection equipment to laboratory testing and evaluation against a specified protocol, and (2) conduct research leading to the development of multiple series of documents, including national standards, user guides, and technical reports. It is anticipated that the testing, evaluation, and research processes will take several years to complete; therefore, NIJ has developed this initial guide for the emergency first responder community in order to facilitate an understanding of biological agent detection equipment.

In conjunction with this program, additional guides, as well as other documents, are being issued in the areas of chemical agent and toxic industrial material detection equipment, decontamination equipment, personal protective equipment, and communications equipment used in conjunction with protective clothing and respiratory equipment.

The information contained in this guide on specific equipment and technologies has been obtained through literature searches and market surveys. *Reference herein to any specific commercial products, processes, or services by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The information and statements contained in this guide shall not be used for the purposes of advertising, nor to imply the endorsement or recommendation of the United States Government.*

With respect to information provided in this guide, neither the United States Government nor any of its employees make any warranty, expressed or implied, including but not limited to the warranties of merchantability and fitness for a particular purpose. Further, neither the United States Government nor any of its employees assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed.

Technical comments, suggestions, and product updates are encouraged from interested parties. They may be addressed to the Office of Law Enforcement Standards, National Institute of Standards and Technology, 100 Bureau Drive, Stop 8102, Gaithersburg, MD 20899–8102. It is anticipated that this guide will be updated periodically.

AN INTRODUCTION TO BIOLOGICAL AGENT DETECTION EQUIPMENT FOR EMERGENCY FIRST RESPONDERS

The end of the cold war has reduced international tension between the super powers. However, ironically enough, this has resulted in regional instability due to a resurgence of nationalistic, religious, and ethnic strife, which presents a real threat to peace in all regions of the globe. Additionally, there has been a remarkable increase in the production and availability of chemical and biological weapons throughout the world. The combination of these factors has significantly increased the possibility of an attack on the United States involving the use of such weapons. Biological agents are often considered to be psychologically the more threatening of the two, and therefore provide more appeal to the terrorist.

Biological agents can be manufactured in facilities that are inexpensive to construct; that resemble pharmaceutical, food, or medical production sites; and that provide no detectable sign that such agents are being produced. One characteristic of biological agents that makes them so attractive to potential users is their remarkably low effective dose; that is, the mass of agent that is required to create the desired effect (incapacitation or death) on the target population. Figure 1 shows the approximate mass in milligrams (mg) of an agent needed to achieve the desired result in comparison to toxins and chemical agents. The mass of a paper clip is included in this diagram as a point of reference. The reader can immediately see the vast differences in effectiveness between biological agents (microbial agents, e.g., bacteria and viruses) and chemical agents. At the extreme, some biological agents are as much as 14 *billion* times more effective than chemical agents, making it easy to see why biological agents are often described as the poor man's atomic bomb. The reader should also note that if a terrorist chooses to use a toxin agent (in order to get relatively rapid effects in a tactical situation), a much greater mass of the toxin agent will have to be employed than if biological agents were being used. This mass of toxin agent in some cases may be equivalent to chemical agent masses.

