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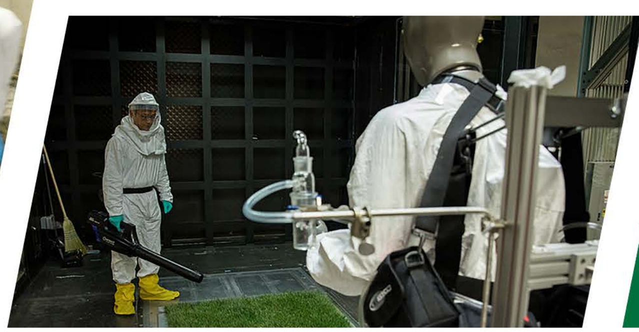
United States
Environmental Protection
Agency

Homeland Security

STRATEGIC RESEARCH ACTION PLAN
2019-2022



Office of Research and Development
Homeland Security

Homeland Security

National Research Program

Strategic Research Action Plan

2019 – 2022

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List of Acronyms

ASTHO	Association of State and Territorial Health Officials
ASTWMO	Association of State and Territorial Waste Management Officials
CAA	Clean Air Act
CBRN	Chemical, biological, radiological, and nuclear
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIPAC	Critical Infrastructure Protection Advisory Committee
CONOPS	Concept of operations
CSS	Chemical Safety for Sustainability
CWA	Clean Water Act
HHS	U.S. Department of Health and Human Services
DHS	U.S. Department of Homeland Security
DOD	U.S. Department of Defense
DPAS	Decontamination Preparedness and Assessment Strategy
DWH	Deepwater Horizon
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERLN	Environmental Response Laboratory Network
ESAM	Environmental Sampling and Analytical Methods
ESF	Emergency Support Function
FAD	Foreign animal diseases
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FSMA	Food Safety Modernization Act
HERA	Health and Environmental Risk Assessment
HSA	Homeland Security Act
HSPD	Homeland Security Presidential Directive
HSRP	Homeland Security Research Program
ICCOPR	Interagency Coordinating Committee for Oil Pollution Research
IMO	International Maritime Organization
NCP	National Contingency Plan
NCPPS	National Contingency Plan Product Schedule
NDRF	National Disaster Recovery Framework
NEBA	Net Environmental Benefit Analysis
NEMA	National Emergency Management Association
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resource Damage Assessment
NRF	National Response Framework
NRP	National Response Plan
NRT	National Response Team
NSPM	National Security Presidential Memorandum
NSTC	(White House) National Science and Technology Council
OAR	U.S. EPA Office of Air and Radiation
OCSPP	U.S. EPA Office of Chemical Safety and Pollution Prevention
OECA	U.S. EPA Office of Enforcement and Compliance

OEM	U.S. EPA Office of Emergency Management
OLEM	U.S. EPA Office of Land and Emergency Management
OPA	Oil Pollution Act
ORCR	U.S. EPA Office of Resource Conservation and Recovery
ORD	U.S. EPA Office of Research and Development
OW	U.S. EPA Office of Water
OWM	U.S. EPA Office of Waste Management
PAL	Provisional Advisory Level
PFAS	Per- and polyfluorinated alkyl substance
PFOA	Perfluorooctanoic acid
PPD	Presidential Policy Directive
RCRA	Resource Conservation and Recovery Act
R&T	Research and Technology
SBIR	Small Business Innovation Research
SDWA	Safe Drinking Water Act
SHC	Sustainable and Healthy Communities
SSWR	Safe and Sustainable Water Resources
S&T	Science and technology
StRAP	Strategic Research Action Plan
USDA	U.S. Department of Agriculture
WCIT	Water Containment Information Tool
WLA	Water Laboratory Alliance
WSD	U.S. EPA Water Security Division
WSTB	Water Security Test Bed

Executive Summary

Caused naturally or by humans, environmental emergencies continue to challenge our nation. The use of chemical threats in Syria and the United Kingdom, the opioid epidemic, and several recent water system contamination incidents that affected hundreds of thousands of people, remind us of the impact that chemical contaminants can have on public health. Further, the radiological contamination following the Fukushima Daiichi nuclear disaster in 2011 demonstrated the significant impact and challenge of cleaning up large-scale contamination incidents. Smaller-scale incidents, such as the attempted ricin poisonings in several communities around the country, also highlight the ever-present threat of terrorism post 2001.

The U.S. Environmental Protection Agency (EPA) is responsible for helping communities prepare for and recover from disasters that result in threats to public health and the environment. The Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) aims to increase the United States' capabilities to prepare for and respond to releases of oil and hazardous substances into the environment, as mandated by Congress. The hazardous substances involved can include chemical, radiological, nuclear, and biological materials. There are considerable gaps in our capabilities to address these risks, including understanding the behavior of contaminants when released into the environment, potential public exposures, determining where contamination is present that may pose an exposure risk, and cleaning up contaminated areas and infrastructure. Enhancing capabilities for response and remediation of contaminated areas and protecting water systems will improve our nation's resilience to environmental catastrophes.

The *Homeland Security Strategic Research Action Plan (StRAP)*, 2019-2022, is a four-year research strategy designed to achieve the following objectives: advance EPA's capabilities and those of our state, tribal, and local partners to respond to and recover from wide-area contamination incidents; and, improve the ability of water utilities to prevent, prepare for, respond to, and recover from water contamination incidents that threaten public health.

EPA's HSRP is organized into three topics supporting these objectives: (1) contaminant characterization and consequence assessment; (2) environmental cleanup and infrastructure remediation; and (3) systems approaches to preparedness and response. Short- and long-term goals accomplished through research areas within these topics outline a strategy for addressing the objectives.

HSRP performs applied research that delivers relevant and timely methods, tools, data, technologies, and technical expertise in support of federal, regional, state, tribal, water system, and local community resilience. HSRP engages partners throughout the research life-cycle to ensure their needs are being met – from identifying scientific capability gaps, to performing research to address those gaps, to formulating and delivering timely and reliable products that fill those gaps, to transitioning and implementing the products via collaborative field studies and exercises. HSRP products provide systems-based approaches to site characterization, risk assessment, and remediation (which includes waste management) to address large-scale contaminated areas and water systems. Federal, state, tribal, and local decision makers will have access to the information and tools they need to prepare for and recover from catastrophes involving environmental contamination incidents that threaten public health.

Introduction

The Homeland Security Strategic Research Action Plan (StRAP) for 2019-2022 is a four-year strategy to deliver research necessary to support the Environmental Protection Agency's (EPA) overall mission to protect human health and the environment, fulfill the EPA's legislative mandates, and advance cross-agency priorities identified in the FY2018-FY2022 EPA Strategic Plan (U.S. EPA, 2018a). This StRAP outlines how EPA's Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) aims to meet the homeland security science needs of the EPA partners and stakeholders. EPA partners include EPA program and regional offices, federal agencies, and state and tribal governments supporting the protection of human health and the environment; stakeholders include local governments, non-governmental organizations, private industries, academic institutions, and others with an interest or investment in public and environmental health.

The Homeland Security StRAP is one of six research plans, one for each of EPA's national research programs in ORD. The six research programs are:

- Air and Energy (A-E)
- Chemical Safety for Sustainability (CSS)
- Homeland Security Research Program (HSRP)
- Health and Environmental Risk Assessment (HERA)
- Safe and Sustainable Water Resources (SSWR)
- Sustainable and Healthy Communities (SHC)

EPA's six strategic research action plans lay the foundation for EPA's research programs to provide focused research that meets the Agency's legislative mandates and the goals outlined in the EPA and ORD Strategic Plans (U.S. EPA, 2018a, 2018c). The StRAPs are designed to guide an ambitious research portfolio that delivers the science and engineering solutions EPA needs to meet its goals now and into the future, while also cultivating an efficient, innovative, and responsive research enterprise.

HSRP addresses science gaps related to remediation of environmental contamination that threatens public health and welfare, as well as science gaps related to environmental quality before, during, and after a disaster. HSRP helps EPA carry out its homeland security and emergency response mission by working closely with its partners to understand the potential threats and consequences of hazardous substance release. HSRP works in coordination with its partners and stakeholders to conduct research that gives decision makers the information they need for their communities and environments to rapidly recover after a disaster.

HSRP's general research approach is to adapt suitable methodologies that have proven effectiveness in a laboratory setting for success in real-world settings. Real-world settings can be challenging because affected environments are not pristine; grime and biofilms complicate the behaviors of sampling and cleanup technologies, thereby affecting responders' ability to sample and remediate sites. Furthermore, some response activities and decisions may occur in sequence where such activities are coupled to, or are dependent on, other response activities and decisions. Human behavior is not always predictable, stakeholder relationships must be negotiated, and risks can be difficult to communicate. HSRP develops information and tools for cleanup, waste management, characterization and assessment of hazards, and application of the latest information in decision-making.

Research to Support the EPA Strategic Plan

The FY2018-FY2022 EPA Strategic Plan is designed to implement the Administrator's priorities for the next five years. This Strategic Plan identifies three overarching strategic goals: 1) A Cleaner, Healthier Environment, 2) More Effective Partnerships, and 3) Greater Certainty, Compliance, and Effectiveness. EPA's research programs are aligned to the Strategic Plan and designed to ensure that the Agency successfully meets the goals and objectives articulated in the Strategic Plan.

The first goal emphasizes EPA's mission of providing a Cleaner, Healthier Environment by improving air quality, providing clean and safe water, revitalizing land and preventing contamination, and ensuring chemical safety. HSRP directly supports this mission through its applied research in response and remediation, a critical component of building resilience.

