NIOSH Emergency Preparedness and Response Program:

Evidence Package for 2007-2017

Exposure monitoring of worker conducting in-situ burning during the Deepwater Horizon response. [Photo credit: NIOSH]

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Abbreviations

ACE	Assessment of Chemical Exposures
ACIP	Advisory Committee on Immunization Practices
AFGE	American Federation of Government Employees
AFL-CIO	American Federation of Labor and Congress of Industrial Organizations
AIHA	American Industrial Hygiene Association
ARC	American Red Cross
ASPR	Office of the Assistant Secretary for Preparedness and Response
ATSDR	Agency for Toxic Substances and Disease Registry
BART	Bay Area Rapid Transit
BOTE	Bio-Response Operational Testing and Evaluation
BP	British Petroleum
CASPER	Community Assessment for Public Health Emergency Response
CBRN	Chemical, biological, radiological, and nuclear
CDC	Centers for Disease Control and Prevention
CDP	Center for Domestic Preparedness
CDPH	Connecticut Department of Public Health
CHRP-E	Contaminated Human Remains Pouch Variant Ebola
CPWR	The Center for Construction Research and Training
CTSs	Civil Support Teams
DART	Division of Applied Research and Technology

DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DoD	Department of Defense
DOHMH	Department of Hygiene and Mental Health
DOS	Department of State
DRMU	Disaster Risk Mitigation Unit
DSR	Division of Safety Research
DSRR	Disaster Science Responder Research
DSHEFS	Division of Surveillance, Hazard Evaluations, and Field Studies
DWH	Deepwater Horizon
EID	Education and Information Division
EIS	Epidemic Intelligence Service
EMS	Emergency Medical Services
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EPR	Emergency preparedness and response
EPRO	Emergency Preparedness and Response Office
ERMS™	Emergency Responder Health Monitoring and Surveillance™
ETUs	Ebola Treatment Units
EUA	Emergency use authorization
EVD	Ebola Virus Disease

FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FERV	Field Emergency Response Vehicle
FDA	Food and Drug Administration
FDNY	Fire Department of New York
FFRs	Filtering facepiece respirators
GAO	Government Accounting Office
GA DPH	Georgia Department of Public Health
HAZMAT	Hazardous Materials Team
HELD	Health Effects Laboratory Division
HHE	Health Hazard Evaluation
HHS	Department of Health and Human Services
IAB	InterAgency Board
ILO	International Labour Organization
IMS	Incident Management System
IND	Improvised nuclear device
IOM	Institute of Medicine
IUOE	International Union of Operating Engineers
LOD	Limits of detection
LRN	Laboratory Response Network
MCDPH	Maricopa County Department of Public Health

MMWR	Morbidity and Mortality Weekly Report
MOU	Memorandum of Understanding
MSF	Médecins Sans Frontiérs (Doctors Without Borders)
NDMS	National Disaster Medical System
NACOSH	National Advisory Committee on Safety and Health
NFPA	National Fire Protection Association
NHP	Non-human primates
NIEHS	National Institute of Environmental Health Sciences
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NORA	National Occupational Research Agenda
NPPTL	National Personal Protective Technology Laboratory
NRT	National Response Team
NYC	New York City
NYCT	New York Metropolitan Transit Authority
OAMS	Office of Administrative and Management Services
OD	Office of the Director
ODH	Ohio Department of Health
OEP	Office of Extramural Programs
OHA	Office of Health Affairs
OPHPR	Office of Public Health Preparedness and Response

OSH	Occupational safety and health
OSHA	Occupational Safety and Health Administration
PAPR	Powered air purifying respirators
PHEP	Public Health Emergency Preparedness
PNNL	Pacific Northwest National Laboratory
PPE	Personal protective equipment
PPT	Personal protective technology
RHD	Respiratory Health Division
RMO	Regional Medical Officer
RRR	Rapid Response Registry
SMEs	Subject matter experts
SNS	Strategic National Stockpile
SoPER	School of Preparedness and Emergency Response
TAD	Technical Assistance Document
TRAIN	Trainfinder Real-time Affiliate Integrated Network
UAC	Unified Area Command
UC	Unified Command
UFCW	United Food and Commercial Workers International Union
USAID	U.S. Agency for International Development
USCG	United States Coast Guard
USDA	United States Department of Agriculture

USPHS	United States Public Health Service Commissioned Corps
UVGI	Ultraviolet germicidal irradiation
WHO	World Health Organization
WSH	Worker Safety and Health
WTC	World Trade Center

Executive Summary

Emergency Preparedness and Response Program Overview

After the 9/11 attacks on the World Trade Center and Pentagon, followed shortly by the anthrax letter attacks, the National Institute for Occupational Safety and Health (NIOSH) created a coordinated emergency preparedness and response program in 2002 to improve its ability to respond to future emergencies and disasters. While initially focusing on terrorism events, NIOSH expanded the program to include research and response planning that protects workers across a range of incidents including, but not limited to, major natural and chemical disasters, terrorist attacks or threats, nuclear accidents, and infectious disease outbreaks. NIOSH is part of the Centers for Disease Control and Prevention and serves as the lead for occupational safety and health during responses. To accomplish this, the NIOSH Emergency Preparedness and Response (EPR) Program focuses on two areas of activities: preparedness and response. While we may not be able to predict the next emergency, we can prepare for them and respond when they occur.

The EPR Program activities described in this package reflect both intramural (work within NIOSH) and extramural (work funded by NIOSH through grants, contracts, and cooperative agreements). The combined intramural and extramural components of the Program described within this package received a total of $40.3 million in funding between fiscal years 2007 and 2017. Nearly 21% of these funds came from supplemental response funding to support the Deepwater Horizon oil spill and the Ebola epidemic.

Current events strongly shape the EPR Program priorities. Emergencies, whether a natural disaster or an emerging infectious disease, dictate and influence the direction of the work. The EPR Program must remain flexible and be responsive to new focus areas and objectives that emerge from newly issued federal policy, plans, and initiatives; responses to emergencies; national level exercises; and emergency supplemental funding. The EPR Program, a critical element of the overall NIOSH portfolio, is designated a core and specialty program. EPR contributed to the research and service goals set in the current NIOSH Strategic Plan.

This evidence package presents the most significant efforts in the areas of preparedness and response completed by the EPR Program over the past decade. These activities are described in three chapters. The first two chapters focus on specific long-term, high-priority projects for the Program: Emergency Responder Health Monitoring and Surveillance System (ERHMS™) and NIOSH Efforts to Increase Anthrax Preparedness and Response Capabilities. The last chapter, Emergency Preparedness Activities and Responses, presents a wide range of chemical, radiation, natural disaster, and infectious disease preparedness and response activities. Each chapter includes details about the inputs, research and translation activities, research findings and products, partners who assist NIOSH in transferring its activities into practice, and evidence that shows the use of NIOSH products and actions. A brief overview of each chapter follows:

Emergency Responder Health Monitoring and Surveillance™ System

Workers are a common denominator at every disaster or novel emergent event, and ensuring the health and safety of response and recovery workers is an essential component of an effective response. However, previous emergency events demonstrated that significant gaps and deficiencies exist in the health monitoring and worker health surveillance afforded to emergency response workers (including police, fire, and emergency medical personnel, as well as other responder groups like public health personnel, cleanup, repair-restoration-recovery workers, and volunteers). In response to this demonstrated need to better protect, equip, and promote the health and safety of emergency responders, NIOSH collaborated with federal agencies, state health departments, and unions to create the ERHMS™ framework. The ERHMS™ framework allows an organization to monitor the health and safety of emergency responders throughout the pre-deployment, deployment, and post-deployment phases of a response. The goals of ERHMS™ are to prevent short-term and long-term illness and injury in emergency responders and to ensure workers can respond safely and effectively to future emergencies.

To help educate workers and support implementation of ERHMS™, NIOSH developed online and classroom-based trainings. Additionally, NIOSH developed a market-ready software product called ERHMS Info Manager™ that allows for the collection of data as

outlined in ERHMS™ throughout all three phases of a response. NIOSH also developed training on how to use the new software. Many examples exist of local and state health departments and federal agencies implementing elements of this framework.

NIOSH Efforts to Increase Anthrax Preparedness and Response Capabilities

Anthrax is an acute infectious disease caused by the spore-forming bacterium *Bacillus anthracis* (*B. anthracis*). *B. anthracis* is a known biological threat agent due in part to the bacteria's high pathogenicity in humans, its ability to be released with no one knowing, and its environmental persistence. Shortly after the 9/11 attacks, letters filled with a white powder containing *B. anthracis* spores were mailed to two U.S. Senators' offices and news media agencies in the Northeast and Florida. Since that time, considerable resources from across the federal government have been invested to address knowledge gaps identified during this event to help the nation better prepare for potential future events. NIOSH has been on the forefront of developing worker health and safety guidance to protect workers who respond to anthrax incidents and developing sampling methods and approaches to support environmental risk assessments. NIOSH has conducted a range of activities related to anthrax preparedness and response: developing sample collection procedures, developing health and safety guidance for responders, responding to anthrax events, training response personnel, and participating in exercises with partners. Although anthrax emergencies are rare, these activities have greatly improved preparedness and response for other emergencies.

Emergency Preparedness Activities and Responses

NIOSH prepares for and responds to a comprehensive range of emergency types by maintaining a cadre of occupational medicine physicians, epidemiologists, industrial hygienists, engineers, and toxicologists who can field deploy or provide technical assistance on occupational hazards and health effects associated with exposures, and make recommendations for health monitoring of response workers. NIOSH's response activities related to complex, large-scale emergencies including the 2001 H1N1 pandemic, 2010 Deepwater Horizon oil spill, and the 2014–2016 Ebola virus disease epidemic. Examples of smaller scale responses, which did not make national headlines

but were important, nevertheless, also illustrate how NIOSH provides expertise and other assistance during emergencies. These responses highlight the breadth and depth of NIOSH capabilities across hazards from radiation incidents to infectious disease outbreaks and the ability to tailor support to the needs of the local jurisdictions. Moreover, this chapter describes NIOSH preparedness activities and underscores NIOSH's ability to effectively work with other agencies to develop national policy and incident-specific response plans, participate in exercises to test those plans, and conduct research to inform policy and guidance and improve our ability to protect workers in future responses.

Chapter 1: Program Overview

NIOSH staff manning the Worker Safety and Health Task Force in the CDC Emergency Operations Center during a response. [Photo credit: NIOSH]

Program History

Emergency preparedness and response (EPR) was established as a separate focal area within the National Institute for Occupational Safety and Health (NIOSH) in 2002. As the federal agency that conducts research and makes recommendations to prevent worker injury and illness, NIOSH sought to build EPR capacity to support the health and safety of response and recovery workers. Prior to the creation of the EPR Program, NIOSH responded to disasters and emergencies in an ad hoc fashion largely based on either proximity to the event or informal professional connections that resulted in requests for assistance. When NIOSH responded to the Exxon Valdez Oil Spill (1989) [NIOSH 1991], Hurricane Andrew (1991), and Oklahoma City bombing (1995) [CDC 1995], the responses were primarily completed by NIOSH's Health Hazard Evaluation (HHE) Program, which has expertise in evaluating workplace conditions and employee health concerns in the field.

After the unprecedented September 11, 2001 attacks on the World Trade Center and Pentagon, NIOSH recognized the need to establish an office to coordinate emergency

preparedness and response activities across the Institute to improve its ability to respond to future emergencies and disasters. Figure 1 shows the significant responses NIOSH has supported since 2001.

The 9/11 attacks, followed closely by the anthrax letter attacks, also prompted a change in how the federal government prepares for and responds to emergency events. Therefore, NIOSH established a terrorism preparedness and response program in 2002 to help ensure adequate representation of occupational safety and health knowledge in this changing landscape. The following year, NIOSH officially named an Assistant Director for Emergency Preparedness. EPR formally became one of NIOSH's cross-sector programs, becoming a core and specialty program when NIOSH reorganized its portfolio of programs in 2016.

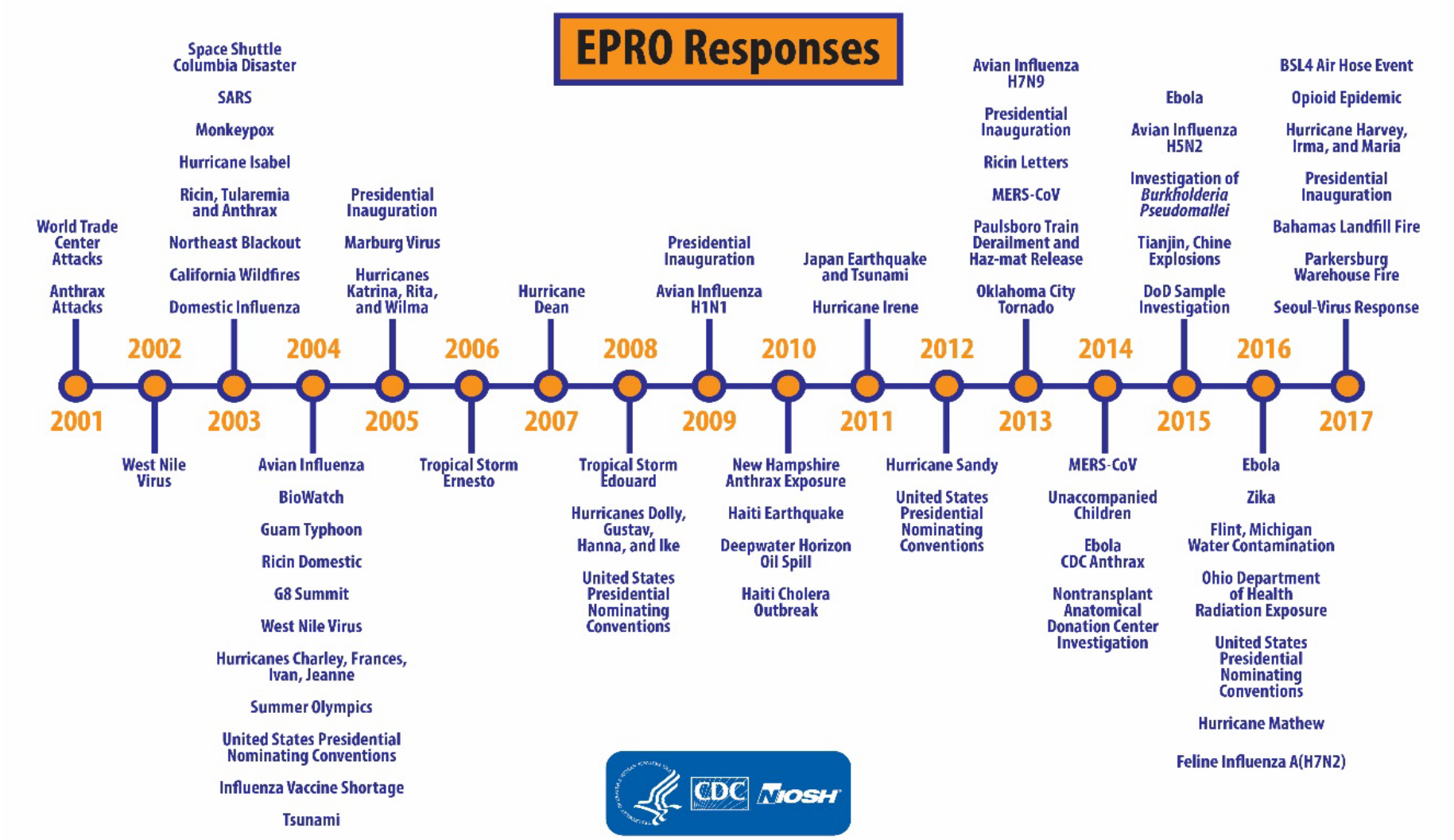
Over the past 15 years, the EPR Program broadened to an all hazards emergency preparedness and response focus. Established in 2003, the Emergency Preparedness and Response Office (EPRO), housed in the Office of the Director, functions as the coordination point for the NIOSH EPR Program and all NIOSH emergency preparedness and response activities. Most recently in 2014, NIOSH established the Disaster Science Responder Research (DSRR) Program to implement a framework allowing occupational safety and health research to start quickly when a disaster or emergency occurs.

Emergency Preparedness and Response Program Focal Areas

Preparedness

NIOSH participates in a variety of preparedness activities to ensure the Institute can successfully respond to a wide range of emergencies, regardless of the type, to help protect the health and safety of workers. NIOSH preparedness efforts include developing response plans, communication materials, and recommendations; conducting exercises and training based on those plans and recommendations; addressing lessons learned from previous responses; conducting research in disaster science; and coordinating interagency efforts through committee and workgroup participation. These preparedness activities occur at the national, state, and local levels, and are collaborative, involving stakeholders and partners. These efforts, which take place prior to an emergency, build trust across agencies, ensure knowledge on roles and responsibilities of each agency, and ultimately allow us to know who to contact during emergencies to have a coordinated response.

Figure 1. Timeline of responses supported by NIOSH since 2001.



Response

NIOSH EPRO staff are on call 24 hours a day, seven days a week, and 365 days a year to respond to emergencies and serve as Emergency Coordinators. While local jurisdictions lead all responses, and NIOSH requires a request or invitation to provide assistance, NIOSH staff stand ready to provide a variety of support when requested. NIOSH response efforts include executing response plans; developing guidance, recommendations, and communication materials tailored to the response needs; providing occupational safety and health technical assistance; and deploying staff to the response site to support local needs. NIOSH contributes its unique expertise to these efforts in areas such as engineering controls, personal protective equipment (PPE), exposure assessment, and other aspects of worker safety and health, including conducting HHEs. Depending on the specific needs of the response, NIOSH can evaluate worker health concerns through health surveys, conduct exposure assessment and monitoring, and evaluate effectiveness of controls such as PPE to protect workers.

Program Resources

Personnel

Emergency Preparedness and Response Office (EPRO)

EPRO consists of a small, interdisciplinary team of seven staff (Figure 2) with backgrounds in industrial hygiene, environmental health, epidemiology, veterinary medicine, and emergency management. Additionally, EPRO staff can reach across the entire Institute to find appropriate staff to deploy to the field during emergencies, provide technical assistance to support response needs, or initiate research. CAPT Lisa Delaney, Associate Director for Emergency Preparedness and Response, in Atlanta, currently leads NIOSH EPRO. CAPT Delaney's involvement in supporting numerous NIOSH emergency response activities began with the 9/11 terrorist attacks, when she worked in the NIOSH HHE program. She joined EPRO in 2006 as an industrial hygienist, serving as Deputy Associate Director for EPRO from 2010–2013, before becoming the Associate Director. CDR Chad Dowell works as the Deputy Associate Director for Emergency Preparedness and Response. He has been with EPRO since 2012 when he transferred from the NIOSH HHE program. CDR Jill Shugart serves as the Emergency Responder Health Monitoring and Surveillance™ (ERHMS™) Coordinator. CDR Jennifer Hornsby-Myers leads NIOSH chemical and radiological/nuclear preparedness activities

as a senior industrial hygienist. CDR Sherry Burrer serves as a staff epidemiologist and senior veterinary officer who leads epidemiology and surveillance efforts. LT Kerton Victory functions as a staff epidemiologist and environmental health officer who supports preparedness and response activities. Ms. Angela Weber leads the DSRR Program. Please see Appendix A for a short biosketch of key EPR Program staff.

Figure 2. Emergency Preparedness and Response Office staff. [Photo credit: NIOSH]

The EPRO is located in Atlanta, Georgia, to facilitate coordination with the Centers for Disease Control and Prevention's (CDC) subject matter experts and emergency preparedness and response groups, including the Emergency Operations Center (EOC). The CDC EOC maintains dedicated staff to monitor current events and a watch desk fields calls from public health partners and the public 24/7. For emergencies requiring response work from multiple CDC groups, CDC can activate the EOC to coordinate resources to support the response. NIOSH leads the occupational safety and health activities during the response.

Emergency Preparedness and Response Program

CAPT Delaney serves as the Manager of the EPR Program, which includes both EPRO and the emergency preparedness and response research conducted across the Institute. Ms. Angela Weber serves as the Program Coordinator, and Dr. Elizabeth Whelan, Chief of Industry Wide Surveillance Branch within the Division of Surveillance, Hazard Evaluation, and Field Studies, serves as the Assistant Program Coordinator. During the period under review, an internal steering committee made up of NIOSH representatives, with interests and backgrounds in emergency response and preparedness, provided input and advised Program leadership. More recently, NIOSH established an internal steering committee made up of representatives from seven NIOSH divisions to offer input and guidance specifically on the conduct of disaster science research. Ms. Weber and Dr. Whelan co-chair the DSRR steering committee.

Funding

The EPR Program has largely been funded by a combination of direct funding from NIOSH and funding from CDC's Office of Public Health Preparedness and Response. Both funding streams support NIOSH intramural efforts, and NIOSH funds extramural emergency preparedness and response research activities, as well. Table 1 summarizes the annual funding for the years under review.

EPR program funding spiked when NIOSH participated in CDC responses to major emergency efforts. For example, in Fiscal Year 2010, NIOSH received an additional $1.1 million for the efforts in response to the Deepwater Horizon oil spill. In Fiscal Year 2015, NIOSH received $7.2 million to support activities related to the Ebola epidemic, including $1.4 million for salaries of NIOSH staff deployed to help manage the epidemic; the remaining funding supported research on issues identified during the epidemic. While some of the Ebola-related research is ongoing and beyond the scope of this review, the EPR program's successes related to Deepwater Horizon oil spill and the Ebola epidemic are highlighted in Chapter 4.

Table 1. EPR Program Funding (in millions) 2007–2017

Fiscal Year	Total Amount
2007	1.5
2008	3.3
2009	3.9
2010	4.6*
2011	3.7
2012	3.0
2013	5.5
2014	2.8
2015	10.0*
2016	2.0

*Denotes years where supplemental funding supported ongoing responses

Facilities

A number of NIOSH divisions, laboratories, and offices from across the Institute support the work of EPR, depending on the type of response and the unique occupational safety and health concerns that arise from it or preparedness and planning technical support needs. The divisions, laboratories, and offices mentioned next have ongoing specific projects, specialized expertise, or activities that support EPR.

Division of Applied Research and Technology (DART), Cincinnati, OH – DART conducts research focused on preventing occupational illness and injury, including developing and evaluating sampling and analytical methods and tools to identify and quantify workplace hazards. They also create strategies and technologies to control exposures to workplace hazards. DART utilizes seven laboratories to conduct research, developing and evaluating engineering control technology for biological, chemical, physical, and ergonomic hazards. DART subject matter experts in exposure assessment and biomonitoring consult and respond to emergencies to provide technical assistance during responses. DART's researchers developed patient isolation controls that could protect healthcare workers during infectious disease pandemics. Currently, they are working on developing improved methods for anthrax sampling.

Division of Safety Research (DSR), Morgantown, WV – DSR research and prevention programs aim to address the leading causes of traumatic injuries and fatalities in the workplace. DSR conducts independent investigations of fire fighter line-of-duty deaths.

Their research contributed largely in helping to prevent injuries and exposures among emergency medical services workers as well as improving the design of ambulances to make them safer. DSR also provides expertise and support on physical hazards such as chain saws injuries, electrical hazards, and motor vehicle safety during responses.

Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS), Cincinnati, OH – DSHEFS conducts occupational health surveillance, workplace HHEs, and research in causes of acute and chronic diseases in workers. DSHEFS has dedicated exposure assessment and industrial hygiene facilities, including a mobile response vehicle used during responses. It has led a number of HHEs to evaluate workplace conditions and responder health concerns during emergencies, including the Deepwater Horizon oil spill and the 2009 H1N1 influenza outbreak.

Education and Information Division (EID), Cincinnati, OH – EID supports the prevention of occupational injuries and disease through targeted information dissemination, training, and the development of quantitative and qualitative risk assessments. EID supports EPR training module development and helps create and maintain critical EPR web pages. EID also oversees the public inquiry phone line, email, and EPR-related inquiries during responses. Finally, EID provides audiovisual and publication support to EPR documents.

Health Effects Laboratory Division (HELD), Morgantown, WV – HELD scientists work in the areas of allergy and clinical immunology, biostatistics and epidemiology, exposure assessment, engineering control, pathology and physiology, toxicology, and molecular biology. HELD has unique laboratory capabilities for evaluating basic toxicology of a wide range of agents and stressors, including an excellent inhalation exposure facility. HELD conducted important research, documenting the aerobiology of influenza and the potential for airborne transmission of influenza. HELD also examined toxicological and physical risk factors that may have contributed to health effects observed in Deepwater Horizon oil spill responders and volunteers.

National Personal Protective Technology Laboratory (NPPTL), Pittsburgh, PA – NPPTL aims to prevent work-related injury, illness, and death by advancing the knowledge and application of personal protective technology (PPT). NPPTL assesses wearability and performance of respirators and other PPE in their Human Subjects Test Laboratory. NPPTL

made significant contributions to the EPR Program through its research in respiratory protection, protective clothing, and factors for PPE use and tolerance.

Office of Extramural Programs (OEP), Atlanta, GA – OEP leads and supports national occupational safety and health research and training programs to reduce work-related injuries and illnesses through a diversified portfolio of high quality extramural research, education, and training in collaboration with global partners. Many extramural research projects contributed to EPR, including projects related to hazard identification or recognition, risk and health communication, health education strategies, recommendations for PPE and clothing, and just-in-time training from Hurricane Sandy response and recovery activities.

Respiratory Health Division (RHD), Morgantown, WV – RHD seeks to protect workers against work-related hazards and exposures that cause or contribute to respiratory illness, injury, and death and to promote workplace-based interventions that improve respiratory health. RHD researchers have contributed to research protecting healthcare workers against bloodborne pathogens and other infectious diseases and support development of guidance documents during responses.

Communication Office, Office of the Director (OD), Washington, DC – The Communication Office promotes, publicizes, and educates NIOSH stakeholders, the media, and partners about core activities, new research, and significant events, while supporting individual researchers in promoting their work. The Communication Office assists in developing outreach materials for partners and dissemination plans for use before and during responses. Through newsletters, social media, and media outreach, they support communicating preparedness messaging to protect and educate workers.

Program Planning

In March 2008, NIOSH held an Emergency Preparedness and Response Research Portfolio Town Hall Meeting in Alexandria, Virginia, to share draft strategic goals, soliciting feedback and discussing possible research to support these goals [NIOSH 2008]. This meeting was open to the public and attended by stakeholders both in and out of the government. Those unable to attend the meeting could submit input to the NIOSH Docket Office. Priority areas identified by attendees and through public comment addressed safety climate, PPE, surveillance, hazard characterization, technological

interventions and engineering controls, environmental microbiology, and biological monitoring of terrorism agents, setting these final goals [NIOSH 2016]:

- Strategic Goal 1: Enhance the health, safety, and resilience of emergency responders by improving the organization of emergency response work.

- Strategic Goal 2: Enhance the health and safety of emergency responders by improving proper selection and use of PPE to reduce responder's hazardous exposures to chemical, biological, radioactive, and nuclear (CBRN) agents, industrial compounds, and other materials.

- Strategic Goal 3: Enhance the health and safety of emergency responders by improving engineering controls and other technological interventions to reduce responder's hazardous exposures to CBRN, industrial compounds, and other hazardous materials.

- Strategic Goal 4: Enhance the health and safety of emergency responders through improved rapid methods for evaluating spatial and temporal distribution of hazardous agents in the air and on surfaces.

- Strategic Goal 5: Improve subgroup awareness, develop targeted messages, and expand subgroup-preferred channels (goal retired in 2009).

- Strategic Goal 6: Enhance the health and safety of emergency responders by improving pertinent surveillance systems.

- Strategic Goal 7: Enhance the health and safety of emergency responders by improving detection, risk assessment, and control of biological threat agents.

- Strategic Goal 8: Enhance the health and safety of emergency responders by utilizing improved biological monitoring methods for exposures to terror agents.

When NIOSH reorganized its program portfolio in 2016, they recognized EPR, a cross-sector program that reaches across multiple industry sectors, as a critical element of the NIOSH portfolio. NIOSH designated EPR as a core and specialty program—these programs represent core activities, mandates, special emphasis areas, and methodological approaches. The EPR Program participated in the recent NIOSH strategic

planning process to develop priorities for fiscal years 2019–2023. EPR also contributed to research goals in the NIOSH Strategic Plan, such as those related to posttraumatic stress disorder, suicide, and depression among public safety workers and set service goals for non-research activities. The EPR program website shows the current consolidated EPR program goals.

In addition to the strategic planning processes like those described previously, current events shape the EPR Program. Emergencies, whether it is a natural disaster or an emerging infectious disease, dictate and influence the direction of the work. The EPR Program must remain flexible and be responsive to new focus areas and objectives that emerge from newly issued federal policy, plans, and initiatives, responses to emergencies, national level exercises, and emergency supplemental funding.

Annually, the EPR Program develops a work plan with detailed milestones with activities designed to meet the overall objectives for the year. The Program documents performance and accomplishments by biannually reporting the actions taken to address these milestones. The program strives to improve its performance during exercises and emergency responses by completing after-action and improvement plan reports. These reports capture observations and feedback from responders to identify which corrective actions to address, if any. These corrective actions are documented in a database and tracked to completion.

External Factors

While NIOSH has made great strides to promote the safety and health of responders before, during, and after responses, continued efforts to expand and improve the body of knowledge in this area is subject to changes in funding, research priorities, and the availability of knowledgeable and experienced researchers. The EPR Program must also be flexible and responsive to new, unanticipated emergency responses, which can dictate future work.

Contents of the Evidence Package

EPR activities are a small, but integral part of the NIOSH mission, supported by various divisions and laboratories within the Institute as well as the NIOSH funded extramural grantees. Currently, other NIOSH programs such as the Public Safety and Traumatic

Injuries Programs complete the work that supports routine firefighting and other traditional first responder research and investigations (e.g., Fire Fighter Fatality Investigation and Prevention Program and ambulance design research); therefore, these activities will not be presented in this evidence package. In addition, the NIOSH Personal Protective Technology (PPT) Program advances the knowledge and application of PPTs. PPE such as respirators, protective clothing, and gloves, play an important role in worker protection to reduce the effects of hazardous exposures, therefore, this work applies to all sectors. This review will focus on PPT work that came from preparedness and response activities. Finally, NIOSH activities related to the administration of the World Trade Center Health (WTC) Program, which provides medical monitoring and treatment for responders at the World Trade Center and related sites in New York City, the Pentagon, and Shanksville, Pennsylvania, are not part of this review.

For the purposes of this review, NIOSH asks the panel to consider only the NIOSH EPR Program's work related to non-routine emergency preparedness and response activities. Specifically, the panel will be asked to consider only the NIOSH EPR Program's work in the following areas: ERHMS™ System, anthrax preparedness and response capabilities, and chemical, radiation, hurricane, and infectious diseases preparedness and response.

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Chapter 2: Emergency Responder Health Monitoring and Surveillance™ (ERHMS™) Program

Responder uses his go kit during a field response. [Photo credit: NIOSH]

Introduction

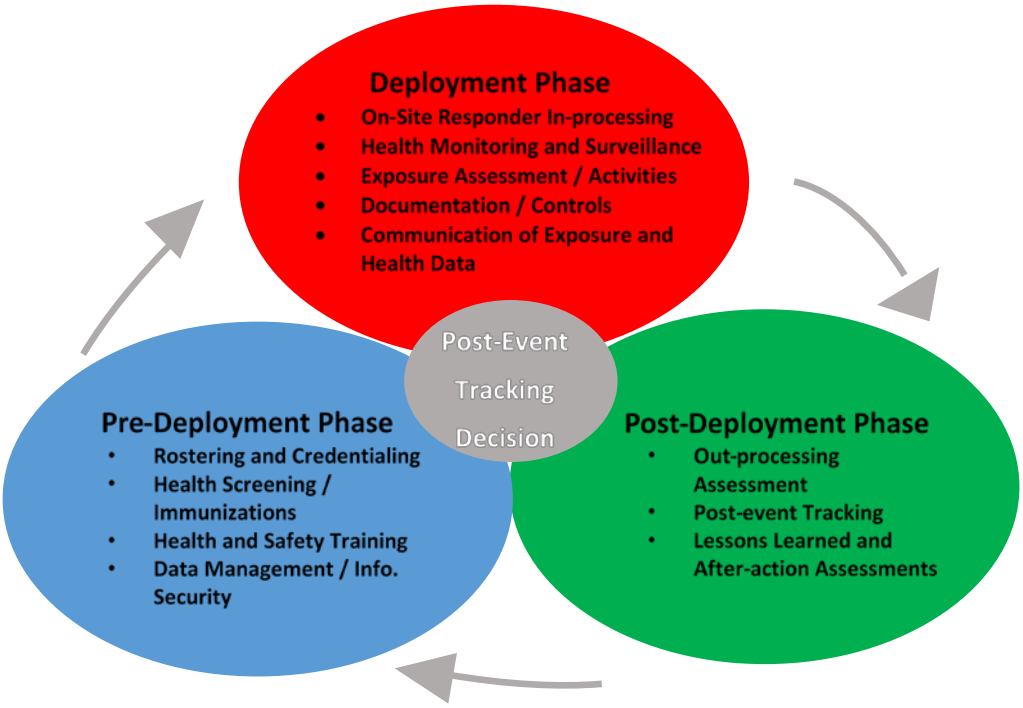
Response workers are a common sight at both large and small disasters and emergent events, and ensuring the health and safety of response and recovery workers is essential to an effective response. The National Response Framework and National Disaster Recovery Framework contain core capabilities and critical tasks that demand strategies to protect worker safety and health. However, previous emergencies demonstrated significant gaps and deficiencies in the health monitoring and surveillance of emergency response workers (including police, fire, and emergency medical personnel, and other responder groups like public health personnel, cleanup, repair and recovery workers, and volunteers). For example, the National Institute for Occupational Safety and Health (NIOSH) and the RAND Corporation's Science and Technology Policy Institute "Protecting Emergency Responders" 2002 and 2004 documents established that the September 11th World Trade Center (WTC) response experienced multiple challenges with personal protective equipment (PPE) [Jackson et al. 2002; Jackson et al. 2004]. These challenges included poorly coordinated hazard monitoring that delayed PPE recommendations and insufficient worksite perimeter control for areas that required

PPE. Since its creation in 2001, the WTC Health Program, which provides medical monitoring and treatment for 9/11 responders, certified over 34,000 responders for at least one WTC-related health condition. Hurricane Katrina Health Hazard Evaluations (HHEs), published in 2007, identified varying ways for recovery contractors to conduct hazard recognition, evaluation, and controls [NIOSH 2007]. Additionally, recovery employees needed readily accessible, understandable information regarding workplace hazards and exposures, and distribution of this information was often challenging and sometimes limited.

In response to this demonstrated need to better protect, equip, and promote the health and safety of emergency responders, NIOSH collaborated with federal agencies, state health departments, and unions to create the Emergency Responder Health Monitoring and Surveillance™ (ERHMS™) System. ERHMS™ is a framework that allows an organization, both large and small and public or private, to monitor the health and safety of emergency responders throughout critical phases of a response. The goals of ERHMS™ are to prevent short-term and long-term illness and injury in emergency responders and to ensure workers can respond safely and effectively to future emergencies.

ERHMS™ aims to ensure that specific activities to protect the health and safety of emergency response and recovery workers are conducted during each of the three phases of a response—pre-deployment, deployment, and post-deployment (Figure 3). During the pre-deployment phase, organizations should ensure workers are properly rostered, credentialed, trained, and fit for duty. Organizations should also make sure that they are able to store all collected information for their responders in a secure manner. During the deployment phase, health monitoring and surveillance should take place to ensure workers are not exposed to unsafe hazards while performing their job tasks. This includes making sure workers have access to potable water, safe food, and secure housing. During the post-deployment phase, workers should be properly demobilized, and it should be determined if long-term tracking is needed. Organizations should hold after-action (debriefing) meetings, documenting the lessons learned to improve future responses.

Figure 3. ERHMS™ framework for each response phase.



NIOSH developed resources and tools to assist organizations with implementing ERHMS™ during each of the response phases. This includes free in-person and online training, and ERHMS Info Manager™ software with an accompanying user guide and training videos.

NIOSH activities described in this chapter support the following EPR Strategic Goals:

- Strategic Goal 1: Enhance the health, safety, and resilience of emergency responders by improving the organization of emergency response work.
- Strategic Goal 4: Enhance the health and safety of emergency responders through improved rapid methods for evaluating spatial and temporal distribution of hazardous agents in the air and on surfaces.
- Strategic Goal 6: Enhance the health and safety of emergency responders by improving pertinent surveillance systems.

Logic Model

Figure 4 is a logic model illustrating how the ERHMS™ Program moves its inputs and activities into practice. Dotted lines indicate anticipated pathways for change while solid lines show established pathways. Descriptions of the logic model elements—Inputs, Activities, Outputs, Transfer and Translation, Intermediate Outcomes, and End Outcomes—follow in detail in the upcoming sections.

Inputs

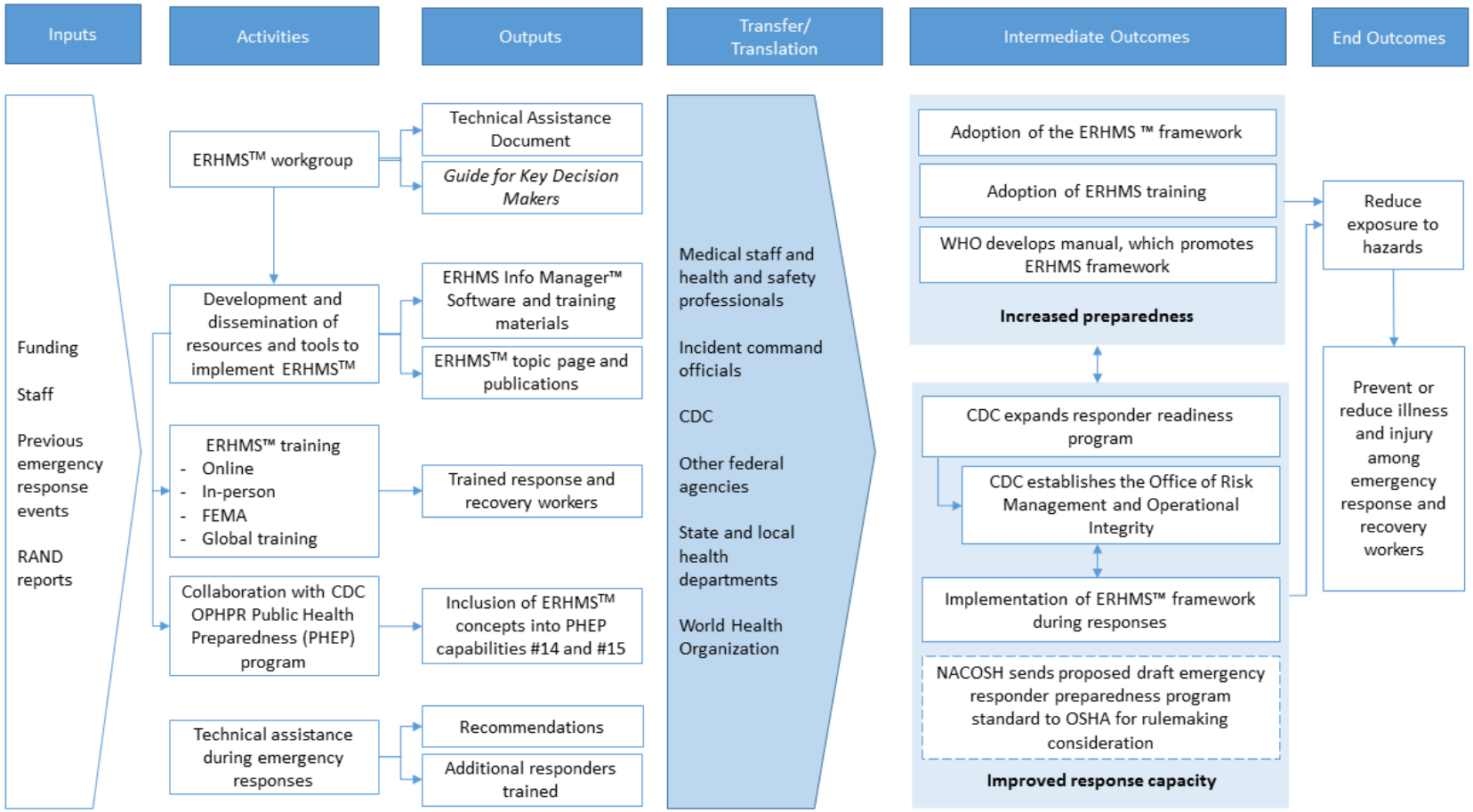
Many inputs contribute to the progress of NIOSH's ERHMS™ Program in addressing the problem of protecting workers during emergency responses:

Staffing

NIOSH efforts related to ERHMS™ primarily occur within the Emergency Preparedness and Response Office (EPRO). This list shows several key staff members and their roles on the ERHMS™ team:

- CDR Jill M. Shugart, MSPH, REHS, CP-FS, is the current NIOSH ERHMS™ Coordinator within EPRO (since January 2017). Her roles include leading a team of EPRO staff to provide training and technical assistance to federal, state, and local agencies on ERHMS™, developing ERHMS Info Manager™ software, a user guide, and training videos for organizations to implement the ERHMS™ framework.
- CAPT Lisa Delaney, MS, CIH, is the Associate Director of EPRO. Her role on the ERHMS™ team is to provide input on ERHMS™ at the Centers for Diseases Control and Prevention (CDC) and NIOSH leadership levels and to offer recommendations to promote the ERHMS™ framework during preparedness initiatives and projects as well as during responses. She also serves as an ERHMS™ trainer as needed.

Figure 4. Logic Model for NIOSH Emergency Responder Health Monitoring and Surveillance™, 2007–2017.



- CDR Chad Dowell, MS, CIH, is the Deputy Associate Director of EPRO. His role is to oversee the development of the ERHMS Info Manager™ software and to monitor the software's contract.

- CDR Sherry Burrer, DVM, MPH-VPH is a Staff Epidemiologist and Senior Veterinary Officer within EPRO. Her role is to provide technical assistance on epidemiological needs for ERHMS™, including developing survey tools, reviewing registry documentation, and providing technical assistance when required. She also serves as an ERHMS™ trainer as needed.