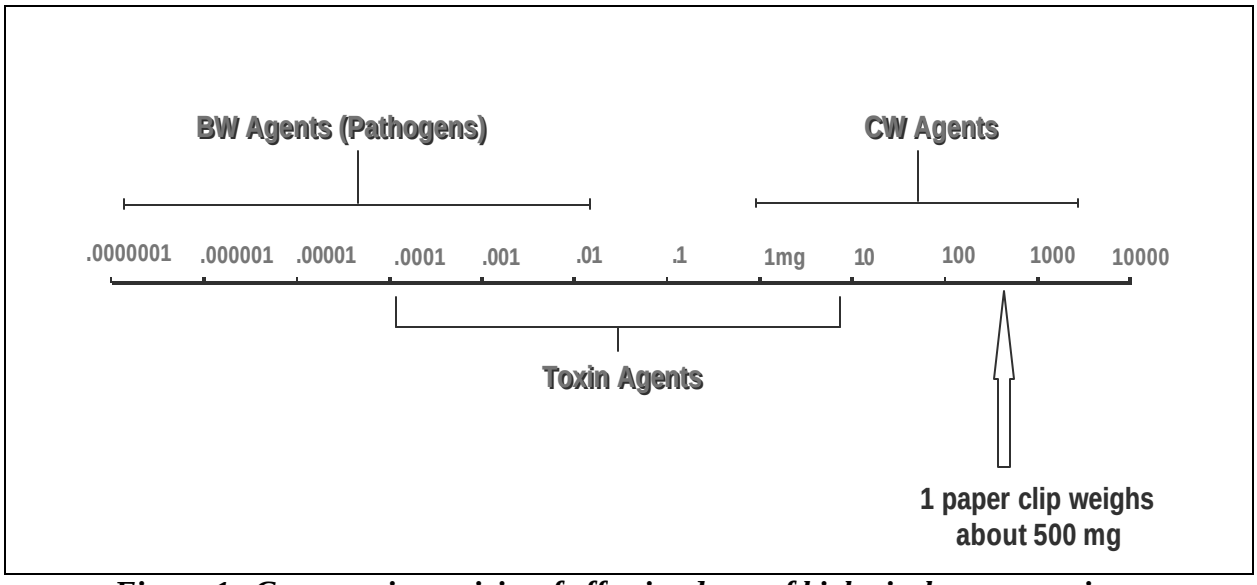

Figure 1. Comparative toxicity of effective doses of biological agents, toxins, and chemical agents

1. INTRODUCTION

The primary purpose of this document is to function as a guide and provide emergency first responders with information to aid them in their understanding of biological agent detection equipment.

This document is divided into seven sections and includes two appendices. Section 2 presents a review of biological agents. Specifically, it discusses the four most common classes of biological agents and provides information that includes epidemiology, symptoms, and treatment. Section 3 provides an overview of the known challenges associated with biological agent detection. Specifically, this section discusses general detection requirements such as ambient environment, selectivity, sensitivity, and sampling. Section 4 provides the reader with background information on the components of biological detection systems. Section 5 discusses known detection technologies, identified as point, standoff, or active standoff detection. Section 6 provides the emergency first responder with information on how to prepare for a biological incident. Section 7 concludes by providing a concise summary of the current state of biological agent detection. Appendix A identifies the sources of information used in developing this document. Appendix B provides contact information (telephone numbers and internet addresses) for State public health laboratories.

2. REVIEW OF BIOLOGICAL AGENTS

This section provides a description of the biological agents likely to be used in a terrorist attack. There are four categories under discussion: bacterial agents (sec. 2.1), viral agents (sec. 2.2), rickettsiae (sec. 2.3), and biological toxins (sec. 2.4).

2.1 Bacterial Agents

Bacteria are small, single-celled organisms, most of which can be grown on solid or in liquid culture media. Under special circumstances, some types of bacteria can transform into spores that are more resistant to cold, heat, drying, chemicals, and radiation than the bacterium itself. Most bacteria do not cause disease in human beings, but those that do cause disease act in two differing mechanisms: by invading the tissues or by producing poisons (toxins). Many bacteria, such as anthrax, have properties that make them attractive as potential warfare agents:

- Retained potency during growth and processing to the end product (biological weapon).
- Long "shelf-life."
- Low biological decay as an aerosol.

Other bacteria require stabilizers to improve their potential for use as biological weapons. Table 2−1 lists some of the common bacterial agents along with possible methods of dissemination, incubation period, symptoms, and treatment.

2.2 Viral Agents

Viruses are the simplest type of microorganism and consist of a nucleocapsid protein coat containing genetic material, either RNA or DNA. Because viruses lack a system for their own metabolism, they require living hosts (cells of an infected organism) for replication. As biological agents, they are attractive because many do not respond to antibiotics. However, their incubation periods are normally longer than for other biological agents, so incapacitation of victims may be delayed. Table 2−2 lists the common viral agents along with possible methods of dissemination, incubation period, symptoms, and treatment.