The second goal of EPA's Strategic Plan is More Effective Partnerships, which enhances shared accountability and increases transparency and public participation for states and tribes.
HSRP works with EPA regional offices to support state and tribal needs and continues to strengthen its direct relationship with states and tribes through partnerships with national associations such as the Environmental Council of the States (ECOS) and the Environmental Research Institute of the States (ERIS), National Environmental Health Association (NEHA) and the Association of State and Territorial Health Officials (ASTHO), the Association of State and Territorial Waste Management Officials (ASTWMO) and the National Emergency Management Association (NEMA).

Greater Certainty, Compliance, and Effectiveness is the final goal of EPA's Strategic Plan. This goal includes the specific objective to prioritize robust science. HSRP helps achieve this by conducting research and providing EPA programs and regions with the scientific support they need to develop innovative solutions to environmental challenges.

Statutory and Policy Context

Since the attacks of September 11, 2001 on the United States, the nation's homeland security enterprise was reconstructed, ultimately leading to better national protection from both natural and anthropogenic disasters. Several statutes give EPA the authority and obligation to respond to emergencies, such as oil spills, and to develop research that would improve hazardous material removal actions primarily through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Clean Water Act (CWA), and Safe Drinking Water Act (SDWA). The Public Health Security and Bioterrorism Preparedness and Response Act required EPA and its partners to help water utilities conduct vulnerability assessments and develop emergency response plans (U.S. EPA, 2018d).

In addition to statutory authorities, the federal government has established many policies through Presidential Directives and National Frameworks that outline EPA's responsibilities with respect to emergencies including acts of terrorism. For example, Homeland Presidential Directive (HSPD) 7[1] helped define federal government roles and responsibilities within the homeland security enterprise for U.S. critical infrastructure, designating EPA as the lead for drinking water and water treatment systems. The National Response Framework (NRF) assigns EPA as the lead agency to take "appropriate actions to prepare for and respond to a threat to public health, welfare, or the environment caused by actual or

[1] HSPD 7 was revoked by Presidential Policy Directive (PPD) 21, which states all plans developed pursuant to HSPD 7 remain in effect until specifically revoked or superseded.

potential oil and hazardous materials incidents… [including those involving] … chemical, biological, radiological, and nuclear substances, whether accidentally or intentionally released."

An extensive listing of statutes and policies that influence EPA's homeland security research is provided in Appendix 2.

Environmental Problems and Program Purpose

In 2001, a few grams of *Bacillus anthracis* (*B. anthracis)* spores (the causative agent for the bacterial disease anthrax) mailed through the U.S. Postal Service resulted in the contamination of several postal facilities and public and private buildings. EPA was tasked to support the cleanup of numerous facilities, facing many challenges. At the time, there were no methods to determine which facilities were contaminated, no capabilities for cleaning up contaminated areas, no means to manage waste generated from cleanup activities, and the government did not fully understand the risk to workers and the public. The ultimate development and adaptation of methods for sampling, analysis, cleanup, waste management, and risk assessment were created on a site-by-site basis and resulted in cleanup efforts taking years and costing taxpayers hundreds of millions of dollars.

The resulting exposure of workers and the public, including five deaths attributed to inhalation of *B. anthracis* spores, made bioterrorism a reality in the United States. The reality of bioterrorism also highlighted the possibility of an ever-growing list of other potential threats (including biological, chemical, and radiological contaminants) being released in urban/suburban environments and the intentional contamination of water systems.

EPA and other federal agencies have invested considerable effort since the incidents in 2001 to build the nation's capabilities. Incremental advances have been made and standardized in: (1) early warning for biological threat release; (2) sampling and analysis methods for indoor areas; (3) cleanup methods for facilities; (4) waste management approaches; and (5) biological risk assessment methodologies. However, the United States continues to lack the full capability and capacity to effectively address large, wide-spread contamination incidents the size of, for example, lower Manhattan, or Washington D.C.'s drinking water distribution system.

The scenarios that challenge our current capabilities are real threats. The 2011 Fukushima nuclear power plant disaster resulted in immense impacts to the public, environment, and the economy of Japan, further exacerbated by the lack of tools and technologies to address the challenge of large and complex environmental cleanup in an area the size of Maryland. The international Ebola outbreak in 2014 demonstrated the challenges of environmental decontamination to stop the spread of disease and manage voluminous biological wastes resulting from cleanup actions and health care delivery. The few Ebola cases in the United States were enough to spotlight the challenges that would be faced in a wide-spread biological incident. A relatively mild accident like the backflow of a dilute industrial chemical into Corpus Christi's distribution system in 2017 caused a ban on water use for much of the city's 300,000 residents for approximately 4 days, causing mass disruption to daily life and huge economic costs. A major incident, such as a highly toxic chemical warfare agent attack on a water system, would likely result in much greater impacts. Chemical warfare agents have been used multiple times recently in the Syrian civil war and in the United Kingdom, highlighting the threat and impact if used in the United States. Natural threats also continue, such as Hurricane Maria damaging much of Puerto Rico's drinking water systems, leading to a lack of safe water and increased waterborne disease incidents.

A disaster that results in wide-spread chemical, biological, radiological, and nuclear (CBRN) contamination over a large outdoor area, or throughout a water and wastewater system, presents a daunting challenge to EPA, state, tribal and local responders in carrying out their responsibilities. Once released into the environment, contaminants can spread via natural forces and human activities. The potential for cross-media spread of contamination is depicted in Figure 1 and represents a sample of the complex scenario that large-scale contamination incidents present to communities.

Figure 1: Schematic Overview of a Wide-Area and Water-System Contamination Incident for Scenario-Based Resilience Planning

Drinking water systems can become contaminated by several mechanisms causing direct threats to public health. Distribution systems can become contaminated when source water becomes polluted to such an extent that treatment plants cannot remove the contamiatnion. Such source water contamination can result from releases by industrial sources caused by accidents or natural disasters. Distrubtion systems can be directly contaminated by industiral accidents, pipe breaks, or intentionally.

There is also considerable uncertainy in the effectiveness of sampling methods and strategies to characterize wide-spread contamination, in decontamination methods to reduce or eliminate contamination in complex urban environments, and in the ability to manage the vast amount of waste that could be generated. Current methods used in previous, smaller-scale CBRN incidents are not readily suitable for deployment over large areas. The dynamic nature of the contaminant within the environment, coupled with the lack of readily-available tools, lead to considerable challenges in ensuring communities are resilient to disasters. The United States needs remediation methods that are rapidly deployable and scalable, with documented effectiveness. With readily-available approaches repurposed from other sectors, responders can adapt methods to address different-sized incidents and unanticipated challenges within finite budget and time contraints.

As a real-world example, consider the release of asbestos-containing ash from a warehouse fire in 2017 that caused wide-area asbestos contamination of North Portland, Oregon. Asbestos-containing debris was thought to have spread as far as two miles on each side of the Willamette River. EPA provided support to the Oregon Department of Environmental Quality to clean up debris and assess the potential for public exposure. This incident presented the challenge of determining where asbestos fibers might have settled over a 13-square mile area and raised concerns for suspended particle (dust) transfer of asbestos into residences. Researchers and responders had to address many questions, such as how to determine which areas were contaminated (both indoors and outdoors); what type of sampling was both effective and technically feasible over the potentially contaminated, large area; and the impact of wind, rain, and human activity on the redistribution of asbestos and, hence, the value of sampling results from a previous day. This incident provided a vivid example of the challenges that would be faced if CBRN contaminants were spread over an urban area.

Science to support response decisions prior to and during a disaster should consider long-term recovery. The decisions and priorities set by an impacted community prior to a disaster (prevention and protection pillars in the National Disaster Recovery Framework (NDRF)) and during the mitigation and response phase of a disaster have a cascading effect on the overall recovery (U.S. DHS, 2016). The importance of community engagement highlights the need to understand the social-environmental system interactions as scienitific solutions to mitigation and response are developed. Contaminant movement, exposure, and human susceptibility are affected by social, as well as environmental systems. So too are decontamination actions and outcomes.

Considering the general widespread contamination scenario discussed above, HSRP focuses on supporting community resilience to disasters by supporting decision makers in addressing questions such as:

- What tools and strategies are available for sampling wide areas or water systems to determine the extent of the contamination?
- How can movement of contaminants in the environment be predicted, monitored, or suppressed in support of sampling, cleanup, and public health decisions?
- How can detection, surveying, monitoring, and sampling information be used to guide public health decisions, including mitigating human exposure potential?
- How can wide areas and water systems be rapidly and safely cleaned up and returned to normalcy?
- How can water systems be protected against contamination incidents?

This StRAP outlines priority research efforts for 2019-2022 intended to address the current highest priority needs with respect to EPA's Homeland Security responsibilities. HSRP also undertakes a systematic examination of potential threats and opportunities (i.e., horizon scanning) to identify scientific challenges that may rise in importance from emerging technologies. For example, recently-developed genome editing technologies are poised to revolutionize the use of biotechnology to benefit mankind. Yet, these technologies could also result in unintended consequences for public health and the environment or be used to develop novel threat agents. Demonstrated by the recent outbreaks of the Ebola, Zika, and avian flu viruses, we should expect unanticipated disease outbreaks to continue to challenge public and animal health and the environment. The increasing capability of computational approaches will revolutionize the prediction of scientific properties (e.g., chemistry, toxicology), enhance decision-support tools, and help manage environmental systems (e.g., monitor whole watersheds, including water distribution systems). However, as such advances become more affordable/accessible, they could have unintended consequences, accentuating the importance of understanding how such effects could be detected and minimized. Finally, recent uses of chemical warfare agents in Syria and the United Kingdom warn of an increased use of these agents that can have impact beyond the intended targets.