- LT Kerton Victory, MSc, PhD is a Staff Epidemiologist and Environmental Health Officer within EPRO. His role is to oversee the CDC accreditation process for both, the in-person and online ERHMS™ training courses. He also serves as an ERHMS™ trainer as needed.

- CAPT Renée Funk, DVM, MPH, MBA, served as the NIOSH ERHMS™ Coordinator within EPRO from 2008-2015. Her roles included providing training and technical assistance to federal, state, and local agencies on ERHMS™, implementing aspects of ERHMS™ during the 2010 Deepwater Horizon response, and helping organizations to implement the ERHMS™ framework.

In 2016, CAPT Bruce Bernard, Chief Medical Officer for the NIOSH Health Hazard Evaluations and Technical Assistance Program, trained nine additional NIOSH staff members on ERHMS™. These staff included, from Morgantown, West Virginia, CDR Tricia Boyles and CDR Jennifer Hornsby-Myers (Office of the Director), and CAPT Rachel Bailey (Respiratory Health Division); from Cincinnati, Ohio, LCDR Judi Eisenberg and Kendra Broadwater (Division of Surveillance, Health Evaluations and Field Studies); from Spokane, Washington, LCDR Alice Shumate (Western States Division) and CDR Kristin Yeoman (Spokane Mining Research Division); from Denver, Colorado, Christa Hale (Western States Division); and from Washington, D.C., CDR Elizabeth Garza (Office of the Director). These NIOSH staff members volunteered to assist the EPRO ERHMS™ Team by serving as ERHMS™ trainers, promoting ERHMS™ within their jurisdictions and among partners, and providing technical assistance on ERHMS™ when needed.

Previous Emergency Response Events

During the WTC attack on September 11, 2001, hundreds of thousands of people were exposed to environmental contaminants, almost 7,000 suffered traumatic injuries, and nearly 3,000 people lost their lives [Lucchini et al. 2017]. Well-documented gaps and deficiencies in the health monitoring and surveillance of emergency response workers were reported following the 9/11 terrorist attacks [Jackson et al. 2004]. As workers from across the United States rushed to New York City to help those affected, there was minimal health tracking and monitoring of workers at the incident, and limited records were kept of what they were exposed to or what type of PPE they may have been wearing early in the response [Crane et al. 2014].

In the process of responding to this incident, 450 response workers died and hundreds more were seriously injured [Jackson et al. 2002]. Consequently, documentation shows that the WTC Health Program certified over 34,000 responders for at least one WTC-related condition (including rhinosinusitis, pulmonary disease, cancers, depression, and anxiety) because of their exposure to airborne toxins and other hazardous conditions. Furthermore, gaps in rostering, monitoring, and surveillance make it difficult if not impossible to assess the full extent of the impact this event had on responder health [Crane et al. 2014; Lucchini et al. 2017]. Unfortunately, gaps in the health monitoring and surveillance of emergency response workers continued during the 2005 response to Hurricanes Katrina and Rita [Bergan et al. 2015; Rusiecki et al. 2014] and during the 2010 Deepwater Horizon (DWH) oil spill response [Kitt et al. 2011; NIOSH 2011].

On April 20, 2010, an explosion on the DWH oil rig led to the largest oil spill in U.S. history. Oil continued to spill into the Gulf of Mexico throughout the summer until workers capped the well in August. Although the ERHMS™ framework was still under development, NIOSH staff saw an opportunity to begin implementing elements of the ERHMS™ framework into the response. This was accomplished primarily by rostering all workers at the event and conducting health surveillance of workers during the pre-deployment and deployment phases of the response. NIOSH staff were able to manually roster over 55,000 workers working across the Gulf region. NIOSH also analyzed and prepared reports of injury and illness data occurring among DWH responders in all locations. We present more information describing NIOSH's DWH response efforts in Chapter 4 Preparedness and Response Activities.

Because of these activities, NIOSH collected many lessons learned:

- Begin worker rostering immediately and integrate it into response activities as soon as possible to ensure all workers participate
- Have a ready-to-use roster form prepared that can be quickly adapted and cleared
- Direct the rostering program through the incident/unified command
- Explore the feasibility of incorporating rostering into existing response programs to improve efficiency
- Develop mechanisms to encourage and facilitate employer participation
- Take maximum advantage of existing data streams that could be used for health surveillance of response workers during the response
- Federal, state, and local agencies should consider developing standardized instruments for baseline occupational surveillance and post-event occupational data collection and analysis that could be easily adapted to specific events and used by various organizations
- Improved occupational injury and illness surveillance may be achieved through enhanced integration and coordination with other surveillance activities at the Department of Health and Human Services (HHS), CDC, and other agencies

NIOSH staff published these lessons learned in a NIOSH-issued report and journal article [Kitt et al. 2011; NIOSH 2012].

RAND Reports

Because of the 9/11 events described previously, NIOSH awarded a contract to the RAND Science and Technology Policy Institute to organize a conference of individuals with primary knowledge of emergency response activities that resulted from participation in the responses to previous terrorist attacks. The specific purpose of the conference was to review PPE and work practices, including training, and to determine how well these practices worked and how they might be improved in future responses [Jackson et al. 2002]. Conference attendees came from a variety of occupations within the response community, including firefighters, police, emergency medical technicians,

construction workers, union officials, and government representatives from local, state, and federal agencies. During the conference, the RAND Institute collected and analyzed a wealth of information about topics including hazard monitoring, PPE, risk communication, responder training, and incident site management. This event resulted in an outline of needs and recommendations for research, training, and other strategic approaches to help protect emergency responders during terrorist attacks. Based on the success of the first RAND report, they subsequently issued an additional three reports that also drew from input received during a workshop, panel discussions, and interviews with experts.

RAND produced the following four reports:

- The first RAND report published in 2002, Protecting Emergency Responders: Lessons Learned from Terrorist Attacks, provides a review of all the information presented at the initial conference [Jackson et al. 2002].

- The second RAND report published in 2003, Protecting Emergency Responders, Volume 2, Community Views of Safety and Health Risks and Personal Protection Needs, focuses on research, implementation, and guidance to protect emergency responders, especially around PPE [LaTourrette et al. 2003].

- The third RAND report published in 2004, Protecting Emergency Responders, Volume 3, Safety Management in Disaster and Terrorism Response, provides a comprehensive set of strategies and tactics for enhancing the safety of responders by preparing before an event and managing after the event [Jackson et al. 2004].

- The fourth RAND report published in 2006, Protecting Emergency Responders, Volume 4, Personal Protective Equipment Guidelines for Structural Collapse Events is a technical resource for incident commander guidelines for emergency response immediately following large structural collapse events [Willis et al. 2006].

The ERHMS™ framework draws heavily from the recommendations in these reports. NIOSH developed guidance and tools to ensure the adherence of best practices to

protect the health and safety of responders during all events, including large-scale events similar to the 9/11 attacks.

Activities, Outputs, Transfer and Translation, and Intermediate Outcomes

ERHMS™ Workgroup

Building off the momentum and valuable information gained from the RAND reports, in 2009, NIOSH staff led an ERHMS™ workgroup aimed to develop the concepts of the ERHMS™ framework. This interagency workgroup consisted of occupational health and safety subject matter experts representing federal, state, and local governments and volunteer agencies: Department of Homeland Security (DHS), Occupational Safety and Health Administration (OSHA), U.S. Coast Guard (USCG), Federal Emergency Management Agency (FEMA), American Red Cross, U.S. Army Corps of Engineers, Oregon Public Health Division, California Department of Public Health, EPA, Federal Interagency Board, Association of Fire Fighters, CPWR—The Center for Construction Research and Training, and the New York City Fire Department.

NIOSH chose workgroup members because of their significant experience in health, safety, and industrial hygiene and their previous involvement in emergency responses. NIOSH obtained valuable and relevant feedback on how to protect workers while conducting emergency response work through the workgroup. The workgroup identified the goal of ERHMS™ as developing a health monitoring and surveillance framework for emergency responders that addresses all phases of a response, including pre-deployment, deployment, and post-deployment phases. The workgroup identified the objectives of ERHMS™ as using the framework to

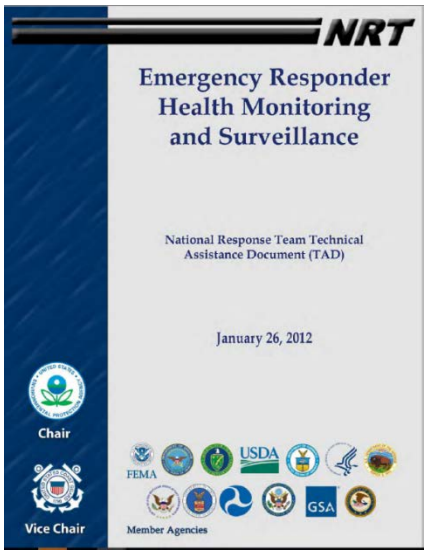
- Identify exposures and/or signs and symptoms early in the course of an emergency response to
    - Prevent or mitigate adverse physical and psychological outcomes
    - Ensure workers maintain their ability to respond effectively
    - Avoid harm to workers throughout the course of response work

- Perform monitoring and ongoing assessment to
    - Assess whether protective measures are adequately provided to the workforce
    - Determine if the protective measures provided are sufficient to prevent or reduce harmful exposures to workers

- Identify which responders need medical referrals and possible enrollment in a long-term health surveillance program

The workgroup members developed the ERHMS™ document containing guidelines and recommendations; the U.S. National Response Team (NRT) adopted this resource as a Technical Assistance Document (TAD) [NRT 2012] (Figure 5). The NRT includes representatives from 15 federal agencies with responsibilities and expertise in emergency response to oil and hazardous substance pollution incidents. The NRT also has responsibilities for interagency planning, policy, and coordination of these incidents.

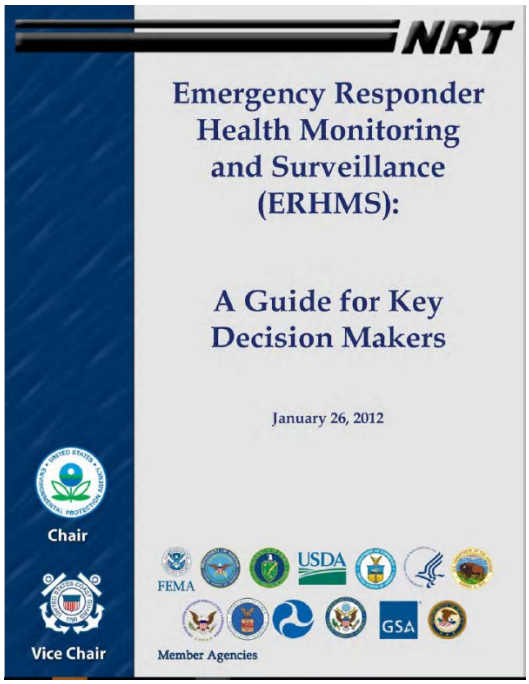
Figure 5. ERHMS™ TAD



This TAD contains guidelines and recommendations—applicable across a range of emergency types, settings, and size—to address all aspects of protecting emergency responders. The document contains a guidance and a tools section, including 11 chapters describing how to protect responders across each of the three ERHMS™ response phases: pre-deployment, deployment-, and post-deployment. The tools section describes how to implement ERHMS™ in real-time, includes example survey

forms, mental health screening, health and safety training tools, and data disclosure forms to complement the guidance section. The workgroup also wrote a 10-page A Guide for Key Decision Makers [NRT 2016], also adopted by the NRT (Figure 6). This guide contains ERHMS™ functions, decision points, and deliverables for use throughout the three deployment phases.

Figure 6. ERHMS™: A Guide for Key Decision Makers



ERHMS Info Manager™

After publication of the ERHMS™ TAD, NIOSH received requests from organizations to develop a software solution to collect ERHMS™ data. To increase an organizations' ability to implement and adopt ERHMS™, NIOSH successfully competed for funding from CDC's Office of Public Health Preparedness and Response (OPHPR) for FY15-FY17, to develop a market-ready software product that allows for data collection throughout the three phases of a response outlined in ERHMS™; the funding included training on how to use the new software as well. The goal: to improve an organizations' preparedness prior to an emergency by developing a product to allow users to manage staff readiness and collect information on rostering, training, and medical screening and to document health monitoring and surveillance information from responders while deployed.

NIOSH developed a prototype version of ERHMS Info Manager™ based on a set of preliminary requirements and conducted an environmental scan of possible software tools available, reaching out to several health departments to get feedback on the viability of the product. All agency feedback indicated the software concept as beneficial. As a result, NIOSH determined that the base software would be Epi-Info™, a free software tool developed by CDC with a custom ERHMS™ wrapper coded in to add any critical ERHMS™ functions missing from the Epi-Info™ software. NIOSH selected a contractor to develop the product, and asked nine state and local public health departments from seven states and territories, including: Wisconsin Department of Public Health, Texas Department of State Health Services, Puerto Rico Department of Health, Idaho Division of Public Health, Georgia Department of Public Health, Delaware Division of Public Health, Fort Bend County Health and Human Services, Texas Region 5 & 6 South, and New Hampshire Department of Health and Human Services, to pilot test the software and provide feedback on its functionality. All issues identified were addressed and participants expressed confidence that the software will be a benefit and improvement to emergency response organizations.

Two rounds of functional testing were also conducted by 22 NIOSH subject matter experts, including epidemiologists, research scientists, industrial hygienists and medical officers, and three members of the ERHMS Info Manager™ and Epi Info™ software teams to include developers and enterprise architects. All issues identified in both rounds of functional testing were addressed or clarified in the software documentation.

The final functionalities of ERHMS Info Manager™ were demonstrated to stakeholders, including NIOSH leadership, organizations previously involved in pilot testing, and stakeholders from the ERHMS™ workgroup. The software was made available in a limited fashion for testing by a group of individuals who expressed interest. A handful of issues were identified and addressed before version 1.0 of the software was finalized and made available.

During the software development cycle, NIOSH staff created five training videos that document the basic functionality of the software and a user guide. To ensure users of the software receive rapid technical assistance, NIOSH staff trained the CDC Epi-Info™ help desk team on how to use ERHMS Info Manager™, and the team agreed to support ERHMS Info Manager™ users with technical issues.

In July 2017, NIOSH released the first version of ERHMS Info Manager™, five training videos, and a user guide. NIOSH updated and created a new ERHMS™ topic page [NIOSH 2018] where users can download ERHMS Info Manager™ and access the five training videos and user guide (Figure 7). NIOSH staff created a standard operating procedure to handle ERHMS Info Manager™ questions that come from the CDC Epi-Info™ help desk team to ensure a smooth transition for new software users with problems and questions.

Figure 7. ERHMS™ Topic Page.

ERHMS Info Manager™ and Epi Info™ project staff added features to the second version of the software based on the feedback received during the pilot and functionality testing conducted for version 1. Additional features will include an improved user interface and the ability for organizations to allow for HIPAA compliant implementation. For example, by enabling users to protect personally identifiable information. NIOSH expects to release version 2 of ERHMS Info Manager™ and an updated user guide in February 2018.

From July 2012 – December 2017, there have been over 39,000 views of the ERHMS™ topic page. From August 2017 – December 2017, there have been more than 1,000

views of the ERHMS Info Manager™ overview webpage and more than 300 views of the ERHMS Info Manager™ webpage where you can download the software.

ERHMS™ Training

Because ERHMS™ presents a new approach to protecting responders before, during, and after emergencies, NIOSH recognized ERHMS™ training as a critical component of the program. NIOSH sought to develop both an in-person training course and online training modules to meet the needs of our diverse group of stakeholders.

ERHMS™ Online Training Course-WB2873

NIOSH developed a comprehensive three-hour web-based ERHMS™ course, available to the public free of charge. Users find this course on the CDC TRAIN website [CDC 2018a], a centralized platform for sharing training with the public health workforce (Figure 8). Over 1,600 learners registered for this course since July 2015 [Victory 2017].

Figure 8. CDC TRAIN ERHMS™ Online Training Course.

One-Day, In-person ERHMS™ Training

NIOSH staff also developed a comprehensive one-day, in-person training course based on the NRT TAD, described previously. The ERHMS™ workgroup developed the course concepts and these course objectives:

1. To understand the system designed to document exposures and health data prior to and during an emergency response,

2. To learn about organizing, sharing, and communicating data for monitoring and assessing emergent events and the health of responders, and

3. To use these data after a response to identify responders who would benefit from medical referral, long-term health surveillance, or who do not need follow-up.

Previous ERHMS™ Training

In 2012, NIOSH partnered with the Agency for Toxic Substances and Disease Registry's (ATSDR) Assessment of Chemical Exposures (ACE) program [ATSDR 2018a] and the CDC's Community Assessment for Public Health Emergency Response (CASPER) program [CDC 2017a] to secure funding from CDC's OPHPR to support regional trainings on a set of disaster epidemiology tools including ERHMS™, ACE, and CASPER. Public health professionals working in state and local health departments were the target audience for this training. The funding covered the travel of attendees and trainers, training materials, and training site costs. Nine regional trainings took place over three years (2013–2016), and 317 public health professionals from health departments from nine states completed the training.

In March 2017, NIOSH staff coordinated and conducted a disaster epidemiology training, including ERHMS™, ACE, and CASPER courses at the request of the West Virginia Bureau for Public Health. The training was held at the West Virginia University School of Public Health in Morgantown, WV. Ninety individuals, including local and state public health staff, Medical Reserve Corps volunteers, students and faculty, were trained.

In May of 2017, NIOSH trained 22 individuals in-person on ERHMS™ at the request of the Oregon Medical Reserve Corps unit in Portland, Oregon. In November of 2017, NIOSH gave an in-person ERHMS™ training (Figure 9) at the request of the Tennessee Valley Section American Industrial Hygiene Association in Knoxville, Tennessee, during their professional development course held at their annual conference—91 participants completed the training, including industrial hygienists and environmental health, safety, and public health professionals.

Figure 9. ERHMS™ training

The CDC School of Preparedness and Emergency Response (SoPER) offers the one-day training ERHMS™ course twice a year, free of charge for CDC staff. Since 2015, NIOSH has trained 135 individuals.

NIOSH staff updated the training materials in 2017 for the in-person courses to ensure all the information was accurate and additional information was included on ERHMS Info Manager™ and examples of how ERHMS™ has been implemented at the federal and state level.

Intermediate Outcome:

- Because of NIOSH staff providing ERHMS™ training at the West Virginia University in March of 2017, the Monongalia County Health Department implemented ERHMS™ during a multi-agency, statewide emergency drill called Operation Dawson Storm [Shugart 2017b]. The emergency drill, conducted in July 2017 in Morgantown, West Virginia, focused on a potential exposure to a radiological source, involving the military, first responders, law enforcement, and public health officials. The health department conducted health monitoring of first responders prior to the drill and after the drill and administered pre- and post-drill questionnaires. They obtained data from 52 responders pre-drill and 33 responders post-drill.

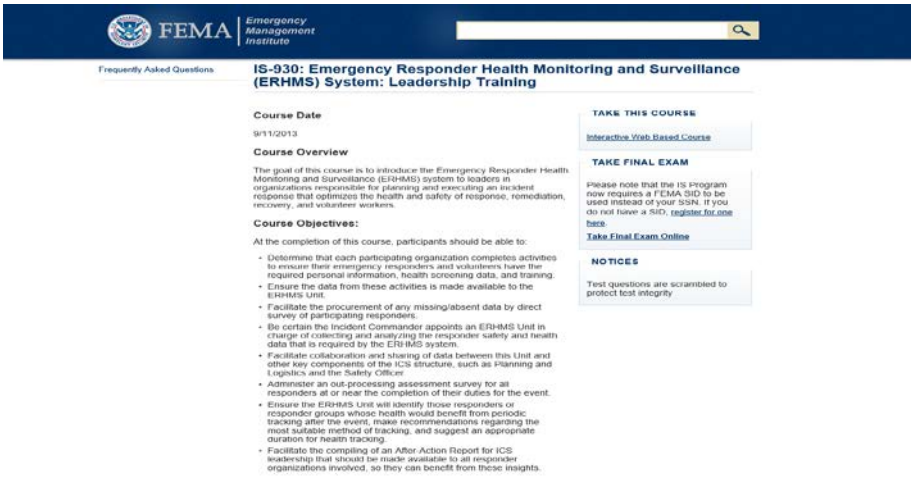
Evaluation Tool

Participants of the OPHPR-supported regional ERHMS™, ACE, and CASPER in-person courses received requests to complete a course evaluation form; however, the in-person CDC SoPER course was not similarly evaluated. In December 2017, to assess the newly updated training and create a consistent, systematic evaluation of all in-person ERHMS™ courses, NIOSH staff developed a one-page evaluation form for all of the in-person ERHMS™ courses. They created two evaluation forms, one for in-person courses presented to a non-CDC audience and one form for in-person CDC SoPER courses. This new evaluation tool aims to capture valuable feedback not only on the course content and on materials used but also on how organizations are able or not able to implement ERHMS™ as a result of the concepts learned in the training class. The evaluation tool will be pilot tested in 2018 during the next scheduled CDC SoPER and non-CDC in-person ERHMS™ courses.

FEMA Independent ERHMS™ Course (IS-930)

NIOSH developed a one-hour FEMA Independent ERHMS™ Course (IS-930), available free of charge to the public on the FEMA website (Figure 10). The target audience for this brief course are leaders of organizations who are responsible for the health and safety of workers or who will serve in an incident command role during a disaster.

Figure 10. FEMA Independent Study ERHMS™ Course



NIOSH staff completed all of the accreditation requirements for the ERHMS™ in-person and the three-hour online courses in 2014 and again in 2017. This included developing content for the 8-hour in-person courses, three hours of content for the online course,

and coordinating a pilot test and evaluation of the online ERHMS™ course with 31 subject matter experts to determine appropriate course length, learning objectives, and course content. Both class types offer continuing education credits for pharmacists (CPEs), physicians (CMEs), nurses (CNEs), veterinarians (AAVSB), certified health education specialists (CHES), and other professionals (CEUs). The three-hour online CDC ERHMS Course offers participants 0.3 to 3.5 CEUs depending on the designated provider for the CEUs. Participants receive CEUs (0.1) for the one-hour FEMA course.

Intermediate Outcome:

- More than 1,726 individuals completed FEMA's ERHMS course [Shugart 2017a].

Global Training

The 2014 West Africa Ebola outbreak demonstrated the challenge of quickly organizing adequate and effective occupational health and safety protections for large numbers of international and local response workers. The outbreak disproportionately impacted healthcare workers in West Africa, with one World Health Organization (WHO) report finding health workers in Guinea, Liberia and Sierra Leone between 21 and 32 times more likely to be infected than the general population [WHO 2015]. In an effort to address these challenges, WHO organized an expert meeting in Geneva, Switzerland, in December 2015, to review existing international tools for protecting the occupational health and safety of healthcare workers and response personnel and to develop recommendations for their adaption to low-income African countries during outbreaks. Workshop participants included representatives from the WHO collaborating centers and research partners from Benin, South Africa, Tanzania, and the United States, as well as WHO and the International Labour Organization (ILO) experts. Two NIOSH staff attended this meeting and presented on the ERHMS™ framework and its concepts.

Building from the first workshop, WHO organized a larger workshop focusing on training high priority African countries on how to protect the health and safety of responders during outbreaks in South Africa the following year. One NIOSH staff member presented on the critical elements of the ERHMS™ framework including how to protect responders from common hazards seen during outbreaks. Thirty-eight national public health officials and emergency management professionals representing 18 countries and

representatives from WHO collaborating centers, WHO, and ILO attended the workshop. WHO planned to use the information gained during this meeting to develop a set of training materials and models of standard operating procedures to build core capacities in Benin and Tanzania.

Intermediate Outcome:

- Building off the success of these two workshops, WHO developed a manual on the occupational safety and health of health workers and responders in public health emergencies to support national authorities and the global workforce. The manual, due to be released in summer 2018, incorporated information NIOSH provided during the trainings and in subsequent development. WHO translated the manual into Spanish and French to reach a broader audience [Kitt 2017].

Table 2. ERHMS™ Trainings (2013-2018).

Training Type	# Trained
CDC SOPER Courses (in-person)	135
Non-CDC Courses (in-person)	520
Global Workshop (in-person)	38
FEMA IS-930 Course (online)	1,726
CDC TRAIN Course* (online)	1,600

*denotes registered trainers only

OPHPR Public Health Emergency Preparedness (PHEP) Cooperative Agreement

In 2011, the CDC OPHPR PHEP Cooperative Agreement Program sought assistance from NIOSH to lead the creation of their capability number 14, *Responder Safety and Health*, one of the 15 public health preparedness capabilities outlined in the PHEP cooperative agreement. This program awards cooperative agreements on a five-year cycle, providing approximately $700 million annually to 50 states, 4 localities, and 8 U.S. territories and freely associated states to build and strengthen their abilities in responding to public health threats [CDC 2011b and CDC 2013]. CDC assists PHEP awardees with technical assistance, best practices, lessons learned, and tools and resources they can use to address the 15 capabilities.

To receive funding, state, local, and territorial health departments must conduct a risk assessment to determine public health, medical, and mental and behavioral risks that may impact their ability to prepare for and respond to emergencies, including at-risk populations (e.g., children, elderly, and pregnant women). The National Standards for State and Local Planning document [CDC 2011b] and PHEP Fact Sheet [CDC 2017b] provide more information. The capabilities also ensure that federal preparedness funds are directed to priority areas within individual jurisdictions. The creation of capability number 14 provides a mechanism for awardees, including state, local, tribal, and territorial health departments, to direct funding towards activities that support responder safety and health. Historically, this has not been a priority or expertise within health departments because few have an occupational safety and health unit.

Additionally, this capability draws heavily from the ERHMS™ framework and concepts and serves as a mechanism to increase awareness of worker safety and health among public health professionals and to promote the use of the ERHMS™ concept to protect workers while they respond to emergencies. The four functions created by NIOSH and outlined within capability number 14 ask the awardees to adopt the following practices: 1) Identify responder safety and health risks, 2) Identify safety and personal protective needs, 3) Coordinate with partners to facilitate risk-specific safety and health training, and 4) Monitor responder safety and health actions [CDC 2011b].

In 2017, NIOSH staff partnered again with CDC PHEP Cooperative Agreement staff to revise the 15 capabilities in order to update the *Public Health Preparedness Capabilities: National Standards for State and Local Planning* document. NIOSH staff used the ERHMS™ framework, concepts, and resources (e.g., trainings, software), developed or improved upon since 2012, to substantially update and improve capability number 14. While examining the rest of the planning document, NIOSH staff identified capability number 15, *Volunteer Management*, as a capability that could benefit from the inclusion of elements from the ERHMS™ framework. Thus, for the first time, staff included ERHMS™ concepts in capability number 15 to ensure that volunteers who participate in a response receive the same protections and guidance as workers.

In 2011, NIOSH led the creation of a responder occupational safety and health PHEP capability that incorporated activities described in ERHMS™ PHEP capability number 14 for *Responder Safety and Health*, and the CDC OPHPR PHEP program that requested its

creation, adding the capability to their *National Standards for State and Local Planning* document [CDC 2011b]. Prior to this, responder safety and health was not part of *their Performance Measures and Specifications and Implementation Guidance* [CDC 2011a, 2013].

During 2013–2016, Idaho worked toward implementing ERHMS™ through the following incremental activities with sub-grants with Public Health Districts: review PHEP Capability number 14 (*Responder Safety and Health*), complete training for monitoring staff and leadership, and pilot test ERHMS Info Manager™. In October 2016, Idaho's preparedness field assignee from CDC developed and facilitated a hands-on exercise to deepen ERHMS™ capabilities and share how the ERHMS™ framework and ERHMS Info Manager™ can be implemented among Public Health Districts. Participants included representatives from state and local epidemiology and preparedness programs. Data were obtained from 15 (79%) of the 19 participants. NIOSH staff presented the findings of this exercise at the 2017 Council of State and Territorial Epidemiologist annual conference in Boise, Idaho [Arkin 2017].

In March 2018, NIOSH conducted the final review of the revised *Public Health Preparedness Capabilities: National Standards for State and Local Planning* document (for publication in 2018); most of the NIOSH edits further incorporating the ERHMS™ framework into capabilities 14 and 15 were accepted. This new language will be in the next round of the CDC OPHPR PHEP Cooperative Agreement. The changes to capability number 14 provide a more detailed outline of the ERHMS™ framework and an increased number of trainings and tools, making it easier for grantees to justify and operationalize the funding and inclusion of responder safety and health policies and activities into their preparedness, response, and recovery plans and actions. Additionally, having the ERHMS™ framework integrated into capability number 15 gives another avenue for grantees to fund and incorporate the ERHMS™ concepts into response and recovery efforts. This will promote and facilitate the inclusion of volunteers in responder safety and health policies and activities.

Adoption of ERHMS™ Framework

2014 Ebola and 2016 Zika Outbreak

The 2014 Ebola outbreak response represented the largest response in CDC history. This unique response, which involved long-duration, international deployments to austere

conditions, required CDC to enhance their existing responder deployment program to meet the distinctive challenges. Early on, CDC staff returning from the field raised concerns regarding their health and safety while deployed to West Africa. As a result, CDC created five separate workgroups to provide health and safety recommendations on how the responder deployment program could be improved for the Ebola response. CDC asked NIOSH staff to assist within EPRO to join the five workgroups: Resiliency and Mental Health, Pre-Deployment, Deployment, Medivac, and Community Guidance [CDC 2016]. NIOSH staff incorporated ERHMS™ concepts into the CDC workgroup recommendations and followed the pre-deployment, deployment, and post-deployment framework the ERHMS™ workgroup created.

Intermediate Outcomes:

- As a result, during the 2014 Ebola outbreak, CDC expanded their Responder Readiness program and established an ERHMS™ unit in the emergency operations center (EOC), called the Disaster Risk Mitigation Unit (DRMU), to manage and implement the recommendations of the five previously mentioned workgroups. DRMU created a pre-deployment coordinator position to work with CDC responders before they deploy to ensure they met all of the health requirements and received proper training. During the deployment phase, DRMU monitored the health and safety of deployed staff and their injuries and illnesses were tracked. In addition, DRMU created a CDC post-deployment coordinator position to determine if any long-term monitoring of responders should be conducted, including any behavioral health needs. The DRMU's function and the positions it created, modeled after the ERHMS™ framework, were very successful and received continued buy-in from key CDC leadership.

  Based on the success and support for a more robust Responder Readiness program, CDC permanently established the DRMU unit, now called the Office of Risk Management and Operational Integrity [CDC 2018b] within the Division of Emergency Operations. Rather than operating only during responses, the CDC staffs this unit full-time and continues to focus on improving the deployment process for staff.

- Because the elements of ERHMS™ implemented during the Ebola response received positive feedback, from both the deployed and their leadership, CDC implemented the same ERHMS™ framework at the beginning of its Zika outbreak response, which started to unfold in the 2016 and 2017 hurricane responses. CDC successfully implemented the framework for all three phases of the 2016 Zika outbreak response. CDC received positive feedback from their responders throughout this process, especially for having a safety officer available onsite during all staff deployments [CDC 2017c].

Hurricane Responses

Hurricanes can cause varying amounts of wind, storm surge, and flood damage; therefore, they pose a considerable threat to human life and safety. Hurricane response and recovery workers are at a particular high risk of exposure to hazards that could result in illness, injury, and death. For the 2017 hurricane season, NIOSH EPRO staff led the Occupational Health Task Force for the CDC EOC's hurricane response—the first time that occupational health operated at the task force level. NIOSH staff advocated and provided technical assistance for the use of the ERHMS™ framework during the hurricane response and recovery.

For example, in October 2017, NIOSH deployed to Austin, Texas, under a FEMA Mission Assignment (Task Order 14/Amendment 15) to implement ERHMS™ in Texas as part of the Hurricane Harvey Recovery Mission. The FEMA Joint Field Office requested NIOSH to staff the Long-Term Responder Health Issues Team under the Health and Social Services Recovery Support Function. This was the first response that HHS used the recovery support functions.

While deployed in Texas, NIOSH staff trained 135 people on ERHMS™. The Texas Department of Social and Health Services requested a webinar training on ERHMS™, and through this webinar, NIOSH staff trained 92 public health professionals across the state, including local and regional staff. The University of Texas, School of Public Health, Southwest Center for Occupational and Environmental Health, a NIOSH-funded Education Research Center, requested NIOSH staff train their faculty, staff, and community partners on ERHMS™ in Houston, Texas. NIOSH staff trained 23 individuals at the school. Because of the school's strong relationship with Harris County, Texas, where much of the hurricane damage remained evident, NIOSH received a request to

introduce the ERHMS™ framework at the Harris County health department where 20 public health professionals attended, including representatives from the Baylor School of Medicine.

Intermediate Outcomes:

- In 2016, as Hurricane Matthew quickly approached, the Georgia Department of Public Health (GA DPH) rapidly developed the Responder Safety, Tracking, and Resilience (R-STAR) system based on the ERHMS™ framework. GA DPH staff registered over 100 responders who completed daily health and safety checks while deployed and who responded to a post-deployment survey about their deployment experience after they demobilized [Grippo et al. 2018]. According to a book chapter written by a previous ERHMS™ staff member [Funk 2018], feedback from participants showed that responders valued someone checking in on them during their deployment. The process also allowed supervisors to account for the health and safety of their responders. Additionally, when a responder reported an injury, GA DPH was able to quickly contact them and provide medical evaluation. By incorporating ERHMS™, the GA DPH successfully met capability 14 for responder safety and health as part of their CDC PHEP cooperative agreement [CDC 2011a, 2013].

- In 2016, NIOSH met with staff from the HHS Assistant Secretary for Preparedness and Response (ASPR) National Disaster Medical System (NDMS) [NDMS 2016] to discuss ERHMS™. The HHS NDMS Program office manages nearly 5,000 volunteer medical professionals from across the U.S. who they can activate in response to a disaster to provide medical care and services. Through their knowledge of the ERHMS™ framework and discussions with NIOSH staff, NDMS created their own pre- and post-deployment surveys for NDMS responders. NDMS utilized the pre-deployment survey found in the ERHMS™ TAD as the basis for their own pre-deployment evaluation of the medical volunteers. They reported using this tool when deploying volunteers during the Zika outbreak [Delaney 2016a].

  In September 2017, HHS ASPR staff again contacted NIOSH to discuss how ERHMS™ could be used during the post-deployment phase for all responders

demobilizing from Puerto Rico, as a result of Hurricane Maria. ASPR was concerned about the behavioral health of their personnel who deployed under the NDMS. NIOSH staff provided ASPR with an overview of ERHMS™ and several post-deployment tools, including demobilization and mental health surveys [Burrer 2017]. After this discussion, NDMS developed an ERHMS™ framework-based post-deployment survey tool for their deployers, requesting NIOSH review and feedback before finalizing the document [Burrer 2017].

OSHA Federal Advisory Committee

Beginning in 2015, EPR staff served on the Emergency Preparedness and Response Subcommittee of OSHA's National Advisory Committee on Safety and Health (NACOSH), OSHA's Federal Advisory Committee, along with other subject matter experts in occupational safety and health and emergency response. The subcommittee aimed to develop and recommend draft regulatory text for a proposed OSHA rule to protect emergency responders and skilled support workers. The subcommittee developed recommendations including draft regulatory text for a proposed rule. The subcommittee members drew from the ERHMS™ framework in developing the draft regulation. Staff provided the draft regulation to NACOSH for their consideration.

Intermediate Outcome:

- The proposed draft Emergency Responder Preparedness Program Standard includes elements of the ERHMS™ framework and proposes including ERHMS™ medical questionnaire tools as non-mandatory appendices. On December 14, 2016, NIOSH EPR presented the draft to the full NACOSH membership, and they voted unanimously to send it to OSHA for additional rulemaking action [Delaney 2016b].

Recent ERHMS™ Publications

Because of NIOSH staff teaching ERHMS™ at the CDC SoPER School, implementing it during CDC emergency activations mentioned previously, CDC National Center for Environmental Health, Environmental Health Services Branch staff asked NIOSH to publish a guest article in the November issue of the *Journal of Environmental Health* published by the National Environmental Health Association. This peer review journal,

with over 20,000 public health professional subscribers, is published 10 times per year. Table 3 contains information on this and others ERHMS publications.

Table 3. ERHMS™ publications

Article or Chapter Name	Author(s)
Utilizing the Emergency Responder Health Monitoring and Surveillance System to Prepare for and Respond to Emergencies	Shugart J, 2017
ERHMS Info Manager User Guide	Shugart et al., 2017
Applications: Emergency Responder Health Monitoring and Surveillance: Successful Application	Funk R, 2018
Assessment of Emergency Responders After a Vinyl Chloride Release from a Train Derailment—New Jersey, 2012	Harris et al., 2011
Protecting Workers in Large-Scale Emergency Responses: NIOSH Experience in the Deepwater Horizon Response	Kitt et al., 2011

In addition, a responder safety and health workgroup, including staff from NIOSH, CDC, and the Michigan Department of Community Health and participants of the Career Epidemiology Field Officer program created a Responder Safety and Health Plan Template [Goode 2016] that can be used by state and local health departments to implement the ERHMS™ framework. The document is largely based off concepts in the ERHMS™ framework. NIOSH staff is planning on publishing this template in 2018.

End Outcomes

The impact of EHRMS™ is a culture of health and safety for both the responders and the supervisors, enabling them to do their jobs more effectively. A number of health departments and response organizations adopted elements of the ERHMS™ framework into their deployment health and safety programs. EHRMS™ also helped CDC to prioritize the health and safety of responders during the Ebola response, ensuring the agency met the needs of the responders, enabling staff to evaluate responders after deployment to ensure their well-being. The success of the Ebola case study strengthened the need for CDC to keep the Office of Risk Management and Operational Integrity (previously named DRMU) intact and use the same framework for the 2016 Zika response and the 2017 hurricane responses.

Literature well documents the concepts and recommended activities (e.g., hazard assessment, pre-exposure assessment, surveillance, monitoring, and post-exposure assessment) within the ERHMS™ framework as the cornerstones of effective approaches in reducing illnesses and injuries in any workforce. The ERHMS™ framework provides a structure that takes a systematic, crosscutting approach as they apply to emergency response and recovery workers pre-, during, and post-deployment activities. This approach connects events previously done in silos, so the collection and sharing of data across all phases of deployment increases access to needed information for critical decision making in every phase, including implementing timely necessary hazard controls (e.g., PPE). In addition, the trainings NIOSH EPR Program conducts provide state, local, tribal, and territorial public health organizations and other response and recovery agencies and organizations with the tools necessary to improve their approach and adopt best practices to response and recovery worker health and safety in future incidents.

Alternative Explanations

While the evidence presented here demonstrates NIOSH's positive effect on responder safety and health through its unique contributions, other organizations have also implemented programs to prepare responders, developed training and other communications materials, and taken actions to protect responders throughout a response.

For example, many organizations, especially larger ones, have tools and programs in place to protect their emergency responders during an event. Specifically, for the pre-deployment phase, the USCG has a medical manual that outlines a well-established comprehensive evaluation of responders before deployment. The National Fire Protection Association (NFPA) has a standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2018], and the American Red Cross has a health status record form requirement for all volunteers before their deployment. During the deployment phase of a response, there are many resources available from OSHA on how to protect responders from specific hazards and select the appropriate PPE. The NRT developed a Fatigue Management Risk Assessment Tool [NRT 2009] and the American Industrial Hygiene Association (AIHA) created an Incident Safety and Health Management Handbook, both of which can be used during operations. During the post-

deployment phase, the DHS uses health-screening questionnaires for their deployed staff. Other tools assess the behavioral health and emotional well-being of responders after a response: the Kessler Psychological Distress Scale (K-6) or (K-10), the Behavioral Risk Factor Surveillance System, the Perceived Stress Scale, the CAGE – AID, and the PsySTART.

NIOSH incorporates all of the above tools into the ERHMS™ NRT TAD main reference document to promote to the responder community. NIOSH plans that by continuing to work with all of our stakeholders, together we will prioritize the health and safety of responders and promote their well-being during all phases of a response.

Future Plans

EPRO plans to collect additional information from previous trainees and others who collaborated on ERHMS™ to provide additional case studies and examples from ERHMS™ framework and ERHMS Info Manager™ results in the field. NIOSH plans to contact the state health departments and volunteer organizations that received NIOSH ERHMS™ training, and other partners that helped with software development, to see how they implement ERHMS™ concepts. This will ensure the relevance and clarity of case studies and ERHMS™ training models so that ERHMS™ can continue successful implementation before, during, and after future responses.

NIOSH plans to collaborate again with ATSDR's ACE program to develop a joint training curriculum for FEMA's Center for Domestic Preparedness (CDP) located in Anniston, Alabama. The CDP identifies, develops, tests, and delivers training to state, local, and tribal emergency response providers. They provide on-site and mobile training at the performance, management, and planning levels. This new joint training curriculum will integrate the ERHMS™ framework with other CDC courses, including ATSDR's ACE and Rapid Responder Registry (RRR) [ATSDR, 2018b], and CPD will offer the training free to state, local, and tribal emergency response providers. As of December 2017, work began in developing the course with CDP. Currently, CDP tentatively scheduled an internal pilot of the course at CDC in the summer of 2018 to review content and concepts. CDP scheduled another pilot in Anniston, Alabama where NIOSH will train instructors to teach the ERHMS course in the fall of 2018.

NIOSH received numerous requests for training on the ERHMS Info Manager™ software, so we are developing a half-day course to add to the current ERHMS™ framework course. NIOSH also plans to continue promoting the ERHMS Info Manager™ software to organizations that can benefit from this framework. NIOSH is working to identify future funding to maintain the ERHMS Info Manager™ software, including releasing future versions of the tool.

Building off the success of the CDC PHEP model, NIOSH also plans to reach out to the ASPR Hospital Preparedness Program (HPP) in 2018 to identify ways ERHMS™ can be implemented by HPP grant recipients throughout the U.S.