2.3 Rickettsiae

Rickettsiae are obligate intracellular bacteria that are intermediate in size between most bacteria and viruses and possess certain characteristics common to both bacteria and viruses. Like bacteria, they have metabolic enzymes and cell membranes, use oxygen, and are susceptible to broad-spectrum antibiotics, but like viruses, they grow only in living cells. Most rickettsiae can be spread only through the bite of infected insects and are not spread through human contact. Table 2−3 lists the common rickettsiae along with possible methods of dissemination, incubation periods, symptoms, and treatment.

2.4 Biological Toxins

Biological toxins are poisons produced by living organisms. It is the poison, not the organism, that produces harmful effects in man. A toxin typically develops naturally in a host organism (for example, saxitoxin is produced by marine algae); however, genetically altered and/or

synthetically manufactured toxins have been produced in a laboratory environment. Biological toxins are most similar to chemical agents in their dissemination and effectiveness. Table 2–4 lists the common biological toxins along with possible methods of dissemination, incubation period, symptoms, and treatment.

Table 2-1. Bacterial agents

Biological Agent/Disease	Anthrax	Brucellosis	E. coli serotype (O157:H7)	Tularemia	Cholera
Likely Method of Dissemination	1. Spores in aerosol 2. Sabotage (food)	1. Aerosol 2. Sabotage (food)	Water and food supply contamination	1. Aerosol 2. Rabbits or ticks	1. Sabotage (food and water) 2. Aerosol
Transmissible Person to Person	No (except cutaneous)	Unknown	Unknown, evidence passed person-to-person in day-care or nursing homes	No	Rare
Incubation Period	1 d to 43 d	1 wk to 3 wk, sometimes months	Unknown	2 d to 10 d	3 d to 5 d
Duration of Illness	3 d to 5 d (usually fatal)	Unknown	5 d to 10 d (most cases)	>2 wk	>1 wk
Lethality	Contact or cutaneous anthrax: fatality rate of 5 % to 20 % Inhalational anthrax: after symptoms appear almost always fatal, regardless of treatment	Low	0 % to 15 % if develop hemolytic uremic syndrome (HUS); 5 % if develop thrombotic thrombocytopenic purpura (TTP)	Moderate if left untreated	Low (<1 %) with treatment; high (>50 %) without
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	Currently no human data	Vaccine under evaluation	No vaccine	No commercially available vaccine	No data on aerosol
Symptoms and Effects	Flu-like, upper-respiratory distress; fever and shock in 3 d to 5 d, followed by death	Irregular prolonged fever, profuse sweating, chills, joint and muscle pain, persistent fatigue	Gastrointestinal (diarrhea, vomiting) dehydration; in severe cases, cardiac arrest and death, HUS, or TTP	Chills; sustained fever; prostration; tendency for pneumonia; enlarged, painful lymph nodes; headache; malaise; anorexia; nonproductive cough	Sudden onset with nausea, vomiting, diarrhea, rapid dehydration, toxemia and collapse
Treatment	Vaccine available for cutaneous, possibly inhalation, anthrax. Cutaneous anthrax responds to antibiotics (penicillin, terramycin, chloromycetin), sulfadiazine, and immune serum. Pulmonary (inhaled) anthrax responds to immune serum in initial stages but is little use after disease is well established. Intestinal, same as for pulmonary	Antibiotics	Antibiotics available; most recover without antibiotics within 5 d to 10 d; do not use antidiarrheal agents	Vaccination using live attenuated organisms reduces severity and transmittability; antibiotics (streptomycin, aureomycin, chloromycetin, doxycycline, tetracycline, and chloramphenical)	Replenish fluids and electrolytes; antibiotics (tetracycline, ciprofloxicin, and erythromycin) enhance effectiveness of rehydration and reduce organism in body
Potential as Biological Agent	High, Iraqi and USSR biological programs worked to develop anthrax as a bio-weapon	Unknown	Unknown	High, if delivered via aerosol form (highly infectious, 90 % to 100 %)	Not appropriate for aerosol delivery