HSRP serves as a foundation for anticipating and communicating scientific issues of which EPA and other stakeholders must be aware, and for ensuring that the research designed to address high priority needs related to existing threats can also support response to all hazards (anticipated and unforeseen).

Problem Statement

Disasters often result in contamination that can threaten public health and the environment. The United States is regularly affected by natural disasters, industrial accidents, and has been the target of intentional contamination incidents with a growing list of chemical, biological, and radiological agents. When scientifically-sound information is not readily available for the potential array of low-probability, high-consequence threats, communities cannot be resilient to these acute, environmental catastrophes.

Program Vision

Federal, state, tribal, and local decision makers have timely access to information and the tools they need to ensure community resilience to catastrophes involving environmental contamination that threatens public health and welfare.

Program Objectives

The HSRP StRAP is focused on addressing two primary research objectives. One primary research objective is to advance EPA capabilities to respond to wide-area contamination incidents. Terrorist-related incidents or natural disasters can result in wide-area contamination with hazardous materials, including oil spills or CBRN agents or materials. Wide-area contamination includes contamination of the built environment (both inside and outside of buildings and semi-enclosed infrastructures such as subways or arenas) and the natural environment. EPA needs effective and affordable cleanup strategies and methods so that affected communities can successfully and rapidly recover.

The second objective is to improve the ability of water utilities to prevent, prepare for, and respond to water contamination that threatens public health. Disasters, anthropogenic or naturally occurring, can impact the ability of water and wastewater utilities to function, including the potential disruption of drinking water supplies to municipalities. To support disaster preparedness, HSRP develops modeling tools that aid the design and operation of water and wastewater systems in a way that decreases their vulnerability to disasters. HSRP has developed tools, technologies, and data to support post-incident responses.

Research Topics

The research to address HSRP partner needs is organized into seven research areas that are categorically under three research topic areas (see Table 1). The research topics depict the research program design at higher level of organization. The research areas are more descriptive of the program; the research areas align with EPA’s response decisions supporting recovery under the NRF, specifically with respect to

EPA's lead role under Emergency Support Function #10 - Oil and Hazardous Materials Response Annex (ESF-10). This general mapping of the ESF-10 response decisions (or planning categories) is also shown in Table 1 alongside the corresponding research topics and research areas. It is recognized that these response decisions are highly interdependent, one decision impacting other decisions. Thus, the research areas are designed to reflect and support this interdependent system of activities through coordination across the program in support of the HSRP's two primary objectives.

Table 1: List of Topics and Research Areas in HSRP

<table>
<tr><th colspan="2">HSRP Research Topics and Area</th><th>ESF-10 Response/Planning Categories</th></tr>
<tr><td>Research Topic 1</td><td>Contaminant characterization and consequence assessment</td><td rowspan="3">• Mitigation of Drinking Water and Waste Water Treatment Plant Operation
• Mitigation of Critical Infrastructure Operation
• Sampling, Monitoring, and Measurements</td></tr>
<tr><td rowspan="2">Research Areas</td><td>Contaminant Fate, Transport, and Exposure</td></tr>
<tr><td>Contaminant Detection/Environmental Sampling and Analysis</td></tr>
<tr><td>Research Topic 2</td><td>Environmental cleanup and infrastructure remediation</td><td rowspan="5">• Environmental Cleanup
• Treatment of Decontamination Water and Contaminated Water
• Waste Management</td></tr>
<tr><td rowspan="4">Research Areas</td><td>Wide-Area Decontamination</td></tr>
<tr><td>Water Treatment and Infrastructure Decontamination</td></tr>
<tr><td>Oil Spill Response</td></tr>
<tr><td>Waste Management</td></tr>
<tr><td>Research Topic 3</td><td>System approaches to preparedness and response</td><td rowspan="2">• Environmental Cleanup Sequencing
• ESF-10 Operations
• Cost Considerations</td></tr>
<tr><td>Research Areas</td><td>Tools to Support Systems-based Decision-Making</td></tr>
</table>

Topic 1: Contaminant Characterization and Consequence Assessment

Effective contaminant characterization provides for understanding the extent and nature of the environmental contamination. Information on contaminant characterization coupled with an understanding of exposure potential can be used to inform the potential consequences of the contamination on public health. Following a CBRN incident or oil spill, EPA may support or lead site characterization and remediation of contaminated water systems and wide areas. Additional characterization of the site may be required during cleanup operations to assess progress and determine waste streams, and to inform site re-occupancy and reuse decisions (sometimes referred to as clearance decisions). EPA's Office of Land and Emergency Management (OLEM) founded the EPA Environmental Response Laboratory Network (ERLN)[2], including the Water Laboratory Alliance (WLA)[3], to establish the capability and capacity for analyzing environmental samples for site characterization, clearance sampling, and remediation after national-scale incidents.

Remediation decisions are made to reduce the risk related to exposure to environmental contamination. However, using environmental characterization data in a risk assessment is not straightforward,

[2] https://www.epa.gov/emergency-response/environmental-response-laboratory-network

[3] https://www.epa.gov/waterlabnetwork

particularly for microbial contamination, due to the uncertainty and variability in the field data as well as uncertainty in how to estimate exposure to the contaminant in the environment. For effective response and remediation, decision makers must have capabilities to rapidly detect contamination, to determine the extent of the contamination, to understand the behavior of the contaminant in the environment, and to assess the impact of the contaminated environment on public health. Many decisions makers may not have ready access to such capabilities.

The research under this topic is planned and executed under two research areas. The first research area addresses how contaminants behave in water systems and the built and natural environment, including the development of capabilities to support decision makers in their assessment of the threat that the contamination poses to public health. The second research area is focused on developing contaminant detection, environmental sampling, and analytical capabilities. Combined, these two research areas provide essential information to support environmental response and remediation decision-making to protect public health and the environment.

Research Area 1: Contaminant Fate, Transport, and Exposure

Knowledge of the persistence, movement, and associated phenomena is closely linked to understanding the risk of exposure and informing the development of sampling, decontamination, and waste management strategies. During the Gotham Shield[4] exercise, impacted state and local decision makers sought information from EPA on the impact of impending rain on their response actions.

Exposure assessment information and models, including understanding the ability of a contaminant released into the environment to continue to pose an exposure threat, can inform public health and cleanup decisions. The persistence of a chemical or biological agent depends on environmental conditions (e.g., temperature, relative humidity, sunlight, etc.) and the material in or on which the chemical or biological agent is bound. For some contaminants, natural attenuation (where naturally-occurring degradation processes are used to reduce the concentration and subsequent exposure) is a viable cleanup option under some circumstances. The impacts of wind and precipitation events, and their ability to move contaminants within an outdoor area, may have a profound impact on subsequent public health risk and the ability of responders to contain and mitigate the contamination. These incidents can also spread contamination into venues that were previously uncontaminated, including storm and sewer collection systems, as well as drinking water sources.

The unintentional or intentional introduction of harmful contaminants into drinking water distribution systems can affect a relatively large area, and can impact the storage tanks, pipes, and pumps used in water distribution systems, service connections to buildings, and water-consuming appliances such as water heaters. Fate and transport information informs actions such as decontamination of water infrastructure, allowing reuse of the system. Additionally, to inform where physical security or other measures are needed to reduce vulnerability of water systems, information and models can help assess the consequences resulting from exposures to CBRN contaminants.

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[4] Operation Gotham Shield was an exercise conducted by FEMA in 2017 testing civil response capabilities to a nuclear weapons attack in the New York City area.

This research area focuses on identifying and quantifying issues related to movement and persistence of contaminants over wide areas and in water and wastewater systems. Research is conducted at the bench- and pilot-scale to understand fate and transport, which will inform decisions regarding sampling, decontamination, waste management, and operational countermeasures. This research area also focuses on assessing exposure to contaminants, for example, through understanding the implications of the sampling results.

Program, regional, state, and/or tribal needs

The needs and corresponding research generally fall into the following categories:

- Persistence of contaminants in and on different types of infrastructure
- Movement of contaminants within and between different types of infrastructure
- Understanding how movement and persistence of contaminants can affect sampling strategies, decontamination, and risk assessment

An example of an output under this research area is a synthesis of information on the fate and persistence of radiological agents on surfaces, which will inform sampling and remediation decisions (Appendix 1, Output HS.1.5056). Research in this area, such as understanding the transport of *B. anthracis* spores will feed into outputs developed under other research areas (e.g., informing vehicle decontamination by understanding fate of contaminants within vehicles passing through contaminated areas) (Appendix 1, Output HS.3.5002). Figure 2 shows an example of research in the aerosol wind tunnel in EPA's facility in Research Triangle Park, NC to assess the re-aerosolization and spread of *B. anthracis* surrogate spores due to human activity, including responders' activities.

For water systems, it's critical to understand how contaminants may adhere to corrosion products or biofilms on pipe walls, which could prolong contamination by desorption, leaching, or otherwise detaching from the pipe surface and into the water over time. Contamination could also impact drinking water treatment plants, wastewater treatment facilities, and storm and sewer collection systems. To better understand the behavior of contaminants in water infrastructure, this research area develops innovative processes for prediction of the fate and transport. Researchers examine the fate and transport of contaminants in drinking water and wastewater systems at bench, pilot, and full-scale. Data on decontamination and contaminant persistence in drinking water and wastewater infrastructure will be included in the Water Contaminant Information Tool (WCIT)[5]. HSRP researchers are developing innovative methods for modeling contaminant fate and transport to enhance water utilities' ability to manage contaminated source water (e.g., water in rivers that is treated for drinking water) and contaminated overland flow. Researchers will develop a tool that predicts the fate and transport of biological contamination in stormwater in a wide-area urban setting (Appendix 1, Output HS.1.5050).