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Chapter 3: NIOSH Efforts to Increase Anthrax Preparedness and Response Capabilities

NIOSH staff prepare to enter hot zone during an internal exercise in 2010. [Photo credit: NIOSH]

Introduction

Anthrax is an acute infectious disease caused by the spore-forming bacterium *Bacillus anthracis* (*B. anthracis*). These spores are highly infective and can cause inhalation, cutaneous, or gastrointestinal anthrax depending on the route of transmission. The mortality rate varies based on the form of the disease and if the patient receives treatment. Inhalation anthrax results from breathing in spores. It is of great concern due to its high fatality rate**:** 45% with treatment and 85–90% without treatment. Cutaneous anthrax occurs when spores contact the skin, usually through cuts or abrasions; most survive with treatment, but without treatment, 20% of cases are fatal. Gastrointestinal anthrax results from eating uncooked meat of animals infected with anthrax; fatality rates are 40% with treatment and over 50% without treatment [CDC 2014a].

Data related to dose-response relationships are limited, preventing experts from estimating the risk of exposure and subsequent risk of disease from environmental

sampling results. Currently, there are no established occupational exposure limits for *B. anthracis* [CDC 2014a]. Person-to-person transmission of the disease is rare. Anthrax infections occur naturally in wild and unvaccinated domestic animals in many countries including the United States (U.S.). Employees exposed to infected animals, meat, or animal products (such as wool or hides) face the risk of *B. anthracis* infection [CDC 2015].

B. anthracis is a known biological threat agent. Beginning in the 20th century, many nations conducted research to weaponize the bacteria as part of their offensive bioweapons program [CDC 2014b]. It is widely considered one of the most likely biological agents to be used in a future bioterrorist attacks. The Centers for Disease Control and Prevention (CDC) and U.S. Department of Agriculture (USDA) designate anthrax as a Tier 1 Select Agent and regulate the possession, use, and transfer of the bacteria [CDC/USDA 2017]. Tier 1 biological agents and toxins present the greatest risk of deliberate misuse with significant potential for mass casualties or devastating effects to the economy, critical infrastructure, or public confidence, and pose a severe threat to the public's health and safety [CDC 2014b].

B. anthracis is an attractive bioweapon due in part to the bacteria's high pathogenicity in humans, its ability to be released with no one knowing, and its environmental persistence. The active bacteria can form a dormant endospore when in a nutrient deficient environment [Zubay 2005]. When in this form, the spore is highly resistant to temperature, humidity, radiation, and disinfectants. Spores can remain dormant for decades and when conditions are suitable, can easily germinate into the active bacterial form again. Emergency response workers, including law enforcement, public health officials, environmental sampling teams, laboratory staff, and healthcare workers are also at risk of *B. anthracis* exposure during an anthrax bioterrorism attack.

Shortly after the September 11, 2001 attacks on the World Trade Center and Pentagon, letters filled with a white powder containing *B. anthracis* spores were mailed to two U.S. Senators' offices and news media agencies in the Northeast and Florida [Hsu et al. 2002; Jernigan et al. 2002; Traeger et al. 2002]. Authorities recovered four letters associated with this incident and confirmed the presence of the powder form of *B. anthracis*. These spores aerosolized into the surrounding air, subsequently, allowing workers to inhale the spores and contaminating the postal facilities where they were processed as well as the

buildings where they were opened. Overall, 43 people tested positive for *B. anthracis* exposure, and health officials considered approximately 10,000 more at risk of possible exposure to the anthrax spores [CDC 2016]. Ultimately, public health departments confirmed 22 cases of anthrax and 5 deaths [CDC 2001b].

Postal workers who handled the letters or worked in a postal facility where the letters were processed accounted for seven of these cases and two of the deaths. Two cases worked at the AMI Publishing Company where contamination was found in the building. The last two cases were the hardest to determine the source of exposure: a Connecticut resident and a New York City hospital employee. Investigators thought that the Connecticut resident's mail might have been cross-contaminated in a mail facility; however, no anthrax spores were ever found in her home [Teshale et al. 2002]. The exposure source of the New York City hospital employee is still unknown. Prior to this attack, there had never been an intentional release of *B. anthracis* in the U.S.; the last case of inhalation anthrax in the U.S. was reported in 1976.

During the 2001 anthrax event, NIOSH was on the forefront of the nation's response. NIOSH worked with CDC, U.S. Postal Service, Environmental Protection Agency (EPA), Federal Bureau of Investigation (FBI), and state and local health departments to determine the source of the attacks, identify contaminated facilities, determine when it was safe to reoccupy facilities, and minimize risk of exposure to workers. A critical step in the initial stages of the response was for staff to determine those potentially exposed to anthrax spores to ensure they received medical countermeasures like vaccinations and antimicrobial medications. Environmental sampling was conducted to identify locations that were contaminated which informs who may have been exposed, possible future exposures, and areas in need of environmental decontamination. NIOSH staff were also part of the response team that conducted environmental evaluations, taking samples of the affected facilities, including the U.S. Postal Facilities where the mail was processed and the companies where the mail was opened.

Since the 2001 anthrax event, considerable resources from across the federal government have been invested to incorporate the lessons learned and address knowledge gaps identified during the event to help the nation better prepare for potential future events. NIOSH activities described in this chapter support the following EPR Strategic Goals:

- Strategic Goal 1: Enhance the health, safety, and resilience of emergency responders by improving the organization of emergency response work.

- Strategic Goal 2: Enhance the health and safety of emergency responders by improving proper selection and use of PPE to reduce responder's hazardous exposures to chemical, biological, radioactive, and nuclear (CBRN)] agents, industrial compounds, and other materials.

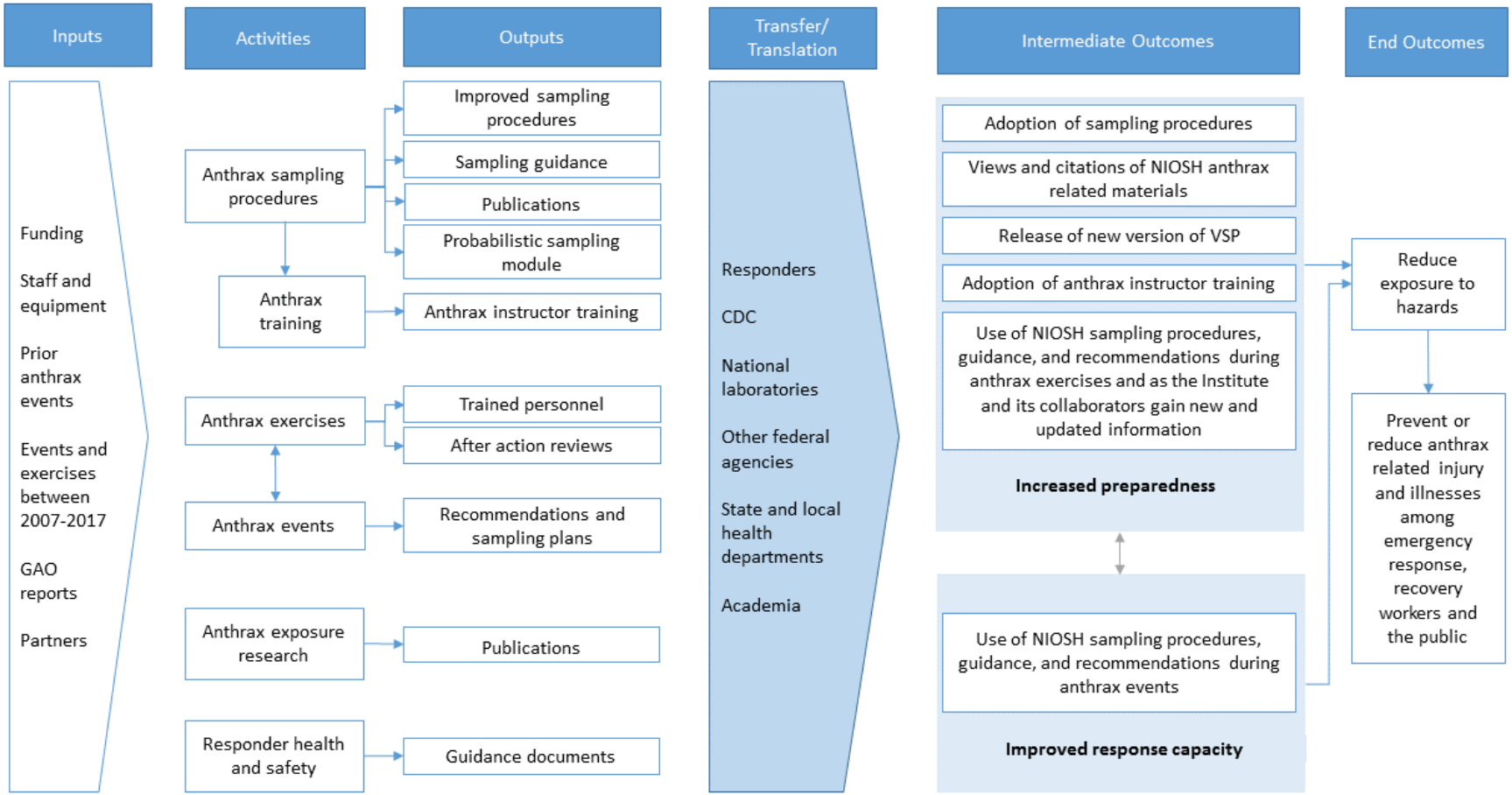
- Strategic Goal 4: Enhance the health and safety of emergency responders through improved rapid methods for evaluating spatial and temporal distribution of hazardous agents in the air and on surfaces.

- Strategic Goal 7: Enhance the health and safety of emergency responders by improving detection, risk assessment, and control of biological threat agents.

Logic Model

Figure 11 is a logic model that illustrates key relationships characterizing how the EPR Program contributes to anthrax preparedness and response as it applies to occupational safety and health (OSH). Dotted lines indicate anticipated pathways while solid lines show established pathways. Further information about the elements of the logic model—Inputs, Activities, Outputs, Transfer and Translation, Intermediate Outcomes, and End Outcomes—follow in detail in the next sections.

Figure 11. Logic Model for NIOSH Anthrax Preparedness and Response Efforts, 2007–2017.



Inputs

NIOSH efforts to increase anthrax preparedness and response capabilities have benefited from a range of inputs from external stakeholders as well as responding to bioterrorism and naturally occurring events. The examples of external input provided next are only a sample of NIOSH's engagement with stakeholders.

Staff and Equipment

NIOSH maintains a small cadre of staff capable of responding to biological events. These staff are located across the Institute and have broad OSH backgrounds. Industrial hygienists and physicians primarily work in the Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS), Hazard Evaluation and Technical Assistance Branch (HETAB); engineers primarily work in the Division of Applied Research and Technology (DART), Engineering and Physical Hazards Branch—both located in Cincinnati, Ohio.

These branches routinely conduct fieldwork, and staff have extensive experience in evaluating occupational hazards and providing recommendations to minimize injury and illness in the workplace. Staff maintain their Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response standard training, complete annual deployment medical and respirator clearance, and receive extensive training in a number of vital areas: proper personal protective equipment (PPE), sample collection methods, sample plan development, building ventilation, particle science, and hazardous goods shipment. NIOSH offers these staff the anthrax vaccination, but participation is optional.

In order to support staff who face possible deployment, the Hazard Evaluation and Technical Assistance Branch maintains the necessary specialized PPE and sampling equipment needed to conduct limited environmental sampling and provide technical assistance in the field. To facilitate a timely response, responders are provided an easily transportable, one-day supply of PPE and sampling equipment at the time of deployment. Additional supplies can be shipped to the field overnight or taken to the scene in NIOSH's Field Emergency Response Vehicle (FERV) (Figure 12). The FERV measures about 51 feet long. Its configuration allows it to serve as a mobile office and

industrial hygiene laboratory to facilitate coordination at the scene and support responder donning of PPE, sample preparation, and team briefings.

Figure 12. NIOSH Field Evaluation and Response Vehicle (FERV). [Photo credit: NIOSH]

Prior Anthrax Events

2001 Anthrax Event

There were many gaps in our understanding on how to respond to an intentional release of *B. anthracis*, including the potential for exposure in the workforce, spore dispersion patterns, sampling methods, use of PPE, decontamination methods, and occupational exposure and clearance criteria limits. NIOSH relied on its industrial hygiene and engineering expertise to guide the response during the 2001 anthrax event, which included previous experience with sampling for microbial agents in the workplace and research on exposure controls.

NIOSH played a critical role in conducting environmental sampling to help identify areas of contamination. NIOSH investigators used a targeted sampling approach to collect samples in locations with the greatest likelihood of being contaminated based on the investigator's professional judgment. Between October 5 and December 25, 2001, staff

collected over 9,500 samples in areas across the U.S. suspected of anthrax contamination including multiple locations in Washington, D.C., New York, New Jersey, Florida, and Missouri. The sampling devices used to collect the samples included dry and wet wipes, dry and wet swabs, vacuum sock, 37-mm cassettes, and impactors.

Shortly after involvement in the 2001 anthrax event, NIOSH, as part of the overall CDC response, quickly developed several documents with recommendations. One document NIOSH developed for sampling teams involved in the response: Procedures for Collecting Environmental Samples for Culturing *Bacillus anthracis*. At the time, no standard methods for collecting these types of environmental samples existed. Staff drew from NIOSH's 20-year history of sampling and analytical method development while incorporating response needs to develop the collection procedures and methodologies. During the 2001 anthrax event, NIOSH researchers conducted preliminary studies in the contaminated facilities to compare sampling methodologies and assess re-aerosolization of spores in the work environment [Sanderson et al. 2004; NIOSH 2004]. NIOSH also issued recommendations for protecting workers from *B. anthracis* exposure including PPE for environmental sampling teams and general OSH practices for workers who handle or process mail [CDC 2001a]. NIOSH updated the sampling procedures and recommendations developed as part of the 2001 anthrax event; these are described later in this chapter.

The NIOSH guidance documents created in response to the 2001 anthrax event led to future foundational studies and guidance documents that helped close knowledge gaps around occupational exposures to *B. anthracis.* NIOSH published several reports with recommendations in the highly read *Morbidity and Mortality Weekly Report* (MMWR):

- Notice to Readers: Protecting Building Environments from Airborne Chemical, Biologic, or Radiologic Attacks
- Notice to Readers: Interim Recommendations for Protecting Workers from Exposure to *Bacillus anthracis* in Work Sites in which Mail is Handled or Processed

2006—New York Drum Maker Diagnosed with Inhalation Anthrax

In 2006, a drum maker from New York City became ill after making native drums using goatskins he had recently purchased and brought back from Africa. He reported not taking protective measures like chemically treating the hides or wearing PPE when making the drums. The public health investigation determined that when the man scraped the hair from the goatskins, he released anthrax spores into the air that he then inhaled. This was the first case of naturally acquired anthrax reported in the U.S. in 30 years.

Figure 13. NIOSH Responder sampling drum head as part of the 2006 New York anthrax response. [Photo credit: NIOSH]

As part of the public health investigation, staff conducted environmental sampling (Figure 13) to confirm the hypothesis that the primary source of exposure to aerosolized *B. anthracis* spores occurred in the workspace and to determine whether the patient's home, a contact's home, or van were contaminated.

NIOSH deployed a team who collaborated with the FBI, New York City Department of Hygiene and Mental Health (NYC DOHMH), and Fire Department of New York (FDNY) to collect environmental samples in four separate locations; these confirmed the presence of contamination in the patient's workplace, home, and van. Environmental and epidemiologic findings suggested that the patient's primary exposure to aerosolized *B.*

anthracis spores resulted from scraping a contaminated hide in his workspace; he then cross-contaminated other areas he visited. These results helped inform future decisions about the need and methods for decontamination to further protect public health.

This was the first inhalation case and the first time the FBI, CDC, and NIOSH responded jointly to a biological event since 2001. While the groups had previously collaborated, it was apparent that the agencies needed additional work to become more familiar with and understand the different, yet complementary, roles and actions of each agency. During this response, NIOSH collected samples in a way that the Laboratory Response Network (LRN), an integrated network of laboratories that can respond to bioterrorism and other public health emergencies, could analyze following the evaluated analytical method. FDNY did not have training, experience, or the necessary equipment to support collecting samples on their own, so they provided decontamination support for the sampling teams.

Following the public health investigation, the EPA conducted their own sampling to further define the extent of contamination and determine the appropriate methods to decontaminate the various areas. The New York City Department of Hygiene and Mental Health, in consultation with the CDC, NIOSH, and EPA, determined the final clearance requirements for the locations.

Events and Exercises between 2007 and 2017

Between 2007 and 2017, NIOSH responded to six additional anthrax responses and participated in five anthrax exercises. These responses and exercises played an important role in increasing NIOSH's anthrax preparedness and response capabilities. Lessons learned, partnerships formed, and knowledge gained through these events informed future response actions and preparedness activities, discussed in more detail later in this chapter.

Government Accounting Office Reports

The 2005 Government Accounting Office (GAO) report, ANTHRAX DETECTION: Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results, assessed federal agencies' activities to detect *B. anthracis* contamination in postal facilities during the 2001 anthrax event. GAO identified a lack of fully evaluated methods

for anthrax sampling, making it difficult to interpret negative results and leading to challenges in providing a known level of confidence in detecting contamination in facilities. Specifically, when sampling resulted in non-detect results (samples with results below the level of detection for the method), it was challenging to know if it was because anthrax was not present, whether it was present but below the analytical limits of detection, or if it were present but not in locations sampled by the investigator.

GAO recommended that the Department of Homeland Security (DHS) coordinate federal agencies to work together to improve anthrax response capabilities. The GAO recommended developing approaches for selecting sampling locations that include probability-based sampling and fully validated sampling methods to improve confidence in results. A probability-based sampling approach applies statistical sampling theory and involves a randomized selection of sampling locations. Previously, for public health response purposes, NIOSH and other investigators used a targeted approach that calls for collecting samples in locations with the greatest likelihood of contamination based on the investigator's professional judgment and knowledge of the event.

In 2012, GAO completed a follow-up investigation to determine the implementation status of its recommendations from the 2005 report, publishing the report: ANTHRAX: DHS Faces Challenges in Validating Methods for Sample Collection and Analysis. In this report, GAO recommended additional validation of collection methods. They also recommended the Department of Health and Human Services (HHS) support DHS in achieving a "mutually acceptable statistically-based sampling approach."

Partners

An important aspect of NIOSH efforts to protect workers from anthrax include interactions with other parts of CDC. NIOSH works closely with laboratory subject matter experts, epidemiologists, and emergency management staff within CDC to prepare for and respond to anthrax events. Additionally, NIOSH collaborates with state and local health departments and other federal agencies, including the EPA, FBI, Department of Energy national laboratories, and DHS on method development and refinement, OSH guidance, response protocols, preparedness exercises, and clearance practices.

Activities, Outputs, Transfer and Translation, and Intermediate Outcomes

NIOSH's role in providing support to anthrax events evolved over time. As described previously, NIOSH brought great knowledge and expertise to the 2001 anthrax event. NIOSH successfully identified the contamination when others could not and provided vital recommendations to protect workers. Often, NIOSH work supported other agencies with sample collection; at times, NIOSH did not have access to all of the sample results, limiting the ability to draw conclusions and provide informed guidance. Since the 2001 event, NIOSH conducted a range of activities related to anthrax preparedness and response including conducting research and reviewing statistical methods to develop sample collection procedures, developing health and safety guidance for responders, responding to anthrax events, training response personnel, and exercising with partners. These activities have helped NIOSH refine its role into one of technical assistance and support rather than sample collectors for other agencies. Furthermore, NIOSH built strong relationships with key response partners, so coordination and access to data improved.

Sampling Procedures

Nonporous Surfaces

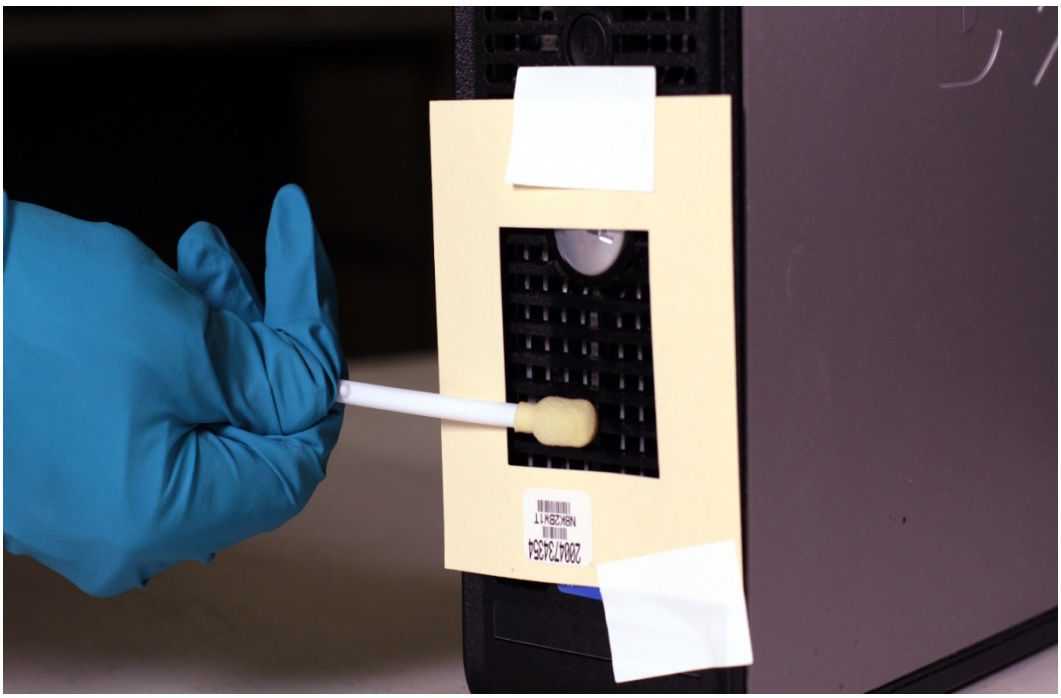
Based on the 2005 GAO report and an identified need to support future events, CDC and NIOSH began to evaluate methods used to collect and analyze samples. CDC and NIOSH intended the new procedures to replace the previous field collection procedures developed ad hoc during the 2001 anthrax event. NIOSH wrote step-by-step sample collection procedures, Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces, on how to collect and package *B. anthracis* samples. Researchers made certain to ensure the collection procedures met the needs of fieldwork (e.g., easy to use while wearing PPE). The intended audience was first responders and sampling teams expected to collect samples during a potential anthrax event.

NIOSH collaborated with the CDC's Division of Healthcare Quality and Promotion that developed the analytical methods to ensure consistency between the field collection and laboratory processing procedures. NIOSH first published the collection procedures in

January 2010, with a revision in April 2012. The sample collection procedures use macrofoam swabs, cellulous sponges, and gauze wipes for collecting on various surface areas from 4 square inches to as large as 144 square inches (Figures 14 and 15). The standardized collection procedures and complementary analytical methods allow responders and researchers to compare results within and across events, supporting scientific study. The collection procedures and analytical methods were evaluated by CDC to provide an understanding of the overall limit of detection, which were not available in the 2001 anthrax event.

Figure 14. Example of a cellulose sponge for collecting a *B. anthracis* sample. [Photo credit: NIOSH]

Figure 15. Example of a macrofoam swab for collecting a *B. anthracis* sample. [Photo credit: NIOSH]



Intermediate Outcomes:

- The evaluated sample collection procedures and analytical methods now serve as the gold standard for collecting and analyzing *B. anthracis* samples during a public health emergency, in environmental laboratories, and conducting field studies. The use of the sample collection procedures helped build national resilience against biological attacks in terms of confidently identifying contaminated areas, evaluating decontamination technologies at the operational level, and as a collaborative interagency response and recovery effort. The Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces document has been viewed 11,881 times between July 2010 and March 2018. In addition to these sampling procedures being used in exercises and anthrax responses (described later in the chapter), other researchers used these procedures in their studies:

    - Researchers from Sandia National Laboratory completed a study of the NIOSH sponge-wipe sample collection procedures to evaluate the effects of low contaminant concentrations and surface materials on recovery

efficiency, false negative rate, limit of detection, and the uncertainties of these quantities [Piepel et al. 2011, SNL 2011].

- EPA researchers used the NIOSH collection procedures in a study evaluating the effects of decontaminant residue on the viability of spores when collected following decontamination [Calfee et al. 2013].
- EPA researchers used the NIOSH collection procedures to evaluate collection efficiencies when sampling multiple surfaces using the same sponge sampler. This sampling method reduces time and resource burdens associated with collecting processing multiple samples [Tufts et al. 2014].
- The Pentagon Force Protection Agency deliberately released a *B. anthracis* surrogate into the outdoor environmental to test the agency's bio-response protocols. The researchers followed the NIOSH sample collection procedures to collect environmental samples as part of the study [Garza et al. 2014].

❖ Other organizations in related fields such as criminal justice and environmental science incorporated the collection procedures into their documents:

- The Biological Evidence Preservation Handbook: Best Practice for Evidence Handlers, a guide produced by the Office of Law Enforcement Standardization, National Institute of Standards and Technology and National Institute of Justice.
- Manual of Environmental Microbiology, Fourth Edition, published by the American Society for Microbiology.

Porous Surfaces

Driven by the 2005 GAO report, and following the development of sample collection procedures and analytical methods for smooth, nonporous surfaces, CDC, NIOSH, and EPA sought to develop a sample collection procedure and corresponding analytical method for porous surfaces. Historically, NIOSH and other response organizations used vacuum socks to collect samples from porous surfaces; this was the preferred collection procedure. In 2011, the CDC LRN Program Office and EPA raised concerns about that

method based on observations during Phase 1 of a field exercise called the Bio-Response Operational Testing and Evaluation or BOTE Project [Weber 2011], discussed later in this chapter. Lab workers observed holes in the vacuum sock seams related to quality control issues during manufacturing. Additionally, in the first phase of the BOTE exercise, responders did not ship the vacuum socks, containing the sample, securely. Both conditions resulted in a potential for sample material exposure during laboratory processing through leaking seams and exposure risk when opening and processing the samples in the receiving laboratory.

NIOSH took immediate actions to address these concerns. First, NIOSH developed the Guidance on packaging and shipping vacuum socks used for the collection of *Bacillus anthracis* samples as a stopgap measure. This guidance addressed sample integrity during shipping to help reduce the receiving lab workers' risk of exposure. NIOSH shared the guidance with EPA prior to Phase 2 of the BOTE exercise.

In 2014, NIOSH collaborated with CDC's Division of Healthcare Quality and Promotion, LRN Program Office, and EPA on the development of a new *B. anthracis* procedure for sampling porous surfaces. Relying on historical methods for collecting microbiological (mold) and other chemical contaminates (lead) from porous surfaces, NIOSH assisted the lab staff in identifying a suitable replacement-sampling device for the vacuum socks. NIOSH worked with other CDC experts to develop a collection procedure that met the needs of fieldwork while being a suitable method for the receiving laboratory to reduce potential exposure. The new sampling procedure they developed uses a 37-mm closed face-sampling cassette, a small housing that holds a filter.

Intermediate Outcomes:

- While not a permanent solution to all of the concerns related to porous sampling using the vacuum sock, EPA began following the new packaging protocols written by NIOSH during Phase 2 of the BOTE Project. The laboratories reported the process for receiving and opening the vacuum socks was "much improved" during Phase 2 of the exercise when EPA followed the new packaging protocols [Delaney 2011]. The laboratory reported far fewer problems with receiving leaking samples; they also reported the samples as much safer to handle and process.

- In 2016, the LRN adopted the new 37-mm cassette as an LRN accepted sample type. LRN no longer accepts the vacuum sock device for processing [Delaney 2016].

- The EPA recently used the new 37-mm cassette collection procedure during the 2016 Underground Transportation Restoration (UTR) Project, a full-scale demonstration evaluating various decontamination methods in a mock subway system. Through on-site participation in the exercise, NIOSH gained valuable feedback from the sampling teams using the collection procedure in the field and identified areas for future improvement [EPA 2017b].

Environmental Sampling Research

In an effort to address concerns raised in the GAO reports, NIOSH researchers conducted studies designed to help narrow the identified response gaps and improve environmental sampling methods as well as the understanding of the performance characteristics of those methods.

NIOSH evaluated the performance of the surface sampling methods for *B. anthracis*, published by NIOSH during the 2001 anthrax event, at very low surface concentrations to improve knowledge on sampling performance [Estill et al. 2009]. Through this evaluation, researchers estimated sampling limits of detection, recovery efficiency, and measurement precision for three sampling methods (swap, wipe, and vacuum sock) used in the 2001 anthrax event. In addition, the research team assessed inter-laboratory variability by comparing sample results analyzed at three laboratories [Estill et al. 2009]. In a separate study, Estill et al. compared air-sampling methods using various collection devices, including Andersen samplers, polytetrafluoroethylene membrane filters, and gelatin filters, at low airborne concentrations of a surrogate *B. anthracis* spore [Estill et al. 2011]. This study resulted in the ability to compare the three methods, determine recovery efficiencies, and estimate limits of detection.

Intermediate Outcome:

- ❖ NIOSH's work to characterize the performance of both current gold standard anthrax collection procedures, commonly used procedures in the 2001 response, and new collection devices helped guide investigators to conduct improved environmental sampling, quantify contamination levels, and conduct risk assessments. This initial research led to additional work by numerous researchers outside NIOSH to further expand our understanding and advance our ability to interpret sampling results [Estill et al. 2009]. According to Google Scholar, as of April 2018, the 2009 Estill et al. article received 49 citations by individuals in nine countries.

In 2005 and 2006, NIOSH conducted foundational research to determine the physical collection efficiency of commercially available filters for collecting airborne bacteria, viruses, and other particles in the nanometer size range [Burton et al. 2006]. While filter sampling appears to be a promising method for the sampling of bacteria, there is a lack of information on the collection characteristics of commonly used filters for bioaerosol sampling for smaller particles. This study used a *B. anthracis* surrogate to represent bacterial sampling. Burton et al. identified polytetrafluoroethylene and polycarbonate filters as promising for collecting bacteria. This information supported later research by CDC and other researchers outside NIOSH pursuing the development of air-sampling methods.

Intermediate Outcome:

- ❖ In 2006, after the LRN phased out the vacuum sock filter sampler, NIOSH research helped inform CDC during the development of the *B. anthracis* porous surface sample-collection procedure and corresponding analytical laboratory method. Specifically, this research supported selecting the filter for the sampling device (37-mm cassette) [Burton et al. 2006]. According to Google Scholar, as of April 2018, the 2006 Burton et al. article received 84 citations

Statistical Methods and Software

In response to the 2005 GAO report calling for probabilistic sampling options (i.e., selecting random sampling locations) to supplement targeted sampling in determining if contamination is present, NIOSH partnered with the Department of Energy's Pacific

Northwest National Laboratory (PNNL) to develop a probabilistic sampling module. The intent was to add this probabilistic sampling module to an existing PNNL sampling support software tool for responders called Visual Sample Plan. The NIOSH-PNNL inter-agency agreement resulted in the development of Bayesian statistical modeling approaches. These approaches allow investigators to determine the number and location of probabilistic samples required to obtain a given level of confidence that no detectable contamination is present, when targeted samples previously taken in an area are negative.

PNNL and NIOSH researchers published this work: An Environmental Sampling Model for Combining Judgment and Randomly Placed Samples and Acceptance Sampling Using Judgmental and Randomly Selected Samples.

NIOSH evaluated the Visual Sample Plan probabilistic sampling module in the 2010 NIOSH internal exercise, explained in the Exercise section.

Intermediate Outcomes:

- In June 2010, PNNL released a new version of Visual Sample Plan (version 6.0 at that time). This included the probabilistic sampling module [PNNL 2015].

Anthrax Training

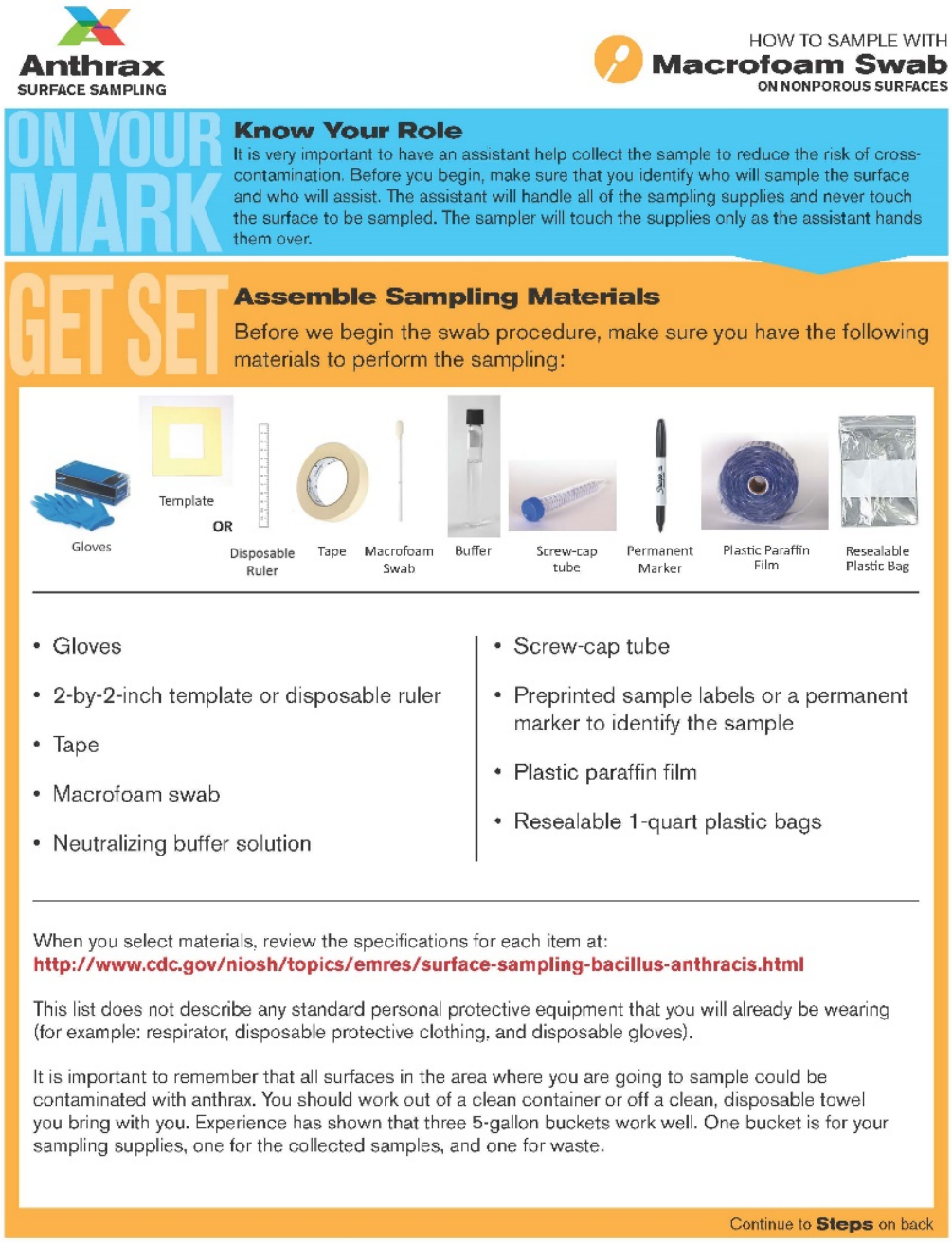
Most local jurisdictions such as hazardous materials (HAZMAT) teams or state health departments do not train on *B. anthracis* sample collection given that it has a low probability of occurring. NIOSH also is not able to deploy staff to all events in order to collect samples for *B. anthracis,* as was the case in the Minnesota inhalation anthrax case in 2011 described later in the chapter. NIOSH also received requests for training on how to collect samples from the Georgia Department of Public Health, Georgia Civil Support Team, and EPA. In response to these requests, NIOSH developed the Anthrax: Instructor Training in 2014. Figure 16 shows a screen shot of the instructional video.

The training is a collection of train-the-trainer resources to teach responders how to collect, decontaminate, and ship samples. Sampling procedures taught in the training follow the Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces document. The instructor training includes a trainer's guide, lecture slides, instructional videos, and handouts. The instructor can use the handouts (an

example is shown in Figure 17) to supplement the training and responders can use the handouts to assist them when collecting samples. In addition, the instructor training includes directions for a hands-on exercise where the instructor or an experienced sampler can observe and coach participants as they practice collecting samples. The total training time is approximately 3 hours 45 minutes. The instructor training is available on the NIOSH website free of charge.

Figure 16. Screen shot of instructional video showing how to sample with macrofoam swab.

Figure 17. Example handout showing how to sample with macrofoam swab.



Through this just-in-time training, NIOSH wants to expand the number of responders who can collect samples when an event occurs. In large metropolitan areas with more robust bioterrorism preparedness programs, this training can be included as a routine training.

In the state of Georgia, select first responders working at fire departments receive training on white powder response and environmental sampling for *B. anthracis*. Georgia uses this program to expand the number of first responders who can respond to events, ensuring that they follow proper procedures with sample collection, supporting both public safety and public health decision making. In order to raise awareness of the Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces document, NIOSH helped develop and deliver the initial three Georgia Suspicious Substance Response Trainings, incorporating our instructor training.

The DHS BioWatch Program is a national program that utilizes air monitoring to quickly identify a biological attacki. Following the detection of a biological threat from a BioWatch sampler, the first phase of the response calls for first response teams to conduct an environmental assessment called Phase I sampling. Phase I sampling includes pre-identified locations around the BioWatch collector. This sampling is critical because it can confirm the initial detector results and help determine if an actual release has happened. The DHS BioWatch Environmental Assessment Team, within the BioWatch Program, coordinates environmental assessment activities across the program and provides guidance, training, and materials to local jurisdictions on how to conduct Phase I sampling.

Intermediate Outcomes:

- Trainers at the Georgia Department of Public Health utilized the NIOSH developed training tool kit to prepare first responders for potential white powder and anthrax events. To date, this program has trained representative from all Georgia Tier 1 and 2 HazMat teams [Delaney 2018b].

- The BioWatch Environmental Assessment Team incorporated the Anthrax Instructor Training into their jurisdictional environmental assessment course for Phase I sampling resulting in numerous response organizations following NIOSH collection procedures [Delaney 2014]. As of March 2017, the BioWatch program trained more than 17 of their 30 BioWatch jurisdictions representing over 800 participants from six different public health disciplines [DHS 2017c; Dowell 2017].

- The National Strategic Research Institute at the University of Nebraska conducts research and develops strategies to combat weapons of mass destruction to support Department of Defense (DoD) operations and national security. It offers domestic and international CBRN training. As part of the National Strategic Research Institute All Hazards Response Training program, they have incorporated NIOSH sampling training materials into their courses [Delaney 2018b; National Strategic Research Institute, no date].

- The main page for the NIOSH developed Anthrax: Instructor Training has been viewed 1,130 times between April 2015 and March 2018.

In 2015, the FBI requested that NIOSH participate in the Bioincident Response Investigation Training and Evaluation workshop, a collaboration between DHS, FBI, and CDC, to train Malaysian law enforcement and public health professionals who play an active role in joint criminal and epidemiological investigations. Course attendees included representatives from the Royal Malaysian Police, the Ministry of Health Malaysia, the Malaysia Ministry of Agriculture and agro-based industry, the Malaysia Ministry of Defense, the Malaysia Fire and Rescue Department, the Malaysia National Security Council, and the Malaysia National Disaster Management Agency.

With the goal to familiarize participants with the structures, resources, and procedures needed to respond to bioincidents, NIOSH conducted training for collecting *B. anthracis* samples using NIOSH collection procedures. At a second train-the-trainer workshop in 2017, attendees learned how to respond to a bioincident. These participants will then train additional law enforcement officials and public health professionals throughout Malaysia as they develop their joint criminal-epidemiological investigation program.

Exercises

Over the last 10 years, NIOSH has participated in a number of exercises related to *B. anthracis* preparedness and response. Participation in these exercises allowed NIOSH to train staff to respond to a bioterrorism event, refine its response capabilities, conduct research, and disseminate NIOSH recommendations and knowledge to other organizations. Key exercises have included the 2010 NIOSH internal exercise, DHS's BOTE Project, Dark Zephyr, CDC's Anthrax Laboratory Surge Exercise, and DHS's UTR Project, each described next.

2010—NIOSH Internal Exercise

NIOSH recognized that staff changes and waning firsthand experience responding to earlier anthrax events limited the pool of experienced responders within the Institute. When researchers working on the Visual Sampling Plan software project (described earlier in this chapter) needed assistance evaluating the probabilistic sampling module in the field, NIOSH saw an opportunity to broaden the scope of the activity to include a full-scale exercise, providing hands-on sample collection training to new staff.

Figure 18. NIOSH Staff member collects a surface sample for *B. anthracis* during the 2010 NIOSH internal exercise. [Photo credit: NIOSH]

In December 2010, experienced NIOSH investigators from three divisions, DSHEFS, DART, and Education and Information Division (EID), and two offices, Office of Administrative and Management Services (OAMS) and Emergency Preparedness and Response Office (EPRO), evaluated the newly developed Visual Sampling Plan probabilistic sampling module in a field setting as part of an emergency response training exercise (Figure 18). The objectives of the exercise were to assess NIOSH responders' ability to use the Visual Sampling Plan probabilistic sampling module, determine the tools and information

needed to execute the software, and train NIOSH staff on common response tasks such as donning and doffing PPE, sample plan development, sample collection, personnel and sample decontamination, and public relations.

This exercise informed how NIOSH would respond to future anthrax-sampling efforts and demonstrated the burden on the response system because of the vast number of samples required for statistical sampling. NIOSH documented the results of the 2010 exercise in the internal document, *Visual Sampling Plan/Hazardous Waste Operations and Emergency Response Exercise: A Report Highlighting the After-Action Review* [Ramsey and Evans 2011]. NIOSH found value in using the Visual Sampling Plan software when investigators believe contamination is present, but results from initial sampling that used targeted sampling were not detectable. While recognizing the utility of this module for special circumstances, NIOSH concluded that this module would not be practical during initial public health investigations due to the resources and time required to execute this type of sampling approach. Because of this conclusion, HHS, with CDC and NIOSH input, later non-concurred with GAO recommendations in the 2012 report ANTHRAX: DHS Faces Challenges in Validating Methods for Sample Collection and Analysis that called for additional work developing and validating statistical sampling approaches [GAO 2012].

2011—Bio-Response Operational Testing and Evaluation (BOTE) Project

In 2011, NIOSH participated in the DHS-sponsored BOTE Project. BOTE was a fully functional, realistic study and exercise to assess a biological incident response from the initial public health and law enforcement response through to environmental remediation. Figure 19 shows the building used to simulate the covert attack. This multi-agency project tested and evaluated field-level decontamination (Phase 1), and an operational exercise (Phase 2) tested a multi-agency (FBI, EPA, DHS, CDC, and DoD) response.