Table 2-1. Bacterial agents-Continued

Biological Agent/Disease	Diphtheria	Glanders	Melioidosis	Plague (Bubonic and Pneumonic)	Typhoid Fever
Likely Method of Dissemination	Unknown	1. Aerosol 2. Cutaneous	1. Food contamination (rodent feces) 2.Inhalation 3.Insect bites 4. Direct contact with infected animals	1. Infected fleas (Bubonic and Pneumonic) 2. Aerosol (Pneumonic)	1. Contact with infected person 2. Contact with contaminated substances
Transmissible Person to Person	High	High	No	High (Pneumonic)	High
Incubation Period	2 d to 5 d	3 d to 5 d	Days	1 d to 3 d	7 d to 14 d
Duration of Illness	Unknown	Unknown	4 d to 20 d	1 d to 6 d (usually fatal)	Unknown
Lethality	5 % to 10 % fatality	50 % to 70 %	Variable	5 % to 10 % if treated Bubonic: 30 % to 75 % if untreated Pneumonic: 95 % if untreated	<1 % if treated; 10 % to 14 % if untreated
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	DPT vaccine 85 % effective; booster recommended every 10 yr	No vaccine	No vaccine	Vaccine not available	Oral vaccine (Vivotif) and single dose injectable vaccine (capsular poly-saccharide antigen); both vaccines are equally effective and offer 65 % to 75 % protection against the disease
Symptoms and Effects	Local infection usually in respiratory passages; delay in treatment can cause damage to heart, kidneys, and central nervous system	Skin lesions, ulcers in skin, mucous membranes, and viscera; if inhaled, upper respiratory tract involvement	Cough, fever, chills, muscle/joint pain, nausea, and vomiting; progressing to death	Enlarged lymph nodes in groin; septicemic (spleen, lungs, meninges affected)	Prolonged fever, lymph tissue involvement; ulceration of intestines; enlargement of spleen; rose-colored spots on skin; constipation or diarrhea
Treatment	Antitoxin extremely effective; antibiotic (penicillin) shortens the duration of illness	Drug therapy (streptomycin and sulfadiazine) is somewhat effective	Antibiotics (doxycycline, chlorothenicol, tetracycline) and sulfadiazine	Doxycycline (100 mg 2x/d for 7 d); ciprofloxicin also effective	Antibiotics (amoxicillin or cotrimoxazole) shorten period of communicability and cure disease rapidly
Potential as Biological Agent	Very low—symptoms not severe enough to incapacitate; rare cases of severe infection	Unknown	Moderate—rare disease, no vaccine available	High—highly infectious, particularly in pneumonic (aerosol) form; lack of stability and loss of virulence complicate its use	Not likely to be deployed via aerosol; more likely for covert contamination of water or food

Table 2-2. Viral agents

Biological Agent/Disease	Marburg Virus	Junin Virus	Rift Valley Fever Virus	Smallpox	Venezuelan Equine Encephalitis
Likely Method of Dissemination	Aerosol	Epidemiology not known	Mosquito-borne; in biological scenario, aerosols or droplets	Aerosol	1. Aerosol 2. Infected vectors
Transmissible Person to Person	Unknown	Unknown	Unknown	High	No
Incubation Period	5 d to 7 d	7 d to 16 d	2 d to 5 d	10 d to 12 d	1 d to 6 d
Duration of Illness	Unknown	16 d	2 d to 5 d	4 wk	Days to weeks
Lethality	25 %	18 %	<1 %	20 % to 40 % (Viriole major) <1 % (Viriole minor)	1 % to 60 %
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	No vaccine	No vaccine	Inactivated vaccine available in limited quantities	Vaccine protects against infection within 3 d to 5 d of exposure	Experimental only: TC–83 protects against 30 LD_{50}s to 500 LD_{50}s in hamsters
Symptoms and Effects	Sudden onset of fever, malaise, muscle pain, headache, and conjunctivitis, followed by sore throat, vomiting, diarrhea, rash, and both internal and external bleeding (begins 5th day). Liver function may be abnormal and platelet function may be impaired.	Hemorrhagic syndrome, chills, sweating, exhaustion and stupor	Febrile illness, sometimes abdominal tenderness; rarely shock, ocular problems	Sudden onset of fever, headache, backache, vomiting, marked prostration, and delirium; small blisters form crusts which fall off 10 d to 40 d after first lesions appear; opportunistic infection	Sudden illness with malaise, spiking fevers, rigors, severe headache, photophobia, and myalgias
Treatment	No specific treatment exists. Severe cases require intensive supportive care, as patients are frequently dehydrated and in need of intravenous fluids.	No specific therapy; supportive therapy essential	No studies, but IV ribavirin (30 mg/kg/6 h for 4 d, then 7.5 mg/kg/8 h for 6 d) should be effective	Vaccinia immune globulin (VIG) and supportive therapy	Supportive treatments only
Potential as Biological Agent	High—actually weaponized by former Soviet Union biological program	Unknown	Difficulties with mosquitos as vectors	Possible, especially since routine smallpox vaccination programs have been eliminated world-wide (part of USSR offense bioprogram)	High—former U.S. and U.S.S.R. offensive biological programs weaponized both liquid and dry forms for aerosol distribution