To support risk-based site-specific decisions during response incidents, decision makers must have methods to assess exposure pathways and exposure models for CBRN contaminants. Exposure-based modeling is a mature field for traditional chemical contaminants like conventional pesticides, but modeling efforts for exposure to biological agents are limited. Research conducted under this area

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[5] https://www.epa.gov/waterdata/water-contaminant-information-tool-wcit

develops or modifies existing exposure models. For example, models for water-based exposures are being developed and incorporated into a tool that estimates consequences for entire water systems (Appendix 1, Output HS.1.5050). Another set of example outputs are Provisional Advisory Levels (PALs). PALs are quantitative risk values for short duration exposures that exceed safe levels, used to inform emergency actions like evacuation and cessation of water service (Appendix 1, Output HS.1.4424).

Figure 2: Assessment of reaerosolization of *B. anthracis* surrogate spores due to typical and response-related human activity (Aerosol Wind Tunnel at EPA's Facility in Research Triangle Park, NC)

Research Area 2: Contaminant Detection/Environmental Sampling and Analysis

Decisions regarding remediation are based largely on the results of infrastructure or site characterization sampling (to establish the extent of contamination) and on clearance sampling (to evaluate the efficacy of the cleanup). The recovery of contaminated areas and infrastructure will be hindered by a lack of consensus on contaminant detection capabilities, sampling strategies, sample collection procedures, and sample analysis methodologies.

HSRP, working with its partners, will address critical gaps related to this research area by evaluating current detection capabilities, developing and/or refining sampling strategies, developing innovative sample collection techniques, and providing sample processing and analysis methodologies. The goal of this research is to develop, synthesize, and compile the protocols into user-friendly and readily-available tools for the EPA response community and homeland security partners and stakeholders. Overall, HSRP provides the science needed to establish detection and sampling strategies for wide areas and water systems. This work will provide the maximum amount of information regarding the extent of contamination while minimizing the sampling and laboratory resources required.

Program, regional, state, and/or tribal needs

Advances have been made in environmental contaminant detection, sampling strategies, sample collection, and sample analysis. However, major gaps remain in these areas, especially as they apply to wide-area biological releases. The currently-accepted surface sampling methods are not practical for wide-area responses because they are very time consuming, labor intensive, and require many samples. Strategies that significantly reduce the cost and time associated with site characterization and clearance sampling are needed to effectively respond to a wide-area incident. Surface sampling approaches that expand collection areas or pool samples collected using historic methods have demonstrated the potential to achieve effective sampling coverage of large areas while reducing the resources required. These "composite sampling" methods have considerable advantages over historical sampling methods that covered more discrete sample sizes.

New sampling methods will, therefore, be further developed to support decision makers during characterization of wide-area incidents. This will be accomplished through research to refine historical methods and develop new and innovative approaches. The focus will be on increasing the capability to sample and analyze complex environmental matrices, such as underground transit systems and outdoor urban areas. Examples of the research include developing field-deployable protocols using novel techniques that include pathogen concentration techniques, commercially available robotic cleaners, wet vacuum-sampling devices, native air filters (e.g., heating, ventilation and air conditioning filters), and activity-based air sampling. HSRP will develop outputs that describe sample collection methods for different environmental media (outdoor construction surfaces, soil and vegetation, air). This will be reported in an overall collection method summary (Appendix 1, Outputs HS.2.5030, and HS.2.3347) and added to the online sample collection information document that is part of the Environmental Sampling and Analytical Methods (ESAM) online tool (Appendix 1, Output HS.2.2269).

The ESAM program[6] continues to be a major focus for HSRP. ESAM is a website that supports the entire environmental characterization process. ESAM includes searchable method queries and downloadable documents for use by responders and the public. During an environmental response, ESAM provides responders and laboratories with the single best available sample collection and analysis method. When using ESAM, decision makers have confidence in the integrity of the data, can quickly interpret the data, and can readily communicate its meaning to the public. HSRP ensures that ESAM includes methods for the highest priority contaminants and is continually updated with the most recent methods. In addition to ESAM, HSRP will identify and develop indoor mapping technologies and data management tools to enhance site characterization capabilities. Collectively, the HSRP tools for characterization, mapping, and data management will help local, state, tribal, and federal emergency response field personnel and their supporting laboratories more efficiently respond to incidents, enabling smooth transitions of samples and data from the field to the laboratory to the decision makers (Appendix 1, Outputs HS.2.2269, HS.2.3346, and HS.2.4486).

HSRP is also looking to address sampling and analysis of bio-contaminated solid waste and wastewater (including water from the decontamination processes) in coordination with OLEM's Office of Resource Conservation and Recovery (ORCR) and the Office of Water's (OW) Office of Waste Management (OWM). Sampling and analysis of solid and liquid waste generated during remediation will be needed to determine if the waste requires treatment or has been adequately treated to allow for transportation as conventional solid or liquid waste. Currently, there is no federal regulatory framework for management of bio-contaminated waste, therefore each state regulates the requirements separately. Regardless of whether regulations specify sampling requirements, response personnel will need effective and feasible waste sampling strategies and methods so that waste treatment/disposal facilities can safely accept treated waste. HSRP will modify existing methods or create new ones, as needed, to characterize bio-contaminated solid waste and wastewater. Sampling protocols for these methods will be included in

[6] https://www.epa.gov/homeland-security-research/sam

ESAM (Appendix 1, Output HS.2.2269) and sampling strategies for water distribution systems will be summarized in a separate output (Appendix 1, Output HS.2.2268).

HSRP researchers are also developing sampling and analysis methods to address emerging chemical threats, including nation state-supported threats and illegal drug manufacture fueling the opioid (e.g., fentanyl) crisis in states and tribes. Local, tribal, state, and federal partners have expressed significant needs regarding characterization, cleanup, and waste management alternatives for these emerging threats, notably the risks posed by abandoned illegal drug manufacture sites or the evolution of chemical agents that do not lend themselves to current rapid detection methodologies. Without sampling and analysis methods, response personnel are very limited in making informed decisions on the extent of contamination, efficacy of cleanup, and proper waste disposal options. The chemical collection and sample analysis methods will be included in the ESAM. In addition, HSRP will develop an output that summarizes chemical sampling strategies for environmental media (Appendix 1, Output HS.2.5030). Existing modeling and mapping capabilities for sampling strategies will be identified and developed to utilize optimal locations and methods (Appendix 1, Outputs HS.2.5030 and HS.2.3346).

Topic 2: Environmental Cleanup and Infrastructure Remediation

After understanding the extent of the contamination and assessing its potential impact on public health, EPA may then be responsible for supporting the cleanup of oil or hazardous contaminants and mitigating their impact on human health and the environment. EPA has a long history and extensive expertise in cleaning up contamination associated with accidental spills and industrial accidents. However, remediating CBRN contamination released over wide areas, such as outdoor urban centers or impacted water systems, is a responsibility for which EPA lacks substantial operational experience. Such a release, including oil spills, can pose a continual challenge with long-standing consequences.

Cleanup includes having the capability to address contaminants in all media within the built and natural environment. Department of Defense (DOD) has expertise in the tactical decontamination of personnel and equipment, but this expertise is not directly applicable to the decontamination of public facilities and outdoor areas. These areas have a variety of porous surfaces and might require more stringent cleanup goals for public re-occupation. Furthermore, water systems pose considerable additional challenges.

HSRP activities in this topic aim to fill the most critical scientific gaps in the capabilities of EPA's response community (identified by HSRP's program office and regional partners) so that when needed, EPA can make the most informed mitigation and remediation decisions. Understanding social, cultural, behavioral, and economic factors is also important to inform effective response decisions that will ultimately lead to healthy community recovery. EPA's tools, methods, and technologies for disaster preparedness and response are designed to improve the ability of our communities, including water utilities, to rapidly recover from a disaster (or contamination incident). To support research needs related to cleanup, HSRP has four research areas under this topic. The first, wide-area decontamination research area, develops capabilities for addressing hazardous contaminants in the environment, including indoor and outdoor areas. The second research area focuses on addressing needs related specifically to water treatment and decontamination of water systems. Research to support response to oil spills is addressed under the third research area. The fourth research area addresses capabilities associated with waste management as part of the response and remediation efforts.

Research will continue to evolve to focus on scalability of cleanup methods and application of the research to additional hazards inside and outside of the traditional CBRN paradigm (as needs and threats emerge). Related to water systems, the focus will continue to move towards more field-scale assessments and improving the overall resilience of water systems to disasters.

Research Area 3: Wide-Area Decontamination

Wide-area contamination requires comprehensive remediation capabilities to help impacted communities recover rapidly and safely. Decision makers developing a remediation strategy seek to identify and secure the most applicable decontamination methods and resources (e.g., workers, equipment, materials, etc.) to execute the identified methods.

For example, critical infrastructure (e.g., government, health care, schools, transportation, energy, communication) in the contaminated area must be restored quickly to minimize both direct and indirect impacts. Wide-area contamination may pose a direct impact on the local community due to health impacts and disruption of services, including possible relocation. Surrounding communities may also be (secondarily) impacted, such as through people being unable to commute to work or disruption of services from the directly impacted area.

HSRP's decontamination research outputs can be used to support decision makers in selecting decontamination options with consideration for safety, resource demand, logistics, training, availability, and technology necessary to remediate a wide-area incident. Researchers will develop methods and critical information for response strategy development and to inform the decision-making process.