During Phase 1 of the project, EPA assessed three decontamination technologies for site remediation to determine the effectiveness and cost-benefit analysis of each decontamination method. Phase 2 of the project was an operational exercise involving key federal agencies that are responsible for the forensic investigation (FBI), public health assessment (CDC and NIOSH), and remediation (EPA) of a contamination event. This novel field project incorporated the release of a harmless *B. anthracis* surrogate into

a two-story building. Participants responded to the event as if a true *B. anthracis* release had occurred.

Figure 19. Tented building used to simulate a covert anthrax release in the BOTE exercise. [Photo credit: NIOSH]

NIOSH participated in this project by providing subject matter experts to lead the OSH component of the public health response. This included providing health and safety expertise, supporting sample plan development, and conducting sampling to identify and characterize contamination to support public health decision-making such as who should receive medical countermeasures. Figure 20 shows a diagram of the activities that took place during Phase 2 of the exercise. NIOSH sampling team decontaminating samples collected as part of the exercise (Figure 21). NIOSH also evaluated the ability to implement rostering of responders using novel field tools following the Emergency Responder Health Monitoring and Surveillance™ (ERHMS™) framework (see Chapter 2, beginning on page 26). NIOSH also participated in numerous interagency coordination and decision-making meetings. This exercise provided another opportunity to prepare NIOSH to respond to an anthrax event as staff gained hands-on experience in donning and doffing PPE, personnel decontamination, sample plan development, sample collection, and inter-agency coordination.

Figure 20. Diagram of BOTE Exercise. TWG = technical working group, FBI = Federal Bureau of Investigation, EPA = Environmental Protection Agency, NCERT = National Criminal Enforcement Response Team, LRN = laboratory response network, IC = incident command, ECC = Environmental Clearance Committee [BOTE 2011].

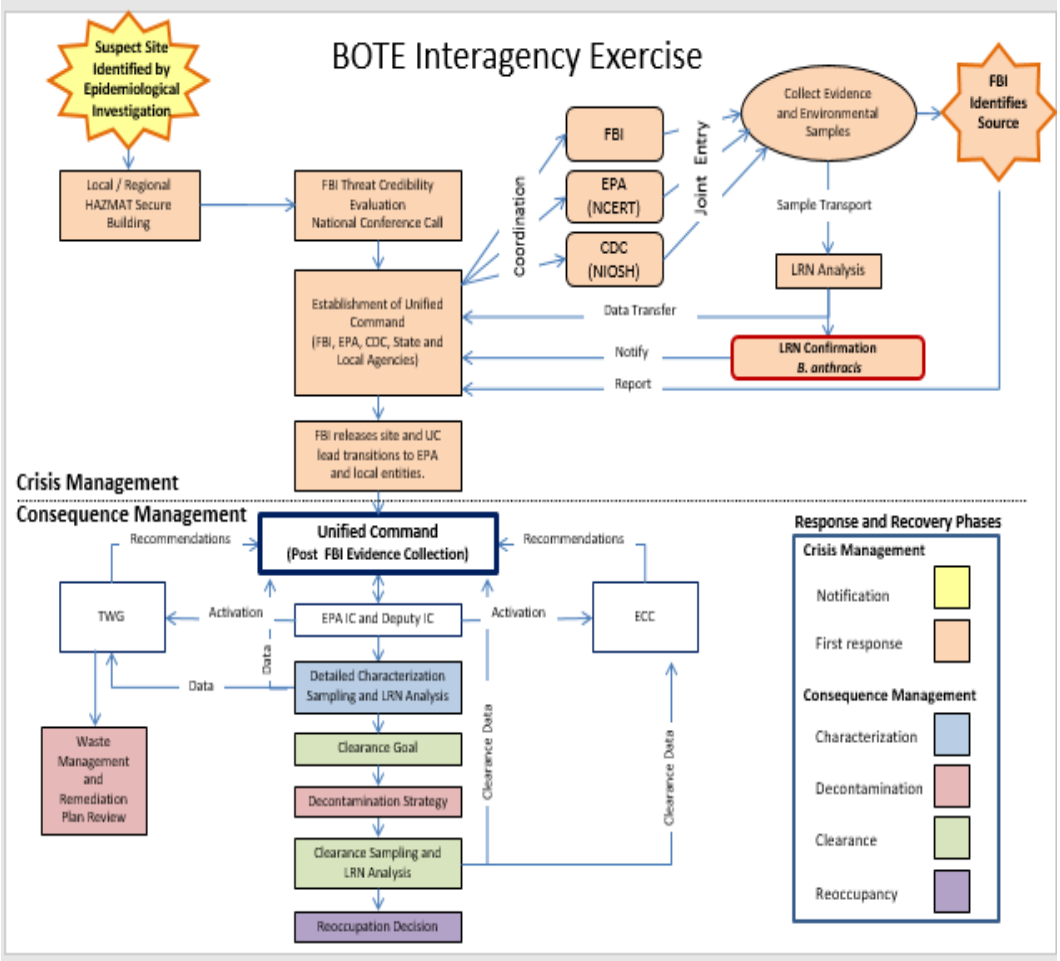


Figure 21. NIOSH sampling team decontaminating samples during the BOTE exercise. [Photo credit: NIOSH]

This project was critical for federal agencies involved in bio-responses to understand response goals and objectives across agencies. While all federal agencies involved in such responses work to protect the public's health, agencies achieve this goal with different objectives. For example, FBI aims to prevent additional attacks and catch the perpetrator, CDC seeks to prevent the public from becoming ill from spore exposure, and EPA looks to clean up the contamination. NIOSH, as part of CDC, strongly supports CDC goals by 1) determining workers possibly exposed during the initial release as well as secondary exposures to response and recovery workers and 2) supporting CDC in identifying community members possibly exposed. Additionally, the project allowed NIOSH to improve coordination with different agencies as the response activities transition throughout the phases of the response. Examples of this include how public health sampling can interfere with a law enforcement investigation, law enforcement sampling can delay public health sampling, and how EPA can use public health data to support decontamination.

Prior to the exercise, planners across agencies recognized that CDC and EPA needed to establish a shared, safe clearance level to use during the BOTE exercise. In other words, what, if any, level of *B. anthracis* spores can remain on surfaces in a building or outdoor

environment after a release. In 2011, prior to BOTE, a group of experts from CDC, NIOSH, and EPA met to discuss the current state-of-the-science on risk assessment, sampling strategies, decontamination technologies, and operational logistics as they related to the development of a clearance strategy. The product of that meeting was the document Interim Clearance Strategy for Environments Contaminated with *Bacillus anthracis*. The group established a clearance goal of no detection of viable spores. CDC and EPA further recommended that field responders use the Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces and follow a targeted sampling approach. This document is the foundation for CDC's and EPA's clearance goals to this day.

Relationships established from the BOTE Project greatly benefited subsequent anthrax and other biological incidents, including the CDC Anthrax Response in 2014, the 2014 Ebola outbreak, and the DoD Sample Investigation in 2015. NIOSH responses to real-world anthrax events are discussed later in this chapter. In 2013, NIOSH worked with the CDC-FBI liaison to develop and sign a formal Memorandum of Understanding (MOU) with the FBI. The Joint Public Health-Law Enforcement Investigations MOU lays out how the two agencies will interact during a response, what information the agencies can share, and what authorities each agency brings to the response [CDC/FBI 2013]. Based on their success, in 2017, CDC and FBI sought to expand the existing bio-response MOU to establish a framework for joint public health and law enforcement collaboration during chemical, radiological, biological, and nuclear incidents [CDC/FBI 2017]. CDC, NIOSH, and EPA are also working on developing a response collaboration MOU that follows the structure of the Joint Public Health-Law Enforcement Investigations MOU.

Intermediate Outcomes:

- EPA, EPA contractors, and DoD Weapons of Mass Destruction Civil Support Teams conducted extensive sampling using the NIOSH sampling procedures during the decontamination study (Phase 1) of BOTE [EPA 2013] and the demonstration exercise (Phase 2) of BOTE [BOTE 2011].

- Support teams followed the clearance goal recommended by CDC and EPA in the 2011 Clearance Strategy document for this exercise and applied to decisions regarding decontamination procedures [BOTE 2011].

2011—Dark Zephyr

In 2011, HHS conducted a series of three tabletop exercises known as Dark Zephyr. The design of this exercise was to examine key federal operational and policy decisions needed to sustain response efforts after the initial dispensing of medical countermeasures for post-exposure prophylaxis. This exercise focused on response and recovery actions beginning 72 hours after a BioWatch sampler detected *B. anthracis* spores.

Participation in this exercise identified areas where NIOSH and OSHA should coordinate on the development of PPE for federal workers and private sector contractors supporting federal agencies in and around contaminated areas. NIOSH recognized that the previously issued 2009 DHS proposed guidance for responders required significant updating to include new knowledge [DHS 2012a]. NIOSH and CDC jointly led a federal interagency working group that developed the publication, Guidance for Protecting Responders' Health During the First Week Following A Wide-Area Aerosol Attack, discussed later in this chapter.

Intermediate Outcomes:

- Numerous websites reference the guidance document:
  - OSHA's Anthrax webpage
  - DHHS Public Health Emergency webpage
  - American College of Veterinary Preventive Medicine newsletter
  - EMS1.com, an online resource for the EMS community
  - Global Biodefense.com, an online news and insights on health security
- CDC's document outlining a prioritization scheme for anthrax vaccination after an event utilizes the risk categorization approach from the responder guidance publication.

2013—CDC's Anthrax Laboratory Surge Exercise

In 2013, NIOSH participated in the CDC Anthrax Laboratory Surge Exercise, designed to test how CDC would respond to a surge in processing anthrax samples, primarily clinical specimens. Through NIOSH's participation in this exercise, CDC recognized that environmental samples would also need to be analyzed and prioritized along with clinical specimens. As a result, CDC invited NIOSH to participate in CDC's Data Collation and

Integration for Public Health Event Responses project. This project, initially funded for anthrax-response data collection, looked at ways to automate storage of all response data into one system to support rapid decision making. NIOSH assisted the programmers in understanding the traditional variables collected with environmental samples, how the data are analyzed, and what conclusions could be drawn from the data understanding the limitations.

Intermediate Outcomes:

- CDC laboratories processed numerous environmental samples, which increased CDC's internal capacity to analyze environmental samples [CDC 2013a]. Through this exercise, CDC trained additional lab staff on how to analyze environmental samples collected following NIOSH collection procedures.

- CDC's internal *Biological Incident Annex to the All Hazards Response Plan* calls for developing prioritization criteria based on the current epidemiologic and environmental investigation needs because the testing results will support both aspects of the response [CDC 2013b].

2016—Underground Transportation Restoration (UTR) Project

In 2016, DHS and EPA asked NIOSH to provide technical assistance to the UTR Project. This project was a collaboration between DHS, EPA, and Lawrence Livermore, Argonne, Pacific Northwest, and Brookhaven National Laboratories to develop capabilities for the rapid return to service of subway systems following the release of a persistent biological agent, such as *B. anthracis*. As part of the federal guidance development, the agencies conducted a field test to explore cost-effective decontamination technologies and isolation techniques for stations, tunnels, and rolling stock (vehicles that move on a railway). EPA requested NIOSH assistance in training the sampling teams on sample collection and providing feedback on the sampling teams' performance. This demonstration project took place at Fort A.P. Hill's Asymmetric Warfare Training Center and involved a mock subway system contaminated with a non-pathogenic surrogate that behaves like *B. anthracis* spores.

In addition to the field test, NIOSH helped validate the draft guidance documents developed for response and decision making by participating in two workshops and tabletop exercises with other federal, state, and local stakeholders from the greater New

York City and San Francisco metro areas. The project led to the first comprehensive federal strategy to decrease time to return a subway system to service following a biological agent event and specific plans tailored to rapidly returning the Metropolitan Transportation Authority New York City Transit (NYCT) and the Bay Area Rapid Transit (BART) systems to service after a biological event.

Intermediate Outcomes:

- EPA staff and its contractors gained experience in sampling methodology after collecting thousands of samples using the NIOSH sampling procedures in the UTR Project [EPA 2017a, b].

- Local jurisdictions plan to use tools incorporating NIOSH sample collection procedures: web-based decision-support tools and guidance specific to recovering NYCT and BART were developed and transitioned to the local jurisdictions. Both NYCT and BART indicated intention to use these plans and tools in future local exercises [Delaney 2018a]. The guidance and tools call for the use of the NIOSH sample collection procedures and apply the joint CDC-EPA clearance criteria to remediation activities [DHS 2016a, b, 2017a, b].

Anthrax Events

In recent years, as local preparedness and response capabilities increased, NIOSH shifted its limited resources towards providing technical assistance on developing sampling plans, including method and sample location selection, and interagency coordination, to provide technical expertise around exposure assessment, OSH guidance, and extent of contamination during responses. However, the Institute continues to maintain a small anthrax response cadre that can provide both remote and onsite technical assistance to state and local health departments, first responder groups, and other federal response agencies. By maintaining a small amount of equipment, PPE, and sampling media, NIOSH can conduct environmental sampling for *B. anthracis* on a limited basis. Over the last decade, NIOSH staff have responded to five anthrax-related events and are prepared to support future events.

2007—Connecticut Drum Maker and Family Member Diagnosed with Cutaneous Anthrax

In 2007, the Connecticut Department of Public Health (CDPH) diagnosed a drum maker and one of his three children with cutaneous anthrax associated with making drums out of goatskins imported from West Africa. A multi-agency investigation that included NIOSH, CDC, EPA, CDPH, the Connecticut Department of Energy and Environmental Protection, and local law enforcement was established. The drum making occurred at the entrance of the family's backyard shed. The children were not involved in the drum making and were prohibited from entering the shed.

EPA conducted extensive environmental sampling of the shed and home, detecting *B. anthracis* spores in both locations. This supported the hypothesis that exposure occurred while the drum maker was handling contaminated hides in the shed. His child was likely exposed through cross-contamination of the home. CDC and NIOSH recommended no detectible growth on culture as the clearance criterion to CDPH, who had authority to allow reoccupancy. Other agencies proposed a less stringent clearance criterion. Extensive decontamination took place before the house and shed post-decontamination samples all reported non-detect [CDC 2008]. Because of the controversial use of no detectible growth on culture as the clearance criterion, later in 2012, EPA and CDC met to address the state of science around establishing clearance criteria. Ultimately, the two agencies agreed on clearance criteria and developed the joint document Interim Clearance Strategy for Environments Contaminated with *Bacillus anthracis* discussed earlier in this chapter.

2009—New Hampshire Drumming Circle Participant Diagnosed with Gastrointestinal Anthrax

In late December 2009, the New Hampshire Department of Health and Human Services diagnosed a case of gastrointestinal anthrax in a participant of a drumming event. Eighty-four people participated in the event and over 50 animal- and synthetic-hide drums were present in the house [CDC 2010a]. EPA and NIOSH developed a joint sampling plan, meeting both public health and decontamination objectives. NIOSH trained EPA contractors to collect the samples using the draft Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces procedures.

Figure 22. Responders entering a building to collect samples for *B. anthracis* during the 2009 New Hampshire investigation. [Photo credit: NIOSH]

EPA collected the samples and the CDC Laboratory Response Network analyzed them using the corresponding analytical methods. Figure 22 shows the sampling team entering the building to collect samples. The sample collection procedures allowed investigators to semi-quantitatively characterize and identify how the exposures occurred (i.e., surface contamination or potential aerosolization). Investigators identified one drum as positive for *B. anthracis*. Based on the location of the positive sample results, investigators concluded that the case was likely exposed to aerosolized spores at the drumming event; other participants were likely exposed, even though investigators did not identify any additional cases [CDC 2010a].

Since the Connecticut Drum Maker Event in 2007, EPA performed studies looking at the efficacy of the individual steps of a seven-step decontamination procedure to understand the spore reduction achieved in the individual steps—this allowed NIOSH and CDC to agree on reoccupancy without post-decontamination clearance sampling. This agreement was because of the semi-quantitative characterization, low contamination levels, and understanding of efficacy in the individual decontamination steps. Subsequently, CDC and NIOSH recommended to the New Hampshire Department

of Health and Human Services to allow reoccupancy based on a prescribed decontamination procedure and process controls.

This event shows the progression of NIOSH's response actions from sample collection to advising on sample collection training, sample plan development, and appropriate countermeasures to prevent workers from becoming ill. It is also the start of a close collaboration between EPA and NIOSH to work collectively to streamline a response and establish a working relationship to support future decontamination studies and demonstrations.

2011—Traveler in Minnesota Diagnosed with Inhalation Anthrax

In 2011, the Minnesota Department of Health diagnosed one case of inhalation anthrax in a Florida resident who had recently traveled to multiple national parks in the northwestern and midwestern states, ending in Minneapolis [Griffith et al. 2014]. Because of the long road trip and multiple national parks visited, health officials found it was difficult to determine where to focus the investigation. Limited data were available to determine the source of exposure, and staff used environmental sampling to help identify the source and focus the investigation. Because it was not feasible to sample all locations along the entire route, NIOSH supported the Minnesota Department of Health in developing a sampling plan that focused on the rental vehicle driven during the trip, personal items, and the resident's home in Florida. NIOSH remotely trained the Minnesota National Guard Civil Support Team and Florida Department of Health on the use of appropriate PPE and on procedures for collecting *B. anthracis* samples. NIOSH also developed a sampling plan and provided it to the sampling team [NIOSH 2011]. NIOSH also provided supplies to support the timely collection of samples. Ultimately, none of the 65 samples tested positive for *B. anthracis,* and it was never determined where the exposure occurred [Griffith et al. 2014].

NIOSH continues to shift toward providing technical assistance on the development of sampling plans and interagency coordination to offer technical expertise around exposure and extent of contamination during responses. As discussed earlier, this event demonstrated the need for prepared, easy to follow instructions and training aids for collecting *B. anthracis* samples following the Surface sampling procedures for *Bacillus anthracis* spores from smooth, non-porous surfaces document.

2014—CDC Laboratory

In 2014, one of CDC's biosafety level 3 labs prepared samples of *B. anthracis* for research in two lower level, biosafety level 2 labs where work with viable spores is prohibited. After workers transferred the samples, they discovered that the procedure used in the biosafety level 3 lab may not have fully inactivated the spores, potentially exposing unprotected workers in the lower level labs to viable spores [CDC 2014c]. CDC requested NIOSH's assistance with assessing potential contamination and exposures in the lower level labs. Working with CDC, NIOSH developed a sampling plan using a targeted approach that focused on locations where spores were most likely to be present based on the laboratory procedures performed on the samples. The purpose of sampling was to determine whether contamination was present in the lab to help inform decisions on discontinuing post-exposure prophylaxis for low risk employees [CDC 2014d].

2015—Department of Defense Sample Investigation

In 2015, Department of Defense (DoD) contract laboratory staff discovered that the DoD had inadvertently sent them viable samples of *B. anthracis* as part of an effort to develop new rapid field-based assays. After a full investigation, 88 primary labs and 106 secondary labs in 9 foreign countries, 50 states, 1 district, and 3 territories received low concentrations of viable *B. anthracis* spores thought to be completely inactivated. NIOSH staffed the CDC response's Worker Safety and Health Team to work with the CDC epidemiologists to help inform the risk assessment. Once the assessment was completed, NIOSH and CDC worked together to develop decontamination guidance for affected laboratories, providing PPE and post-exposure prophylaxis recommendations for the decontamination workers. NIOSH also coordinated response activities with OSHA and EPA—the first time CDC requested an EPA liaison to staff the CDC Emergency Operations Center (EOC). This helped with a mutual understanding and coordination between the two agencies. Both agencies agreed this was a successful model to follow in future events requiring close coordination between agencies.

2016—Minnesota Positive BioWatch Sample

In 2016, the Minnesota Department of Health collected a positive *B. anthracis* sample from an early-warning BioWatch detector, an environmental sampler for biological threats [MDH 2016]. After notification of the positive result, NIOSH quickly placed a team on call in case Minnesota requested technical assistance or training on sample

collection. Although they did not ultimately request NIOSH assistance, NIOSH's ability to stand up a team quickly demonstrates an ongoing commitment to support events in a timely manner [Seitz 2016].

Intermediate Outcomes:

- Field-sampling teams consistently used CDC-NIOSH collection procedures to identify and assess the degree of contamination related to potential anthrax cases. The use of standardized methods allows for comparison of environmental sampling results across events and can support future research studies focusing on environmental contamination [Sullivan et al. 2011].

- In response to the Florida traveler inhalation case, the Minnesota Civil Support Teams, Minnesota Department of Health, and Florida Department of Health all conducted sampling following NIOSH-developed sampling plans, using NIOSH equipment and supplies [Griffith et al. 2014]. Based on the non-detect sampling results, the Minnesota Department of Health and Florida Department of Health determined that no decontamination was required. The rental vehicle and traveler's home were determined to be safe and allowed to be returned to the rental company. Additionally, the personal items in the rental vehicle were returned to the case's family [Griffith et al. 2014].

- In the case of the Connecticut Drum Maker Event, the CDPH adopted CDC and NIOSH's recommended clearance strategy goals for re-occupancy [CDC 2008].

Anthrax Exposure Research

In order to inform outside organizations' (i.e., local police, fire, and hazmat; FBI; state health departments; and private companies/organizations) response protocols, NIOSH worked with Canadian researchers to simulate a letter release of *B. anthracis* in an office setting. Kournikakis et al., using an anthrax simulant, sought to characterize the dissemination of spores in a building, personal contamination, and potential inhalation exposure of the individual opening the letter [Kournikakis et al. 2011]. Additionally, the investigators examined the effects of letter opener movement on exposures and potential mitigation steps to reduce exposures [Kournikakis et al. 2009]. Results of the study indicated that most of the letter opener's exposure occurred immediately after

opening the letter. The letter opener remaining seated after opening the letter while co-workers vacated the area minimized the risk of cross-contamination. Researchers also noted that closing office doors while vacating and shutting down the heating, ventilation, and air conditioning systems reduced spore concentrations outside the area where the letter was opened.

Based on the findings from the Kournikakis research, CDC collaborated with NIOSH and updated recommendations for persons receiving a letter or package containing a suspicious powder. CDC based the previous guidance, issued in October 2001, on professional judgement [CDC 2001a, 2011].

Intermediate Outcomes:

- Using the results from the study, CDC updated and distributed the guidance document, Update: How to handle envelopes or packages suspected of containing the bacteria that causes anthrax (*Bacillus anthracis*), via the Epi-X communication channel [CDC 2011, EPI-X 2011]. Epi-X is CDC's web-based, secure communication channel that includes state and local health departments, poison control centers, and other public health professionals.

- Subsequently, the Wisconsin Bureau of Communicable Diseases and Emergency Response Public Health Preparedness Program issued Handling Powder-Contaminated Letters or Packages guidance and the Missouri Department of Health and Senior Services issued an updated Health Advisory How to Handle Situations Involving Suspicious Powdery Substances (Updated 2013) that incorporated the new CDC guidance [Missouri Department of Health and Senior Services 2013; Wisconsin Bureau of Communicable Diseases and Emergency Response Public Health Preparedness Program 2012].

Responder Health and Safety

Expanding on guidance issued in 2001 to protect anthrax responders and incorporating CBRN-certified PPE, NIOSH developed the document Recommendations for the Selection and Use of Respirators and Protective Clothing for Protection Against Biological Agents. It provides recommendations on the type of respiratory protection and protective clothing according to anticipated level of risk associated with various responses. For

example, it recommends very high levels of PPE protection when responding to an unknown bioincident or one where ongoing dissemination of a biological agent is occurring and lower levels for events from letter releases where the agent is no longer being generated. The basis of the document comes from current understanding of the potential agents and existing recommendations for biological aerosols and is oriented toward acts of terrorism.

As part of a federal interagency working group, NIOSH co-authored the publication, Guidance for Protecting Responders' Health During the First Week Following A Wide-Area Aerosol Anthrax Attack. This document educates first responders on protective actions they should take in the event of a wide-area anthrax release. NIOSH and CDC collaborated with DHS to finalize the guidance in 2012 after being in draft format for several years. NIOSH-CDC updated the recommendations for medical countermeasures, PPE, and safe work practices. This is the first comprehensive guidance document for assisting first responders in developing OSH plans for a wide-area *B. anthracis* event [DHS 2012b]. In a Lancet commentary, Katz et al. reference this guidance, stating, "plans and disease-specific activities have been invaluable and have dramatically improved global preparedness and response capacity for biological threats."

In 2009, NIOSH staff served on the Advisory Committee on Immunization Practices (ACIP) Anthrax Vaccine Workgroup that updated previous anthrax vaccine recommendations from 2002. Based on new advances and information, the working group made substantial changes to the previous recommendations [CDC 2010b].

Intermediate Outcomes:

- In 2012, the Georgia Department of Public Health issued Guidance for First Responders (911, EMS, EMA Personnel, Law Enforcement, Fire Fighters, Others): Dealing with Suspicious Letters, Packages, and Unknown Substances. This document outlines how responders should assess the threat of a suspicious incident involving unknown substances and describes coordination activities between public health and law enforcement. It recommends following the NIOSH anthrax collection procedures when trace contamination is present; PPE for HAZMAT teams is consistent with NIOSH recommendations and also referenced in the document [Georgia Department of Public Health 2012].

- ❖ The following books and fact sheets referenced NIOSH's PPE recommendations:
    - Biosecurity and Bioterrorism Containing and Preventing Biological Threats [Ryan 2016]
    - Koenig and Schultz's Disaster Medicine Comprehensive Principles and Practices [Koenig and Schultz 2010]
    - Emergency Public Health Preparedness and Response [Kapur and Smith 2010]
    - Understanding, Assessing, and Responding to Terrorism, Protecting Critical Infrastructure and Personnel [Bennett 2018]
    - Hazardous Materials Managing the Incident [Noll et al. 2012]
    - DuPont Clothing for anthrax response fact sheet [DuPont 2013]
    - National Institute of Standards and Technology (NIST) Technical Note 1776 Best Practices for Sample Collection and Transport During an Initial Response to Potential Biothreat Materials [NIST 2012]
- ❖ Guidance for Protecting Responders' Health During the First Week Following A Wide-Area Aerosol Anthrax Attack has been viewed 22,761 times between July 2011 and March 2018.
- ❖ The 2009 ACIP vaccination recommendations address special worker populations who may be at increased risk of exposure [CDC 2010b].

End Outcomes

The evidence presented here suggests that NIOSH's unique contributions and extensive collaborations positively affected local, state, and federal preparedness and response efforts related to anthrax for more than a decade. Prior to 2001, no validated sampling methods existed, and the nation was not prepared to respond to the environmental or the OSH needs of an anthrax event. Due in large part to NIOSH's efforts, validated methods, training tools, and knowledgeable teams capable of responding are now available. Fortunately, while no major anthrax incidents occurred in the past decade,

NIOSH demonstrated the impact of their activities in isolated incidents involving naturally occurring anthrax and human laboratory error. In those incidents, responders had 1) access to health and safety guidance on how to safely respond and 2) appropriate tools to quickly characterize contamination and inform public health decision making. Over time, organizations have increased their adoption of NIOSH outputs. As evidenced by the events described previously, state and local entities require less on-site assistance as they were more prepared to respond independently.

Alternative Explanations

Other organizations have taken actions to improve preparedness, particularly in the area of environmental assessment and methods development. For example, EPA and national laboratories pursued research on improving anthrax-sampling methods and published their work [EPA 2013; SNL 2011]. This chapter references many of these reports and papers as they built on NIOSH's work [Grinshpun et al. 2017], often consulting with NIOSH for assistance as they complete their work. CDC has played a key role in developing laboratory-processing procedures that LRN adopted. In some cases, the decision on which collection devices to use in the field was first determined based on CDC laboratory activities. The DHS BioWatch Program developed their own sample collection training. First responder groups across the country, responsible for collecting samples after a positive BioWatch result, received this training. State health departments and research institutes also offer trainings to improve the anthrax response capabilities of their responders.

Future Plans

Anthrax preparedness and response continue to be a priority focus area for NIOSH. Federal, state, and local agencies continue to conduct exercises and develop response plans for anthrax, because it is considered a worst case biological agent scenario due to its environmental persistence. NIOSH still needs to conduct additional research to address gaps in knowledge and to further refine sampling methods. NIOSH is committed to continue work in this area. NIOSH will continue to participate in monthly CDC Anthrax Management Team calls to ensure coordination and collaboration on preparedness and response activities across the agency. Within the federal family, NIOSH, CDC, and EPA are

working to formalize partnerships that describe how the agencies will interact, share information, and coordinate during anthrax responses.

NIOSH is currently designing and testing an alternative inlet nozzle for use with the *B. anthracis* porous surface sample collection procedure. This project aims to increase both the sample area and the speed at which samples are collected. NIOSH is also planning to convert the 37-mm cassette collection procedures described in scientific publications into a NIOSH method, incorporating the new inlet nozzle once developed, it will be included in the NIOSH Manual of Analytical Methods.

The ACIP Anthrax Workgroup reformed to review the newly available data on the current anthrax vaccine called Anthrax Vaccine Adsorbed and to evaluate a new anthrax vaccine currently in Phase-3 clinical trials. NIOSH staff are participating on this workgroup to revise recommendations for the use of Anthrax Vaccine Adsorbed for pre- and post-exposure prophylaxis and to consider use of the new vaccine.

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Chapter 4: Emergency Preparedness Activities and Responses

NIOSH staff member preparing go kits for a pending deployment. [Photo credit: NIOSH]

Introduction

At the location of virtually any emergency response or incident, regardless of type, you will find response and recovery workers. Ensuring the health and safety of these emergency responders and other workers is a vital part of any response. Even after the immediate response activities end, workers continue to face hazardous conditions as they undertake recovery efforts. NIOSH actively prepares to participate in these responses to protect workers across a range of events including major natural and chemical disasters, terrorist attacks or threats, nuclear accidents, or infectious disease outbreaks. To that end, the Emergency Preparedness and Response (EPR) Program focuses on two areas of activity: preparedness and response. While we cannot predict when the next emergency will strike, or what it will be, we can prepare and respond to these events when they occur.

NIOSH is equipped to provide a broad range of field response and consultative expertise across a wide range of emergency types. As part of pre-event planning and

preparedness activities, NIOSH maintains a small team of occupational medicine physicians, epidemiologists, industrial hygienists, engineers, and toxicologists. This team can field deploy to provide on-site assessments about occupational hazards and health effects related to exposures, implement or increase occupational surveillance, and offer recommendations for health monitoring of response workers. NIOSH, with considerable expertise in environmental monitoring, maintains the ability to quickly mobilize and provide experienced staff who can develop and carry out complex sampling strategies in harsh environments.

The EPR Program supports advancing NIOSH's response capabilities through professional development of staff including specialized response training. Additionally, NIOSH maintains sampling supplies and personal protective equipment (PPE) that can be used to support fieldwork. Personnel deployment readiness includes advance completion of medical clearance and respirator fit testing of core staff who routinely deploy; those selected to deploy at a moment's notice receive the same pre deployment assessments. EPRO also maintains a list of subject matter experts (SMEs) who remain on call during National Special Security Events like the President's State of the Union or the Super Bowl. These SMEs are available to serve as an emergency advisory team if needed to respond to any incidents that arise during these events. EPRO staff participate in numerous internal CDC/NIOSH work groups and committees as well as external groups to ensure the consideration of occupational safety and health (OSH) as groups and committees develop guidance documents, communication materials, and strategic and operational response plans. These efforts also result in increased coordination among key responder groups that NIOSH will work with during responses.

There are several routes for NIOSH involvement in responses. Requests for NIOSH assistance can come directly from local response agencies, including employers and employees, state and local governments, or from other federal agencies. More often, CDC notifies NIOSH with requests for assistance, and based on the needs of the response, NIOSH determines what support is best. Depending on the size and type of incident, CDC decides whether the lead program manages the response within their Center or if the CDC Emergency Operations Center (EOC) should be activated to coordinate the response. The lead program typically manages small, short duration responses of less than 50 people. The CDC EOC manages larger responses requiring

extensive interagency coordination, involving political sensitivities, or with high complexity or media interest.

The EOC serves as the central location for coordinating and supporting staff, information, communications, and security issues associated with the response. CDC utilizes the Incident Management System (IMS) structure and NIOSH leads the Worker Safety and Health Team or Task Force to conduct OSH activities. This team sits within the Scientific Response Section that provides the operational scientific and technical competencies for the response. Teams are activated based on the functional needs of the response. Working within the EOC IMS structure facilitates sharing of situational awareness across teams and ensures consistent messaging. Additionally, IMS includes a thorough clearance process to rapidly clear response-related documents, such as scientific guidance and manuscripts, communication products, and press materials; this process may include the document's review by other federal agencies and groups.

This chapter provides examples of NIOSH efforts and outcomes related to protecting response and recovery workers during both complex, large-scale events and small-scale emergency responses. Descriptions in this chapter include NIOSH's response activities related to the 2009 H1N1 pandemic and other influenza outbreaks, 2010 Deepwater Horizon (DWH) oil spill, and the 2014–2016 Ebola virus epidemic. There are examples of NIOSH support to smaller-scale responses that did not make national headlines, but were, nonetheless, important. These responses highlight the complexity and extent of NIOSH's capabilities across a wide range of hazards from radiation incidents to infectious disease outbreaks. They also demonstrate how staff can tailor their support to the needs of the local jurisdictions. Finally, this chapter describes NIOSH preparedness activities and underscores NIOSH's ability to effectively work with other agencies to develop national policy and incident-specific response plans, participate in exercises to test those plans, and conduct research to inform policy and guidance and improve the ability to protect workers in future responses.

NIOSH activities described in this chapter support the following EPR Strategic Goals:

- Strategic Goal 1: Enhance the health, safety, and resilience of emergency responders by improving the organization of emergency response work.

- Strategic Goal 2: Enhance the health and safety of emergency responders by improving proper selection and use of PPE to reduce responder's hazardous exposures to chemical, biological, radioactive, nuclear (CBRN) agents, industrial compounds, and other materials.

- Strategic Goal 3: Enhance the health and safety of emergency responders by improving engineering controls and other technological interventions to reduce responder's hazardous exposures to CBRN, industrial compounds, and other hazardous materials.

- Strategic Goal 4: Enhance the health and safety of emergency responders through improved rapid methods for evaluating spatial and temporal distribution of hazardous agents in the air and on surfaces.

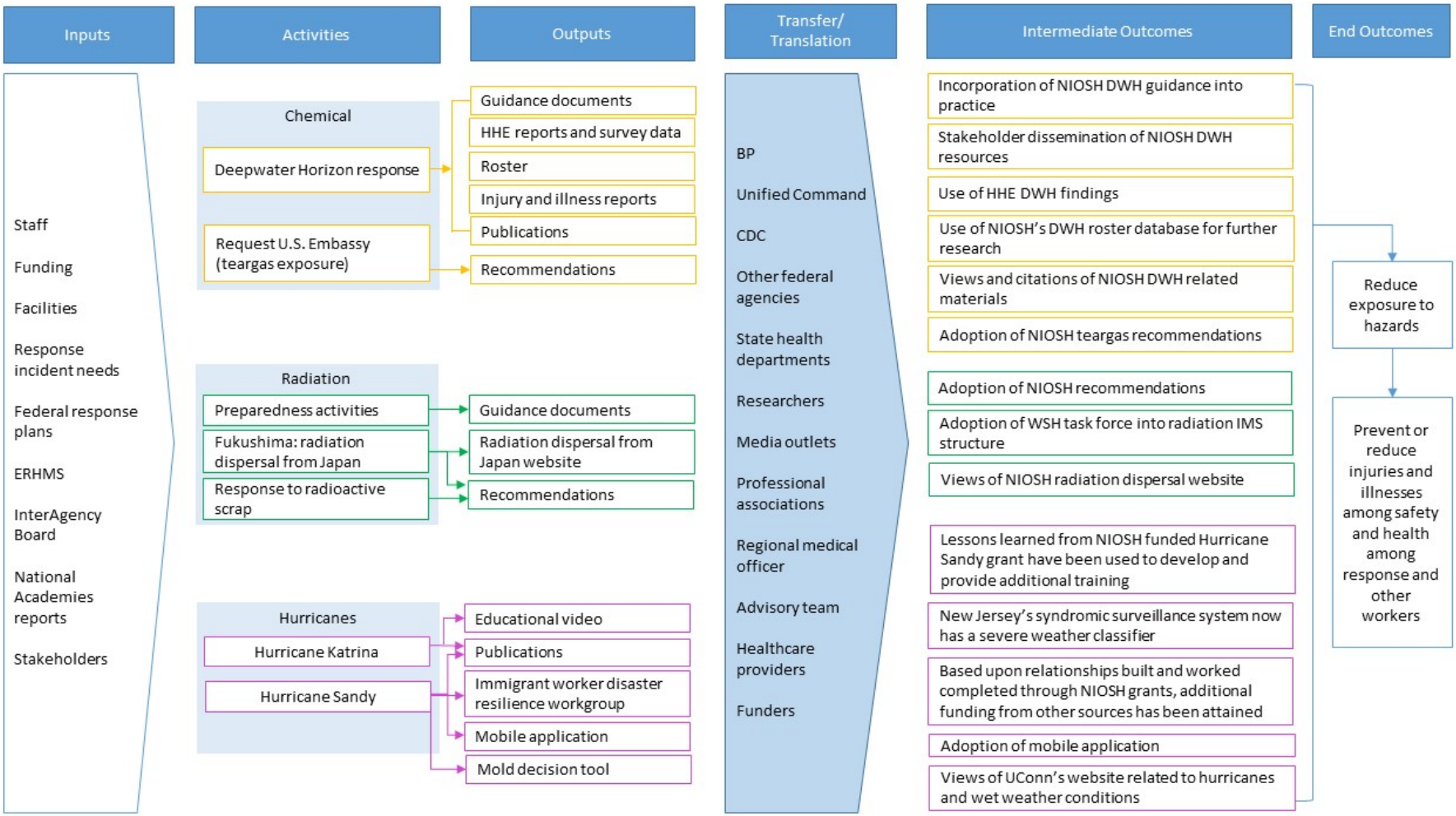
- Strategic Goal 6: Enhance the health and safety of emergency responders by improving pertinent surveillance systems.

- Strategic Goal 7: Enhance the health and safety of emergency responders by improving detection, risk assessment, and control of biological threat agents.

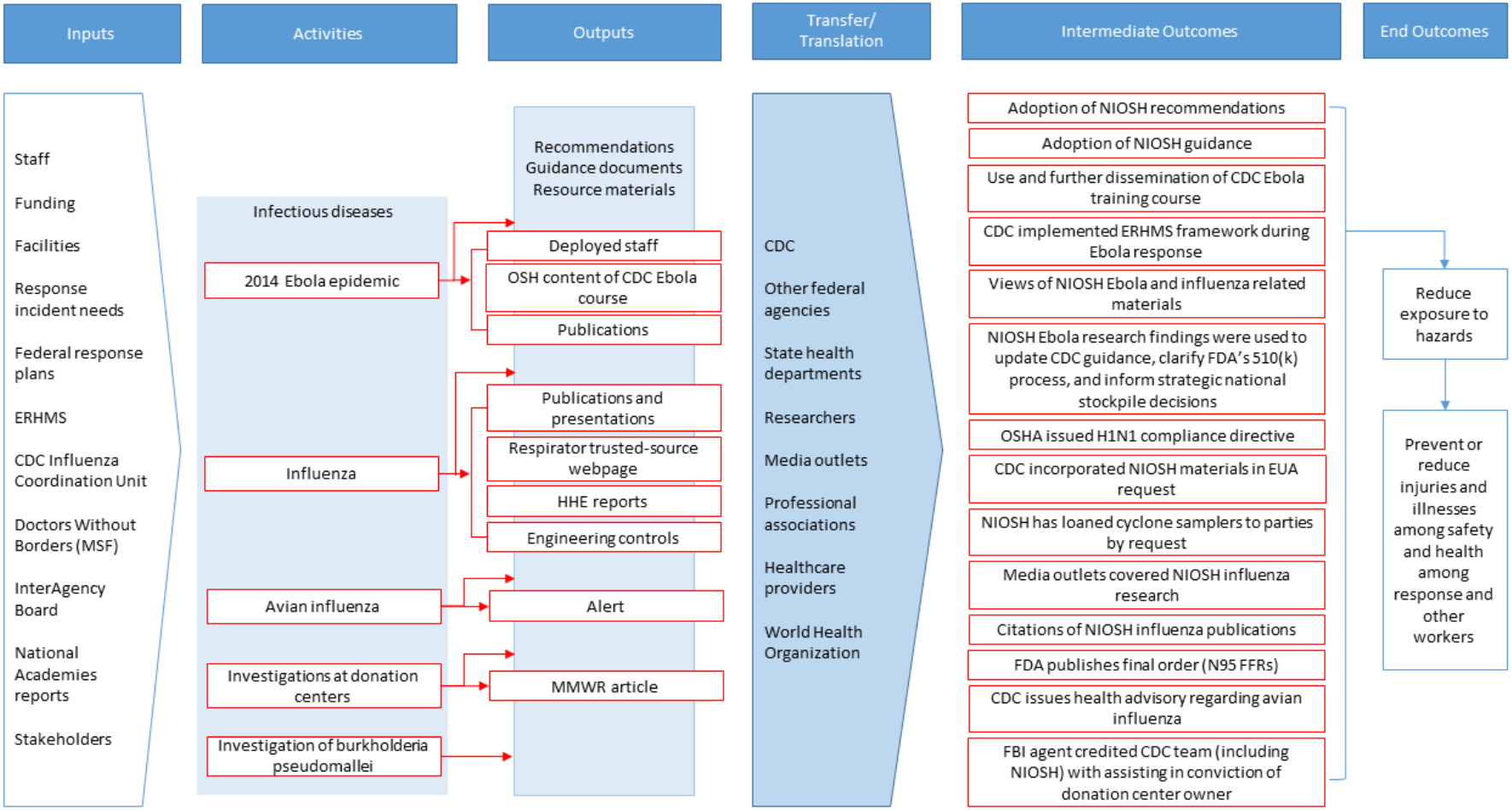
Logic Model

Figure 23 is a logic model that illustrates key relationships characterizing how the EPR Program contributes to emergency preparedness activities and natural or manmade disaster responses as it applies to OSH. Dotted lines indicate anticipated pathways while solid lines show established pathways. Descriptions of the elements of the logic model—Inputs, Activities, Outputs, Transfer and Translation, Intermediate Outcomes, and End Outcomes—follow in upcoming sections.