Table 2-2. Viral agents-Continued

Biological Agent/Disease	Yellow Fever Virus	Dengue Fever Virus	Ebola Virus	Congo-Crimean Hemorrhagic Fever Virus
Likely Method of Dissemination	Mosquito-borne	Mosquito-borne	1. Direct contact 2. Aerosol (BA)	Unknown
Transmissible Person to Person	No	No	Moderate	Yes
Incubation Period	3 d to 6 d	3 d to 15 d	4 d to 16 d	7 d to 12 d
Duration of Illness	2 wk	1 wk	Death between 7 d to 16 d	9 d to 12 d
Lethality	10 % to 20 % death in severe cases or full recovery after 2 d to 3 d	5 % average case fatality by producing shock and hemorrhage, leading to death	High for Zaire strain; moderate with Sudan	15 % to 20 %
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	Vaccine available; confers immunity for >10 yr	Vaccine available	No vaccine	No vaccine available; prophylactic ribavirin may be effective
Symptoms and Effects	Sudden onset of chills, fever, prostration, aches, muscular pain, congestion, severe gastrointestinal disturbances, liver damage and jaundice; hemorrhage from skin and gums	Sudden onset of fever, chills, intense headache, pain behind eyes, joint and muscle pain, exhaustion and prostration	Mild febrile illness, then vomiting, diarrhea, rash, kidney and liver failure, internal and external hemorrhage (begins 5th day), and petechiae	Fever, easy bleeding, petechiae, hypotension and shock; flushing of face and chest, edema, vomiting, diarrhea
Treatment	No specific treatment; supportive treatment (bed rest and fluids) for even the mildest cases	No specific therapy; supportive therapy essential	No specific therapy; supportive therapy essential	No specific treatment
Potential as Biological Agent	High, if efficient dissemination device is employed	Unknown	Former Soviet Union	Unknown

Table 2-3. Rickettsiae

Biological Agent/Disease	Endemic Typhus	Epidemic Typhus	Q Fever	Rocky Mountain Spotted Fever
Likely Method of Dissemination	1. Contaminated feces 2. Infected insect larvae 3. Rat or flea bites	1. Contaminated feces 2. Infected insect larvae	1. Sabotage (food supply) 2. Aerosol	Infected wood ticks
Transmissible Person to Person	No	No	Rare	No
Incubation Period	6 d to 14 d	6 d to 15 d	14 d to 26 d	3 d to 14 d
Duration of Illness	Unknown	Unknown	Weeks	Unknown
Lethality	1 %, increasing in people >50 yr old	10 % to 40 % untreated; increases with age	Very low	15 % to 20 % untreated (higher in adults); treated—death rare with specific therapy (tetracycline or chloramphenicol)
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	Unknown	Vaccine confers protection of uncertain duration	94 % protection against 3500 LD_{50}s in guinea pigs	No vaccine
Symptoms and Effects	Sudden onset of headache, chills, prostration, fever, pain; maculae eruption on 5^{th} day to 6^{th} day on upper body, spreading to all but palms, soles, or face, but milder than epidemic form	Sudden onset of headache, chills, prostration, fever, pain; maculae eruption on 5^{th} day to 6^{th} day on upper body, spreading to all but palms, soles, or face	Mild symptoms (chills, headaches, fever, chest pains, perspiration, loss of appetite)	Fever and joint pain, muscular pain; skin rash that spreads rapidly from ankles and wrists to legs, arms, and chest; aversion to light
Treatment	Antibiotics (tetracycline and chloramphenicol); supportive treatment and prevention of secondary infections	Antibiotics (tetracycline and chloramphenicol); supportive treatment and prevention of secondary infections	Tetracycline (500 mg/ 6 h, 5 d to 7 d) or doxycycline (100 mg/ 12 h, 5 d to 7 d) also, combined Erthyromycin (500 mg/6 h) and rifampin (600 mg/d)	Antibiotics—tetracycline or chloramphenicol
Potential as Biological Agent	Uncertain—broad range of incubation (6 d to 14 d) period could cause infection of force deploying biological agent	Uncertain—broad range of incubation (6 d to 14 d) period could cause infection of force deploying biological agent	Highly infectious, is delivered in aerosol form. Dried agent is very stable; stable in aerosol form.	Unknown