Program, regional, state, and/or tribal needs

Following a wide-area incident, local response authorities need access to decontamination methods that are effective, feasible, and versatile for various contamination situations. Since there is no universal decontamination method that is applicable for all combinations of environments and contaminants, decision makers seek information to help them decide on the most appropriate site-specific approaches. Information to assist decision makers includes understanding the effectiveness and impact of various decontamination approaches for contaminated areas depending on conditions and priorities (e.g., urgency, contamination level, surface/media types, etc.) for remediation.

Decontamination of public and residential areas is challenging due to the complexity of the material types and their different uses within communities. Common outdoor surfaces such as soil, concrete, brick, and asphalt pose significant decontamination challenges due to their porous and reactive nature. To meet the capability gap posed by outdoor surfaces, HSRP will continue to evaluate and develop decontamination methods that are effective for outdoor surfaces under various environmental conditions. Results will be summarized in summary outputs (Appendix 1, Outputs HS.3.5002, HS.3.5064, HS.3.641, and HS.3.5006), and will be used to inform the development of trade-off and strategic-consideration decision-support tools (Appendix 1, Output HS.7.5039).

Rapid decontamination methods are needed to clean up critical infrastructure and enable continuous operation. Examples of critical infrastructure include water and wastewater utilities (discussed in the next research area), hospitals, electrical power utilities, and transportation systems. Some critical infrastructure contains sensitive and valuable instruments/equipment; therefore, the decontamination process must be designed to protect this equipment from damage so that the infrastructure can be promptly returned to service. In addition to the summary outputs supporting biological and chemical threat response, HSRP will produce specific outputs that describe decontamination methods for these threats that are compatible with sensitive and valuable items (Appendix 1, Outputs HS.3.5060 and HS.3.1165).

Response to contamination incidents affecting residential and commercial areas may be delayed until resources are available, as federal, state, tribal, and local government resources are devoted to critical infrastructure. Research is needed to develop feasible decontamination methods for residential and commercial areas that are widely available, user-friendly, economical, and safe. To meet this need, HSRP will identify widely-applicable decontamination methods by surveying: (1) CBRN decontamination methods previously used by national and international agencies; (2) equipment commonly available in municipalities (e.g., street sweepers, orchard sprayers, sanitation trucks, and snow plows) that could be repurposed to support remediation; and (3) household maintenance activities for indoor and outdoor decontamination (including social, cultural, behavioral, and economic factors).

The methods identified will be developed as field-usable decontamination options via laboratory and field studies. Figure 3 shows one example of this, depicting an orchard sprayer that could be used to rapidly spray liquid decontaminants over large areas. Decontamination methods using common municipal or commercial equipment and household maintenance activities are innovative approaches that will reduce contamination exposure to the public and decrease the need for decontamination resources that may be needed elsewhere. HSRP will also conduct research to develop gross decontamination methods that can be safely and rapidly deployable for remediation. While these methods may not ultimately achieve a cleanup goal, they can help to reduce exposure potential until additional decontamination methods can be deployed as necessary. An example output from this research is listed in Appendix 1 as Output HS.3.5006, providing decision makers information on widely-available and user-friendly decontamination options for wide-area radiological incident response.

Remediation of a CBRN wide-area incident requires an extensive number of decisions that span numerous areas of expertise. These decision points, and the tools and models that support them, are tightly intertwined and should employ a holistic solution. HSRP will produce user-friendly tools to assess numerous factors (e.g., efficacy, availability, logistics, worker training, diminishing returns) that can be considered when selecting the most appropriate decontamination options following a wide-area incident. Information regarding an array of decontamination methods will be incorporated into these decision-support tools (Appendix 1, Output HS.7.5039). To ensure the tools are relevant and easy to use, HSRP will request input from local, state, tribal, and federal governments as part of the output development process.

Figure 3: Demonstration of the use of an orchard air blast sprayer for the decontamination of a subway station during an operational technology demonstration

Research Area 4: Water Treatment and Infrastructure Decontamination

Resilient water infrastructure systems can facilitate quick and effective decision-making during emergency situations to ensure access to adequate water capacity and quality. Decontamination of drinking water systems following intentional contamination, or after a natural disaster (e.g., pipe breaks, storms, earthquakes) is critical for effectively resuming operation and restoring water distribution for drinking purposes, as well as other applications such as fire protection, hospital, and industrial use. For example, EPA Region 6 in Texas requested assistance to address contamination from an asphalt emulsifying agent, Indulin AA-86, that had contaminated Corpus Christi's water supply leading to a temporary suspension of use. ORD scientists provided data on flushing chemical contaminants to help with the cleanup. ORD also helped the region evaluate the toxicity and possible risks associated with ingesting water contaminated with Indulin AA-86 and the water-soluble salt from the product. The researchers established a health-based action level for the contaminant in support of an immediate need by the region, state, and the city to protect public health.

Drinking water distribution systems, household plumbing, and appliances are increasingly vulnerable to interruption in service from a terrorist attack, industrial accident, or extreme weather events. Water systems can also be impacted significantly if their source water is affected by natural disasters and/or spills of industrial chemicals and oils. This vulnerability presents operational challenges in maintaining good water quality to protect human health and ensure water availability for fire protection and other vital uses. Natural and man-made incidents further exacerbate the declining integrity of our aging water infrastructure. Regardless of the source of contamination, the ability to reliably and cost effectively decontaminate miles of distribution system pipes and plumbing is critical to rapidly returning the system to service. Making swift and effective decisions will help minimize impacts to partners, the time to return to service, and associated costs.

Wastewater infrastructure is also vulnerable to contamination incidents. Depending on the contaminant, the incident may impact the operation of wastewater treatment (e.g., worker safety, sludge, aeration), which in turn can disrupt wastewater collection or result in the discharge of untreated waste to receiving waters. Contaminants in the wastewater treatment process may end up in the biosolids, which in turn may impact reuse (e.g., land application).

Program, regional, state, and/or tribal needs

To address the challenges mentioned above, an HSRP priority is to provide tools and methodologies to inform decontamination of water infrastructure, management of the contaminated water, and resumption of operations. Discussions with the drinking water management community and recommendations from Water Critical Infrastructure Protection Advisory Committee (CIPAC) emphasize the importance of water infrastructure decontamination and testing of methods and technologies on a large-scale system, representative of a real drinking water distribution system. To address this need, HSRP constructed the Water Security Test Bed (WSTB)[7] in at Idaho National Laboratory to conduct water infrastructure research at the full-scale (see Figure 4). Through operational technology demonstrations and exercises (e.g., tabletops, full-scale exercises), WSTB research can be used by emergency response and water-sector communities to fully understand the operation, application, and performance of these tools and techniques. In consultation with stakeholders, HSRP plans to expand current research to include additional contaminants, materials, and scenarios, such as:

- Decontamination methodologies (including automatic flushing) for various contaminants
- Consequences of a cyberattack on water distribution systems
- Effectiveness of in-line contaminant detectors
- Pipe materials in water distribution systems (e.g., iron, concrete, PVC, PEX, etc.)
- Wash-water treatment methodologies
- Water system modeling tools

Example outputs from this work include summarizing decontamination approaches and incident detection methods for water infrastructure (Appendix 1, Outputs HS.4.470, HS.4.663, and HS.4.662), including methods to extrapolate the research for contaminants not directly addressed and methods to support disinfection for *Legionella pneumophila.*

EPA also supports wastewater utilities by providing tools and data that help them respond to and recover from contamination incidents and other disasters. Data from HSRP's water infrastructure and decontamination research will be used in tools developed by OW and the response community, including state, tribal, and local responders. Contamination of source waters will be addressed through the Drinking Water Source Vulnerability and Emergency Management Tool, which identifies upstream hazards using geographic information system (GIS) databases and models to determine travel time to downstream drinking water intakes, as well as leading edge, peak, and trailing edge contaminant levels. The technical basis for a water/wastewater decontamination and treatment technology tool will be developed for integration into EPA Water Security Division's (WSD) Decontamination Preparedness and Assessment Strategy (DPAS).

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[7] https://www.epa.gov/homeland-security-research/water-security-test-bed

The enhanced capability of water systems to predict future system behavior and evaluate the implications of response decisions will improve emergency response and shorten the time needed to resume operations. As such, real-time modeling tools can support accurate hydraulic and water quality predictions. Modeling tools can also enable rapid and effective decisions. HSRP has developed tools and technologies[8] to assist water infrastructure systems in identifying, evaluating, and improving their resilience to man-made or natural disasters, whether by changing operations or by redesigning and retrofitting the infrastructure. These system-specific tools need to be tested and adapted to be applicable for wastewater, stormwater, source water, and water reuse applications. In addition, a complete watershed system approach needs to be explored to examine the effects of one system's perturbation on another.

Initial HSRP research efforts have focused on developing prototype decision-support tools for drinking water systems. HSRP will focus on expanding these tools to "all hazards", validating their results with real-world data, and using the tools in case study applications with partner drinking water utilities.

Figure 4: Aerial view of the Water Security Test Bed

Research Area 5: Oil Spill Response Support

EPA is responsible for responding to and assessing environmental releases of oil that occur over land, on inland waters, and in the ocean (in conjunction with the U.S. Coast Guard). Oil spills can affect human and ecological health, as well as the economy, by impacting water (including drinking water supplies), air quality, ecosystem health, or by directly exposing humans and ecological life to toxic constituents. Atypical oil spills (e.g., deep sea and prolonged releases, such as the 2010 Deepwater Horizon spill) have highlighted the capabilities and limitations of current spill response methods and of the ecological and

[8] Information on existing EPA tools developed by HSRP can be found at https://www.epa.gov/homeland-security-research.

human health concerns associated with certain spill mitigation technologies. Federal, state, tribal, and local governments, especially those who rely on aquatic resources, are concerned regarding the toxicity of oil- and spill-treating agents on aquatic flora and fauna, their fate in the environment, and the effects on impacted shorelines and wetlands.