Figure 23. Logic Model for NIOSH Emergency Preparedness Activities and Responses, 2007–2017.



Continued, Logic Model for NIOSH Emergency Preparedness Activities and Responses, 2007–2017.



Inputs

Response Incident Needs

The unique nature of a response and the challenges that may arise vary. Therefore, NIOSH must be flexible, apply previous preparedness and response knowledge, and work with stakeholders and partners to meet the needs of the specific response.

Federal Response Plans

Presidential Policy Directive 8

In 2011, President Obama issued Presidential Policy Directive 8 to strengthen domestic security and resilience through a systematic preparedness process to address the threats of greatest risk to national security. Shortly afterward, the Department of Homeland Security (DHS) developed a national preparedness goal that defines the core capabilities and five mission areas (Prevention, Protection, Mitigation, Response, and Recovery) necessary to be successful. The National Response Framework and the National Disaster Recovery Framework further describe the core capabilities related to OSH. These frameworks guide how the nation responds and recovers to all types of disasters [DHS 2013, 2016].

National Oil and Hazardous Substances Pollution Contingency Plan

The National Oil and Hazardous Substances Pollution Contingency Plan outlines how the federal government will respond to oil spills and hazardous substance releases. Under this plan, the National Response Team (NRT), a standing group of 16 federal agencies, takes responsibility for coordinating the interagency planning and response to an oil and hazardous materials release. NIOSH is a member of the NRT along with other federal agencies that have OSH responsibilities.

CDC All-Hazards Plan

The CDC All-Hazards Plan is a framework by which CDC provides emergency preparedness and response operations planning in support of all-hazard events or incidents, both natural and man-made, affecting public health. It provides internal guidance on how CDC prepares for, responds to, and recovers from a public health incident. CDC developed specific annexes to different categories of response (e.g., biological, chemical, radiation); the annexes further describe capabilities unique to that

category of response. Within annexes, CDC developed appendices that detail the scientific and technical information, policies, and procedures related to a specific response or threat. For example, CDC developed a pandemic influenza appendix to the biological incident annex [CDC 2013, CDC 2017a].

National Influenza Plans

The Homeland Security Council, a committee that provides advice and recommendations to the President on homeland security, issued the National Strategy for Pandemic Influenza in 2005 to guide pandemic preparedness planning [HSC 2005]. The strategy document outlined three pillars: *Preparedness and Communication*, *Surveillance and Detection*, and *Response and Containment*. The following year, the Homeland Security Council released the Implementation Plan for the National Strategy [HSC 2006]. This implementation plan provides additional details on the roles and responsibilities of the federal, state, and local governments, the private sector, and communities. At the same time, the Department of Health and Human Services (HHS) developed the HHS Influenza Plan that addressed the specific roles of the agencies within the department, listed planning assumptions, and provided guidance to state and local health departments [HHS 2005]. HHS updated their plan in 2017; the changes reflect recent advancements and additional efforts to improve pandemic preparedness [HHS 2017].

Emergency Responder Health Monitoring and Surveillance (ERHMS)

In 2012, NIOSH led a workgroup that created the Emergency Responder Health Monitoring and Surveillance System™ (ERHMS™) to describe a framework for how to protect response and recovery workers before, during, and after a deployment. The recommendations for protecting workers can be implemented by organizations, prior to a response as part of preparedness activities but also be addressed during a response. NIOSH uses the guidance, guidelines, and tools described in ERHMS™ to help prepare for and respond to emergencies.

CDC Influenza Coordination Unit

In 2006, with the Implementation Plan for the National Strategy, CDC created an internal task force with representatives from across CDC to address public health priorities assigned to CDC. The task force worked on coordinating efforts to improve

CDC's pandemic preparedness, tracking tasks to completion, and synchronizing exercises. This group evolved over the decade, and today it continues as a programmatic entity called the Influenza Coordination Unit. The unit synchronizes and coordinates all pandemic influenza preparedness activities at CDC as well as between CDC and HHS's Office of the Assistant Secretary for Preparedness and Response (ASPR).

Doctors Without Borders

Médecins Sans Frontiéres (MSF), also known as Doctors Without Borders, is an international humanitarian non-governmental organization that provides medical aid in developing countries or war-torn regions. MSF played a critical role in providing medical care to Ebola patients during the Ebola outbreak in West Africa. During the Ebola virus outbreak, NIOSH worked with MSF that expressed interest in understanding the effect of heat with various PPE combinations for healthcare workers providing care to Ebola virus disease patients. MSF provided in-kind PPE ensembles for NIOSH to evaluate.

InterAgency Board

NIOSH participates on the InterAgency Board (IAB) that works to strengthen the nation's ability to prepare for and respond safely and effectively to emergencies, including CBRN incidents. The IAB is composed of state, local, and federal first responders. NIOSH participates on the following IAB Subgroups: Equipment, Health, Medical & Responder Safety, and Standards Coordination.

National Academies Reports

In the mid-2000s, NIOSH sought authoritative program reviews from the National Academies on the relevance and impact of a range of NIOSH programs. This included the Respiratory Disease Research Program and the Personal Protective Technology Research Program, which are relevant to occupational disease transmission and PPE, respectively. In addition, in 2005, NIOSH established a Committee on PPE for Workplace Safety and Health with the National Academies, which NIOSH also funded. A number of other National Academies reports provided input into NIOSH efforts to improve the use of PPE to protect healthcare workers from infectious hazards [IOM 2006, 2007; Liverman and Goldfrank 2007; Liverman et al. 2009].

NIOSH anticipated the challenges of an influenza pandemic and, in 2008, commissioned the National Academies to produce a report, Preparing for an Influenza Pandemic: Personal Protective Equipment for Healthcare Workers [Liverman and Goldfrank 2007]. This report contained recommendations focused in three major areas: understanding influenza transmission, worker safety through appropriate use of PPE, and innovation and strengthening PPE design, testing, and certification. From the standpoint of understanding influenza transmission, the report noted the need for current research to evaluate the potential for airborne transmission and to understand better the potential for transmission across the droplet aerosol continuum. NIOSH researchers initiated new studies and other activities to address these recommendations, described later in this chapter.

Stakeholders

NIOSH efforts for preparedness and response activities benefited from the input of a range of stakeholders; a sample of which follows next:

State of the Sector I Healthcare and Social Assistance: Identification of Research Opportunities for the Next Decade of NORA

The 2009 State of the Sector report produced by the National Occupational Research Agenda (NORA) Healthcare and Social Assistance Sector Council addresses the "magnitude and consequences of known and emerging health and safety problems, critical research gaps, and research needs that should be addressed" [NIOSH 2009a]. NORA identified a range of knowledge gaps and research opportunities for infectious hazards that included needing surveillance, characterizing transmission pathways better, assessing effectiveness interventions and disseminating those effective interventions, and improving the technology and appropriate use of PPE and engineering controls. As a result of the NORA report, NIOSH researchers began new studies and other activities addressing the recommendations. Descriptions of these activities come later in this chapter.

CDC and other Federal Partners

As will be shown throughout this chapter, interactions with other parts of CDC play an extremely important role in NIOSH efforts to protect workers during response activities. We also closely coordinate and collaborate with other federal agencies including the

Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), DHS, National Institute of Environmental Health Sciences (NIEHS), and the Federal Bureau of Investigation (FBI). In addition, NIOSH and the Food and Drug Administration (FDA) share responsibilities for certification and approval of respirators, and in efforts to better serve the public, work to coordinate efforts. NIOSH is also a member of the National Response Framework's Worker Safety and Health Support Annex, a group of agencies coordinated by OSHA to assure response and recovery worker safety and health during incidents requiring a coordinated Federal response [FEMA 2008]. Through this alliance, NIOSH obtains important input during emergencies. In this chapter are examples of how NIOSH collaborates with these agencies to inform NIOSH planning and response activities.

Activities, Outputs, Transfer and Translation, and Intermediate Outcomes

Section 1: Chemicals

Deepwater Horizon Response

The explosion on the DWH oil rig on April 20, 2010, caused the deaths of 11 workers and injuries to another 17 workers. In the weeks and months that followed, the large amounts of crude oil released from the Macondo Well made it the largest oil spill in U.S. history. At its peak, more than 47,000 workers responded to the oil spill: 42,000 response and cleanup workers hired by the responsible party, British Petroleum (BP), and its contractors; 1,600 National Guard members; and more than 2,400 federal employees. Thousands of workers engaged in onshore and offshore containment and cleanup activities [Allen 2010]. Concerns about the potential effects of the spill on human and environmental health in the Gulf, including potential risks to response workers, prompted an unprecedented response from agencies across federal, state, and local governments.

At the invitation of OSHA, NIOSH staff deployed May 3, 2010, quickly integrating into the response incident management structure. NIOSH's role was to establish a roster of response workers and volunteers and to provide independent support to the Unified Command (UC) by working with OSHA to anticipate and address the OSH needs of response workers. Throughout the response, OSHA and NIOSH provided safety and health expertise and guidance to all levels of the UC: the local incident command posts, the Unified Area Command, and the National Incident Command. A specialized health and safety team consisting of industrial hygienists from OSHA, NIOSH, U.S. Coast Guard, EPA, the U.S. Department of Interior, and BP and its contractors met daily to review the previous day's air sampling results and identify additional health and safety concerns to address [Michaels and Howard 2012].

Until the 2014 Ebola outbreak, the DWH response effort was the largest activation of NIOSH personnel to a response in the history of the Institute. This response was unique because the roughly 87 days of uncontrolled discharge of oil created unprecedented challenges in meeting the needs of a prolonged acute response. To address the response needs, NIOSH activated for four months (May 1, 2010 to August 31, 2010). Over 250 staff provided support to the response; of these, 106 staff field deployed during those four months, with some staff deploying multiple times across the five-state Gulf region. Staff typically deployed for two-week increments.

Through the Vessels of Opportunity program, BP hired local residents, like fishermen who owned private vessels, to conduct response efforts. On May 26, 2010, seven Louisiana fishermen, from five different vessels, were hospitalized with symptoms believed related to exposures during response activities. Subsequently, the Louisiana Department of Health and Hospitals received reports of 10 more response workers hospitalized in Louisiana. These hospitalizations raised concerns among the UC and triggered additional response actions.

NIOSH contributed to protecting oil cleanup workers through five main efforts: (1) providing technical guidance through a joint OSHA/NIOSH publication and other educational resources; (2) conducting health hazard evaluations (HHEs) (see Figure 24); (3) developing a voluntary roster of workers who participated in the response; (4) analyzing injury and illness data provided to NIOSH by BP safety officials; and (5)

conducting toxicity testing studies. Descriptions of these efforts follow in upcoming sections.

Figure 14. NIOSH staff preparing to conduct exposure monitoring on source control workers during the Deepwater Horizon response. [Photo credit: NIOSH]

Technical Guidance

NIOSH developed seven guidance documents and four informational communication products to assist incident response leadership, employers, employees, and health professionals in recognizing and preventing work-related acute illness, injury, and mental distress during response work as well as potential long-term physical and mental health effects. These documents were either developed at the request of UC, BP, or because NIOSH identified an information gap. For example, after the fishermen were hospitalized, the BP Safety Office requested that NIOSH provide guidance on the medical screening of workers hired for response and cleanup work to help develop parameters for fitness of duty. Within a month, NIOSH developed, cleared, and posted recommendations for medical pre-placement evaluation for health professionals. NIOSH posted this document, as well as the other guidance and educational resources, to the NIOSH Deepwater Horizon Response: Gulf of Mexico Oil Cleanup website and shared this guidance with the response leadership. Those documents are listed next.

NIOSH developed these guidance documents to protect DWH response and volunteer workers issued during the response:

- NIOSH/OSHA Interim Guidance for Protecting Deepwater Horizon Response Workers and Volunteers: Describes anticipated hazards and DWH-specific recommendations on how to protect workers.
- Chemical Exposure Assessment Considerations for Use in Evaluating Deepwater Horizon Response Workers and Volunteers: Discusses the chemical exposure portion of a health and safety plan, and provides guidance for OSH professionals with developing industrial hygiene sampling plans.
- Managing Traumatic Incident Stress for Deepwater Horizon Response and Volunteer Workers: Provides recommendations (in a pamphlet form) to help manage responder stress and fatigue during and after a response.
- Medical Pre-Placement Evaluation for Workers Engaged in the Deepwater Horizon Response: Provides recommendations on pre-placement evaluation for health professionals who provide primary care to workers or volunteers who may be involved in the DWH response.
- Medical Pre-Placement Evaluation Indicators for Health Professionals: Provides guidance to health professionals on specific elements of a pre-placement evaluation and conditions that may need further medical attention or work restrictions.
- Protecting Workers and Volunteers Responding On-Shore to Hurricanes from the Gulf of Mexico: Provides recommendations in preventing injury and illness during hurricane response activities in the context of the DWH response.
- Reducing Occupational Exposures while Working with Dispersants during the Gulf Oil Spill Response: Provides recommendations on ways to protect workers from potential exposures to dispersants.

NIOSH developed these educational resources to protect DWH response and volunteer workers issued during the response:

- Managing Your Stress: Tips for Deepwater Horizon Response and Volunteer Workers: Describes (in pamphlet form) ordinary reactions to stress that responders may experience during or after response work.
- NIOSH Interim Respiratory Protection Recommendations for Deepwater Horizon Response Workers: Describes NIOSH respiratory protection recommendations by response activity in easy to read matrix format.
- Staying Safe and Healthy on the Job! For Deepwater Horizon Response Workers (in English, Vietnamese, and Spanish): Describes NIOSH recommendations for workers, in a short fact sheet format, on how they can stay safe during response work.
- NIOSH Summary of Potential Hazards to Deepwater Horizon Response Workers: Describes potential hazards to response workers in easy to read table.

A key guidance document from those listed is NIOSH/OSHA Interim Guidance for Protecting Deepwater Horizon Response Workers and Volunteers. This was the first time NIOSH and OSHA released a co-branded guidance document during an emergency response. In this document, NIOSH and OSHA sought to describe the most relevant OSH hazards that response workers faced and approaches needed to protect those workers. This guidance also included specific respirator recommendations according to job task. Over several weeks, NIOSH and OSHA worked closely to draft the guidance and submit it for extensive clearance within each organization prior to release. NIOSH and OSHA worked with the Unified Area Command to prioritize the implementation of issues not yet implemented. Due to the success of this effort, NIOSH continues to work with OSHA and other federal agencies to issue co-branded guidance during emergencies.

Intermediate Outcomes:

- ❖ Many different responding agencies incorporated NIOSH guidance into their practices:
  - BP used the NIOSH recommendations for medical pre-placement to help direct private practitioners and BP staff who set up camps to hire workers in and around the Gulf near Venice and Grand Isle, Louisiana [Delaney 2017a].
  - The UC adopted NIOSH and OSHA recommendations for the use of respiratory protection for workers involved in decontamination or activities near the source to control the oil spill and cap the well [Michaels and Howard 2012].
  - The NIEHS Worker Education and Training Program, in coordination with OSHA, developed the Safety and Health Awareness for Oil Spill Cleanup Workers training tool. Along with other health and safety sources, NIEHS incorporated NIOSH recommendations into the training tool [NIEHS/OSHA 2010]. This training was given throughout the region and OSHA staff distributed the booklet to workers involved in oil spill cleanup across the Gulf Coast [OSHA 2010].
  - The American Petroleum Institute Oil Spill Prevention Fact Sheet Dispersants: Human Health and Safety cites the NIOSH and OSHA interim guidance document.

- Chapter 8, Fatigue-related Regulations and Guidelines, of the book, *Human Fatigue Risk Management: Improving Safety in the Chemical Processing*, featured NIOSH's fatigue prevention guidance for the DWH response as reported in the NIOSH and OSHA interim guidance document.

❖ Other agencies disseminated NIOSH DWH resources:

- EPA's Response to BP Spill in the Gulf of Mexico website linked to the NIOSH website
- The Louisiana Department of Health's DWH Behavioral Health website linked to the NIOSH DWH website.
- The Alabama Department of Public Health DWH website linked to NIOSH DWH website resources.

❖ The main NIOSH DEEPWATER HORIZON RESPONSE: Gulf of Mexico Oil Cleanup webpage has been viewed 38,942 times between June 2010 and March 2018. The NIOSH/OSHA Interim Guidance for Protecting Deepwater Horizon Response Workers and Volunteers was the most viewed guidance document developed during the response with 21,537 views between June 2010 and March 2018.

Health Hazard Evaluations

A key challenge in this response was the lack of understanding of the threats posed by the main exposures to crude oil, weathered oil, chemical dispersant, combinations thereof, and other potentially hazardous conditions. Additionally, workers performed a variety of tasks resulting in different exposure profiles; therefore, making it difficult to understand exposure scenarios for many different groups of workers, including the varying degrees they were affected. The NIOSH HHEs were an important activity to improve our understanding of the impacts to workers.

On May 28, 2010, NIOSH received a request for an HHE from BP management concerning health effects experienced by responders to the oil release. The hospitalization, on May 26, 2010, of seven fishermen working in BP's Vessels of Opportunity program in the Gulf of Mexico prompted the HHE request. The fishermen were hospitalized for symptoms initially believed to be related to exposures experienced during their response activities, particularly booming and skimming oil.

During the HHE planning process, BP requested that NIOSH expand the scope of the HHE to include all major offshore response activities. On June 22, 2010, BP submitted a second HHE request to investigate potential hazards associated with onshore response activities. In total, NIOSH HHEs covered seven work categories: beach cleanup; wildlife rehabilitation; source control; in situ burns; oil booming, skimming and vacuuming; dispersant operations; and decontamination and waste management activities. Additionally, NIOSH conducted psychological work-stress focus group sessions with safety officers.

The goals of the NIOSH HHEs were to describe acute health effects, evaluate occupational exposures in qualitative or quantitative assessments, and generate hypotheses regarding symptoms potentially related to work activities, not to describe or investigate potential long-term or chronic health effects. NIOSH HHE teams of physicians, industrial hygienists, epidemiologists, and engineers deployed across the Gulf Region to conduct these evaluations both onshore and on the water. NIOSH reported the results of these investigations in a series of nine interim reports and a final overall summary report posted on the NIOSH website. These nine interim reports provide background, methods, findings, conclusions, and, where appropriate, interim recommendations. NIOSH distributed the full reports electronically to key contacts for each work activity evaluated. Print and electronic media interviewed NIOSH staff throughout the response, helping to allay concerns and rumors that circulated in the community about the potential hazards of response work.

NIOSH developed nine interim HHE reports and a final report:

- Health Hazard Evaluation of Deepwater Horizon response workers: final report: Summarizes the evaluations, conclusions, and recommendations from the offshore and onshore HHE investigations.
- Interim report 1: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of hospitalized fishermen and dispersant work.
- Interim report 2: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of infirmary logs and workers conducting in-situ burning and oil vacuuming operations.

- Interim report 3: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of workers conducting oil skimming and dispersant work.
- Interim report 4: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of Vessels of Opportunity workers performing skimming from floating city, and source control workers, shown in Figure 25.
- Interim report 5: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of wildlife-cleaning and rehabilitation workers.
- Interim report 6: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of acute health affects among USCG and other safety personnel and response workers hospitalized in LA from May 28–June 22, 2010.
- Interim report 7: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of beach cleaning workers.
- Interim report 8: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of vessel and equipment decontamination and waste management workers.
- Interim report 9: Health Hazard Evaluation of Deepwater Horizon response workers: Evaluation of bulk sampling, health symptom surveys, and psychosocial and work organizations assessments.

Figure 25. NIOSH staff preparing to conduct exposure monitoring on workers at the source. [Photo credit: NIOSH]

The HHE exposure monitoring data showed that chemical exposure levels for workers performing onshore and offshore activities, for the most part, were well below occupational exposure limits; only carbon monoxide was identified above an occupational exposure limit. An evaluation of offshore and onshore workers identified heat as a major problem contributing to dehydration and heat exhaustion among some workers. NIOSH concluded that the initial illness in the hospitalized fishermen was unlikely to be related to dispersant exposure, but other work-related factors (e.g., heat, fatigue, and unpleasant odor from cleaners) may have contributed to their symptoms. NIOSH sampling results were consistent with industrial hygiene sampling results from OSHA and BP and its contractors. In an effort to be fully transparent with the completed work, NIOSH made the individual exposure monitoring and health survey data collected during the HHEs available in a spreadsheet format on the NIOSH DHW website. Three separate files were posted: (1) HHE Exposure Monitoring Data, (2) HHE Health Survey Data—Offshore Activities, and (3) HHE Health and Observational Survey Data—Onshore Activities.

Intermediate Outcomes*:*

- ❖ UC and BP used the results from the HHE activities, along with data from OSHA and BP and its contractors, to better protect response and cleanup workers. Because BP hired the majority of response workers, the HHEs influenced BP's safety training and PPE selection decisions as well as health monitoring, as reported in the BP document titled Protecting Worker and Public Health.

- ❖ Dissemination of NIOSH HHE reports by others:

  - The Gulf Future Coalition, a local community engagement group committed to providing long-term support to protect the environment and the Gulf Coast for future generations, created a webpage to provide a comprehensive and accessible collection of public health resources regarding the DWH disaster. This webpage includes links to the NIOSH HHE reports.

  - The Alabama Department of Public Health's DWH webpage links to NIOSH DWH resources.

  - The American Petroleum Institute Energy Dispersants Fact Sheets Introduction to Dispersants and Dispersants: Human Health and Safety referenced NIOSH's HHE Summary Report when discussing potential for human health effects.

- ❖ The NIOSH HHE reports on DWH were viewed 7,848 times between June 2010 and March 2018.

Response Worker Rostering Efforts

NIOSH supported UC in establishing a systematic roster of workers participating in response cleanup efforts. The Emergency Responder Health Monitoring and Surveillance (ERHMS) Interagency Workgroup, led by NIOSH, drafted recommendations for what ultimately became the NRT's Technical Assistance document; they also developed the concept for the worker roster. Chapter 2, beginning on page 26, contains detailed information about NIOSH ERHMS activities. As a direct result of the lessons learned from the response to the World Trade Center attacks in 2001, NIOSH decided to collect roster

information prospectively rather than retrospectively. In this way, a more accurate record of workers who responded to the oil spill exists. To our knowledge, this was the first time that a prospective, centralized roster of workers had ever been developed for an event of this magnitude [NIOSH 2011a].

The purpose of the roster was three-fold: (1) to create a written record of those who participated in the DWH response activities, (2) to collect information on the nature of their projected work assignments and the training they received, and (3) to have a way to contact responders about possible work-related symptoms of illness or injury during and after the event, as needed.

In order to gather this information, NIOSH developed a one-page roster form consisting of questions about the responder and his or her response activities. Additionally, as required by law, NIOSH developed a data use disclosure sheet describing how NIOSH would use the information, keep it private, and how to contact NIOSH with questions. All forms were available in English, Spanish, and Vietnamese, reflecting the diverse group of responders. Workers completed the roster at training areas prior to hiring. NIOSH staff visited staging areas (where trained workers reported for duty daily) in Louisiana, Mississippi, Alabama, and Florida to roster workers who were already on the job, shown in Figure 26. These teams encountered many challenges in locating and visiting these remote locations. As response needs changed, so did the staging areas, which required tremendous coordination with UC. A web-based form was also available later in the summer.

Figure 26. NIOSH staff member administers the roster form to workers during the DWH response. [Photo credit: NIOSH]

Ultimately, more than 55,000 workers completed the roster form over the course of the response. NIOSH issued a final report detailing the demographics of the worker population rostered and posted it to the NIOSH website. Additionally, NIOSH established a mechanism to grant access to the roster of qualified, external researchers interested in conducting disaster research [NIOSH 2011a]. Because NRT's Technical Assistance Document, which presents the ERHMS™ framework concepts, was still in draft form at the time of the oil spill, the workgroup made changes to incorporate lessons learned from the rostering effort to improve the quality and relevance of the content. The workgroup incorporated the most important forms and templates, including the rostering forms created specifically for this response, into the tools section of the NRT Technical Assistance document [NRT 2012].

Intermediate Outcomes:

- ❖ Researchers have studied only seven of 38 major oil spills to assess human health effects [Kwok et al. 2017]. NIOSH's response activities have been important in informing and supporting subsequent research. In addition to issuing reports detailing NIOSH DWH findings and sharing HHE data, NIOSH believed it critical to support studies. Therefore, NIOSH established a policy allowing qualified external researchers to recruit individuals in the roster to participate in future studies of possible persistent or long-term health effects. NIEHS initiated the GuLF STUDY, a prospective cohort study designed to examine human health effects of persons involved in the DWH oil spill response and cleanup [Kwok et al. 2017], using NIOSH's roster database as one source to identify participants. The GuLF STUDY resulted in numerous publications, with more coming in future years. Additionally, NIOSH air sampling and health surveillance activities contributed to ongoing research of oil spill and response workers. Kwok et al. acknowledged using NIOSH surveillance reports to help inform outcomes of interest for the study [Kwok et al. 2017].

- ❖ EHS Today, a highly acclaimed OSH magazine, wrote a brief article on the Deepwater Horizon Roster Summary Report results, linking directly to the report [Walter 2011]. EHS Works (a blog from the American Society of Safety Engineers) wrote a blog post about NIOSH's rostering efforts, also linking to report [PSJ 2011].

Analyses of Injury and Illness Data

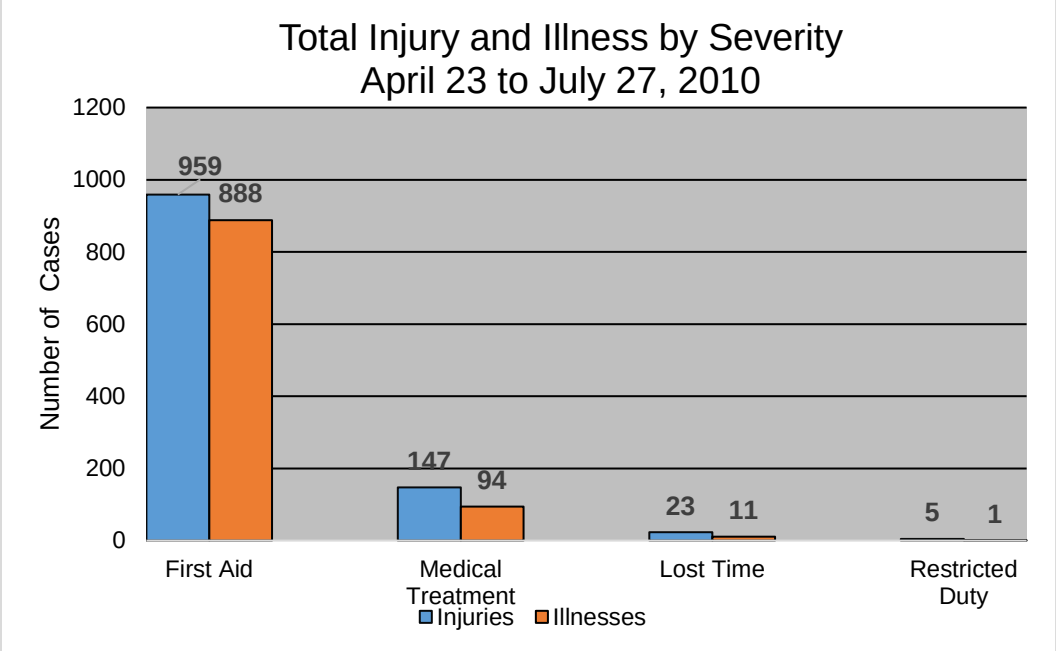
UAC safety officers, situated at staging areas across the Gulf Coast, used incident forms to collect reports of injury and illness among BP employees, contract workers, federal-state-local responders, and volunteers. BP granted NIOSH epidemiologists access to this data. NIOSH produced four reports of illness and injuries covering data collected from April 23 to July 27, 2010 [NIOSH 2010a]:

- NIOSH Report of Deepwater Horizon Response/Unified Area Command Illness and Injury Data (April 23—July 27, 2010: Provides a basic overview and analysis of illness and injury of DWH response workers recorded by safety officials.

- NIOSH Report of Deepwater Horizon Response/Unified Area Command Illness and Injury Data (April 23—July 8, 2010: Provides a basic overview and analysis of illness and injury of DWH response workers recorded by safety officials.
- NIOSH Report of Deepwater Horizon Response/Unified Area Command Illness and Injury Data (April 23—June 20, 2010: Provides a basic overview and analysis of illness and injury of DWH response workers recorded by safety officials.
- NIOSH Report of Deepwater Horizon Response/Unified Area Command Illness and Injury Data (April 23—June 6, 2010: Provides a basic overview and analysis of illness and injury of DWH response workers recorded by safety officials.

Figure 27 depicts the total number of injuries and illness among workers by severity during this time. With these reports, NIOSH aimed to promote public health through enhanced awareness of the risks associated with response work in the Gulf. NIOSH made these reports available to various safety and health stakeholders, including UAC safety officials, federal partners such as OSHA, state health departments, unions, and other worker groups, as well as to the public through the NIOSH website. In addition, in an effort to improve the quality of the data collected, NIOSH, along with other partners, provided feedback on the incident form itself.

Figure 27. Total injury and illness by severity among DHW responders, April 23—July 27, 2010.



Notes:

- Medical Treatment refers to any case requiring treatment beyond first aid, but which did not result in restricted duty or lost time.
- Two cases had insufficient information to include in this graph.

Intermediate Outcomes:

❖ To improve the quality of the data collected, BP revised the injury and illness incident forms based on input from NIOSH and feedback from other federal officials [NIOSH 2010b].

❖ Examples of stakeholders and partners reporting and sharing the NIOSH reports include

- The Mississippi State Department of Health's Morbidity Report (June 2010, Volume 36, Number 6) references and links to the NIOSH Report of NIOSH Report of DWH Response/Unified Area Command Illness and Injury Data—April 23 —June 6, 2010.
- The Safety, Health and Environmental Body of Knowledge webpage has the NIOSH Report of DWH/Unified Area Command Illness and Injury Data (April 23—July 27, 2010 available to registered members of the American Society of Safety Engineers Body of Knowledge.
- The book, Coastal Hazards, discusses the NIOSH Report of DWH/Unified Area Command Illness and Injury Data (April 23—July 27, 2010 in Chapter 25, Coastal Hazards from Oil Spills, of the book [Gundlach 2013].

❖ Media NOLA, a project of Tulane University, posted an article, Health Consequences of the BP Oil Spill, describing the results from the NIOSH Report of DWH/Unified Area Command Illness and Injury Data (April 23—July 27, 2010).

❖ The four injury and illness reports mentioned above have been downloaded 3,539 times between June 2010 and March 2018.

Toxicity Testing Studies

NIOSH initiated acute animal toxicity studies designed to assess the effects of the most commonly utilized dispersant, COREXIT 9500A (obtained from the manufacturer NALCO Holding Company, Naperville, Illinois). Specifically, inhalation studies measured pulmonary, cardiovascular, and central nervous system outcomes and dermal exposure studies assessed hypersensitivity and immune-mediated responses. Because all dispersant produced by the manufacturer was directed to be sold and used for oil cleanup, NIOSH sought special permission to obtain this product for the study. NIOSH was successful in doing so because of the strong relationship we had established with the UAC.

Effects of COREXIT 9500A included signs of breathing difficulty, a transient increase in blood pressure in response to vasoactive drugs, and changes in proteins involved in brain function that lasted seven days post-exposure. However, there were no signs of lung inflammation at either time. Research showed COREXIT 9500A to be a potent dermal irritant that elicited a hypersensitivity response in experimental animals. Dermal exposure to crude oil was found to be immunosuppressive. Although the findings alone do not provide sufficient information for definitive risk assessment, they do provide insight into the effects of crude oil and COREXIT 9500A, suggesting avenues for additional research [Roberts et al. 2014].

The first six papers describing NIOSH research findings were published in a single issue of the *Journal of Toxicology and Environmental Health* [Castranova 2011, Goldsmith 2011, Roberts 2011, Krajnak 2011, Sriram 2011, Anderson 2011]. Findings from an additional study to determine if there were longer-term health effects with repeated exposure to COREXIT was published in *Environmental Health Insights* [Roberts et al. 2014]. A final manuscript describing the effects of repetitive COREXIT exposure on the central nervous is in preparation.

Animal toxicity studies are being used at NIOSH to examine the in vivo and in vitro effects of inhaled DWH surrogate crude oil on the lung, brain, immune system, cardiovascular system and blood. NIOSH investigators are using techniques that had been utilized in earlier DWH dispersant studies.

Intermediate Outcome:

- Articles focusing on other non-occupational research topics, such as consequences of oil disasters on the environment and animals, have cited NIOSH research and findings on this topic (See Table 4 for Google Scholar citation counts as of May 18, 2018). Although the citations for these papers are somewhat low, this is likely due to the very narrow audience for these toxicology studies.

Table 4. Citations of select journal articles using NIOSH study material.

Article Name	Author	Times cited thru May 2018
Bioactivity of oil dispersant used in the Deepwater Horizon cleanup operation	Castranova et al. 2011	5
Pulmonary effects after acute inhalation of oil dispersant (COREXIT EC9500A) in rats	Roberts et al. 2011	24
Acute effects of COREXIT EC9500A on cardiovascular function in rats	Krajnak et al. 2011	25
Potential immunotoxicological health effects following exposure to COREXIT 9500A during cleanup of the Deepwater Horizon oil spill	Anderson et al. 2011	38
Neurotoxicity following acute inhalation exposure to the oil dispersant COREXIT EC9500A	Sriram et al. 2011	24
A Computer Controlled Whole-Body Inhalation Exposure System for the Oil Dispersant COREXIT EC9500A	Goldsmith et al. 2011	10
Evaluation of pulmonary and systemic toxicity of oil dispersant (COREXIT EC9500A) following acute repeated inhalation exposure	Roberts et al. 2015	3

Lasting Impact of DWH

At the time, DWH was the largest activation of NIOSH resources to an emergency response. The response activities presented opportunities to further expand our knowledge of protecting workers during large-scale emergency responses. NIOSH addressed after-action challenges by drafting peer-reviewed papers to provide frameworks and decision processes for standing up research during disasters and determining when biological monitoring is warranted. NIOSH captured the lessons learned in the documents listed next, which have been critical in helping NIOSH develop its approach to disaster science research:

- Lessons Learned from the Deepwater Horizon Response—NIOSH numbered publication describing NIOSH response activities, lessons learned, and next steps [NIOSH 2011b].
- Science Blog: NIOSH's Role in the Deepwater Horizon Response—A blog article summarizing NIOSH response activities and allowing for open lines of communications with workers and stakeholders through blog comments [Spahr 2010].
- Peer-reviewed publications:
    - Senior NIOSH scientists developed a decision process to help determine when to conduct responder health research following disasters [Decker et al. 2013a].
    - Senior NIOSH scientists developed a decision framework for when to perform biomonitoring in an emergency response, either as part of a health investigation or for research purposes [Decker et al. 2013b].
    - Two papers described NIOSH's response activities. The first paper describes the DWH response experience and how it deepened the knowledge gained from other large-scale disaster responses, including the World Trade Center attack and Hurricane Katrina [Kitt et al. 2011]. The second paper, co-authored by the heads of OSHA and NIOSH, provided a review of the contributions of NIOSH and OSHA in the response [Michaels and Howard 2012].

Intermediate Outcomes:

- ❖ Dissemination of NIOSH DWH publications by those external to NIOSH:
  - The American Society of Engineers promoted the NIOSH Science Blog NIOSH's Role in the Deepwater Horizon Response on its webpage.
  - American College of Occupational and Environmental Medicine wrote a press release on the NIOSH article, Protecting workers in large-scale emergency responses: NIOSH experience in the Deepwater Horizon response.
  - Occupational Health and Safety Magazine wrote a brief article, NIOSH Describes Worker Protections After Deepwater Horizon Disaster, summarizing the report, Protecting workers in large-scale emergency responses: NIOSH experience in the Deepwater Horizon response.
  - The National Institutes of Health stood up a Disaster Research Response Program to improve and enhance disaster science research. The Disaster Research Response Program, in collaboration with the National Library of Medicine, established a website with links to important data collection tools and resources for use by disaster science investigators. Four tools developed by NIOSH while responding to DWH are located on that site.
- ❖ The Center for Progressive Reform evaluated the federal response to the DWH response. In their report, From Ship to Shore: Reforming the National Contingency Plan to Improve Protections for Oil Spill Cleanup Workers, they highlight resources OSHA and NIOSH brought to the response as well as gave recommendations to improve the federal response. The report highlights the following NIOSH activities:
  - OSHA and NIOSH developed a "matrix" of various tasks that cleanup workers did, providing a model that could be used to improve planning for future oil spills.
  - NIOSH worked to compile a roster of all workers involved in the cleanup to track health effects more readily.

- NIOSH completed HHEs and published interim reports of the work, before the final report.

Request from U.S. Department of State, U.S. Embassy Caracas, Venezuela: Teargas Exposure Remediation Inquiry

In May 2017, the CDC Washington Office received a request for technical information from the Regional Medical Officer (RMO) for the U.S. Embassy in Caracas, Venezuela. At that time, there were almost daily protests in Caracas where teargas was used frequently. The RMO received questions regarding risks of exposure to and methods for neutralizing teargas exposure. The Officer was following the CDC's website guidance, which advises the use of copious amounts of plain water to rinse all exposed areas and to move away from the potential contact zones in the city; but personnel had to travel through zones that placed them at risk for exposure. He contacted CDC requesting any data that might help determine if the CDC guidance of using water only or the use of a buffered solution with baking soda was more effective at neutralizing the teargas exposure.

The CDC Washington Office referred the RMO to NIOSH for assistance. NIOSH conducted an expedited literature review and discussed this request with the FBI National Laboratory in Quantico, Virginia, that has experience and knowledge on teargas health effects. There are three types of teargas commonly used as riot control agents. A mixture of baking soda, sodium carbonate, and benzalkonium has been shown to be effective against only one type of teargas. There is no scientific evidence that baking soda alone will have any effect. However, soap and water has been recommended for decontamination for all three agents. NIOSH quickly recommended that the RMO continue following the CDC guidelines rather than implement new guidance using baking soda given the scenario described and the uncertainty around what type of teargas would be used on any given day.

Intermediate Outcome:

- ❖ The RMO incorporated the information into a training program for U.S. Embassy staff [Hornsby-Myers 2017].

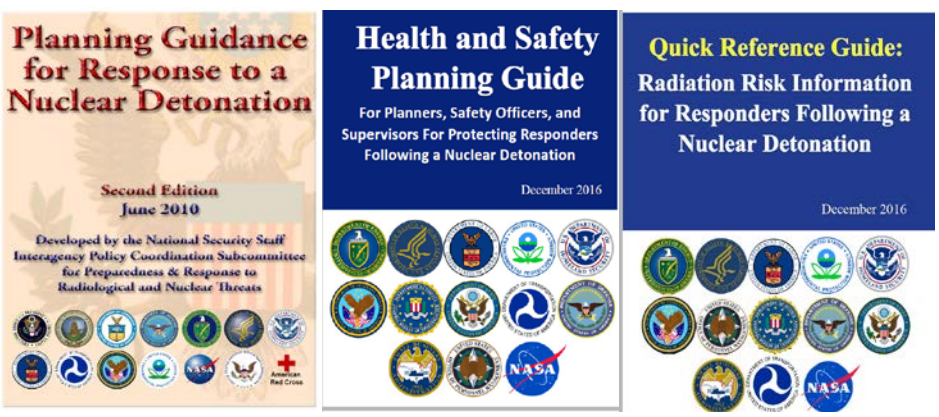
Section 2: Radiation

Planning and preparing for a successful response to radiological and nuclear threats is a major component of the EPR portfolio, although, radiological and nuclear emergencies are rare. NIOSH participates in interagency coordination teams and subcommittees to develop planning guidance to support a federal government response. NIOSH participation in exercises let us work through those federal plans, address challenges and gaps in preparedness and response, and train staff to support response. Our largest response in this area occurred after the Fukushima Daiichi nuclear power plant was damaged by a tsunami in 2011 leading to the release of radioactive material. We describe some of our radiological and nuclear preparedness and response activities next.

Preparedness Activities

NIOSH was a member of a federal interagency subcommittee, the Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats, led by the Executive Office of the President that was tasked with updating existing First Edition Planning Guidance. The Planning Guidance for Response to a Nuclear Detonation, second edition, June 2010 (Figure 28) [NSS 2010] superseded the first edition. The planning guidance provides emergency planners with nuclear detonation-specific response recommendations to maximize the preservation of life in the event of an urban nuclear detonation. The guidance addresses many topics: scale of destruction, shelter and evacuation strategies, unparalleled medical demands, management of nuclear casualties, and how to manage various radiation doses.

Figure 28: Examples of interagency radiation planning guides.



While the Subcommittee developed the planning guidance, they recognized that separate guidance focusing solely on protecting responders after a nuclear detonation was needed to provide detailed information for both responders and emergency planners. To that end, NIOSH co-authored the interagency guidance, Health and Safety Planning Guide for Planners, Safety Officers, and Supervisors For Protecting Responders Following a Nuclear Detonation (Dec 2016), as a supplement to the planning guidance, to assist in the preparation for health and safety management in the event of a successful improvised nuclear device (IND) event [NSS 2016a]. The health and safety planning guide defines responders as a diverse set of individuals, critical to mitigating the potential catastrophic effects of an IND. These responders include professional and traditional first responders, the emergency management community, public health and medical professionals, skilled support personnel, and emergency service and critical infrastructure personnel. Responders may be governmental, volunteer, or private sector organizations. The National Security Council led Domestic Readiness Group approved the health and safety planning guide for publication by on November 17, 2016. This group is convened by the White House to develop and coordinate EPR policies and address issues that cannot be resolved at lower levels.