Table 2-4. Biological toxins

Biological Agent/Disease	Botulinum Toxin	Staphylococcal enterotoxin B	Tricothecene mycotoxins	Ricin (Isolated from Castor Beans)	Saxitoxin
Likely Method of Dissemination	1. Aerosol 2. Sabotage (food and water)	1. Sabotage (food supply) 2. Aerosol	1. Aerosol 2. Sabotage	1. Aerosol 2. Sabotage (food & water)	Contaminated shellfish; in biological scenario, inhalation or toxic projectile
Transmissible Person to Person	No	No	No	No	No
Incubation Period	Variable (hours to days)	3 h to 12 h	2 h to 4 h	Hours to days	5 min to 1 h
Duration of Illness	Death in 24 h to 72 h; lasts months if not lethal	Hours	Days to months	Days—death within 10 d to 12 d for ingestion	Death in 2 h to 12 h
Lethality	5 % to 60 %, untreated <5 % treated	<1 %	Moderate	100 %, without treatment	High without respiratory support
Vaccine Efficacy (for aerosol exposure)/ Antitoxin	Botulism antitoxin (IND) Prophylaxis toxoid (IND) Toxolide	No vaccine	No vaccine	No vaccine	No vaccine
Symptoms and Effects	Ptosis; weakness, dizziness, dry mouth and throat, blurred vision and diplopia, flaccid paralysis	Sudden chills, fever, headache, myalgia, nonproductive cough, nausea, vomiting and diarrhea	Skin—pain, pruritis, redness and vesicles, sloughing of epidermis; respiratory—nose and throat pain, discharge, sneezing, coughing, chest pain, hemoptysis	Weakness, fever, cough, pulmonary edema, severe respiratory distress	Light headedness, tingling of extremities, visual disturbances, memory loss, respiratory distress, death
Treatment	Antitoxin with respiratory support (ventilation)	Pain relievers and cough suppressants for mild cases; for severe cases, may need mechanical breathing and fluid replenishment	No specific antidote or therapeutic regimen is available; supportive and symptomatic care	Oxygen, plus drugs to reduce inflammation and support cardiac and circulatory functions; if ingested, empty the stomach and intestines; replace lost fluids	Induce vomiting, provide respiratory care, including artificial respiration
Potential as Biological Agent	Not very toxic via aerosol route; extremely lethal if delivered orally. Since covert poisoning is indistinguishable from natural botulism, poisoning could have limited use	Moderate—could be used in food and limited amounts of water (for example, at salad bars); LD_{50} is sufficiently small to prevent detection	High—used in aerosol form ("yellow rain") in Laos, Kampuchea and Afghanistan (through 1981)	Has been used in 1978—Markov murder (see app. A, ref. 6); included on prohibited Schedule I chemicals list for Chemical Weapons Convention; high potential for use in aerosol form	Moderate, aerosol form is highly toxic