Program, regional, state, and/or tribal needs

The National Contingency Plan (NCP) includes a Product Schedule (NCPPS) for commercially available spill-treating agents (e.g., dispersants, surface washing agents, herders, solidifiers) (U.S. EPA, 2018b). The CWA and the Oil Pollution Act (OPA) give authority to EPA to prepare and maintain this schedule. The NCP also requires that EPA maintain reference oils for product testing. HSRP develops and refines the protocols for product effectiveness and toxicity that are used to inform regulatory actions. This research also provides guidance for emergency responders on product performance and trade-offs to potentially impacted communities and ecosystems. Research in support of this guidance is dedicated to:

- NCPPS efficacy protocol development: Currently, the focus includes developing efficacy tests for surface washing agents, solidifiers, and chemical herders, and evaluating product performance in fresh and salt waters (Appendix 1, Output HS.5.5048).
- Toxicity of oils and oil spill-treating agents: Developing toxicity procedures and threshold determinations for regulatory listing and establishing LC_{50} values (i.e., the lethal concentration required to kill 50% of the species population tested) for a range of crude oils (Appendix 1, Output HS.5.5047).
- NCP reference oil evaluation: Evaluating potential reference oils for dispersant effectiveness, chemical characterization, and toxicity to enable EPA's Office of Emergency Management (OEM) to select new reference oils (Appendix 1, Output HS.5.5047).

In addition, efficient oil spill response requires the ability to rapidly characterize the behavior, transport, fate, and effects of various oils and spill agents, including diluted bitumen, which is particularly difficult to remediate and exhibits unique chemical and physical behavior. To protect communities and ecosystems, further research is needed on the chemical characterization, biodegradation, weathering, and toxicity of a range of oils and spill agents. Studies at the bench-, laboratory-, and field-scale improve our ability to minimize environmental and human impacts from spills and serve to calibrate numerical models of oil tracking. Understanding environmental behavior informs predictions of oil fate and transport and helps establish appropriate response, remediation, and restoration methods, including Net Environmental Benefit Analysis (NEBA) Natural Resource Damage Assessment (NRDA).[9] Research supporting these needs includes:

- Degradation of oil- and spill- treating agents: Characterizing fate processes (e.g., biodegradation) and toxicity of oil exposed to NCPPS agents that are not intended to be recovered from the environment and evaluating degradation of oil encapsulated in ice or under sediments (Appendix 1, Output HS.5.5047).
- Oil toxicity and exposure pathways: Evaluating unconventional oils, including diluted bitumen, to determine the fate and transport when discharged to the aquatic ecosystem, and evaluating

[9] NEBA is used to balance trade-offs during oil spill response for considering the most appropriate options to minimize the impact of the spill. Additional information on NEBA can be found at http://www.oilspillprevention.org/oil-spill-cleanup/oil-spill-cleanup-toolkit/net-environmental-benefit-analysis-neba (last accessed July 24, 2018).

additional new species for toxicity testing beyond current test species for oil-agent mixtures (Appendix 1, Output HS.5.5048).
- Behavior of oil and spill-treating agents at laboratory-, tank-, and field-scale: Performing comparative analyses of spill detection sensors, determining oil behavior for validation of subsea blowout models, evaluating agent effectiveness as a function of oil weathering and environmental conditions, and assessing *in situ* burn efficiencies.

A portion of ORD oil spill research is reserved for emergency response technical support, spill exercises and area planning, interagency working groups, and emerging issues (e.g., Arctic spill planning and increased shipment of diluted bitumen via rail, barge, and pipeline). Focus topics are ever-evolving but current research is dedicated but not limited to:

- Oil tracking tools and emergency response technical support: Evaluating oil spill detection assays and establishing cutting-edge technologies for oil slick thickness estimates for decision-making in skimming and burning (Appendix 1, Output HS.5.5049).
- Spill planning and guidance formulation: Coordinating interagency activities, including research on International Maritime Organization (IMO) dispersant guidelines, updates to the National Response Team (NRT) science and technology factsheet, and formulation of the six-year Interagency Coordinating Committee for Oil Pollution Research (ICCOPR) plan.

ORD oil spill research includes experiments over large scales, such as spill simulations using wave tank facilities, like Ohmsett at the Naval Weapons Station Earle in New Jersey (Figure 5, left panel), and at small scales for evaluating the performance of spill-treating agents on the NCP Product Schedule (Figure 5, right panel).

Figure 5: Photo of spill simulations using the Ohmsett wave tank facility at the Naval Weapons Station Earle in New Jersey (left panel) and laboratory evaluation of the performance of spill-treating agents (right panel).

Research Area 6: Waste Management

Waste management presents considerable challenges during any large-scale disaster; additional challenges will exist during a wide-area CBRN incident. For example, there is currently no federal regulatory framework for bio-contaminated waste. The existing disposal capacity for radiologically-contaminated waste is likely only a fraction of what would be needed in a large-scale radiological or nuclear incident. Environmental remediation after the Fukushima Daiichi accident is estimated to have generated over 37 million tons of waste, much of it soil.[10] Waste staging and on-site waste minimization and treatment will be critical to allow remediation efforts to proceed. The waste streams include materials impacted by the contamination incident, as well as waste generated through the decontamination process. As a marker of how challenging waste management can be for highly pathogenic or toxic contaminants, the single Ebola patient in New York City generated 352 drums of waste (335 drums from patient treatment, 17 drums from apartment cleanup) and the total cost for disposal was $1,120,000.[11]

In addition to solid waste, large volumes of contaminated water may be generated during flushing of contaminated infrastructure or decontamination operations. With the current goal of containing and treating much of the waste on-site (by discharging to surface water, a wastewater treatment plant, stormwater, or combined systems), these waste streams may be difficult to manage[12].

Program, regional, state, and/or tribal needs

Decision makers need sound science and tools to assist in planning for and conducting waste management activities effectively. Information is needed to:

- Support effective staging of waste and waste minimization and treatment, and assess the fate and transport of contaminants in disposal facilities.
- Prove the ability of existing treatment technologies (e.g., incineration) to destroy acutely toxic chemicals when they are associated with building materials and other materials that may be contaminated after an incident.
- Test and further develop scalable water treatment and containment methods (potentially recycling the water for further use) to support effective management of contaminated water.
- Predict the effectiveness of treatment methods for contaminants that lack treatment data in preparation for unknown water system contamination threats.

To support these needs, HSRP will develop an all hazards tool on EPA's Geoplatform[13] that analyzes GIS layers to determine optimal waste staging locations; estimate the cost, time, and logistical requirements associated with transporting large volumes of waste; and assist state, tribal, and local governments in determining optimal waste transport options and routes. HSRP will also continue to develop tools to support estimations of waste volumes that are needed to develop waste management plans, including evaluation of advanced technologies (e.g., aerial photography, remote sensing) for waste estimation post-incident. Ultimately, HSRP will develop synthesis documents that will be incorporated into decision-support tools that assist state, tribal, and local governments in developing and executing their

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[10] This estimate was derived from materials presented by the Government of Japan, Ministry of the Environment. The presentation is titled "Environmental Remediation in Japan", dated March 2018, and accessed at http://josen.env.go.jp/en/pdf/progressseet_progress_on_cleanup_efforts.pdf (last accessed July 24, 2018).

[11] This information was provided by EPA Region 2 in a presentation that can be accessed at https://www.nrt.org/site/download.ashx?counter=3098 (last accessed July 24, 2018).

[12] Discharging to Hazardous Material Water Treatment Facilities is also an option in some areas of the country.

[13] https://epa.maps.arcgis.com/

waste management plans, pre- and/or post-incident[14]. Specifically, the program will integrate its tools into EPA's forthcoming pre-planning waste management and response tool (Appendix 1, Output HS.6.5008).

HSRP will continue to develop and test methods for the minimization and treatment of CBRN-contaminated waste (Appendix 1, Output HS.6.5009). Efforts range from developing field-usable treatment technologies for pathogen-contaminated waste (Appendix 1, Output HS.6.5010)—a key gap identified during the recent Underground Transit Restoration Operational Technology Demonstration[15] (see Figure 6)—to developing treatment technologies for chemical threat-contaminated building and outdoor materials. HSRP will also develop innovative approaches to manage niche waste streams, like vehicles, to overcome the limitation or prohibitions of using existing processes for recycling and salvage.

Chemical contaminants, biological agents, and radiological agents ending up in water and other complex matrices (e.g., wastewater collection systems) during emergency situations pose significant, and often unique, treatment challenges. Some of these contaminants (e.g., PFAS in firefighting foam) can be generated during initial response activities. HSRP is evaluating on-site water treatment technologies to address the need for treating chemically-contaminated water on-site or at the contamination source (Appendix 1, Output HS.6.5010). This research will inform a water treatment selection framework within the OW's DPAS tool.

Decision makers and waste treatment operators need information to facilitate their acceptance of waste for treatment or disposal. HSRP will examine the impact of contaminated water on wastewater infrastructure and support the development of management options, such as those needed for management of contaminated biosolids and membranes. HSRP will also work to understand the characteristics of the treated water and how it might impact wastewater, stormwater, or combined sewer systems (Appendix 1, Output HS.6.5010). HSRP will share information on difficult-to-treat perfluorooctanesulfonic acid (PFOS) and shorter chain perfluoroalkyl sulfonic acids in collected wash water with ORD's SSWR program, recognizing the cross-program interest, along with leveraging other research of mutual interest.