NIOSH co-authored the Quick Reference Guide: Radiation Risk Information for Responders Following a Nuclear Detonation (December 2016), which supports the Planning Guidance for Response to a Nuclear Detonation [NSS 2016b]. NIOSH designed the Quick Reference Guide to provide responders with specific guidance and recommendations about the radiation risks associated with responding to an IND event, so they can protect themselves. It is intended to be part of preparation training with the Health and Safety Planning Guide for Planners and Supervisors For Protecting First Responders Following A Nuclear Detonation. The Quick Reference Guide provides basic information responders will need for the first 24 to 72 hours after a nuclear detonation, and are not applicable to other, less extreme, radiological events.

Since 2003, NIOSH has been a member of the Advisory Team for Environment, Food, and Health (Advisory Team), a radiological emergency response group tasked with providing protective action recommendations to state, local, and territorial governments following a radiological incident. This team of SMEs is composed of federal agency staff, including EPA, FDA, CDC, and the U.S. Department of Agriculture (USDA).

Team participants provide coordinated advice and recommendations to federal, state, local, and tribal governments for use during radiation emergencies. NIOSH staff provide worker safety and health expertise to the Advisory Team for radiation emergency preparation, during an event, and for use in exercises. Examples of NIOSH's work within the Advisory Team structure to support radiation preparedness and response activities follow in this section.

Over the last decade, NIOSH participated in eight national-level radiation preparedness exercises involving numerous federal agencies. Each exercise focused on a different radiation emergency scenario (e.g., radiological dispersal devices, INDs, nuclear power plant accidents) affecting various geographic areas of the U.S. One or two NIOSH staff deployed to the exercise location to work in the field response office or to the CDC EOC to play out an activation. The Advisory Team was activated in all eight exercises from 2007 through 2017, and NIOSH provided technical assistance during these exercises as part of the team and independently from the team structure. NIOSH staff participated in dozens of smaller ingestion pathway exercises, assisting the Advisory Team on worker safety and health issues. Knowledge gained and lessons learned from participating in these exercises informed the development of the three interagency radiation-planning guides described earlier [NSS 2010, 2016a, b].

In 2017, NIOSH staff participated in the 2017 Nuclear Radiological Preparedness Training and Exercise Program (Nuc/Rad TEP) [CDC 2017c] with CDC's radiation program. The Nuc/Rad TEP was led by the CDC Office of Public Health Preparedness and Response, Division of Emergency Operations, Plans, Training, Exercise and Evaluation Branch. The Nuc/Rad TEP included a series of focused tabletop exercises, drills, and workshops, between October 2016 and April 2017, to better prepare CDC for the FEMA-led exercise that served as the U.S. government large-scale exercise for FY17, Gotham Shield (GS 17). GS 17 evaluates the whole community effort to prevent, protect from, respond to, and plan initial recovery activities following the effects of an IND attack in a large U.S. city. The GS 17 exercise took place April 24–27, 2017. Because of NIOSH's efforts and participation in these activities, CDC asked NIOSH to lead a Worker Safety and Health (WSH) Task Force in the EOC to address all occupational issues that arose during the exercise. Participating in these exercises allowed NIOSH to train staff on responding to a

radiation event, build partnerships with critical response agencies, and disseminate NIOSH recommendations and knowledge.

Following the exercise, NIOSH was requested to participate in CDC Division of State and Local Readiness' two radiation/nuclear focus calls in the fall of 2017. One call was with the state of Hawaii and one call was with Guam and the Commonwealth of Northern Mariana Islands. NIOSH participated as a part of a CDC wide panel on these calls and provided information on worker safety and health.

Intermediate Outcomes:

- The Advisory Team used NIOSH's recommendations in exercises concerning worker exposure limits, PPE recommendations, and health monitoring. For example, during the most recent Gotham Shield exercise, the Advisory Team consulted with NIOSH staff on dose limits for worker radiation exposure as part of developing the Health and Safety Plan in coordination with OSHA and FEMA.

- As a result of the GS 17 exercise, CDC recognized the value of having a WSH Task Force, making the Task Force a permanent part of the radiation IMS structure within the EOC and incorporating lessons learned into internal planning documents.

Fukushima: Radiation Dispersal from Japan

On March 11, 2011, a 9.0 magnitude earthquake hit the east coast of Japan, triggering a tsunami. These events killed thousands of people and caused serious, widespread damage to buildings, roads, and power lines, particularly along the east coast of the Tohoku region. Damage to the Fukushima Daiichi nuclear power plant, after the earthquake and tsunami, resulted in a leak of radioactive material from the facility. CDC activated the EOC, and NIOSH staffed the WSH Task Force to support OSH activities.

NIOSH received multiple requests for information from other federal agencies (i.e., DOS, DHS, and OSHA), workers at ports of entry, longshoreman, flight attendants and their respective unions, CDC EOC teams, and the Advisory Team on how this international event could affect public health in the U.S. For example, when the White House National Security Council considered setting a ceiling limit of 4 Bq/cm^2 level of contamination for

packages and cargo coming into U.S. ports, the Department of Transportation (DOT) and the White House National Security Staff requested input from NIOSH. NIOSH radiation SMEs performed a radiation-exposure pathway analysis to estimate potential effective doses to workers who faced exposure to contaminated cargo at ports [NIOSH 2011c]. NIOSH drew these conclusions:

> *Based on the proposed screening procedures, an assumed measured uniform surface contamination level of 4 Bq/cm^2, and the radionuclides proposed by the National Security Staff, the evaluation indicates that workers involved in screening and handling luggage and cargo at ports of entry would not receive an effective dose in excess of OSHA's ionizing radiation standard. Although the screening procedures and surface contamination standard are consistent with federal occupational safety and health standards, states with approved state plans may enforce more stringent standards.*

Furthermore, given the number of information requests, NIOSH developed the Radiation Dispersal from Japan website to disseminate information to American workers on the risks, or lack of risks, associated with people and materials coming from the affected areas. The website included information and recommendations for workers in the transportation, delivery, and maritime industries as well as aviation aircrew staff.

Numerous federal agencies reached out to NIOSH about how to protect their workforce during this radiation emergency. The FEMA Administrator asked the DHS Office of Health Affairs (OHA) to work with NIOSH to set up a Registry for Urban Search and Rescue (USAR) teams returning from Japan. NIOSH assisted DHS OHA with the development of a post-deployment health-screening questionnaire and an OSH Safety Advisory on radiation concerns. Previously, NIOSH had provided guidance on medical requirements and decontamination procedures to the U.S. State Department employees assigned to the U.S. Embassy in Tokyo who evacuated from the tsunami-impacted area to Fukushima prior to its failure.

At the request of CDC's EOC, NIOSH provided recommendations on which dosimeters to purchase for their deploying staff to ensure the dosimeters collected the data needed to protect workers. NIOSH also advised on what training was needed on how to use the dosimeters.

NIOSH provided technical assistance to a major airline carrier's occupational health group on an assessment of a flight attendant who had flown to Japan after the earthquake. The flight attendant was concerned his/her recent health symptoms were caused by radiation poisoning. NIOSH staff consulted with the treating physician and recommended testing of the thyroid. NIOSH staff completed calculations to estimate any missed dose that may have gone undetected due to the time lapse between the potential exposure and the testing. NIOSH determined that any missed dose was negligible and provided this information to the airline's occupational medical group who then shared it with the treating physician.

In March 2012, at the invitation of the Strategic Capabilities Policy Director in the National Security Staff within the Executive Office of the President, NIOSH participated in a scenario driven, facilitated discussion designed to identify and examine key lessons learned from the Fukushima nuclear disaster. NIOSH's work in general and as well as with OSHA on the surface contamination standard was recognized as a key success during the Fukushima event.

Intermediate Outcomes:

- In part, due to the determination made by NIOSH regarding estimated exposures below OSHA standards, the DOT refrained from enforcing Hazardous Materials Regulations provisions for cargo containers that had surface radioactive contamination allowing the containers to come through the port of entry [Miller 2012].

- DHS OHA incorporated NIOSH recommendations in an *Occupational Health and Safety Advisory* on potential radiation concerns and shared it with DHS employees.

- CDC's EOC purchased radiation dosimeters and trained staff on their proper use along with the hazards in the environment they might encounter based on NIOSH recommendations.

- The physician treating the flight attendant who had concerns about radiation poisoning used the information provided by NIOSH to counsel the patient.

- The Radiation Dispersal from Japan website was viewed 17,607 times between March 2011 and March 2018. The subpages, including Worker Information, CDC Civilian Aircrew Recommendations, Environmental Radiation Monitoring, Potassium Iodide, and Radiation Basics were viewed a cumulative 31,029 times between January 2011 and March 2018.

Response to Radioactive Scrap Found in Scrap Metal Facility, Massillon, Ohio: February through March, 2016

In February 2016, the Ohio Department of Health (ODH) contacted NIOSH concerning potential worker exposures to radioactive scrap in material delivered to a scrap metal facility. Initially, the ODH medical director and assistant chief of the ODH Bureau of Environmental Health and Radiation Protection requested a NIOSH consult on medical testing of employees. As the incident evolved, ODH requested a NIOSH radiation SME deploy to Ohio to help with the investigation and response. A specialized radiation support team from the Department of Energy called the Radiological Assistance Program also provided on-site support. Investigators determined that a release of a brachytherapy source (sealed radiation source used to treat cancer) into the metal waste stream had occurred.

NIOSH's SME on worker radiation exposures accompanied ODH representatives to the scrap metal facility to provide on-site technical assistance concerning the health and safety of the facility workers by interviewing workers and observing the survey of the facility by the Department of Energy Radiological Assistance Program Team. NIOSH radiation experts provided recommendations on which bioassay methods that could assess workers who may have been exposed to radiation or radioactive materials (possibly radium-226). In anticipation of a possible need for bioassay testing (whole-body or lung counting and urinalysis/fecal analysis), NIOSH identified laboratories that offered this type of testing.

As the investigation unfolded, NIOSH provided technical assistance to ODH as they developed communication materials to share with the employees about the incident and impacts to their health. NIOSH estimated potential exposures from inhalation using data from grab and air samples collected by the decontamination contractors and provided the results to ODH. NIOSH also evaluated the gamma spectroscopy results from environmental samples collected by a health physics contractor and analyzed by

an external laboratory. Based on these results, NIOSH's expert opinion was that if workers were exposed by inhalation or ingestion, the dose would be so low as to be indistinguishable from background. Given the low amounts, NIOSH believed it unlikely radiation would be detected using *in vivo* (whole-body or lung counting) or *in vitro* (urinalysis/fecal analysis) bioassay. NIOSH staff participated in discussions with ODH and the facility management concerning whether or not to perform bioassay testing on employees, sharing their expert opinion and recommendations. Investigators found, secured, and removed the source of radiation contamination and the area successfully decontaminated.

Intermediate Outcome:

- ODH incorporated NIOSH radiation expertise in talking points used to communicate with potentially exposed employees at the scrap metal facility. ODH and the facility management accepted the NIOSH recommendations and determined bioassay testing including whole-body or lung counting and urinalysis for radium-226 was not necessary.

Section 3: Hurricanes

Hurricanes of varying degrees of severity occur annually. They are one of the more predictable disasters that can be planned for and have some advanced warning when they occur. The OSH hazards that arise from hurricane disaster work are well known and include exposures to mold during clean-up, injury hazards associated with debris removal and remediation, and heat stress. Prior to each hurricane season, which runs June 1 to November 30, several organizations make predictions about the number of hurricanes expected for the upcoming season [NOAA 2018, CSU 2018]. As a result, emergency management and public health officials in hurricane impacted states have a wealth of experience preparing for and responding to hurricanes and are typically able to support the response with local resources. NIOSH traditionally has a limited role in providing support to hurricane disaster responses. NIOSH has developed a Storm, Flood, and Hurricane Response website which contains informational materials to address common OSH concerns. NIOSH distributes this information in various forms before, during, and after the response to ensure responders and recovery workers are aware of our recommendations (see example guidance in Figure 29). NIOSH also answers

technical questions on OSH concerns that may arise during a response, helps educate response organizations on OSH through the ERHMS™ program (previously discussed in Chapter 2), and when funds are available support research to better prepare for the next hurricane.

Figure 29. Cover to the NIOSH Hurricane Key Messages for Employers, Workers, and Volunteers document developed for the 2017 hurricane season.

Hurricane Katrina

Hurricane Katrina devastated New Orleans in August 2005 with high winds and floods that impacted approximately 80% of the city for several weeks [Dolfman et al. 2007]. In the aftermath of the hurricane, response and recovery workers risked a variety of injuries and illnesses. In addition to working with CDC's EOC during this incident and deploying staff to the impacted areas, NIOSH's Office of Extramural Programs (OEP) funded four investigator-initiated project addressing inhalation hazards, development of medical surveillance tools, evaluation of mental health effects, and assessment of training effectiveness. It is worth noting that NIOSH did not receive dedicated funds to

research this particular disaster, unlike other emergencies where funds were available immediately. Because of this, the earliest study of the four funded projects did not begin until two years (2007) after the hurricane, with the next one beginning in 2009, and the two remaining beginning in 2010.

Inhalation Hazards during the Recovery Phase of a Response

In 2007, Rando et al. at Tulane University evaluated respiratory effects in workers from post-Katrina related airborne exposures. Researchers performed a 5-year study with a group of 898 workers from the New Orleans area who performed various recovery activities including debris removal, sewer and waterline repair, and mold remediation [Hnizdo et al. 2010]. Significant findings were identified for post-Katrina sinus symptoms, transient fever with cough, and new onset asthma for those who performed recovery and restoration work [Hnizdo et al. 2010; Rando et al. 2012]. Findings from this study indicate an ongoing need to continue surveillance well beyond the initial response to identify and minimize inhalation exposures.

OnLine Medical Surveillance Program for Louisiana Fire Fighters

In 2009, Moline et al. at the Feinstein Institute for Medical Research initiated a 4-year pilot study to develop an online surveillance program for Louisiana fire fighters to assess their health outcomes associated with the hurricane responses. The process began by emailing each individual participant a link seeking their consent to participate in the study, and requested them to complete medical and exposure history questionnaires. After this step, the medical office completing the physical exams would contact the participant to schedule an in-person appointment with a physician. On that day, blood and urine would be collected, a pulmonary function testwould be performed, and chest x-rays also completed. All results were stored in a single, HIPAA-compliant electronic record from which raw data could extracted for analysis. All participants received a letter with their results, and if urgent findings were identified, medical staff would call the participant. Investigators noted that recruitment of fire fighters was challenging as approximately 75% of the active workforce did not take part in the response and recovery efforts associated with Hurricanes Katrina or Rita [Moline 2014].

Investigators reported to NIOSH that 71 fire fighters completed the informed consent forms and questionnaire, while 53 also completed the medical exam. Results indicated that 65% of the participating fire fighters reported having upper respiratory symptoms,

31% reported lower respiratory symptoms, 37% reported cough, and 23% reported skin irritation during and/or after the initial rescue phase of the response. Additionally, fire fighters who reported floodwater exposures over 72 hours were more likely to have lower respiratory symptoms and shortness of breath. Fire fighters also reported persistent mental health symptoms including increased rates of sleep disturbances, anxiety, flashbacks, irritability, and difficulty in concentration [Moline 2014]. The online data collection process that was developed for this study has served as the as the basis to create additional medical surveillance databases at Northwell Health [Robison 2018a].

Evaluation of Long-Term Mental Health Effects in Police Officers

In 2010, Violanti et al. initiated a three-year study to assess associations between stress and long-term psychosocial trauma (six years later) experienced by New Orleans Police Department officers following Hurricane Katrina. Male officers reported higher average depressive symptoms and stress while female officers had higher posttraumatic stress symptom scores [McCanlies et al. 2014]. Additionally, over the six years following the storm, participants reported an increase in life changes related to work, family, health, and financial matters as well as depression, stress, and traumatic symptoms [Heavey et al. 2015]. As found with many disasters, study authors noted that first responders in particular are repeatedly exposed to unpredictable circumstances, therefore requiring a variety of assistance resources to help them deal more effectively with the impact of the response [McCanlies et al. 2017, McCanlies et al. 2014; Leppma et al. 2018; McCanlies 2018].

Occupational Health Training for Day Laborers

Lara and colleagues at the RAND Corporation developed, piloted, and evaluated an intervention for Hispanic day labors who had disproportionate risk while working construction jobs. Researchers created an 11 minute educational video in Spanish featuring 3 case studies injuries among day laborers at construction sites and what could have been done differently. The training video sought to increase knowledge and use of preventive behaviors for occupational risks during post-disaster construction and cleanup. This mode of training was chosen because it was feasible to deliver in clinic and community settings. Researchers randomized data from 98 Hispanic day laborers into intervention or control group, and found that the video intervention was associated

with statistically significantly improved knowledge and intended behavior outcomes, compared to the control group. Behavior outcomes were measured using two sub-scales, one on "Self-advocacy" behaviors (e.g., asking employers about possible dangers), and a second on "Other Protective Actions" (e.g checking their own protective equipment head to toe, using a ladder correctly) [Lara and Geschwind 2015].

Hurricane Sandy

Hurricane Sandy made landfall near Atlantic City, New Jersey, on October 29, 2012. The storm impacted a densely populated area of over 900 miles, exposing millions of residents to floodwater and high winds. A large percentage of homes were impacted by the storm, and as is commonly experienced following a natural disaster of this magnitude, there was a shortage of trained and experienced contractors to do the work. Consequently, many homeowners, volunteers, and non-professional laborers did the work without appropriate training and use of personal protective equipment to prevent exposures to mold and other hazardous conditions.

In 2013, CDC, and consequently NIOSH, received funding for Hurricane Sandy research under the Disaster Relief Appropriation Act of 2013 to provide support for disaster research to assess injury and illnesses associated with the hurricane. In regards to response and recovery workers, this also included nontraditional workers such as cleanup crews, homeowners, and volunteers. This funding mechanism was significant, because unlike previous natural disasters, this provided funding to commission research evaluating a variety of areas of concern, including response and recovery workers. Although 11 months passed before HHS actually received the funding, this was considered a rapid timeline for research funds to be made available relative to past experiences [Carbone and Wright 2016].

In addition to working with CDC's EOC during this incident and deploying staff to the impacted areas (as was also the case with Hurricane Katrina), NIOSH's OEP funded five investigator-initiated project possible hazards and adverse health effects among response and recovery workers, such as Latino day laborers, EMS personnel, tree care and services, Red Cross shelter personnel, and volunteer laborers. Some of the findings from these research studies benefited the more recent response to Hurricane Maria.

Reducing Occupational Hazards of Sandy-Related Work of Immigrant Day Laborers

Markowitz and colleagues at Queens College conducted an intervention project for Latino construction day laborers, a common workforce deployed during recovery efforts following natural disasters. The data collected consisted of workplace injury and exposure assessments, potential barriers for occupational safety and health practices, and the development and evaluation of previously-developed education materials and training practices. As part of this project, researchers developed a novel approach using a mobile application to facilitate workplace assessments that participants to report hazards via a user-friendly checklist in addition to documenting work conditions with photos. The mobile application led to the completion of 175 workplace assessments by 16 workers. The predominant hazards noted by the construction workers included dust, electrical hazards, mold, and injuries related to cement demolition [Cuervo et al. 2017]. The mobile application was shared with investigators in Houston following the 2017 hurricanes and with several workers centers [Weber 2018a].

The researchers also founded the Immigrant Worker Disaster Resilience Workgroup with several community based organizations, in order to incorporate them into the disaster response structure and build long-term preparedness capacity [Cuervo et al. 2017]. Since the grant ended, this Workgroup has become a resource to local organizations interested in worker safety and health. Trained members of the workgroup are now members of the United Steelworkers Special Emergency Response Teams and have been part of the organized response to recent disasters including in Puerto Rico and Houston where Spanish language trained responders were especially needed. Workgroup membership has also expanded to include approximately 15 different workers centers in New York City, New Jersey, Westchester and Long Island [Weber 2018a].

More recently, investigators shared PPE program materials developed as part of the NIOSH study during the 2017 hurricane and wildland fire season. This included information on how to set up such a program with local Occupational Health practitioners in Texas, Florida, Puerto Rico, and California. N95 filtering facepiece respirators (FFRs) were distributed in some of these locations [Weber 2018a].

Intermediate Outcomes:

- A comprehensive training kit has been developed which includes a trainer's guide, a PowerPoint training presentation, and worker handouts [Weber 2018a]. Lessons learned through the project have been applied to develop and implement additional training programs funded by the NY State Department of Labor that also incorporate OSHA 10 and OSHA 30 material. Training is provided in Spanish to Latino immigrant construction and cleaning workers. With the $300,000 provided under the NY State Department of Labor program, investigators have provided training to over 1,500 workers with more than 20,000 training hours. The training has been conducted by member organizations involved in the Immigrant Worker Disaster Resiliency Workgroup [Weber 2018a]. The relationships built during this project have led to further projects. The Workgroup successfully competed for three training grants (totaling over $400,000) to continue training workers [Weber 2018a].

- The experience and approach to training for Hurricane Sandy is being utilized by several of the workers centers affiliated with the Workgroup to address infectious disease preparedness training with NIEHS funding [Weber 2018a].

Development of an Occupational Health Syndromic Surveillance System for Disasters

This research project by the New Jersey Department of Health & Senior Services aimed to 1) summarize work-related injuries and acute illnesses in New Jersey after Hurricane Sandy through analyses of statewide data sources; identify gaps in existing data sources; and provide recommendations for strategies for future occuptional health surveillance; and 2) convene focus groups among three first responder worker populations. This study allowed the researchers to evaluate the existing state syndromic surveillance system to identify work-related injuries in real-time using Emergency Department (ED) visits. A tree-related classifier, using a chief-complaint field text from ED visits in real-time, was developed and subsequently identified an increase in tree-related injuries associated with clean-up activities. The three workforces of interest in this project included emergency medical services (EMS), tree care companies, and response volunteers. Findings from this study indicated that the greatest number of injuries occurred during the recovery phase rather than initial response. The focus group

participants described exposures to hazardous materials and conditions including floodwater, downed power lines, animals, feces, mold, hostile residents, downed trees, and extending workshifts greater than 16 hours per day [Marshall et al. 2016].

Results of this study have been shared with stakeholders, including the Committee to Advance Arboriculture New Jersey, and the Tree Care Industry Association [Robison 2018b]. The principal investigator, Margaret Lumia, PhD, MPH, contributed to the work-related outcomes section of the *Syndromic Surveillance Climate and Health Guidance Document: How Jurisdictions Can Use Surveillance to Quantify and track Climate-Related Health Impacts*, which was published in September 2017 [CSTE Climate and Health Syndromic Surveillance Workgroup 2017].

Based on the results from this project, the New Jersey state based Syndromic Surveillance System has been incorporated as another occupational health surveillance data source to supplementcurrent surveillance efforts. This work is being used to expand current surveillance capabilities by identifying other occupational injuries and illnesses that may occur during future disasters such as monitoring heat-related illnesses, CO poisoning, and chemical exposures. Researchers are now able to capture occupational injuries and illnesses in real-time which is important during emergencies and non-emergencies. There is often a time delay in receiving work-related injury and illness data through traditional data sources, such as hospital discharge data. There can be a lag time of three months to three years which does not allow rapid response when required [Robison 2018b].

Intermediate Outcomes:

- The state syndromic surveillance system now has a severe weather classifier which allows their staff to easily identify cases that are related to natural disasters allowing them to identify more cases. For example, in March 2018, 41 (37%) of the CO exposures captured by the syndromic surveillance system were flagged as “hurricane”, during the time NJ experienced four Nor’ Easters. These CO injuries may have been a result of the use of generators [Robison 2018b].

- The syndromic surveillance system was used in 2015 when it captured injuries reported by six firefighters exposed to a liquid coating during a fire at a warehouse [Robison 2018b].

- The results from this project lead to additional funding under the ASPR Collaborative Scientific Research Related to Recovery from Hurricane Sandy: Tree Hazards 1 HITEP140016-01-00 (Rosen). A journal article on this second research project was recently published [Marshall et al. 2018]

- The collaborations developed with the tree care community during both the NIOSH and ASPR grants, emphasized gaps in training tree care workers, especially Spanish-speaking workers. One of the grant recipient's collaborators, The Committee for the Advancement of Arboriculture, applied for and received a Susan Harwood Training Grant in 2016 with a focus on capacity to train municipal and Spanish-speaking workers on machine and fall hazards [Robison 2018].

Worker Safety Training Effectiveness in Preventing Exposures

Following Hurricane Sandy, residents and volunteers assisted in the remediation of homes facing exposure to mold, asbestos, and other contaminants. As a result, the New York City (NYC) Department of Health and Mental Hygiene (DOHMH) saw the need to educate this population in safe work practices for handling contaminated debris and using personal protective equipment (PPE). On behalf of DOHMH, more than seventy 1-hour and 3-hour trainings were conducted. A field survey of 429 people who performed mold remediation activities and participated in the DOHMH-sponsored worker-safety training programs found over 61 statistically significant associations between symptoms of illness and occupational and environmental exposures. Depression affected the highest number of participants (6.5%) [Reilly et al. 2016].

Assessing and Managing Health Risks from Fugitive Chemicals after Hurricanes

Hurricane Sandy caused severe flooding to areas in New York City where heavy industrial facilities are in close proximity to residential communities. "Fugitive" chemicals from industrial zones are dispersed through floodwaters to recovery sites, where they become potential hazardous exposures for recovery workers. Using a community-based risk assessment approach, researchers identified over 2,000 chemical source points in the study area, finding more than 800 chemical hazards present across sites. The findings showed that without PPE, naphthalene, phthalates, lead, and ethylene glycol had the highest exposure potential.

Task type and environmental condidtions impacted the effectiveness of protective clothing to reduce exposure. For example high boots reduced exposure by more than 50% for certain activities, while a 30% reduction could be achieved by wearing a mask, especially in dry areas. However, researchers found impermeable gloves the most effective ar reducing exposure in nearly all cases. Community partners are using this project's results to make recommendations to NYC agencies for chemical testing in advance of a future storm (meaning which chemicals and which geographic areas), working with NYC agencies and industrial businesses to better secure chemicals, and creating educational materials for the public on the importance of protective gear [Shih and Chaisson 2016].

Preventing Mold Exposure

This study by the University of Connecticut focused on research and training to increase knowledge and prevent exposures to mold and to identify health effects among response and recovery workers including construction workers in states impacted by Hurricane Sandy. Focus group findings identified worker and resident groups as anxious over uncertainty about mold exposures and a distrust of government officials and others served as a barrier to taking actions that would prevent mold exposure. Additional findings indicated that these barriers were most difficult to overcome for poor residents and marginalized workers. Knowledge about respirator selection and use was inadequate among all targeted groups. This study also informed the development of risk communication messages for those potentially exposed to mold Researchers developed a decision tool to instruct workers on how to determine their suitability for mold cleanup work and how to choose PPE and cleanup work practices appropriate for the situation [Bennett 2015].

Researchers provided summaries of their findings to multiple States and other stakeholders facing hurricanes and other flood-related weather events. Most of the agencies contacted responded that they found the materials useful. For example, one state wrote back, "Wow, this is really extensive! We will be using these resources on a regular basis. Thanks." Another state wrote, "Thank you so much for reaching out and providing these resources for us! As you can probably imagine, we've been getting a lot of questions about mold. These fact sheets are VERY helpful! Thanks, also, for the additional links! We really appreciate your assistance!"

Intermediate Outcomes:

- Between March 2017 and April 2018, the resources designed for health providers as part of this grant has been the fourth most popular page on their web site. This material specifically addresses hurricane and wet weather considerations including evaluating patients for potential exposures and assessing PPE needs [Robison 2018c].

- The NIOSH grants allowed University of Connecticut to update their course *Guidance for Clinicians on the Recognition and Management of Health Effects Related to Mold Exposure and Moisture Indoors* that was first offered in 2004. Since offering the course in October 2017, there have been over 508 page views [Robison 2018c].

Section 4: Infectious Diseases

2014 Ebola Epidemic

In 2014, the world experienced the largest Ebola epidemic to date. The first case was reported in March 2014 in Guinea and quickly spread to Liberia and Sierra Leone. During the first year, the epidemic caused more than 10 times as many Ebola cases than the combined total of those reported in previous Ebola outbreaks. Travel-associated cases appeared in Nigeria, Mali, Senegal, and even countries outside of West Africa, including the United States. More than 28,000 people had suspected, probable, or confirmed Ebola, and more than 11,000 deaths were reported between December 2013 and April 2016 [WHO Ebola Response Team 2016]. These numbers are likely higher because many cases went undiagnosed and unreported.

In the U.S., doctors diagnosed four patients with Ebola and seven patients received treatment after medical evacuation from West Africa [CDC 2014a; Dahl 2016]. In September 2014, a traveler from Liberia who visited Dallas, Texas, was diagnosed with Ebola and admitted to the hospital [CDC 2014a]. In October 2014, two healthcare workers who provided care to the Liberian traveler in Dallas received subsequent Ebola diagnoses, and in the same month, an aid worker returning to NYC from Guinea was diagnosed with Ebola. The seven Ebola patients evacuated from West Africa received

treatment at Emory University Hospital in Atlanta, Georgia, and the Nebraska Medicine-Nebraska Medical Center in Omaha, Nebraska.

The public health response to the Ebola epidemic was unprecedented, and the federal government's response was multi-faceted. The primary mission was to provide support to stop the outbreak at the source in West Africa. However, the U.S. government was also expected to support domestic preparedness activities to care for possible Ebola cases. CDC deployed staff to West Africa within a week of the initial report of Ebola, ultimately deploying more than 1,400 staff to Guinea, Liberia, and Sierra Leone [CDC 2016a]. Thousands more personnel supported the response from the U.S. CDC collaborated with partners such as the ministries of health in West Africa, the World Health Organization (WHO), the CDC Foundation, Médecins Sans Frontiéres (MSF), and other nonprofits and parts of the federal government. NIOSH played a significant role in the Ebola response, one that illustrates our unique contributions and important role in the broader CDC and U.S. government response to help protect workers' health and safety [CDC 2016a].

During the Ebola response, numerous studies showed that improving OSH for healthcare workers as critical. WHO reported that healthcare workers were 21 to 32 times more likely to be infected than the general population [WHO 2015]. NIOSH contributed to a 2015 report showing that healthcare workers in Guinea had a 42-fold greater cumulative incidence of Ebola infection than the general adult population there [CDC 2015a]. Another report indicated that Ebola killed about 8% of the healthcare workers in Liberia and about 7% in Sierra Leone [Evans et al. 2015]. In addition to healthcare workers, other workers expressed concerns about possible risk of Ebola exposure and illness. NIOSH worked to assist general businesses, targeting worker populations in the U.S., including airport services, cargo ship, law enforcement, waste management, food service, and wastewater workers. These workers play an important role in providing critical services to both the healthcare sector as well as the general population.

Overall, 207 NIOSH staff supported the CDC response, contributing 71,312 hours. Major NIOSH activities included:

- Coordinating NIOSH staff to support the response through international and domestic deployments
- Coordinating the CDC safety officers in West Africa
- Developing worker safety and health guidance and communication materials
- Researching the appropriate PPE for the situation
- Responding to public inquiries

Deployments

During July 2014 to March 2016, NIOSH made 146 domestic deployments and 104 international deployments to five different countries. Domestically, staff deployed to hospitals, quarantine stations, training centers, and CDC headquarters. Internationally, staff deployed to support the greater CDC response in West Africa and to provide medical care to healthcare workers through the U.S. Public Health Service (PHS) Commissioned Corps. Figure 30 shows deployed NIOSH safety officers in Freetown, Sierra Leone.

Figure 30. NIOSH staff deployed as safety officers in Freetown, Sierra Leone [Photo Credit: NIOSH]

Within days of identifying the first case of Ebola in Texas, CDC deployed a team to provide technical assistance to the hospital on how to treat the patient safely. CDC deployed additional staff to Ohio, where an Ebola-infected nurse traveled prior to

becoming ill. In total, five NIOSH staff deployed to provide assistance in identifying other workers at risk of Ebola exposure with the ultimate goal to prevent additional transmission. NIOSH staff conducted contact tracings, advised how to set up the patient care area, and assisted with training staff on PPE donning and doffing and other safe practices for caring for Ebola patients.

Intermediate Outcome:

- The Dallas hospital adopted CDC team recommendations that included NIOSH recommendations on strengthening existing engineering and administrative controls, standardizing PPE ensemble, training on PPE use, and implementing a system of trained observers to supervise staff PPE use [Cummings et al. 2016].

To prepare the nation for possible domestic Ebola cases, the CDC developed a tiered approach to provide care to patients with suspected or confirmed Ebola. In order to prepare healthcare facilities and state health officials in implementing the tiered approach, CDC created multi-disciplinary teams to give onsite assistance to select management and personnel of these facilities, reviewing their plans to care for patients with suspected or confirmed Ebola. The composition of the teams included experts in ventilation, PPE, and worker safety, primarily from NIOSH, and medical officers, epidemiologists, and laboratory experts from CDC. Over a 24-month period, the teams visited 81 facilities, in 21 states and Washington, D.C., considered Ebola treatment centers; teams also visited approximately 40 Ebola assessment facilities. NIOSH provided expertise in several areas: assessing and providing assistance in patient movement throughout the facility to minimize worker and other patient exposures, training and appropriate use of PPE, waste handling and management, and healthcare worker safety and health.

Intermediate Outcome:

- As part of the CDC multi-disciplinary teams, NIOSH incorporated guidance documents into the CDC Assessment Tool for Ebola Treatment Centers and Assessment Hospitals [CDC 2015b]. CDC and NIOSH staff used the tool during visits to the 81 facilities to determine if the appropriate infection prevention control policies, procedures, and supplies were in place—including access and

training on wearing PPE—to allow healthcare personnel to provide care safely [CDC 2016b].

CDC implemented enhanced Ebola screening operations at quarantine stations at five airports that received incoming flights from affected West Africa nations to identify and isolate any travelers who may have Ebola. NIOSH staff supported traveler screenings, and after recognizing a deficiency in the existing PPE program, they developed a training program to educate quarantine staff on proper PPE use.

Intermediate Outcome:

- Airport officials used NIOSH guidance when setting up airport quarantine stations to develop policies and procedures to protect their staff and Custom and Border Protection officers from possible exposure when performing primary and secondary Ebola screenings. Airport personnel screened approximately 38,000 travelers at the five airports from October 2015 to February 2016, with one traveler subsequently determined to have Ebola [CDC 2016c]. None of the screening workers became ill.

CDC coordinated the development and delivery of the course, Preparing Healthcare Workers to Work in Ebola Treatment Units (ETUs) in Africa, to better prepare U.S. healthcare workers volunteering to care for Ebola patients in Africa. NIOSH provided occupational safety and health content and extensive review of the training modules to ensure it aligned with existing recommendations and best practices. NIOSH deployed one staff member to CDC to help develop the course and then travel to Anniston, Alabama, to deliver parts of the course. He lectured on worker safety and health and proper PPE use. He also directed the hands-on-scenarios where participants donned PPE, practiced providing safe care in a mock Ebola treatment unit, mimicked moving through a treatment unit, and then simulated properly exiting and doffing PPE.

Intermediate Outcome:

- The CDC course, Preparing Healthcare Workers to Work in Ebola Treatment Units (ETUs) in Africa, incorporated NIOSH expertise in the worker safety and health guidelines. CDC provided the 3-day course for over 600 healthcare workers intending to work in an ETU in Africa. This included 276 U.S. PHS

Commissioned Corps officers who would travel to the Monrovia Medical Unit to provide direct patient care [CDC 2016b]. CDC disseminated the course curriculum as a training toolkit so other organizations could implement the course. The overview page for training course has been viewed 21,122 times between October 2014 and March 2018 and the main page for the training toolkit has been viewed 1,639 times since January 2015. The toolkit received a Bronze Award for Web-based Resources in the 17th annual Digital Health Awards℠ program.

NIOSH staff supported CDC efforts to control Ebola by augmenting the International and Vaccine Task Forces. NIOSH staff conducted surveillance, contact tracing, data management, vaccination, communication, and health education [CDC 2016a].

As part USPHS's mission to provide direct patient care to medical workers infected while caring for Ebola patients, two NIOSH staff deployed to the Monrovia Medical Unit as part of a 75 officer cadre. The NIOSH officers received assignments to the Safety and Preventative Medicine teams. They gave technical guidance and produced policies, procedures, and protocols for worker safety and health. They also provided hands-on infection prevention, control, and decontamination operations for the facility, medical equipment, and patients.

Intermediate Outcome:

- At the Monrovia Medical Unit, NIOSH staff developed policies, procedures, and protocols used while the unit was active [Dowell 2018]. Over 200 officers deployed to the 25-bed facility and cared for 42 patients from nine different nations, including 18 healthcare responders with Ebola [Commissioned Corps 2014; Government of Liberia 2015].

Over the years, NIOSH has worked closely with CDC's internal health and safety group responsible for protecting the health and safety of CDC staff, including while working in the EOC and deployed to the field. Early in the Ebola response, CDC recognized a need to develop a more robust deployment program because of the additional complexities and dangers faced in West Africa. NIOSH advocated for the establishment of a unit to implement the ERHMS™ framework to improve the health and safety of staff who deploy. In response, CDC stood up the Disaster Risk Mitigation Unit to manage the pre-,

during, and post-deployment activities as outlined in ERHMS. Once established, 14 NIOSH staff deployed to the Disaster Risk Mitigation Unit or the CDC employee health clinic to support more than 2,400 field deployments. Figure 31 shows a NIOSH staff member giving a health and safety briefing to newly arrived staff in Sierra Leone. See Chapter 2, beginning on page 26, for more information on ERHMS™ [CDC 2016d].

Figure 30. NIOSH staff member, serving as a safety officer, giving a health and safety briefing to deployed CDC staff in West Africa. [Photo credit: NIOSH]

Intermediate Outcomes:

- The over 1,400 CDC staff who deployed internationally returned home safely. The enhanced pre-deployment medical clearance process prevented at least two staff with previously unrecognized serious medical conditions from deploying. During the new pre-deployment process, CDC provided NIOSH guidance documents to all staff pre-deployment, including the documents The Buddy System and Interim NIOSH Training for Emergency Responders: Reducing Risks Associated with Long Work Hours. CDC also provided the jointly developed NIOSH and OSHA document, Preventing Worker Fatigue Among Ebola Healthcare Workers and Responses, to deployers. In post-deployment surveys, CDC deployers reported feeling safer during their deployments after CDC implemented the safety officer role (explained next) in West Africa and created

the Disaster Risk Mitigation Unit, the unit responsible for implementing the ERHMS™ framework [CDC 2016d].

- NIOSH advocated for the establishment of in-country safety officers to ensure the safety and health of CDC staff while deployed to countries with active cases of Ebola. NIOSH deployed CDC's first two safety officers to Liberia in November 2014. From November 2014 to March 2016, NIOSH deployed 17 safety officers to Sierra Leone, Liberia, and Guinea. The safety officers were responsible for coordinating with U.S. Embassy security officials, providing in-country health and safety training, managing ill staff, identifying medical care as needed, investigating hazards, conducting injury and illness surveillance, and managing equipment used by staff in the field.

Technical Guidance

Prior to 2014, Ebola outbreaks traditionally occurred in remote villages in Africa. Because of this, there was very limited guidance and recommendations available. The guidance that did exist, did not meet the needs of this unique epidemic. Additionally, there was no Ebola domestic preparedness plan, as domestic cases of Ebola were unimagined. As a result, NIOSH received numerous inquiries from employers, employees, labor unions, volunteer organizations, and the public on how to protect against Ebola infection. In response, working with CDC, NIOSH immediately developed guidance documents and communications materials focusing on worker health and safety or provided significant OSH content to guidance documents and communications led by CDC.

During the response, NIOSH included representatives from OSHA, health and safety organizations, PPE manufacturers and professional organizations, and labor unions in communications on the development and status of publications. Through a collaboration with the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) and OSHA, NIOSH routinely held calls with the following organizations to keep them aware of our activities, documents we were developing, and to solicit feedback on draft guidance [Dowell 2014a]:

- American Federation of Labor and Congress of Industrial Organizations
- American Federation of Government Employees (AFGE)
- United Food and Commercial Workers International Union (UFCW)
- International Union of Operating Engineers (IUOE)
- New York State Laborers' Union
- International Association of Fire Fighters
- Service Employees International Union
- National Association of Letter Carriers
- New York State Nurses Association
- Association of Flight Attendants-CWA
- International Association of Machinists and Aerospace Workers
- American Federation of State, County and Municipal Employees
- Communications Workers of America
- Transport Workers Union of America
- International Union, United Automobile, Aerospace and Agricultural Implement Workers of America
- National Nurses United
- International Brotherhood of Teamsters
- Transportation Trades Department, AFL-CIO
- American Federation of Teachers Nurses and Health Professionals
- Laborers' Health and Safety Fund of North America
- International Chemical Workers Union Council
- International Union of Operating Engineers National Training Fund—National HAZMAT Program
- United Steelworkers, Tony Mazzocchi Center for Health, Safety and Environmental Education
- The University of Illinois at Chicago
- International Safety Equipment Association
- Health Industry Distributors Association

The following guidance documents and communication materials were developed and posted to the NIOSH Ebola topic page during the response:

- Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Hospitals, Including Procedures for Donning and Doffing PPE: Provides guidance to protect healthcare workers and other patients at facilities providing care to a patient with confirmed Ebola or a person under investigation who is clinically unstable or has bleeding, vomiting, or diarrhea by describing protocols for using PPE.
- For U.S. Healthcare Settings: Donning and Doffing Personal Protective Equipment (PPE) for Evaluating Persons Under Investigation (PUIs) for Ebola Who Are Clinically Stable and Do Not Have Bleeding, Vomiting, or Diarrhea: Provides guidance on the processes for donning and doffing PPE for healthcare workers and staff who are evaluating a patient under investigation who is clinically stable and does not have bleeding, vomiting, or diarrhea.
- Frequently Asked Questions for Guidance on Personal Protective Equipment to Be Used by Healthcare Workers During Management of Patients with Confirmed Ebola or Persons Under Investigation (PUI) for Ebola Who are Clinically Unstable or have Bleeding, Vomiting or Diarrhea in U.S. Hospitals, Including Procedures for Donning and Doffing: Provides answers to frequently asked questions on the updated Ebola PPE guidance clarifying certain points.
- Considerations for Selecting Protective Clothing used in Healthcare for Protection against Microorganisms in Blood and Body Fluids: Provides an overview of scientific evidence and information on national and international standards, test methods, and specifications for fluid-resistant and impermeable gowns and coveralls used in healthcare.
- Personal Protective Equipment and Ebola: Presents the CDC PPE guidance and links to NIOSH-approved respirators for protection against Ebola virus.