3. CHALLENGES TO BIOLOGICAL AGENT DETECTION

Biological agents are effective in very low doses. Therefore, biological agent detection systems need to exhibit high **sensitivity** (i.e., be able to *detect* very small amounts of biological agents). The complex and rapidly changing environmental background also requires these detection systems to exhibit a high degree of **selectivity** (i.e., be able to *discriminate* biological agents from other harmless biological and nonbiological material present in the environment). A third challenge that needs to be addressed is **speed** or **response**. These combined requirements provide a significant technical challenge. Additionally, there has been limited development in the area of biological agent detection equipment in the commercial market (i.e., hand-held devices). There are several detection systems being developed and tested by the military that show promise. However, these systems are relatively complicated, require training for successful operation and maintenance, and are expensive to purchase and operate. It is expected that over the course of the next 5 years, commercial instrumentation, hardened for use in the field, may become available at reasonable costs.

The purpose of this section is to identify some of the major challenges associated with biological agent detection. Specifically, section 3.1 addresses challenges associated with the ambient environment, section 3.2 discusses challenges with selectivity, section 3.3 discusses challenges with sensitivity, and section 3.4 addresses challenges with sampling.

3.1 The Ambient Environment

The environment in which we live and operate is an extremely complex and dynamic medium. The meteorological, physical, chemical, and biological constituents of a "normal" atmospheric environment all impact our ability to detect biological agents. In order to understand the complex effect that the ambient environment can have on biological agent detection, the remainder of this section discusses specifics of the particulate background, the biological background, and the optical background, respectively.

3.1.1 The Particulate Background

Particulates in the atmosphere originate from a number of sources. Dust, dirt, pollen, and fog are all examples of naturally occurring particulates found in the air. Man-made particulates such as engine exhaust, smoke, and industrial effluents (smokestacks) also contribute significantly to the environmental particulate background. Therefore, the particulate background can be defined as the combination of natural and man-made particles in the atmosphere that are nonpathogenic (does not cause disease) in nature. Biological agents (not including toxins) consist of particulates of pathogenic (disease causing) cells. The particulate background can change on a minute-by-minute basis depending on the meteorological conditions at the time. For example, the particulate background next to a road will change dramatically depending on whether there is traffic on the road disturbing the dust, or if the road is empty. Likewise, if there is little wind, not many particulates are carried into the atmosphere; however, when the wind begins to blow, it can carry many particulates from the immediate vicinity, as well as from remote locations. The challenge for a biological detection system is to be able to discriminate between all of the naturally occurring particulates and the biological agent particulates.

Particle counters can be used to monitor changes in the particulate background on a real-time basis because these systems see particles in the air and can count them. If the number of particles increases rapidly, it is possible that biological agents are being used; however, **it must be stressed that particle counters cannot determine if the particulates are dust, pollen, engine exhaust, or biological agents**. Other, more sensitive and selective, tests must be performed on the particulates to determine if biological agents are present. Particle counters are best used in a detection system where the particle counter activates a sampler that collects a sample of the particles for a more detailed analysis.

3.1.2 The Biological Background

Our environment is filled with living creatures that form a large and complex biological background from which we must identify biological agents. The challenge for a biological agent detection system is to be able to pick out a specific signal from the biological agent while rejecting, or at best minimizing, any signals originating from the nonpathogenic (nontoxic) biological background. This is a significant challenge given the amount of biological particulates in the environment. Research has identified a variety of potential bio-aerosol sources (i.e., adjoining crop fields that are fertilized with "night soil," garbage incinerators, landfills, industrial areas, and dairy farms). Studies have shown that the concentration of bio-aerosols depends on the location of the measurement. In Oregon, a study showed that the concentration of bio-aerosol in an urban setting was six times greater than along the coast and almost three times greater than in a rural setting.

Data shown in figure 3–1 suggest that not only do biological aerosols vary by location, they also vary significantly by time of day.