[14] EPA has developed guidance on how to construct pre-incident waste management plans and provided resources to support their development. Please see: https://www.epa.gov/homeland-security-waste/waste-management-benefits-planning-and-mitigation-activities-homeland#preincident

[15] The Underground Transport Restoration Project was a collaborative effort between U.S. DHS, U.S. EPA, and local stakeholders designed to develop capabilities for the rapid return to service of underground transportation systems after a biological incident.

Figure 6: Testing of on-site solid waste treatment approaches.

Topic 3: Systems Approaches to Preparedness and Response

Transitioning the research into fieldable capabilities involves ensuring that decision makers and responders have knowledge of and access to the latest information. Decision makers need access to tools and information built from a systems approach where each of the research areas are brought together through their interdependencies and relative impacts. This topic area addresses the development of systems-based tools by pulling together the connected elements of the previous two research topics (contaminant characterization and consequence assessment, environmental cleanup and infrastructure remediation) to provide technical support and decision-support tools. This topic focuses on ensuring that information is readily and easily accessible during an emergency.

Research Area 7: Tools to Support Systems-based Decision Making

During a wide-area incident, the response community needs tools to rapidly assess the incident, including access to emerging technologies capable of surveying, detecting, and monitoring the event. HSRP models and tools enhance the timeliness of disaster recovery by providing metrics and decision support, ensuring decision makers have access to information on technologies for characterizing or remediating environments after various CBRN agent-related incidents. The response community also needs tools that consider timeframes and costs to evaluating viable options from economic or social standpoints, as well as tools that retain flexibility in remediation activities due to the complexity, uncertainty, and dynamic nature of a wide-area incident. HSRP recognizes the need to develop a baseline model and simulation tools for comparing or measuring decisions against the true resiliency of a community.

Program, regional, state, and/or tribal needs

A great number of decision-support tools have already been developed under HSRP, covering a wide range of hazards. These support tools individually consume separate sources of data, making them susceptible to becoming obsolete and costly to update. The response community has sought EPA's assistance in developing a centralized and routinely-maintained database for monitoring and surveying the latest decontamination, mitigation, and waste treatment technologies/methods (Appendix 1, Output HS.7.5039). A database could store up-to-date data derived from HSRP literature reviews, studies, and tools in a web-based searchable platform, greatly enhancing response, planning, and preparedness capabilities and efficiencies. HSRP will also develop and integrate a cost model for predicting the economic and social survivability of urban areas according to a range of geographically-specific criteria (Appendix 1, Output HS.7.5039). The model could then connect to other HSRP tools (such as the Waste Estimation Support Tool[16]) to provide end-users with a tool to assess community viability based on selected technologies.

In addition to selecting the appropriate technologies and considering resource needs, the consequences of remediation activities and the impact to the follow-on activities must be carefully considered. The effectiveness of remediation activities is difficult to predict due to the complexity, uncertainty, and dynamic nature of a wide-area incident. HSRP plans to develop a tool that can simulate the remediation effectiveness of various response activities that will be helpful for a wide-area response (Appendix 1, Output HS.7.5039). This work will build on existing support tools and will provide quantitative estimations for the following items:

- The impact of selecting certain methods (decontamination, sampling, and waste treatment) on the overall remediation
- Bottlenecks in the remediation activities
- Resource availability and demand for remediation
- Testing of future decision-support-tool feasibility before development/deployment
- Testing of future methods/technologies before investment.

Another significant gap for a wide-area incident is the need to collect and communicate data effectively. Inefficiencies in this process can hamper recovery efforts and potentially put lives and the environment at risk. There is a need to develop a framework and identify potential technologies for collecting and synthesizing information to better inform situational awareness, decision-making, and management of data during a response. This includes communication of information to decision makers, ultimately to inform the public regarding exposure risks, risk management, and response activities at the federal, state, tribal, and local level. HSRP will address this gap by developing tools for community stakeholders to conduct self-assessments of their community environmental resilience to disasters (Appendix 1, Output HS.7.5041).

Program Design

The ORD StRAPs are guided by EPA's Strategic Plan and the ORD Strategic Plan. The StRAPs position ORD to contribute to EPA meeting its strategic measures. The HSRP StRAP provides a vision and blueprint for advancing homeland security research in ways that meet legislative and policy mandates and address the highest priority partner needs. HSRP supports EPA's responsibilities to prepare for and respond to

[16] https://www.epa.gov/homeland-security-research/waste-estimation-support-tool

acute disasters by conducting short-term, applied scientific research. The foundation of the program focuses on CBRN contamination resulting from intentional or unintentional incidents.

Program Components

HSRP research will continue to be conducted at EPA facilities (intramural) and off-site (extramural) at grantee or contractor laboratories. Extramural research, funded through interagency agreements, grants, and contracts, complements and expands the intramural research program by engaging the Agency with the nation's leading scientists and engineers. This broad engagement is particularly valuable where additional expertise and capabilities are needed from the scientific community to provide an expanded strategic response to an environmental challenge and to address important gaps in scientific expertise. EPA also participates in similarly focused Small Business Innovation Research (SBIR)[17] efforts established by the Small Business Innovation Development Act of 1982.

ORD recognizes that EPA program and regional, state, and tribal partners must respond to emerging, unforeseen needs that can benefit from ORD research and technical expertise. ORD works with partners to balance the relative importance of these emerging needs with other research activities and to ensure agreement in any changes in research direction with respect to available resources. HSRP promotes the development of innovative commercial technologies to address environmental challenges. HSRP does this through vehicles including SBIR, innovative incentive programs (e.g., citizen prizes/awards to drive crowd sourcing of inventive approaches), and ORD internal innovative challenges (e.g., Pathfinder Innovative Projects).

HSRP collaborates with other ORD research programs and with other federal departments/agencies to address the most pressing needs related to an "all hazards" approach to disasters. HSRP also finds multiple uses of its research by applying, when appropriate, its products to EPA's needs that are not otherwise met. One example is the Ebola Outbreak in 2014; although this was a natural outbreak with major response efforts led by the Centers for Disease Control (CDC), EPA's expertise was requested related to environmental cleanup and waste treatment and disposal. HSRP provided necessary expertise on environmental decontamination, personal protective equipment decontamination, and solid waste and wastewater management through adaptation of its work with other biological agents. An essential component of HSRP is the ability to adapt and apply its research to meet unforeseen challenges in a timely manner.

Developing resilience at the community level is a critical aspect of building sustainability, especially for communities that have greater exposure to disasters and are more vulnerable to their impacts. Communities that "prepare for, absorb and recover" (National Research Council, 2012) from disasters will, in turn, have more sustainable economic, environmental, and social systems. By developing and transitioning effective tools and guidance to community decision makers, including emergency management officials and water and wastewater utility owners and operators, HSRP is helping communities to prepare for and more rapidly recover from these incidents.

A significant and critical component of the HSRP is providing technical support to our partners and stakeholders. Technical support is provided to aid in the development of guidance (for example, supporting development of threat agent quick reference guides by the National Response Team), teaching end-users how to deploy HSRP-developed products, and supporting decision makers during incident response. A significant portion of staff time is devoted to providing such technical support, serving to effectively transition the research to developed solutions and capabilities.

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[17] https://www.epa.gov/sbir

Solutions-Driven Research

ORD is renewing and expanding its commitment to producing research that addresses real-world problems and helps EPA program and regional offices, state and local agencies, as well as tribal organizations, to make timely decisions based on science. This commitment includes exploring ways to improve research processes through the application of a solutions-driven research framework.

This research framework emphasizes:

1) Planned partner and stakeholder engagement throughout the research process, starting with problem formulation and informing all elements of research planning, implementation, dissemination, transition, and evaluation
2) A focus on research outputs identified in collaboration with partners and stakeholders
3) Coordination, communication, and collaboration both among ORD researchers and between researchers and partners to develop integrated research that multiplies value to partners and stakeholders
4) Application of research outputs in cooperation with partners and stakeholders to solve complex environmental problems, and to test the feasibility, appropriateness, meaningfulness, and effectiveness of the solutions.

Risk communication is a central factor in this framework, allowing people to understand their risks and adopt protective behaviors, as well as informing risk management decisions. ORD will emphasize advances in the science of risk communication and apply best practices for communicating risk to different audiences across HSRP and the other national research programs.

EPA Partner and Stakeholder Involvement

In line with ORD's strategic measure to increase the percentage of research products that meet customer needs, the HSRP StRAP FY19-22 guides ORD research to address the high-priority needs of the Agency and its partners and stakeholders. Numerous EPA program offices and regions implement EPA's homeland security responsibilities. EPA's Office of Homeland Security, within the Administrator's Office, coordinates all EPA activities relating to homeland security. HSRP's primary partners include EPA's OW, OLEM, and each of the Agency's ten regional offices. Additional EPA partners include The Office of Chemical Safety and Pollution Prevention (OCSPP), the Office of Air and Radiation (OAR), the Office of Enforcement and Compliance Assurance (OECA), and the Office of Policy's Office of Sustainable Communities.

Much of the implementation and enforcement of homeland security responses is operationalized at local, state, and tribal levels. EPA serves mostly in a technical support role to these decision makers and first responders, as well as to water and wastewater utilities. Input from these partners is relayed to the EPA regional and program offices, who then incorporate this information into the programmatic needs that are transmitted to HSRP. The HSRP engages directly with the Association of State Drinking Water Administrators[18] and the Association of Clean Water Associations[19]; these stakeholders are on the front lines supporting water and wastewater systems in responding to operational and emergency response challenges. ORD will also seek additional state, tribal, and local input more directly during the

[18] https://www.asdwa.org/

[19] https://www.acwa-us.org/

implementation of the 2019-2022 StRAP. Engagements with ECOS and ERIS, as discussed previously, are coordinated across all six EPA National Research Programs, as their needs are broad and influence each program. The HSRP specifically engages with ASTHO, ASTWMO, and NEMA, coordinating across programs as appropriate; these associations have a more specifically focused relevance with respect to the mission of the HSRP.