- Interim NIOSH Training for Emergency Responders: Reducing Risks Associated with Long Work Hours: Assists response workers in caring for themselves during catastrophic events.

- Guidance for Safe Handling of Human Remains of Ebola Patients in U. S. Hospitals and Mortuaries: Provides guidance to protect against the postmortem spread of Ebola infection at the site of death, prior to transport, during transport, at the mortuary, and during final disposition of remains.

- Mortuary Guidance Job Aid: Postmortem Preparation in a Hospital Room: Job aid that accompanies the *Guidance for Safe Handling of Human Remains of Ebola Patients in U.S. Hospitals and Mortuaries*.

- Interim Guidance for Healthcare Workers Providing Care in West African Countries Affected by the Ebola Outbreak: Limiting Heat Burden While Wearing Personal Protective Equipment (PPE): Provides recommendations for healthcare workers on how to limit heat burden and prevent heat-related illnesses while wearing PPE during treatment of Ebola patients.

- Interim Guidance for U.S. Businesses, Employers, and Business Travelers to Prevent Exposures to Ebola (no longer available): Helps businesses protect their employees from potential Ebola exposure when traveling to or working in countries with Ebola outbreaks, or after they return to the United States.

- Questions and Answers about Ebola for U.S. Businesses, Employers, and Business Travelers (no longer available): Provides answers to frequently asked questions on for business travelers, with guidance clarifying certain points.

- Interim Guidance for Managers and Workers Handling Untreated Sewage from Individuals with Ebola in the United States: Provides recommendations for workers on the types of PPE to use and proper hygiene for the safe handling of untreated sewage that may contain Ebola virus.

- Frequently Asked Questions (FAQs) on Interim Guidance for Managers and Workers Handling Untreated Sewage from Suspected or Confirmed Individuals with Ebola in the U.S.: Provides answers to frequently asked questions on the *Interim Guidance for Managers and Workers Handling Untreated Sewage from Individuals with Ebola in the United States*.

- Fighting Ebola: A Grand Challenge for Development - How NIOSH is Helping Design Improved Personal Protective Equipment for Healthcare Workers: NIOSH Science Blog post describes the Ebola Grand Challenge and NIOSH contributions to it.

- Limiting Heat Burden While Wearing Personal Protective Equipment (PPE): PowerPoint presentation in PDF form outlining prevention of heat-related illness when wearing PPE in the hot, humid conditions of the West African Ebola epidemic.

- Prevent Heat-Related Illness: Poster describing simple steps that healthcare workers wearing PPE in Western Africa can take to avoid heat illness.

- NIOSH Personal Protective Equipment Information (PPE-Info): guidance to assist end users (e.g., healthcare staff, procurement specialists, infection preventionists, and PPE users) in selecting gowns and coveralls in accordance with the CDC Ebola PPE guidance.

- NIOSH-Approved Powered Air-Purified Respirators Meeting CDC Criteria for Ebola: Webpage to assist staff involve in PPE selection with PAPR options consistent with the CDC Ebola guidance.

Fact Sheets:

- The Buddy System: Fact sheet describing the importance of deploying in two-person teams who share the responsibility for each other's safety and well-being.

- Preventing Worker Fatigue Among Ebola Healthcare Workers and Responders: OSHA and NIOSH fact sheet that provides recommendations to prevent worker fatigue among Ebola healthcare workers and responders.

- Ebola Information for Airline Customer Service Representatives: Fact sheet providing information to airline customer service representatives on how to protect themselves from potential Ebola exposure.

- Ebola Information for Airport Retail and Food Service Workers: Fact sheet providing information to airport retail and food service workers on how to protect themselves from potential Ebola exposure.

- Ebola Information for Airport Passenger Assistance Workers: Fact sheet providing information to airport passenger assistance workers on how to protect themselves from potential Ebola exposure.
- Ebola Information for Airport Custodial Staff: Fact sheet providing information to airport custodial staff on how to protect themselves from potential Ebola exposure.
- Ebola Information for Airport Baggage and Cargo Handlers: Fact sheet providing information to airport baggage and cargo handlers on how to protect themselves from potential Ebola exposure.
- Ebola Information for Law Enforcement Professionals in US: Fact sheet providing information to law enforcement professionals on how to protect themselves from potential Ebola exposure.
- Safe Handling, Treatment, Transport and Disposal of Ebola-Contaminated Waste: OSHA, NIOSH, and EPA fact sheet that provides recommendations to protect workers from exposure to Ebola virus during waste management.

In addition to these documents, various publications record NIOSH contributions to the Ebola response. For example, CDC and NIOSH co-authored a Morbidity and Mortality Weekly Report (MMWR) article that presents an overview of CDC contributions and impact to improve infection control in health care settings during the response [CDC 2016b]. A NIOSH investigator was the first author of a publication describing the CDC response to strengthen infection control at the Texas hospital where two nurses became infected after providing care to a patient who acquired Ebola infection in Africa [Cummings et al. 2016]. Another publication first-authored by a NIOSH investigator described leaks in walls separating patient compartments from driver compartments as an important hazard for ambulance workers in Sierra Leone, describing simple steps to waterproofing those walls to protect ambulance workers [Casey et al. 2015]. NIOSH also provided other prevention services, for example, working to ensure that healthcare workers used the appropriate type of gowns. We describe PPE research next, in the Personal Protective Equipment section.

During the Ebola response, numerous groups reached out to NIOSH for OSH expertise, including PPE, to support them as they developed their own guidance and training

products. These groups included international health organizations, professional associations, and other federal agencies. NIOSH provided direct and indirect assistance to these groups including presentations, phone consultations, document review, in-person meetings. For example, WHO invited a NIOSH PPE expert to Geneva, Switzerland to participate in a rapid guidance development group meeting to inform the development of the WHO rapid advice guidelines. NIOSH also presented the Interim Guidance for Managers and Workers Handling Untreated Sewage from Individuals with Ebola in the United States during the August 2016 Water Research Foundation's Protecting Wastewater Treatment Plant Operators from High-Consequence Pathogens webcast [Water Environment & Reuse Foundation 2016].

Intermediate Outcomes:

- ❖ CDC incorporated NIOSH guidance into several of their documents:
    - In September 2014, CDC and ASPR advised all hospitals to prepare for the possibility that a person in West Africa with Ebola could travel to the U.S., and they distributed a checklist to guide hospitals' preparedness [Bedard 2014]. At that time, CDC and ASPR incorporated NIOSH guidance into the *Detailed Hospital Checklist for Ebola Preparedness* document (no longer available) [CDC 2014b].
    - CDC and ASPR used NIOSH guidance throughout the response as they held numerous webinars with hospitals and emergency medical services to prepare the various groups for the possibility that an Ebola patient could need transportation and treatment [ASPR 2018].
    - CDC and ASPR also incorporated NIOSH guidance into the CDC and ASPR Checklist for Health Coalitions for Ebola Preparedness. This checklist, as well as other Ebola healthcare guidance documents, was implemented at the 81 facilities considered Ebola treatment centers. As mentioned previously, NIOSH staff supported CDC teams providing assistance to these healthcare facilities and state health officials as they prepared for a possible epidemic.

❖ Other organizations incorporated NIOSH PPE guidance and specifications into their guidance documents and trainings:

- NIOSH PPE science was incorporated into the WHO rapid advice guidelines, Personal protective equipment in the context of filovirus disease outbreak response and Personal protective equipment for use in a filovirus disease outbreak [WHO 2014a, 2016]. Information was also included in the WHO Interim guidance Infection prevention and control guidance for care of patients in health-care settings, with focus on Ebola [WHO 2014b]. These documents were used to guide WHO and numerous countries and organizations that supported the international response.

- NIOSH PPE specifications were adopted by OSHA in their PPE Selection Matrix for Occupational Exposure to Ebola Virus fact sheet that provided PPE guidance to a wide variety of occupations [Dowell 2014b].

- The InterAgency Board cites the NIOSH PPE recommendations in their guidance Recommendations on Selection and Use of Personal Protective Equipment for First Responders against Ebola Exposure Hazards.

- Johns Hopkins University, Salesforce Foundation, Miami University, Association for Professionals in Infection Control and Epidemiology, and the Society for Healthcare Epidemiology of America developed a series of videos demonstrating the PPE donning and doffing procedures described in the CDC PPE guidance (which was co-authored by NIOSH) for healthcare workers entering the hospital room of a known or suspected Ebola patient.

- The National Funeral Directors Association adapted the CDC guidance (which was authored by NIOSH), and numerous state funeral directors associations have shared it [NFDA, no date]. NFDA also held the webinar Are You Ready for an Ebola Call? Critical Actions and Key Safety Practices for Funeral Professionals that references the guidance.

- The NIOSH Guidance for Safe Handling of Human Remains of Ebola Patients in U.S. Hospitals and Mortuaries and Mortuary Guidance Job Aid has proven useful for additional highly pathogenic virus cases, in addition to Ebola, when alternate guidance is not available. The New Jersey Department of Health used the guidance to handle the remains of a patient who died from Lassa fever in 2015. The patient contracted the virus in West Africa. The mortuary team was able to safely handle, transport, and dispose of this patient without becoming infected [Gressel 2015].

- The Water Environmental Research Foundation is currently using the Interim Guidance for Managers and Workers Handling Untreated Sewage from Individuals with Ebola in the United States to develop new national PPE guidance for wastewater technicians [MacDonald Gibson et al. 2016].

❖ Numerous organizations have used and cited NIOSH guidance documents. The following list shows some examples:

- CDC: Interim Guidance for U.S. Residence Decontamination for Ebola and Removal of Contaminated Waste

- CDC: Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus

- OSHA: Cleaning and Decontamination of Ebola on Surfaces

- OSHA: PPE Selection Matrix for Occupational Exposure to Ebola Virus

- CDC: Guidance on Air Medical Transport (AMT) for Patients with Ebola Virus Disease (EVD)

- CDC: Considerations for U.S Healthcare Facilities to Ensure Adequate Supplies of Personal Protective Equipment (PPE) for Ebola Preparedness

- CDC: Increasing Supply of Ebola-specific Personal Protective Equipment for U.S. Hospitals

- CDC: Respiratory Protection for Ebola (video)
- CDC, Johns Hopkins University, Salesforce Foundation, Miami University, Association for Professionals in Infection Control and Epidemiology, and the Society for Healthcare Epidemiology of America: Guidance for Donning and Doffing Personal Protective Equipment (PPE) During Management of Patients with Ebola Virus Disease in U.S. Hospitals
- Medscape and CDC: Ebola: Donning and Doffing of Personal Protective Equipment (PPE).
- CDC: Identify, Isolate, Inform: Ambulatory Care Evaluation of Patients with Possible Ebola Virus Disease (Ebola).
- CDC: Guidance for Screening and Caring for Pregnant Women with Ebola Virus Disease for Healthcare Providers in U.S. Hospitals
- CDC: Infection Prevention and Control Recommendations for Hospitalized Patients Under Investigation (PUIs) for Ebola Virus Disease (EVD) in U.S. Hospitals
- CDC: Guidance for Collection, Transport and Submission of Specimens for Ebola Virus Testing
- CDC: Recommendations for Safely Performing Acute Hemodialysis in Patients with Ebola Virus Disease (EVD) in U.S. Hospitals
- CDC: Procedures for Safe Handling and Management of Ebola-Associated Waste
- CDC: Think EBOLA Early recognition is critical for infection control
- CDC: When Caring for Patients Under Investigation (PUIs) or Patients with Confirmed Ebola Virus Disease (EVD)
- ASPR and CDC: Detailed Hospital Checklist for Ebola Preparedness

- ASPR and CDC: Checklist for Healthcare Coalitions for Ebola Preparedness
- ASPR: EMS Infectious Disease Playbook
- California OSHA: Cal/OSHA Interim Guidance on Ebola Virus in Inpatient Hospital Settings
- CDC: Preparing Healthcare Workers to Work in Ebola Treatment Units (ETUs) in Africa
- CDC: Guidance for U.S. Laboratories for Managing and Testing Routine Clinical Specimens When There is a Concern About Ebola Virus Disease
- CDC: Interim Guidance Regarding Compliance with Select Agent Regulations for Laboratories Handling Patient Specimens Under Investigation or Confirmed for Ebola Virus Disease (EVD)
- CDC: Interim Guidance for Emergency Medical Services (EMS) Systems and 9-1-1 Public Safety Answering Points (PSAPs) for Management of Patients Under Investigation (PUIs) for Ebola Virus Disease (EVD) in the United States
- CDC: Identify, Isolate, Inform: Emergency Medical Services (EMS) Systems and 9-1-1 Public Safety Answering Points (PSAPs) for Management of Patients Who Present with Possible Ebola Virus Disease (Ebola) in the United States
- ASPR and CDC Detailed Emergency Medical Services (EMS) Checklist for Ebola Preparedness
- CDC: Guidance on Air Medical Transport (AMT) for Patients with Ebola Virus Disease (EVD)
- WHO: Personal protective equipment in the context of filovirus disease outbreak response

- WHO: Personal protective equipment for use in a filovirus disease outbreak
- WHO: Interim Infection Prevention and Control Guidance for Care of Patients with Suspected or Confirmed Filovirus Haemorrhagic Fever in Health-Care Settings, with Focus on Ebola
- IAB: Recommendations on Selection and Use of Personal Protective Equipment for First Responders against Ebola Exposure Hazards
- Joint Commission: Your Lab and Ebola: What you need to know from the CDC and The Joint Commission (Online event)
- Joint Commission: Ebola Preparedness: A CDC/Joint Commission Webinar Replay
- 3M: Personal Protective Equipment (PPE) for Ebola Virus Disease (EVD)

❖ The main NIOSH Ebola web page was viewed 64,422 times between July 2014 and March 2018, with most views occurring between October and December 2014, coinciding with the peak of the domestic response. The individual NIOSH guidance and communications products were collectively viewed or downloaded over 1,231,738 times between October 2014 and March 2018. The top five NIOSH Ebola products included:

- Guidance on Personal Protective Equipment (PPE) To Be Used By Healthcare Workers during Management of Patients with Confirmed Ebola or Persons under Investigation (PUIs) for Ebola who are Clinically Unstable or Have Bleeding, Vomiting, or Diarrhea in U.S. Hospitals, Including Procedures for Donning and Doffing PPE: viewed 836,671 times
- Guidance for Safe Handling of Human Remains of Ebola Patients in U. S. Hospitals and Mortuaries: viewed 184,983 times
- For U.S. Healthcare Settings: Donning and Doffing Personal Protective Equipment (PPE) for Evaluating Persons Under Investigation (PUIs) for

Ebola Who Are Clinically Stable and Do Not Have Bleeding, Vomiting, or Diarrhea: viewed 28,302 times

- Considerations for U.S. Healthcare Facilities to Ensure Adequate Supplies of Personal Protective equipment (PPE) for Ebola Preparedness: viewed 26,590 times

- Interim Guidance for Managers and Workers Handling Untreated Sewage from Individuals with Ebola in the United States: viewed 26,109 times

Personal Protective Equipment Research

PPE played an unprecedented role during the Ebola response, both internationally and domestically. In both settings, CDC had never before provided such direct and standardized guidance (e.g., only two recommended PPE ensemble options) to protect healthcare workers. As a result, healthcare workers wore PPE not used previously in patient care settings, for example, coveralls. During the response, questions about PPE use surfaced. For example, healthcare workers in West Africa expressed concerns about the extreme heat and humidity, which led to a reported reduced amount of time they could safely provide patient care while wearing the required PPE. At the request of MSF, NIOSH conducted research to understand factors associated with heat stress and PPE ensemble design features and how the intermix of heat and design affect comfort and job performance.

Researchers evaluated the PPE using both a unique sweating thermal manikin and human subjects, shown in Figures 32 and 33 respectively, in an environmental chamber that replicated the temperature and humidity conditions experienced in West Africa. Published research findings involving use of sweating thermal manikins and later with volunteer human test subjects confirmed that PPE ensembles utilizing coveralls with moderate to high degrees of impermeability shortened the time to reach critical core temperatures [Coca et al. 2015 and Coca et al. 2017]. Studies involving human subjects showed that P100 FFRs retained better fit than N95 FFRs under hot, humid conditions resembling West Africa without additional physiologic or subjective impact [Kim et al. 2016].

Figure 32. NIOSH PPE research looking at heat stress using manikins. [Photo credit: NIOSH]

Figure 33. NIOSH PPE research looking at heat stress using a human subject. [Photo credit: NIOSH]

NIOSH collaborated with the U.S. Agency for International Development (USAID), White House Office of Science and Technology Policy, CDC, and DoD to hold the Fighting Ebola: A Grand Challenge for Development [USAID 2015]. The Grand Challenge was a competition to stimulate private sector innovations to address gaps in the Ebola response, including developing fluid-resistant PPE able to protect healthcare workers from Ebola yet still be tolerable in hot, humid West Africa healthcare facilities. Fourteen innovations were identified, including the Re-Engineered Health Care Worker Suit and A Safer and Faster-Doffing PPE for Frontline Health Workers [USAID 2015]. NIOSH tested innovative PPE prototypes as well as PPE cooling systems proposed in response to the Grand Challenge as part of this evaluation effort. As expected, cooling devices allowed for prolonged exercise in heat while wearing Ebola PPE. Comparing across different types of cooling devices, those using ice and water circulating systems were found to provide more physiological benefits than vests with phase change materials [Quinn 2017].

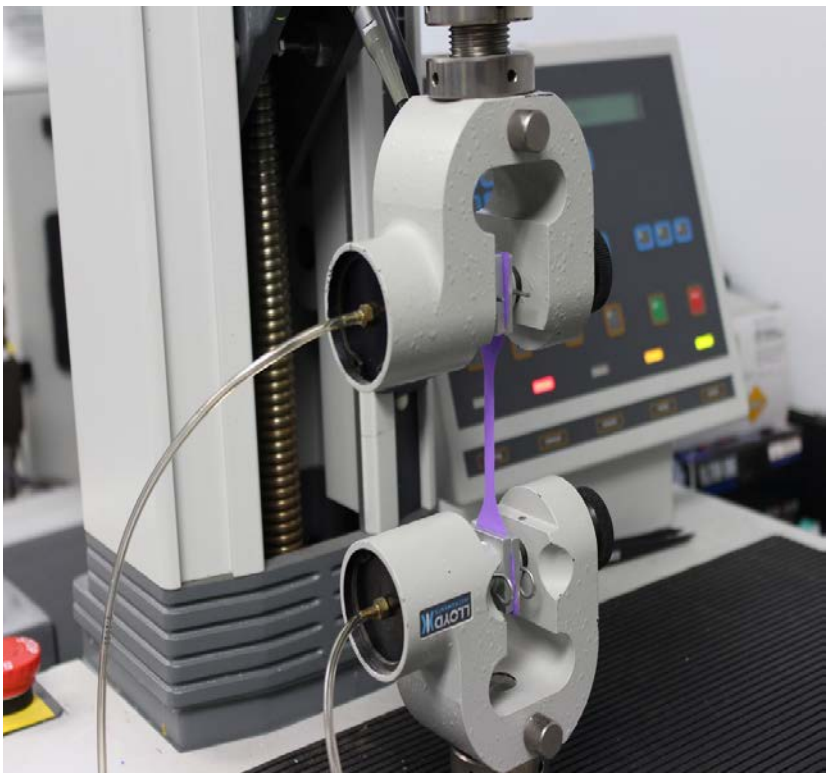
After the 2009 H1N1 influenza pandemic, NIOSH initiated a research project to assist with the development of a new industry standard specification for non-sterile isolation gowns intended for use in healthcare settings. Preliminary research findings were made available during the Ebola epidemic and used to inform PPE selection and use guidance. In this study, 22 models of isolation gowns from six different manufacturers were

evaluated for a variety of performance requirements. The most surprising finding was that only 13 of the 20 models met their stated liquid barrier performance.

Another topic originally identified during the influenza pandemic, but also of importance to the Ebola response was the need for better data on PPE usage, burn rate, and stockpile levels. In 2008, NIOSH initiated research to gather data on respirator inventory levels, but during the Ebola response expanded to include multiple types of PPE [Yarbrough 2016]. By 2017, the national PPE surveillance and monitoring system had expanded to include over 20 hospitals. NIOSH also collaborated with American Association of Occupational Health Nurses on surveys to identify the prevalence of different respirator models in use at hospitals across the country in 2014 and then again in 2015. The study also sought to explore if the emergency preparedness climate associated with Ebola virus disease changed the landscape of respirator use and awareness [Wizner 2016].

NIOSH was also able to stand up research quickly during the Ebola epidemic to address practical problems related to the CDC PPE guidance. For example, the CDC PPE guidance recommended disinfecting gloved hands after every step in the doffing procedures. This required multiple applications of alcohol-based hand rubs on medical exam gloves, yet little was known about how this would affect glove properties. NIOSH evaluated the alcohol's effects on the gloves, shown in Figure 34, and showed that the application reduced their tensile strength, with nitrile gloves affected more than latex. Ultimately, NIOSH concluded that latex gloves and some nitrile gloves should be safe to use according to the CDC doffing guidance [Gao et al. 2016].

Figure 34. Tensile property testing of glove specimen following application of disinfectant. [Photo credit: NIOSH]



In another study, NIOSH evaluated the ability of five gowns and four coveralls to resist penetration of body fluids simulants using an elbow lean test. Swatches cut from continuous regions of one gown and two coveralls did not have any strikethrough. For discontinuous regions, only one type of gown consistently resisted fluid strikethrough [Jaques et al. 2016]. The study was used to justify changes made in the August 2015 CDC Ebola PPE guidance which included updated language that recommends purchasers select gowns and coveralls tested by an ISO 17025 certified third party laboratory. The CDC Strategic National Stockpile (SNS) used NIOSH as a resource to better understand PPE performance. In one example, SNS requested that NIOSH evaluate a SNS stockpiled surgical gown to determine if the gown model met the appropriate liquid barrier performance standard. NIOSH concluded that there was not sufficient evidence to challenge the manufacturer's claim of the gowns being compliant with the requirements of the relevant industry standard [NIOSH 2017a].

These findings underscore the importance of assessing conformity of PPE to performance standards. NIOSH was able to use this research to quickly develop the document, Considerations for Selecting Protective Clothing used in Healthcare for

Protection against Microorganisms in Blood and Body Fluids. This document discusses the various performance standards that healthcare workers should take into consideration when selecting gowns and coveralls for dermal protection in the healthcare setting.

Intermediate Outcomes:

- Data on the impact of wearing specific combinations of PPE were nonexistent prior to the NIOSH studies using a thermal manikin and human subjects. Results from these studies were used to refine the WHO PPE recommendations and to help educate workers on the amount of time they could safely work in the PPE [WHO 2017].

- CDC used study results of glove performance with multiple rounds of disinfection and penetration of gowns and coveralls to support incorporating PPE performance standards as part of the PPE guidance, incorporating the results of the studies into the Ebola PPE Frequently Ask Questions document. By specifying the performance standards, healthcare facilities could make informed purchases of PPE that would protect healthcare workers when use appropriately.

- NIOSH findings that a number of isolation gowns failed to meet recognized industry standards for liquid barrier protection was cited by WHO to support the need for improved premarket testing and post-market evaluation of gowns according to standardized test methods by third party laboratories. The higher than expected number of failures with the isolation gowns was also used by the FDA to clarify interpretation of its 510(k) process for clearing class I and class II devices [FDA 2015].

- NIOSH PPE surveillance research was used by the SNS to help them decide which respirators to include in the stockpile based on commonality among health care workers [Gorman 2017]. In an emergency, it is advantageous to provide familiar respirators to responders to decrease just-in-time fit testing and training needed to properly use the respirator. In 2016, HHS published its Ebola Response Improvement Plan and identified the NIOSH PPE surveillance

and monitoring project as a key priority going forward for refining guidance for U.S. government and facility-level PPE stockpiling [ASPR 2017].

Influenza

Influenza (flu) is a contagious respiratory illness caused by influenza viruses; it can lead to mild to severe illness. Influenza can be spread person to person when in close contact with people with flu. CDC estimates that influenza caused between 9.2 million and 35.6 million illnesses and between 12,000 and 56,000 deaths annually since 2010. [CDC 2018a]. Influenza viruses are notable in their ability to change or mutate either quickly (antigenic shift) or slowly (antigenic drift) over time, which results in a lack of immunity in the population. Additionally, the virus can survive in multiple hosts including humans, swine, and domestic and wild birds. Because of these characteristics, influenza is a pandemic threat. A pandemic of influenza occurs when a novel influenza virus emerges that is able to infect people easily and can spread efficiently between people [CDC 2018b].

In the early 2000s, a novel non-human avian influenza virus strain (H5N1) in Southeast Asia that infected birds began to cause severe illness in a small number of people. The public health community was concerned the virus could mutate into a new pandemic strain that transmitted easily between people. In response, the U.S. government increased efforts to ensure our nation was prepared to protect the public against a pandemic threat [HHS 2005, HSC 2005]. Because influenza is a well-recognized occupational hazard, NIOSH also began planning efforts to protect workers.

While healthcare workers treating influenza patients are seen as the highest risk workers [OSHA 2007], many other occupations requiring high frequency contact with the public are also at risk. A study conducted in 2000 estimated the annual direct costs of influenza in the U.S for hospital, doctor office visits, and medications were at $4.6 billion [Cox et al. 2000; Lacey 1995; NIOSH 2018]. The study also found that the flu causes U.S. workers to lose up to 111 million workdays at an estimated $7 billion a year in sick days and lost productivity [Lacey 1995; NIOSH 2018]. A more recent study done in 2018 estimated that lost productivity due to sick days is now closer to 9.4 billion using recent statistics and employment numbers [Scipioni 2018]. This section will provide examples of NIOSH efforts and impacts related to protecting workers from seasonal, avian, and pandemic influenza.

NIOSH Efforts Prior to the 2009 H1N1 Influenza Pandemic

In response to Federal pandemic planning requirements, NIOSH stood up the Interdivisional Pandemic Influenza Task Force consisting of 35 NIOSH staff to address the more than 80 tasks assigned to NIOSH. NIOSH authors developed eight guidance documents focusing on the transportation industry with recommendations to protect workers.

NIOSH staff participated in four exercises designed to test CDC's ability to effectively respond to a pandemic and inform the EOC organizational structure. Participation in these exercises played a critical role in training 21 NIOSH staff to respond successfully to a real-world pandemic. NIOSH incorporated important worker health and safety issues, including surveillance, into these exercises, which raised response leadership awareness of the unique occupational needs that may happen during a pandemic. The overall pre-H1N1 pandemic preparedness efforts resulted in more than 50 NIOSH staff who received training to respond to a pandemic, strengthened relationships with key CDC partners, and laid the groundwork for how future NIOSH responses would be organized.

2009 H1N1 Influenza Pandemic

The most recent influenza pandemic occurred in 2009. From April 2009, with first reports of the virus in the U.S., to April 2010, the pandemic caused about 60.8 million cases of influenza and about 12,469 deaths [Shrestha et al. 2011]. Eighty-seven percent of the deaths occurred in those younger than 65 years of age. The CDC EOC activated immediately and NIOSH staffed the Worker Safety and Health Team to respond to OSH inquiries and needs. NIOSH was an important contributor to the overall CDC and national response, in particular contributing its unique expertise related to engineering controls, PPE, and occupational health issues.

Although NIOSH developed many documents in the years leading up to the pandemic, additional guidance documents, communication materials, and educational materials were needed to respond to the initial outbreak in the spring of 2009—and also to prepare for the fall 2009 influenza season. Workers needed additional clarity on the proper use of respiratory protection and the difference between respirators and face masks. In response, NIOSH created several documents to address this knowledge gap. For example, NIOSH developed a poster and two podcasts describing how to properly don and doff respirators. Additionally, NIOSH collaborated with CDC to develop

guidance on the use of face masks and respirators to decrease influenza H1N1 virus exposure for both community and non-healthcare occupational settings. This guidance document further described the differences between face masks and respirators.

The following nine work products were developed and posted to the NIOSH website during this response:

- Occupational Issues Associated with H1N1 Influenza Virus (Swine Flu): Provides access to a range of resources for worker protection.
- Interim Guidance for Management of Influenza-Like Illness aboard Commercial Aircraft during the 2009-10 Influenza Season: Provides interim guidance for commercial airline industry regarding flights arriving in or departing from U.S. airports.
- Questions and Answers Regarding Respiratory Protection for Infection Control Measures for 2009 H1N1 Influenza among Healthcare Personnel: Provides supplemental information to assist healthcare facilities in optimizing respirator use in case of shortages
- How to Properly Put On and Take Off a Disposable Respirator: Describes step-by-step instructions in poster format for donning, fit checking and doffing a disposable respirator.
- CDC Podcast: General Instructions for Disposable Respirators: Demonstrates in video format how to properly don and doff a respirator.
- CDC Podcast: Use of Facemasks and Respirators: Demonstrates how to put on and take off a disposable respirator.
- Regarding Respiratory Protection for Infection Control Measures for 2009 H1N1 Influenza among Healthcare Personnel: Provides information to assist healthcare facilities in optimizing implementation of recommended respiratory protection practices when shortages exist.
- N95 Respirators and Surgical Masks Blog: Provides information on the difference between respirators and surgical masks and discusses how they protect workers.
- Risk of Serious Illness Among Healthcare Personnel Associated With 2009 H1N1 Influenza: What is NIOSH Learning?: Summarizes NIOSH activities and recommendations to protect healthcare personnel.

During the initial response to the pandemic, CDC, in collaboration with NIOSH, immediately issued respiratory protection recommendations, along with other protective interventions to protect healthcare workers. As we learned more about the illness severity and how the pandemic strain spread, eliminating the respiratory protection recommendation was debated. A lack of research about the relative contribution of airborne versus droplet routes of transmission and uncertainty about the effectiveness of respiratory protection in preventing transmission created challenges in reaching agreement on the appropriate recommendations. To resolve these differences, CDC and OSHA sought guidance from IOM in preparation for the beginning of the 2009 fall influenza season. IOM assembled the Committee on Respiratory Protection for Healthcare Workers in the Workplace Against Novel H1N1 Influenza A. NIOSH actively participated in this process and one NIOSH staff presented at the IOM workshop. The report issued by the committee recommended that healthcare workers in close contact with infected individuals use fit-tested N95 FFRs. It also recommended increased research on influenza transmission [Liverman et al. 2009].

As a result, CDC continued to recommend the use of respiratory protection for healthcare workers caring for patients infected with 2009 H1N1 influenza. CDC, in close collaboration with NIOSH, issued updated infection control guidance: Interim Recommendations for Facemask and Respirator Use to Reduce 2009 Influenza A (H1N1) Virus Transmission. This guidance also included recommendations for face mask and respirators in non-healthcare occupational settings.

Direct communication with stakeholders was also an important part of the pandemic response. NIOSH coordinated weekly calls with labor stakeholders and experts at CDC and OSHA to keep them up-to-date on developments, learn about their concerns, and answer questions. For example, if labor asked a specific question, NIOSH identified the CDC expert able to answer the question and would invite that expert to give a short presentation at the weekly call. Due to the success of this call, NIOSH continued coordinating these calls between labor stakeholders, CDC, and OSHA during large-scale responses.

Intermediate Outcomes:

- During the 2009 H1N1 influenza pandemic, CDC incorporated NIOSH input into the following guidance:

  - Interim Guidance on Infection Control Measures for 2009 H1N1 Influenza in Healthcare Settings, Including Protection of Healthcare Personnel: Provides guidance on infection control and health and safety for healthcare personnel to stay protected from 2009 H1N1.

  - CDC Guidance for Businesses and Employers to Plan and Respond to the 2009–2010 Influenza Season: Provides guidance to help decrease the spread of influenza in non-healthcare workplaces.

  - Interim Guidance for Emergency Medical Services (EMS) Systems and 9-1-1 Public Safety Answering points (PSAPs) for Management of Patients with Confirmed or Suspected Swine-Origin Influenza A (H1N1) Infection: Provides guidance for medical first responder personnel on how to safely respond to patients.

  - Interim Guidance for Management of Influenza-Like Illness aboard Commercial Aircraft during the 2009-10 Influenza Season: Provides guidance for the commercial airline industry on how flight crew members can safely manage ill passengers.

  - Interim Guidance for Cruise Ships during the 2009-10 Influenza Season: Provides guidance on how cruise ship management and medical staff can safety manage ill persons on board a ship.

- OSHA issued a compliance directive to ensure their Compliance Safety and Health Officers had uniform procedures to inspect workplaces where employees had high or very high risk of exposure to the 2009 H1N1 influenza virus. In advance of the release of the compliance directive, the Acting Assistant Secretary of Labor for OSHA issued a statement referencing the CDC respiratory recommendations. OSHA's National News Release states that the compliance directive, "closely follows the CDC guidance."

- The top five viewed or downloaded NIOSH influenza products included:
    - Interim Recommendations for Facemask and Respirator Use to Reduce 2009 Influenza A (H1N1) Virus Transmission: viewed 1,051,866 times between April 2009 and March 2018
    - Regarding Respiratory Protection for Infection Control Measures for 2009 H1N1 Influenza among Healthcare Personnel: viewed 151,308 times between July 2009 and March 2018
    - Interim Guidance for Management of Influenza-Like Illness aboard Commercial Aircraft during the 2009-10 Influenza Season: viewed 61,569 times between April 2009 and March 2018
    - Questions and Answers Regarding Respiratory Protection for Infection Control Measures for 2009 H1N1 Influenza among Healthcare Personnel: viewed 51,091 times between October 2009 and March 2018
    - Occupational Issues Associated with H1N1 Influenza Virus (Swine Flu): viewed 20,561 times between April 2010 and March 2018

Actions to address respirator shortages

Implementing IOM's recommendation on respirator use was not simple. Supply chain shortages for PPE, especially FFRs, were a significant concern [HHS 2012]. A paper published in 2015 estimates that healthcare workers would need 1.7 to 7.3 billion respirators for protection during a pandemic [Carias et al. 2015]. NIOSH engaged in numerous efforts before and during the pandemic to address issues related to respirator supply and demand, including several research studies. One of these studies focused on the reusability of FFRs by conducting laboratory studies to understand: (1) how well decontamination methods work, (2) what effect decontamination has on FFR performance, and (3) the risks that can happen when handling a respirator contaminated with virus [Viscusi 2011].

Another key issue was that the FDA had not cleared, for use in healthcare settings as medical devices, many respirators stored in the national stockpile and certified by

NIOSH for use in workplaces. During the pandemic, NIOSH worked closely with CDC to complete the necessary paperwork and activities to request and seek an emergency use authorization (EUA) from FDA. EUAs allow unapproved medical products or unapproved uses of medical products in an emergency. NIOSH also established its Respirator Trusted-Source Information webpage to assist purchasers in finding respiratory protection approved by NIOSH and cleared by the FDA.

Intermediate Outcomes:

- CDC incorporated NIOSH respirator and poster communication materials in the EUA request, a required component to meet the EUA. Consequently, FDA issued an EUA permitting respiratory protection devices from the SNS to be released to the states for use in protecting healthcare workers [FDA 2009a, b]. A portion of the stockpiled respirators were released in the spring of 2009. During the fall of 2009, CDC requested a briefing to determine whether to release additional respirators. NIOSH staff worked on the decision brief and participated in briefing senior CDC leadership on this issue. Based on the briefing provided, response leadership decided to release more stockpiled respirators to states for use [CDC 2010].

- NIOSH research on FFR reuse and decontamination was used by stakeholders during the pandemic. For example, the United Kingdom's Health Protection Agency cited NIOSH research in its 2009 interim advice on extending the lifespan of respirators [HPA 2009] and the Association for Professional in Infection Control and Epidemiology (APIC) cited NIOSH research to support recommendations found in a position paper on extended use and reuse of respirators [APIC 2009].

Influenza Surveillance

The U.S. influenza surveillance system is a collaborative effort between CDC and its many partners in state, local, and territorial health departments, public health and clinical laboratories, vital statistics offices, healthcare providers, clinics, and emergency departments. This network helps identify influenza outbreaks such as the 2009 H1N1 pandemic, and it has improved over the years to monitor and identify clusters or future outbreaks.

The influenza surveillance activities within NIOSH fit into the bigger picture of CDC influenza surveillance activities that monitor disease burden; virus characteristics; vaccine or antivirals availability, use, and adverse events; medical care or infrastructure; school and workforce protection, and other non-pharmaceutical interventions.

NIOSH conducted and collaborated in many surveillance projects related to the 2009 H1N1 influenza pandemic. One such study, done collaboratively by CDC, NIOSH, and state and local health officials, evaluated healthcare workers with influenza who likely become infected at work [Wise et al. 2011]. Few reported having worn surgical masks or N95 FFRs during all encounters with potentially infected patients, highlighting the need for adherence to comprehensive infection control precautions. Suarthana et al. sought to assess the distribution of influenza by occupation and industry in the early phase of the pandemic, during April to July 2009. They reported that 32% of employed, infected individuals worked in the healthcare sector. Among the non-healthcare sector, the largest proportion of individuals worked in public administration, educational services, accommodations, and food services [Suarthana et al. 2010].

During the 2009 H1N1 influenza virus pandemic, NIOSH did a pilot study to test the feasibility of using national surveillance of workplace absenteeism to assess the pandemic's impact on the workplace. Researchers completed this study to plan for preparedness and continuity of operations and to contribute to health awareness during the emergency response. The pilot study found that systems for monitoring workplace absenteeism should be included in pandemic preparedness planning and underscored the challenges in conducting real-time absenteeism in workplaces [Groenewold et al. 2013]. Building on lessons learned from this pilot study, NIOSH collaborated with the CDC Influenza Coordination Unit and DOL Bureau of Labor Statistics to develop a surveillance method that monitors the impact of pandemic influenza on the non-healthcare worker population using Current Population Survey data. This activity is offering a more complete picture regarding the community-level impact of influenza pandemics by providing insight into the burden of disease not captured by traditional medical visit-based influenza surveillance.

Health Hazard Evaluations

NIOSH completed seven HHEs during the response that addressed a variety of worker concerns ranging from assessing respiratory protection to vaccine coverage. One HHE

was a response to a request from California OSHA about fit concerns for a specific respirator model from the state stockpiles used to protect healthcare workers from exposure to the 2009 H1N1 virus. NIOSH conducted performance testing to assess the filter efficiency and completed fit testing using human subjects to evaluate the stockpiled respirators. NIOSH concluded that there were no defects in the respirators or concerns of non-compliance [NIOSH 2010c]. In July 2009, the HHE program evaluated respiratory protection for federal immigration and customs agency employees during the H1N1 pandemic [NIOSH 2009b]. The evaluation revealed that most employees who responded to the survey had face-to-face contact with immigrants in jobs. This contact puts them at risk of getting respiratory infections such as influenza. However, NIOSH found the agency's written respiratory protection procedures comprehensive and the quality of the respirator fit-testing procedures observed were good [NIOSH 2009b].

The HHE program also evaluated knowledge, attitudes, and practices regarding influenza vaccination among employees at childcare centers. The evaluation of 37 childcare centers found low rates of H1N1 and seasonal influenza vaccination among employees because of beliefs that employees did not need the vaccine, that the vaccine did not work, and that the vaccine was not safe [NIOSH 2011d]. NIOSH created a fact sheet targeting childcare employees to dispel misunderstandings about influenza and the influenza vaccine, which was distributed to the childcare centers and the local health departments [NIOSH 2013]. In addition to this HHE report, this HHE activity was published in two peer reviewed journals [de Perio et al. 2012a; de Perio et al. 2014a]. NIOSH also published an article in an early childhood education professionals magazine, *How to Boost Flu Vaccination Rates Among Employees in Your Program* [de Perio et al. 2012b].

In another HHE report, investigators collected air and surface samples in two dental practices to assess potential exposures to influenza viruses. NIOSH also administered a symptom survey to dental staff [NIOSH 2011e]. While NIOSH did not find 2009 H1N1 influenza in air or surface samples, investigators found seasonal influenza virus in air samples during one visit. Vaccination rates for both seasonal and pandemic vaccine were low in these practices. NIOSH recommended that management encourage vaccination and screen patients for influenza symptoms before visits.

Finally, NIOSH evaluated an outbreak of 2009 H1N1 influenza in an internal medicine residency program [NIOSH 2010d]. Investigators found deficiencies in adherence to recommended infection control practices, including use of PPE and work restrictions for ill health care personnel. NIOSH authors published in the American Journal of Infection Control a paper summarizing these activities [de Perio et al. 2012c].

NIOSH also provided technical assistance to the New York State Department of Health regarding their plans to develop a reporting system to receive absentee data on students and staff. The NIOSH assistance specifically involved consultation on four questionnaires used to conduct surveillance of influenza-like illness to mitigate potential impact of 2009 H1N1 influenza and also potential future influenza outbreaks [NIOSH 2010e]. NIOSH provided technical assistance to the National Association of School Nurses – objectives included minimizing impact of H1N1 and seasonal influenza on school nurses. The NIOSH assistance specifically involved planning and development of web-based survey administered in May 2010 – approximately 1200 nurses completed the survey [NIOSH 2010f].

Intermediate Outcomes:

- ❖ Analyzing follow-up surveys sent one year after the issuance of the HHE reports, NIOSH found that many of the businesses had implemented the recommendations [Delaney 2018a].

    - The head of the Department of Internal Medicine of the residency program reported implementing eight of the NIOSH recommendations including developing procedures to track ill staff and excluding them from work, training staff on signs and symptoms of influenza, and implementing a respiratory protection program [Delaney 2018a].

    - The office manager and owner of the dental practices reported encouraging staff to get annual influenza vaccinations and developing procedures to track ill employees and excluding them from work. The owner noted a positive impact of the NIOSH HHE, and that staff became more aware of the role the environment plays in transmitting colds and influenza [Delaney 2018a].

- Childcare center directors reported using NIOSH influenza education materials by posting them in visible areas of the centers and distributing to employees and center families. Two center directors reported discussing influenza with staff during meetings. Center directors reported that these materials generated informal discussion about influenza and the vaccine among staff, and they believed these materials influenced their employees to get the vaccine [NIOSH 2012a].