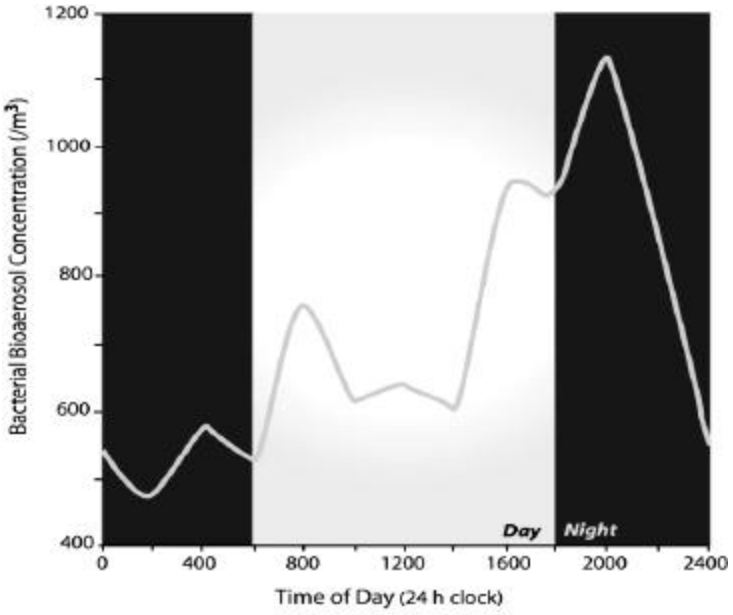

Figure 3-1. Airborne bacterial concentration fluctuation in a single day[4]

[4]Aerosolized bacterial concentration fluctuation over a 24 h period. The vertical (y) axis is bacterial concentration per cubic meter of air. The horizontal (x) axis is the time of day; shaded regions represent nighttime hours, and the clear region is daytime hours. The graph shows that in the early morning hours, the airborne bacterial concentration is low, but it increases rapidly during daylight, reaching a maximum at 8:00 a.m. It then falls to a lower level for most of the day and significantly increases towards the end of the day.

3.1.3 The Optical Background

Systems such as laser or passive infrared (IR) systems rely on optical properties for detection of biological agents. They can be affected by micron range particulates, as well as by other obstructions to visibility such as rain, fog, snow, and dust. Aerosols and precipitation may act like mirrors, reflecting and diffusing the light energy to and from the detector, and in the case of some aerosols, return false signatures (e.g., fluorescence from engine exhaust and pollens may confuse some ultraviolet (UV) based systems). Consequently, different standoff systems are affected to different degrees by precipitation and aerosols. Infrared-based systems, as a rule, tend to be less affected by atmospheric clarity than UV-based systems.

3.2 Selectivity of the Detection System

Detection systems must exhibit a high degree of selectivity for biological agents. The selectivity of a detection system can be defined as its ability to discriminate between the target agent and the environmental interferants. The degree to which the selectivity of a system is affected by interferants depends on the type of measurement being conducted. For example, dust and pollen can be considered interferants for a particle counter, while water vapor and fog are interferants for standoff IR detection systems. For biological agent monitoring, the most difficult interferants originate from the biological background (i.e., live nonpathogenic matter). Generally, the more selective systems require more sample processing and multiple detectors. A single system for detection of biological agents in the environment that exhibits high selectivity currently does not exist as a commercially available item. The selective systems currently developed by the military are limited to detection of a small number of agents and are prohibitively expensive.

3.3 Sensitivity

Detection systems must exhibit high sensitivity for the biological agents because of the agent's low effective doses (fig. 1). Sensitivity can be defined as the smallest amount of target agent that gives a reproducible response above the system noise for a detector. The system noise can be defined as the random fluctuation of the detector response and is generally associated with small variations in electronic output. Other noise that degrades the sensitivity is caused by interferants in the environment. In a perfect detection system, the system sensitivity (only dependent on the electronic noise) defines how much of the target agent can be detected. Interferants cause the sensitivity to decrease because the system needs more of the target agent to distinguish it from the interferants.

3.4 Sampling

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 reaersolization 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.

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 particlates in the air is especially difficult due to the low effective doses of these agents. To sample biological agents effectively, samplers are used that pass large volumes of air through the sampler, dispersing the small amount of agent contained in a large volume of air into a small volume of water, thereby forming a concentrated mixture of particulates in water. By concentrating the biological particulates, current detection systems that are not able to detect biological agents at low dose levels can detect the biological agents in the concentrated mixture.