❖ Users downloaded the NIOSH article describing the daycare center HHE [de Perio et al. 2012a] 399 times.

Influenza Transmission Research

NIOSH as well as other entities have repeatedly identified improving and understanding basic knowledge of influenza transmission as an important NIOSH research priority [Liverman and Goldfrank 2007]. NIOSH conducts research on protecting health care providers and other workers from infectious diseases including influenza, with a significant portion aiming to understand how the influenza virus is transmitted. The program utilizes both clinical and lab-based approaches to answer research questions.

NIOSH published 41 peer-reviewed manuscripts, 6 book chapters, and presented 59 abstracts/invited talks at scientific meetings on influenza transmission research since 2007. Influenza is known to be transmitted through respiratory secretions containing the virus. Airborne transmission of influenza by small aerosols over longer distances is debated in the literature. Some of this work is reviewed on the NIOSH Influenza (Flu) in the Workplace topic page [NIOSH 2017b]. The NIOSH research prior to the 2009 H1N1 influenza pandemic helped inform guidance on reducing viral transmission during the influenza outbreak and continues to inform response planning. Brief descriptions of examples of NIOSH work that has been published follows.

To complete these aerobiology studies, NIOSH researchers developed and manufactured a two-stage cyclone bioaerosol sampler that collects air samples and separates airborne particles into three size fractions: greater than 4 µm, 1-4 µm, and less than 1 µm. Researchers used this sampler for collecting and size-fractionation of influenza-containing aerosols, followed by quantification of virus aerosols using quantitative reverse transcription polymerase chain reaction [Blachere et al. 2007].

Investigators at West Virginia University, who had successfully competed and received funding under the NIOSH *Prevention of Airborne Infections in Occupational Settings* [NIOSH 2006] funding opportunity announcement, used this novel methodology. Researchers wanted to investigate levels of airborne virus in an emergency department and an urgent care clinic operated by West Virginia University [Blachere et al. 2009; Lindsley et al. 2010a]. Both studies detected the highest levels of influenza RNA in places and times when the number of influenza patients was at its highest. The studies also found 42%–53% of the influenza viral RNA contained in airborne particles less than 4 μm in aerodynamic diameter (the respirable size fraction).

Another study using this methodology evaluated the influenza virus in cough-generated aerosol particles from people with influenza [Lindsley et al. 2010b]. The study found that coughs and exhalations generated aerosols containing small, potentially inhalable infectious influenza virus particles. A follow-on study the size and amount of aerosol particles produced by people with influenza and again when they recovered was assessed [Lindsley 2012a]. The study found people produced more aerosols when ill and the average number of particles expelled when coughing varied widely from person-to-person. In addition, other studies used a model system with a coughing manikin and a breathing manikin in an environmental chamber to perform controlled experiments, studying the behavior of airborne influenza virus and the performance of various types of PPE to protect the breathing manikin from the coughing manikin [Lindsley et al. 2012b; Lindsley et al. 2013]. Figure 35 shows the study set up in the simulated examination room. A study published using this methodology showed that high humidity (40%–45%) can inactivate virus particles aerosolized by the coughing manikin and low humidity (20%–25%) improves survival [Noti et al. 2013]. Furthermore, researchers used this methodology to evaluate protection of the breathing manikin. The results demonstrated that a poorly fitted respirator performed no better than a face mask [Noti et al. 2012]; however, one study showed that a face shield markedly reduced exposure to large infectious aerosol droplets, whereas, smaller droplets can flow around the face shield and be inhaled [Lindsley et al. 2014].

Figure 35. A simulated examination room with coughing (left) and breathing simulators (right) to study the behavior of airborne influenza virus. [Photo credit: NIOSH]

Intermediate Outcomes:

- CDC incorporated NIOSH input in CDC's Interim Guidance on Infection Control Measures for 2009 H1N1 In respiratory protection guidance, which was developed to prevent influenza transmission. Healthcare stakeholders view the guidance as authoritative and, thus, having real impact on healthcare facilities. For example, influential groups such as The Joint Commission [The Joint Commission 2012] and OSHA [OSHA 2009] prominently cited the influenza guidance.

- NIOSH researchers have loaned samplers to conduct influenza transmission research in the U.S. and internationally. In all, NIOSH loaned 525 samplers 66 investigators across 15 countries. In addition, 40 large two-stage samplers were manufactured by NIOSH for use by the HHE program [Delaney 2017b].

- Nineteen mainstream media reports, including Forbes, NBC News, and WebMD, covered the NIOSH influenza transmission research showing that high humidity can reduce the viability of the influenza virus [Delaney 2017b].

- A NIOSH PLoS One article describing efforts to measure airborne influenza virus from human coughs was among the top 1% most cited article [Noti 2017].

Table 5. Citations of selected publications

Article Name	Author(s)	Times Cited Thru May 2018
Bioaerosol sampling for the detection of aerosolized influenza virus	Blachere et al. 2007	40
Measurement of airborne influenza virus in a hospital emergency department	Blachere et al. 2009	243
Distribution of airborne influenza virus and respiratory syncytial virus in an urgent care medical clinic	Lindsley et al. 2010	119
Measurements of airborne influenza virus in aerosol particles from human coughs	Lindsley et al. 2010	170
Enhanced detection of infectious airborne influenza virus	Blachere et al. 2011	26
Viable influenza A virus in airborne particles from human coughs	Lindsley et al. 2015	21
Dispersion and exposure to a cough-generated aerosol in a simulated medical examination room	Lindsley et al. 2012	30
High humidity leads to loss of infectious influenza virus from simulated coughs	Noti et al. 2013	46
Detection of infectious influenza virus in cough aerosols generated in a simulated patient examination room	Noti et al. 2012	62

Influenza Intervention Research

To extend supplies of disposable N95 FFRs in shortages, NIOSH proposed extended use and re-use of respirators [NIOSH 2014a]. Extended use refers to continuously wearing a respirator across multiple patient encounters, without removal or re-donning between encounters. Re-use refers to removing the respirator and re-donning between patient encounters. Potential contamination of the respirator is associated with both of these practices. Furthermore, re-use of disposable N95 FFRs may have greater risks of self-

contamination from touching the respirator for donning and doffing with each encounter. An IOM recommendation from 2006 [IOM 2006] suggested re-using FFRs in conjunction with medical masks (also known as surgical masks) worn over the FFRs to prevent surface contamination (with the medical masks discarded during each doffing) [Sinkule et al. 2012].

A series of NIOSH studies critically evaluated potential approaches to extended use and re-use of disposable N95 FFRs. NIOSH evaluated the effect of wearing a face mask over an FFR on breathing quality and resistance and found that it had minimal effect on physical work performance. However, the face mask did prevent the opening of exhalation valves, so NIOSH recommended against this practice when using FFRs with these valves [Roberge et al. 2010; Sinkule et al. 2012]. NIOSH also examined FFR contamination and decontamination, developed disease transmission models, and compared the effectiveness of the FFR to face masks to protect against influenza [Fisher et al. 2010, Fisher et al. 2014, Fisher and Shaffer 2010, 2011, 2014; Noti et al. 2013]. Based on this analysis, NIOSH suggested that any decision to implement FFR reuse or extended use practices should also take in to account pathogen- or event-specific information. NIOSH defined the factors that should be considered (e.g., potential for self-inoculation, potential for secondary exposures) and determined that extended use of FFRs should be the *generally* preferred practice due to self-inoculation concerns. NIOSH further concluded that hospital administrators should ensure all staff are re-trained on proper donning and doffing procedures if a re-use practice is implemented. Finally, NIOSH evaluated the potential for re-aerosolization of virus from a contaminated FFR using a surrogate for airborne pathogenic viruses. [Fisher et al. 2012]. While NIOSH determined the risk was minimal, risk assessments must be updated as new viruses emerge. NIOSH produced a comprehensive review article [Fisher and Shaffer 2014] and developed guidance [NIOSH 2014a] to outline the scientific basis and to disseminate the new recommendations. NIOSH also developed a detailed influenza respiratory protection research webpage to highlight the extensive research and findings from this reusability work that produced over 16 peer-review papers [NIOSH 2017c].

NIOSH also participated with CDC in a series of surveys to estimate influenza vaccine coverage among workers, especially those at greatest risk for contracting influenza.

These surveys sampled an opt-in internet panel of workers in healthcare settings. The results from the survey showed an estimated 79% coverage of high-risk workers during the 2015–2016 influenza season, similar to the 77% coverage during 2014–2015 season [CDC 2016e], and compared with 63.5% rate reported for the 2010–2011 season [CDC 2011]. A report published in 2012 identified nursing home assistants as an important target for influenza vaccination, with vaccination rates estimated to be about 37% [Groenewold et al. 2012].

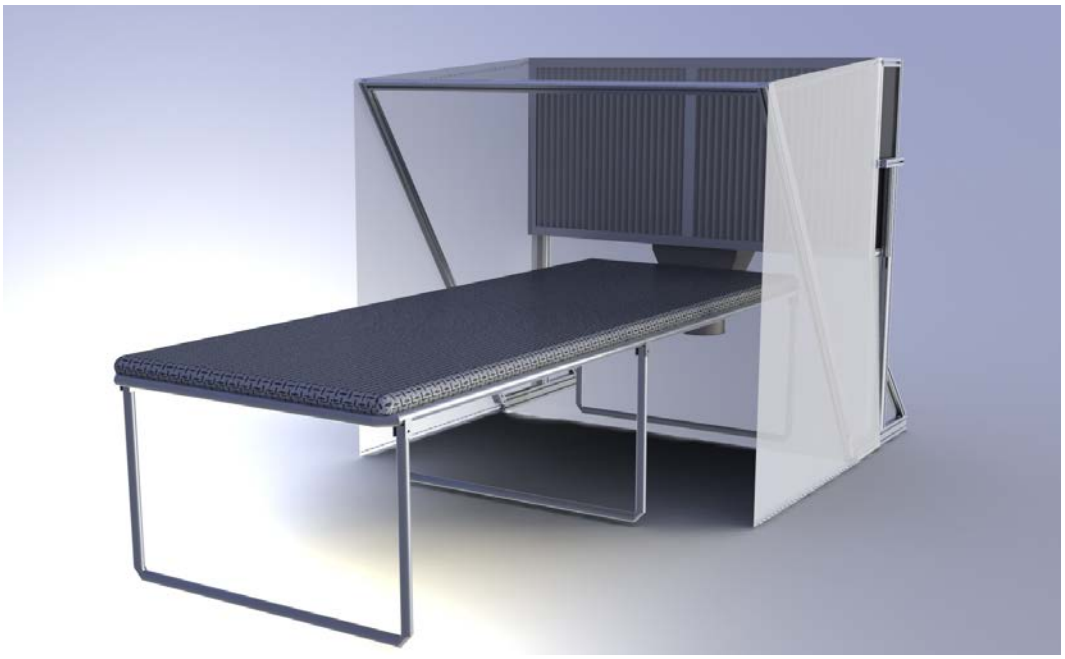
Engineering Infection Controls

Engineering controls, like local exhaust ventilation, are high on the hierarchy of controls used to protect workers from workplace hazards. They remove or reduce a hazard, or they place a barrier between the worker and the hazard. Well-designed engineering controls are preferred over PPE because engineering controls can be highly effective in protecting workers, and they generally place less of the burden upon worker actions. NIOSH researchers are involved in the following research efforts focused on developing and evaluating engineering controls to reduce the spread of infectious disease in healthcare settings.

New research at NIOSH focuses on ambulances and their ventilation design, engineering controls, and decontamination. The research seeks to make emergency workers inside ambulances less likely to face exposure to infectious diseases [NIOSH 2017d]. This research studied airflow patterns within a common government-specification ambulance module and evaluated whether these patterns expose emergency response workers to contamination from patients. Researchers then used these findings to identify engineering control interventions to reduce the workplace exposure risk to airborne infectious contaminants such as the flu virus. NIOSH also recently conducted a study on ambulance disinfection using ultraviolet germicidal irradiation (UVGI) [Lindsley et al. 2017]. The results demonstrated that UVGI systems can reduce microbial surface contamination in ambulance compartments, but the systems must be rigorously validated before deployment. Furthermore, researchers found that optimizing the UVGI fixture position and increasing the UV reflectivity of the interior surfaces can substantially improve the performance of a UVGI system and reduce the time required for disinfection.

NIOSH researchers led a project to develop an inexpensive and easy way to install a patient isolation system, shown in Figure 36, in hospital environments where traditional airborne infection isolation rooms are limited. The research identified the requirements to set up and use expedient isolation areas to control exposures to infectious aerosol, calculated the expected performance of the measures, and gave recommendations for developing and using the areas to meet the need for isolating airborne infections during surge events (Mead 2004, NIOSH 2012b). Governmental or private organizations and healthcare facilities can use findings from this research to develop emergency response guidance to control exposures to infectious aerosols. Some guidance documents external to NIOSH have already used results from this study, and leading to the development of similar engineering controls for non-traditional healthcare settings using computational fluid dynamics [Thatiparti et al. 2017].

Figure 36. 3D rendering of the ventilated headboard. [Photo credit: NIOSH].



NIOSH FDA Unified Process for Regulating N95 Filtering Facepiece Respirators

NIOSH pursued efforts with FDA to establish a unified process to regulate N95 FFRs identified as needed to protect workers during infectious disease outbreaks. To be approved by NIOSH and cleared by FDA, a respirator must go through both agencies for approval [NIOSH 2014b]. NIOSH approval focuses on the ability to protect against airborne particles, and the FDA clearance process focuses on issues such as

biocompatibility, flammability, and fluid resistance. In 2017, NIOSH funded the IOM to convene a workshop to discuss best approaches to implementing a unified approval process where NIOSH completes all necessary testing [IOM 2017]. In follow up to the IOM report, NIOSH and the FDA established a Memorandum of Understanding to finalize the approach to implementing the unified process. The FDA issued a federal register notice proposing its intent to exempt surgical N95 FFRs from 510(k) premarket notification [FDA 2017].

This exemption will decrease the regulatory burden on the medical device industry, and eliminate private costs and expenditures required to comply with certain federal regulations. This final order eliminates redundancy since manufacturers will only have to submit an application to one agency (NIOSH), rather than two (NIOSH and FDA). NIOSH will insure these devices continue to provide the expected level of protection, and are safe for their intended use. NIOSH will continue to evaluate the manufacturer's data for biocompatibility, flammability, and fluid resistance during the approval process as the FDA did previously. The conformity assessment process includes post-market audits that will involve conducting all required tests. NIOSH will conduct those tests for a sample of products in accordance with the appropriate federal and consensus standards [Approval of respiratory protective devices 2004].

Intermediate Outcome:

- FDA published a final order in May 2018 to exempt N95 FFRs intended for use in healthcare settings from premarket notification requirements [FDA 2018].

Avian Influenza

Avian influenza (or bird flu) is a bird disease caused by infection with avian influenza A viruses, which are routinely detected in wild birds and can transmit the infection to domestic poultry. Around the world, including North America, avian influenza A outbreaks occur in poultry from time to time. These outbreaks have occurred in backyard and commercial flocks and in live bird markets in Southeast Asia. Influenza usually causes only mild or asymptomatic infection in birds, but in some cases, it can cause severe illness and death in birds [CDC 2016f]. Due to both biosecurity and public health concerns, depopulation of the infected flocks is done to contain the spread of the virus.

Avian influenza A viruses usually do not infect humans; however, sporadic cases have been reported. People can be infected when they come in to contact with the virus present in the droppings, saliva, and nasal secretions of infected birds. Avian influenza A virus outbreaks in poultry have been associated with illness and death in humans in Asia, Africa, Europe, the Pacific, and the Near East. In very rare instances, some avian influenza A viruses have caused illness in humans in North America [CDC 2017d]. These viruses can be transmitted to unprotected workers who have contact with infected wild birds, poultry, or contaminated materials or surfaces. NIOSH has identified poultry growers, workers at egg production facilities, veterinarians, and disease control workers at risk of avian influenza infection, and have taken steps to protect them [NIOSH 2008a].

In 2008, NIOSH published an Alert: Protecting Poultry Workers from Avian Influenza (Bird Flu) with recommendations that poultry workers, and poultry operation owners and operators can follow to protect themselves from avian influenza [NIOSH 2008b]. A peer-reviewed paper based on this alert was also published [MacMahon et al. 2008]. The alert was one of the first to target specifically the protection of eradication workers involved in avian depopulation activities and for protecting poultry workers at risk of exposure to avian influenza.

NIOSH continues to support avian influenza outbreak response efforts by coordinating with CDC to address national health needs associated with preventing the spread of avian influenza virus to unprotected workers. In 2013, the first human infections with avian influenza A (H7N9) were identified in China [CDC 2018a]. Infections were associated with close contact with poultry, generally at live bird markets. CDC immediately stood up a response which included activating the NIOSH Worker Safety and Health Team. As part of planning efforts, NIOSH provided expert consultation to CDC and to the White House's National Security Staff on PPE, identifying solutions to reduce demand and increase supplies for respiratory protection [CDC 2018a].

From December 2014 through August 2015, a highly pathogenic avian influenza H5 virus caused outbreaks among backyard and commercial flocks in the United States. CDC and NIOSH co-developed Recommendations for Worker Protection and Use of Personal Protective Equipment (PPE) to Reduce Exposure to Highly Pathogenic Avian Influenza A H5 Viruses to protect poultry workers and responders. AgriSafe Network, an organization that supports agricultural health and safety professionals, and the NIOSH-

funded Agricultural Safety and Health Center sought to develop guidance for small producers not covered by OSHA. NIOSH provided scientific expertise to AgriSafe to support the development of their Avian Influenza Personal Protective Equipment (PPE) Guidelines. Because of this collaboration, NIOSH and AgriSafe signed a Memorandum of Understanding (MOU) to enable future possible work. CDC and NIOSH co-developed the CDC Interim Guidance for Landfill Workers in the United States Disposing of Poultry Carcasses During Outbreaks of Highly Pathogenic Avian Influenza to provide recommendations to protect workers disposing of poultry carcasses. The USDA Animal and Plant Health Inspection Service requested this guidance [CDC 2016g].

Intermediate Outcomes:

- AgriSafe incorporated NIOSH recommendations and information in their Avian Influenza PPE Guidelines.
- CDC issued the Health Advisory, Bird Infections with Highly-Pathogenic Avian Influenza A (H5N2), (H5N8), and (H5N1) Viruses: Recommendations for Human Health Investigations and Response, through the Health Alert Network (HAN). This Health Advisory contained recommendations for human health investigations and response to the HPAI H5 outbreak in birds, including a section on worker protection, which also cited the NIOSH worker guidance.
- USDA references the CDC-NIOSH landfill worker guidance in their publication, Landfill Disposal Guidance—Recommended Waste Acceptance Practices for Landfills, which recommends that landfill operators follow this guidance. USDA also posted the CDC-NIOSH guidance on their emergency management website.

Investigations at Non-Transplant Anatomical Donation Centers

Non-transplant anatomical donation centers engage in the recovery and distribution of human bodies or parts donated for medical education, surgical training, or research. Workers at these centers perform preparation and dissection procedures on thousands of human cadavers and anatomical materials every year. This growing industry is unregulated compared with the industry involved with materials to be transplanted into living recipients.

During 2014–2015, NIOSH responded to three requests for investigations regarding exposures to blood-borne pathogens among workers at three different non-transplant anatomical donation centers nationwide. NIOSH investigators worked closely with colleagues from the FBI, CDC, and state and local public health partners. Criminal and public health concerns included the way in which these centers screened and handled donors with infectious diseases.

After the FBI raided an Arizona center as part of a criminal investigation for fraud, the NIOSH team worked with Arizona public health officials to identify current and former employees at risk of blood-borne pathogen exposures. At the request of the Maricopa County Department of Public Health (MCDPH), NIOSH investigators drafted a notification letter to send to employees who worked at this center. NIOSH worked with MCDPH to arrange for follow-up employee testing for HIV, Hepatitis B, Hepatitis C, and tuberculosis. In April 2014, the center closed, therefore, eliminating further risks to employees. NIOSH investigators led the effort to publish an MMWR article on the investigation in that same month. Through its publication and further dissemination by news outlets nationwide, the MMWR notified thousands of readers and potential end-users of the risks associated with these materials. This report also contained recommendations on safe handling and shipping practices for workers in the industry when handling materials [CDC 2014c].

NIOSH investigated a second center also in Arizona because an incident involving the shipment of human heads across international boundaries prompted investigation by CDC's Select Agents Program, which in turn sought expertise from NIOSH. Institute investigators worked with the CDC team and led the assessment of potential employee exposures to blood-borne pathogens and compliance with existing regulations. During the on-site visit, the NIOSH team observed work practices, interviewed all 18 employees present, and reviewed injury and illness logs and all employee files for hepatitis B vaccination status. The team identified deficiencies in the documentation and management of employee hepatitis B vaccination and needlestick injuries. After the visit, the team issued a letter to the company detailing the findings and recommendations [NIOSH 2014c].

At the request of the FBI, NIOSH participated in an investigation of another center in Illinois. NIOSH investigators accompanied partners from several federal agencies on a

raid of the center, leading the public health aspect of the investigation. The criminal investigation included allegations of improper screening and disclosure of donors with infectious diseases. The NIOSH team reviewed the company's written exposure control plan and criteria for screening and excluding donors with infectious diseases. They interviewed all seven employees, including the owner, about work practices and exposures. Through these interviews, investigators discovered work practices of concern including the recapping of needles and deficiencies in hand hygiene. The NIOSH team sent a letter to the center via the FBI with findings and recommendations [de Perio and Harney 2015a].

As a direct result of this investigation, industry leaders and the federal agencies involved (CDC, FBI, DOT) began high-level discussions about OSH best practices and the need for regulation and oversight of the industry; these discussions continue today. NIOSH's collaboration with the FBI fostered a closer working relationship and a greater understanding of the perspectives of the two agencies when handling criminal matters with public health implications.

Intermediate Outcomes:

- The MCDPH notified 22 employees about their potential exposures in writing using the NIOSH-drafted letter. While none of those tested were found to have any infections, MCDPH identified six employees who did not have immunity to hepatitis B and recommended that they receive hepatitis B vaccinations [dePerio 2014b].

- In response to the NIOSH team's recommendations, the second Arizona center improved compliance for handling hepatitis B vaccinations, needlestick injuries, and training of its 19 employees. In a letter from the company, management representatives reported that they had taken corrective action in response to all nine of the recommendations [Cover and Shreves 2014].

- In response to the team's recommendations, the Illinois center notified and arranged testing for its current and former employees for blood-borne pathogens [Harney 2015].

- The American Medical Education and Research Association (AMERA), a peer recognized accreditation organization for the industry nationwide, incorporated the NIOSH team's recommendations from the first two investigations into their revised accreditation procedures and standards published in late 2014 [AMERA 2014].

- In January 2018, a federal court found the owner of one of these donation centers guilty and convicted him of eight counts of wire fraud and one count of illegal transportation of hazardous material. The U.S. Attorney's Office acknowledged the CDC team which included NIOSH staff in their press release of the conviction. The FBI special agent working the case sent an email communication thanking all those involved in the investigation, stating that the defendant would not have been brought to justice without our assistance [Delaney 2018b].

Investigation of *Burkholderia pseudomallei* at a Non-Human Primate Research Center

Burkholderia pseudomallei (*B. pseudomallei*), is a Tier I select agent: these are biological agents and toxins presenting the greatest risk of deliberate misuse with significant and disastrous effects. The bacteria can cause melioidosis through direct contact with contaminated soil and water. The signs and symptoms of infection vary and can include fever, respiratory distress, joint pain, or seizures. In December 2014, CDC was contacted about three melioidosis cases in non-human primates (NHP) located in a breeding colony housing >4,100 NHPs. The breeding colony was located within a larger primate research facility, where, in a nearby Biosafety Level 3 (BSL-3) laboratory, researchers were working with *B. pseudomallei*. The center supports medical research utilizing NHPs (primarily rhesus macaques) and rodents and is registered with the Federal Select Agent Program to use certain select agents, including *B. pseudomallei*.

CDC launched an Epi-Aid investigation and worked with many partners including local, state, and other federal agencies (FBI, USDA, EPA). Representatives from state, local, and federal agencies established a UAC. NIOSH participated in daily coordination calls and led the Worker Safety and Health Team. At the request of EPA, NIOSH reviewed the on-site health and safety plan and provided comments. NIOSH also provided consultation on environmental sampling. All select agent research at the primate

research facility were suspended until the findings of the investigation could be addressed [CDC 2015c, d].

In February 2015, a NIOSH investigator made an on-site visit to assist CDC's Select Agent Program and USDA personnel in evaluating whether a subset of center staff with access to both the BSL-3 laboratory and the NHP breeding colony caused the release of *B. pseudomallei* from the BSL-3 laboratory. The NIOSH investigator evaluated whether work practices related to the center's OSH program could have been contributing factors in the release. These efforts focused on interviewing key facility personnel, as well as reviewing employee injury and incident reports, injury and illness reporting procedures and policies, written respiratory protection program, and new employee safety training including the BSL-3 visitor training.

In March 2015, NIOSH investigators made a second on-site visit to the facility when the Epi-Aid expanded to include evaluating employee safety and health risks associated with the onsite veterinary hospital that provided care to the animals in the primate research facility. During the visit, the NIOSH team reviewed injury and illness logs and the hospital's standard operating procedures for relevant infection prevention and observed work practices. The team also interviewed 44 veterinary, animal husbandry, and facilities employees who spent any time in the veterinary hospital about work activities, NHP exposures, training, and health.

The NIOSH team concluded that employees working in the veterinary hospital had potential exposures to blood, body fluids, and infectious agents from NHPs. The center had a good occupational safety program with regard to hazards from NHPs. The NIOSH team made recommendations to further improve employee health and safety by increasing oversight of day-to-day safety behaviors, adopting additional sharps safety measures, and updating PPE hazard assessments [de Perio and Harney 2015b].

The NIOSH team's collaboration with local, state, and federal partners fostered a closer working relationship between the agencies regarding select agents. Through discussions with CDC's Select Agent Program, additional health and safety opportunities surrounding them were identified. One example relates to the re-use of disposable respirators in biosafety laboratories. NIOSH provided a memo describing the issue and

recommending against reusing disposable respirators with certain infectious agents. NIOSH developed and posted a Q&A on this topic to the NIOSH website.

Intermediate Outcome:

- Two of NIOSH's findings included improved PPE practices. While no infection with *B. pseudomallei* was identified among employees, all employees with access to BSL-3 facilities were re-trained on adherence to biosafety protocols and proper PPE donning and doffing procedures.

End Outcomes

The desired end outcome of the NIOSH EPR Program is the reduction of injury, illness, and death among response and recovery workers. Currently, no national surveillance system exists that tracks the injury, illness, and death of workers during emergencies. However, with the adoption of NIOSH response-specific guidance by NIOSH partners and other stakeholders, actions to protect the health and safety of response and recovery workers have been implemented. When emergencies occur or newly emerging threats are identified, stakeholders and partners come to NIOSH seeking recommendations to protect these workers. The response leadership, employers, or professional associations adopt these recommendations in real-time. The Ebola epidemic serves as an example. NIOSH staff, through the provision of on-site assistance, directly observed the use of the CDC Ebola healthcare PPE donning and doffing practices in hospitals. Alternatively, NIOSH develops recommendations and guidance in advance of an emergency that may never happen. National response plans and policy documents incorporate these recommendations into preparedness plans.

While the U.S. has been fortunate not to experience a catastrophic, radiological emergency, NIOSH has partnered with many federal agencies to ensure the nation is prepared to respond to such an event. Measuring the impact of NIOSH preparedness work for emergencies that have not occurred proves challenging. However, the planning and preparedness process for one emergency type, which brings together many different federal agencies and partners, ensures a more successful response to any emergency. For example, the basis of existing response plans for Ebola come from knowledge on outbreaks in remote areas of Africa. With no prior Ebola expertise, NIOSH

quickly leveraged existing response knowledge for other infectious diseases to respond successfully to the epidemic.

Alternative Explanations

Although NIOSH has been at the forefront of OSH during emergency responses, many other organizations, institutions, and federal and state government agencies contributed to efforts to protect and improve response and recovery worker health in this area. For example, OSHA, through regional and national staff, provides compliance assistance both in the field and remotely. OSHA has also developed educational materials and eTools that offer information about how to protect responders against a variety of hazards that are possibly encountered during emergencies [OSHA 2018]. The NIEHS Worker Training Program funds organizations to develop and give health and safety trainings to workers who handle hazardous materials or respond to emergency releases of hazardous materials [NIEHS 2018].

Federal and state agencies maintain their own internal health and safety programs that develop their own policies to protect their workforce. The National Incident Management System, which describes a nationwide approach for agencies to work together to prepare for and respond to emergencies, specifically calls for the creation of a Safety Officer responsible for personnel safety and preparing a site-specific health and safety plan [FEMA 2017]. While these agencies also responded during emergencies by providing educational materials, conducting hazard identification and mitigation activities, and providing training, many of the organizations utilized NIOSH guidance in these activities. Furthermore, in some cases, NIOSH co-creates and jointly issues guidance. During the response to the DWH Oil Spill, NIOSH and OSHA co-developed guidance to protect response workers and volunteers. During the Ebola Epidemic, NIOSH, OSHA, and EPA co-developed a fact sheet with recommendations to protect workers from exposure to Ebola virus during waste management.

Future Plans

Although emergencies are unpredictable, NIOSH will continue to be ready to respond when they occur. In order to ensure NIOSH is prepared to respond, NIOSH EPRO will continue to maintain staff on-call lists with the CDC EOC along with SME lists for

National Special Security Events. NIOSH EPRO will take continuing education and other courses focusing on EPR and emergency management to stay current in the area.

Influenza planning and preparedness activities will continue to be an important component of the EPR portfolio. NIOSH will help plan and participate in a CDC-wide influenza exercise September 2018 to test and refine response plans. This exercise will address respirator availability, a key preparedness activity. NIOSH will also participate in a national level influenza exercise, planned for early 2019.

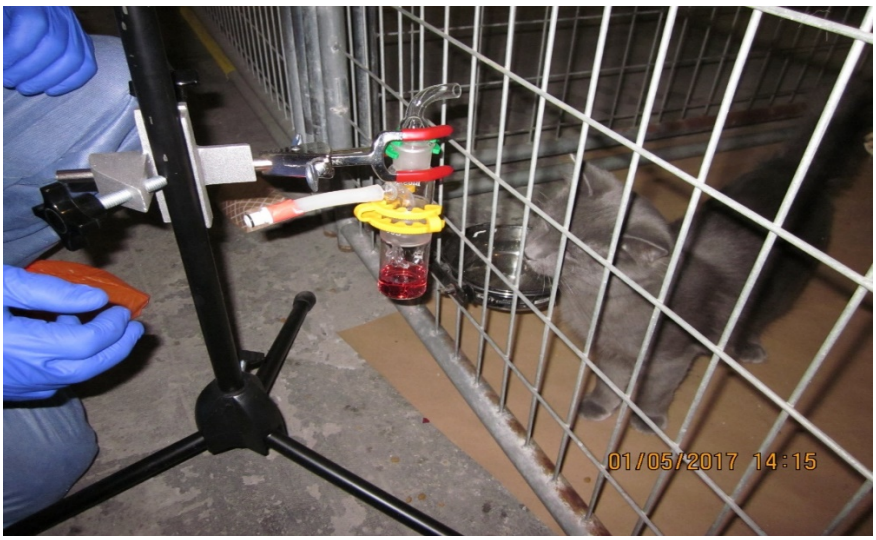
NIOSH partnered with other parts of CDC, the Veterans Administration (VA), and Johns Hopkins University to support the Respiratory Protection Effectiveness Clinical Trial (ResPECT) to critically evaluate whether using N95 FFRs provides substantial incremental benefit compared with face masks as part of a comprehensive program to prevent acute respiratory illness (including influenza) in healthcare workers [Radonovich et al. 2016]. The study was a prospective, multi-season, cluster-randomized comparative effectiveness clinical trial conducted at seven study sites, including three university-based medical centers (Johns Hopkins Health System, Denver Health, and Denver Children's Hospital) and four VA Health Systems (New York, NY; Denver, CO; Houston, TX; and Washington, DC). Approximately 5,000 human subjects enrolled for the study. Researchers completed data collection in August of 2015, and a manuscript has been prepared.

Because storage may affect the performance of the respirator, potentially allowing a higher level of particulate penetration than expected, NIOSH, in collaboration with CDC's Influenza Coordination Unit, is conducting a three-year study to determine best practices and conditions for respirator stockpiling. From March to October 2018, NIOSH will test materials from more than 10 stockpiles to determine the impact of storage conditions (e.g., temperature and humidity), noting degradation over time. NIOSH is also standing up a study to determine the feasibility and acceptability of U.S. healthcare delivery organizations to routinely utilize reusable respirators or rapidly convert to their use during a public health emergency. Demonstration projects will be conducted in collaboration with private and academic sector health care organizations. Demonstrations will focus on determining the ability to conduct just-in-time fit testing, education, and training; feasibility for inpatient care; and determining the mechanism for disinfection.

In fiscal year 2018, CDC is holding a series of workshops, tabletop exercises, drills, and functional exercises focused on improving CDC's nuclear and radiological preparedness capabilities. NIOSH staff will assist in planning and participate in this second phase of CDC's Nuclear and Radiological Preparedness Program, which builds on previous internal exercises and last year's national exercise Gotham Shield. NIOSH has also prepared a manuscript describing efforts to model potential radiation exposure to first receivers and volunteers performing triage in public shelters after a nuclear detonation. Exposure to elevated levels of external ionizing radiation may pose a health hazard to first responders and NIOSH sought to understand the exposure potential to these groups.

Results from research and projects initiated by the Disaster Science Responder Research (DSRR) Program are expected in the coming years. One project focuses on developing exposure assessment plans for the first 72 hours following a disaster. Exposures during the first 72 hours following an incident are often the most intense, unique, and most poorly characterized. This project aims to provide responders with the tools needed to assess worker exposures at the start of the response to identify immediate remedial actions. The output of this project will be exposure assessment plans to be piloted in actual disasters to improve responder safety and health. NIOSH also completed a pilot study assessing the potential for aerosol transmission during the care of cats infected with avian influenza (H7N2) in early 2017, shown in figure 37. A manuscript has been prepared and is current in journal review [Blachere et al. 2018].

Figure 37. NIOSH staff collecting air sample looking at potential aerosol transmission during care of cats infected with avian influenza. [Photo credit: NIOSH]



Ideally, many disaster-science research projects could be implemented rapidly at or near the start of the response. In order to achieve this aim, the EPR Program is working closely with the NIOSH Associate Director for Science Office to develop a rapid research protocol and a robust and rapid ethical review process that reduces the time required to initiate research during disasters.

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Appendix A: Biosketches of Key EPR Program Staff

Captain Lisa Delaney, MS, CIH

Associate Director for Emergency Preparedness and Response

CAPT Lisa Delany joined the National Institute for Occupational Safety and Health (NIOSH) in 1999 after graduating with a Master of Science degree in Environmental Health and Industrial Hygiene from the University of Cincinnati. CAPT Delaney currently serves as the Associate Director for Emergency Preparedness and Response at NIOSH where she coordinates NIOSH's response to emergencies, ensures federal response plans incorporate occupational safety and health protection measures, and promotes research in the area of protecting first responders during emergencies. CAPT Delaney directs deployment of NIOSH staff providing disaster technical assistance and leads the Emergency Preparedness and Response Office (EPRO). She also serves as a senior-level technical reviewer and coauthor of Institute responder safety and health policy, plans, training, and exercise documents.

CAPT Delaney responded to nearly every major domestic emergency beginning with the September 11th attacks and, most recently, the 2017 hurricane responses. CAPT Delaney specializes in biological emergency responses with a focus on understanding the role the environment plays in disease transmission and protecting workers during these responses. She led NIOSH's response to the 2014–2016 Ebola epidemic and deployed to Sierra Leone as the Safety Officer. CAPT Delaney has served as the Pandemic Influenza Coordinator for NIOSH since 2006, and she is a leading expert in the environmental assessment of *Bacillus anthracis*. She has coauthored a range of anthrax guidance documents related to worker protection, sample collection procedures, and interagency sampling strategies.

Commander Chad Dowell, MS, CIH

Deputy Associate Director for Emergency Preparedness and Response

CDR Chad Dowell joined NIOSH in 2002 after graduating with a Master of Science degree in Environmental, Safety, and Health Management from The University of Findlay. CDR Dowell currently serves as the NIOSH Deputy Associate Director for Emergency Preparedness and Response where he coordinates NIOSH's emergency preparedness and response activities, works to advance research and collaborations to protect the health and safety of responders, and oversees the EPRO budget. CDR Dowell has been involved in many NIOSH response efforts since 2005. He deployed to the field to support the DWH response and several anthrax events. For other responses to hurricanes, Ebola, Influenza, Seoul-virus, and ricin events, he has provided remote technical assistance. He also oversees the development of the Emergency Responder Health Monitoring and Surveillance (ERHMS) Info Manager software. Additionally, CDR Dowell serves as the NIOSH Coordinator for Part G of the Ryan White HIV/AIDS Treatment Extension Act of 2009. CDR Dowell formerly served as an industrial hygienist in the NIOSH Health Hazard Evaluation (HHE) Program where he conducted field research on exposures and health effects in a variety of industrial settings.

Commander Sherry Burrer, DVM, MPH-VPH, DACVPM

CDR Sherry Burrer received both her Doctorate of Veterinary Medicine and Master of Public Health degrees from The Ohio State University and is board certified in veterinary preventive medicine. She was a member of the Centers for Disease Control and Prevention's (CDC) Epidemic Intelligence Service (EIS) Fellowship class of 2008 and, during that time, was assigned to the New Hampshire Department of Health and Human Services. Additionally, in 2011, she completed the CDC Preventive Medicine Fellowship at NIOSH EPRO. After spending time in other areas within CDC, including syndromic surveillance and environmental health, CDR Burrer recently returned to NIOSH's EPRO to serve as epidemiologist and senior veterinary officer. CDR Burrer has led and published on research and responses in the areas of syndromic surveillance, community assessment, at-risk populations, and emergency preparedness and response.

Commander Jennifer Hornsby-Myers, MS, CIH

CDR Jennifer Hornsby-Myers has served in NIOSH's EPRO for nearly 18 years. She currently serves as the EPRO Regional Operations Director, and in her tenure, also served as the EPRO Deputy Director. CDR Hornsby-Myers is EPRO's subject matter expert for preparedness and response activities related to chemical, radiological, and nuclear events. She represents NIOSH on high-level working groups such as the National Response Framework Worker Safety & Health Annex Cooperating Agency's Committee, the National Response Team's Worker Safety & Health Committee, and the White House Domestic Chemical Defense IPC. She also currently serves on the White House Interagency Working Group tasked to create whole-of-government recommendations for law enforcement officers so these workers can safely respond to protect both the public and themselves during the current opioid crisis. CDR Hornsby-Myers has deployed such disasters as Hurricane Katrina, the 2010 Haiti Earthquake, and Liberia during the Ebola epidemic. She also coauthored many U.S. Government preparedness documents that provide guidance and recommendations for first responders to ensure they are better prepared to respond safely.

Commander Jill Shugart, MSPH, REHS

CDR Jill Shugart is a Senior Environmental Health Specialist in NIOSH EPRO and serves as the NIOSH ERHMS Coordinator. Over the past 14 years, she has worked on a variety of environmental and occupational health and safety issues both domestically and internationally with multiple federal, state, local, and tribal entities in the Indian Health Service, the Agency for Toxic Substances and Disease Registry (ATSDR), the Assistant Secretary for Preparedness and Response's (ASPR), and the CDC's Vessel Sanitation Program. She has prepared for and responded to several public health emergencies, including hurricanes, floods, oil spills, Ebola, Zika, and other infectious disease outbreaks.

Lieutenant Kerton Victory, PhD, MSc

LT Kerton Victory is an Environmental Health Officer and Epidemiologist in NIOSH EPRO. LT Victory recently graduated from the EIS Fellowship where he was assigned to the NIOSH HHE Program in Cincinnati, Ohio, from August 2014 to May 2016. During his EIS experience, LT Victory worked on several projects, including evaluating crystalline silica

exposures among granite countertop workers and evaluating Missouri's Adult Blood Lead Epidemiology and Surveillance program. Additionally, LT Victory provided technical assistance in epidemiology and emergency preparedness for the Ebola epidemic, including deployments to the Republic of Guinea and Dallas, Texas, where Ebola was transmitted to two healthcare workers.

Angela M. Weber, MS

Ms. Angela Weber earned her Master of Science degree from the University of Cincinnati's Environmental Health Department in the College of Medicine. She currently serves as the Program Coordinator for CDC's NIOSH Disaster Science Responder Research (DSRR) Program, located within EPRO. As Program Coordinator, she works to advance research and stakeholder collaborations to protect the health and safety of the emergency responders and recovery workers who participate in responses to natural and manmade disasters and novel emergent incidents.

Over her more than 20 years at CDC, Ms. Weber has prepared for and responded to a variety of infectious disease outbreaks and occupational health and safety issues, both domestically and internationally, including severe acute respiratory syndrome (SARS), multiple anthrax and ricin incidents, Ebola virus epidemic, and hurricane disasters. She formerly served as an industrial hygienist in the NIOSH HHE Program; in the National Center for Environmental Health, Office of Terrorism Preparedness and Emergency Response; and in the National Center for Emerging and Zoonotic Infectious Diseases, Division of Preparedness and Emerging Infections. Ms. Weber recently served as a research coordinator, designing studies for CDC's Office of Environmental Microbiology to address gaps identified during infectious disease outbreaks related to bioterrorism agents.

Elizabeth Whelan, PhD

Dr. Whelan received her PhD in epidemiology from the University of North Carolina at Chapel Hill in 1991, joining NIOSH as an EIS Officer that same year. In 2004, she became Chief of the Industrywide Studies Branch in the Division of Surveillance, Hazard Evaluations, and Field Studies. Dr. Whelan has over 20 years of experience conducting occupational epidemiology studies, and her research interests include reproductive

health, take-home exposures, occupational cancer, and emergency response research. Dr. Whelan also serves as co-chair of the NIOSH DSRR Steering Committee.