HSRP's innovative oil spill research supports OEM, OW, and technical support to the regions, states, tribes, and other regulatory authorities. This research has fostered strong collaboration with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Coast Guard, Department of Interior's Bureau of Safety and Environmental Enforcement, and the U.S. Geological Survey (USGS). Additionally, this research effort is in collaboration with Canada's Department of Fisheries and Oceans, the American Petroleum Institute, and other industry members. Needs related to this research area are developed in coordination with EPA and federal partners. EPA participates on the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR)[20] with fifteen federal agencies. The committee focuses on providing updates on oil research, discussing collaboration plans, and developing ways for research to translate to response efforts.

As indicated in the Solutions-Driven Research section above, end-users of HSRP research will find scientific products most useful if they are closely involved with the research program from the outset. HSRP addresses prioritized needs based on specific problems identified through defined interactions with HSRP's partners. The process of understanding and prioritizing the needs of HSRP's partners is collaborative and involves discussion of current capabilities and desired end states and is informed by DHS-led threat assessments. EPA's mission and strategic direction further informs prioritization of needs. In addition, water utilities convey their needs through the water sector's Critical Infrastructure Protection Advisory Committee (CIPAC) (U.S. DHS, 2018), managed out of DHS and co-led by EPA's OW. This group periodically releases research priorities, such as the Roadmap to a Secure and Resilient Water and Wastewater Sector (Water and Wastewater Sector Strategic Roadmap Work Group, 2017), and these priorities inform HSRP research on this topic. For oil spill-specific needs, HSRP coordinates with EPA partners and other federal agencies, including NOAA, the U.S. Coast Guard, and the National Response Team (NRT).

HSRP collaborates extensively with other federal agencies whose missions support environmental disaster response, particularly those where there is overlapping or complementary mission space with EPA. HSRP works closely with the DHS, DOD, Department of Health and Human Services (HHS), USDA, and others to leverage their homeland security/environmental disaster science efforts. These interactions range from high-level strategic planning and coordination managed by the White House's National Science and Technology Council[21] to staff collaboration on individual research efforts.

[20] https://www.dco.uscg.mil/ICCOPR/Members/
[21] ORD HSRP participates on the National Science and Technology Council's (NSTC) Committee on Environment and the Committee on Homeland and National Security.

Anticipated Research Accomplishments and Projected Impacts

Some of the anticipated research accomplishments from across HSRP and their intended impacts or outcomes are highlighted below.

Advancing Resources for Characterization after a Wide-Area Contamination Incident

HSRP is developing ESAM[22] as a comprehensive online source for all information needed to conduct characterization activities after a CBRN incident. During a large environmental response, ESAM provides responders and laboratories with the single best available sample collection and analysis method. When a single method is used, decision makers can feel confident about data integrity and can more easily interpret and communicate the information. Over the period of the StRAP, the analytical methods and sample collection information contained in ESAM will be updated. Sampling procedures and information will be added to support the development of sampling strategies. New methods for sample collection will be developed and added for priority biological agents on urban and outdoor surfaces and in air, solid waste, and wastewater. Sample collection methods for chemical threats in water and on surfaces will be developed for inclusion in ESAM.

Developing a Decontamination and Water Treatment Technology Selection Tool

Water contamination incidents continue to threaten the delivery of clean water. To address this concern, HSRP will continue to conduct pilot to field-scale technology testing for water infrastructure decontamination and water treatment. Findings from this research, as well as previously completed research, will be used to construct a tool to assist water utilities in selecting decontamination and water treatment technologies. The tool will consider technology efficacy and operational considerations when providing the end-user options for the selection of an appropriate technology. The tool will be developed in collaboration with technology end-users and incorporated into OW's DPAS, a tool used directly by water utilities to prepare for and respond to water contamination incidents.

Improving Approaches for Response to Emerging Chemical Threats

Fentanyl and its analogs (e.g., carfentanil and 3-methyl fentanyl) are compounds of increasing concern to states, tribes, and local public health and environmental agencies due to their increased availability, extreme toxicity, and increasing misuse. HSRP will continue to address state, tribal, and local needs related to fentanyl and its analogs by developing sampling and analysis methods and proven decontamination options in environmental matrices (specifically, surfaces and water). To assist in interpreting these data and informing emergency response activities, HSRP will develop exposure values that describe health effects based on dosage. The ability of decontamination techniques to clean up fentanyl and its analogs on different types of surfaces (porous and non-porous) will be assessed initially at the lab-scale, prior to testing methods in the field for transition to responders. The development of sampling, analysis, and decontamination methods will provide an update to the recently released fentanyl fact sheet for responders, filling gaps in knowledge and capabilities that were recognized during the development of the fact sheet. Field demonstrations and updates to the fact sheet will provide an opportunity to transition the most effective sampling and decontamination methods to end-users. This

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[22] https://www.epa.gov/homeland-security-research/environmental-sampling-analytical-methods-esam-program-home

research will allow EPA to make cleanup recommendations and offer solutions to first responders across the country.

Scalable Approaches for Remediation after a Wide-Area Radiological Incident

Federal government cleanup resources will be extremely stretched after a wide-area radiological incident, like the Fukushima Daiichi Nuclear Power Plant accident. Innovative decontamination approaches that can be safely employed by the public and state, tribal, and local government will be needed. HSRP is developing the technical information required for state, tribal, and local agencies to develop self-help decontamination instructions for owner/occupants or their contractors. HSRP is also developing radiological and nuclear response-specific "how-to" documents for operators on the use of municipal, construction, farm, and critical-infrastructure-specific equipment. These resources will greatly increase local communities' self-sufficiency after a wide-area radiological or nuclear incident and decrease the time needed to recover.

Field-scale Assessment and Demonstration of Wide-Area Biological Response Capabilities

HSRP partners often express the high priority need for capabilities and information to support response to a wide-area biological incident, specifically response to a large urban area intentionally contaminated with *B. anthracis* spores. Over the course of this 4-year StRAP, HSRP, in coordination with OLEM, and in close collaboration with other EPA partners and stakeholders, including states, regions, and other federal agencies, plans to work with the DHS Science and Technology Directorate and the U.S. Coast Guard to develop wide-area biological response capabilities and test them in the laboratory and in the field, resulting in generic guidance and tools to support a wide-area biological incident response. These efforts will then culminate in a field-scale (operational) wide-area biological response demonstration to assess and improve developed capabilities.

Conclusion

HSRP works with EPA program and regional, federal, state, tribal, and local partners, and other stakeholders, to improve the nation's resilience to "all hazards". HSRP works closely with these partners and stakeholders to understand the challenges posed by CBRN threats, including oil spills, regardless of the cause of the contaminant/threat release and to develop capabilities to aid in rapid response. This response includes capabilities to support pre-incident planning, detection of contamination, characterization of the environment to determine the extent of contamination and its potential threat to public health, hazard mitigation, cleanup of the contaminated environment including built infrastructure, and effective waste management.

An underlying principle of the program is to understand the capabilities of communities and residents as they address historical and emerging threats and how this experience factors into the current and future state of community environmental resilience. The program focuses on the many challenges associated with wide-area contamination, including improving the nation's water infrastructure protection and resilience. Proven characterization, risk assessment, and cleanup approaches provide a deterrence to terrorist activities because timely and effective responses serve to minimize the overall impact of an incident (Pavel, 2012).

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Appendices

Appendix 1: Summary Table of Proposed Outputs for Homeland Security Research Program (FY2019 -2022)

The following table lists the expected Outputs from the Homeland Security Research Program, organized by topic. It should be noted that the Outputs may change as new scientific findings emerge. Outputs are also contingent on budget appropriations. The Research Need that the Output is addressing is provided in the table; these needs were defined through the HSRP's partner involvement process. Specific research Products to address these Outputs will be identified and implemented through continued engagement with partners.

Research Area	Program, Regional, State and/or Tribal Need	Output Title
Topic 1: Contaminant Characterization and Consequence Assessment		
1. Contaminant Fate, Transport, and Exposure	Fate of radiological contaminants in the environment after a wide-area release	HS.1.5056) FY22 - Fate, transport, and containment of rad contaminants in urban environments
	A process to determine a cleanup goal for chemical warfare agents and their degradates Understanding and applying fate and transport of chemical, biological, and radiological contaminants resulting from water infrastructure contamination to improve risk management decisions Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service	HS.1.5050) FY22 - Potential exposure pathway assessment to contaminants in water and wastewater systems
	Review, Clearance, and Dissemination of Provisional Advisory Levels (PALs) for high priority chemical contaminants	HS.1.4424) FY22 - PALs for hazardous chemicals and PALs User Guide
2. Contaminant Detection/ Environmental Sampling and Analysis	Need for continuance of systematic development of sampling and analytical methods for analysis of priority chemical agents (for example CWAs, precursors, degradates, TICs) and their degradation products for all environmental matrices (this includes waste matrices).	HS.2.5030) FY22 - Sampling strategies for chemical incidents
	Sampling methods and strategies are needed for outdoor urban surfaces	HS.2.3347) FY21 - Sampling strategies for wide-area biological incidents

Research Area	Program, Regional, State and/or Tribal Need	Output Title
	Strategies for sample collection, processing, and analysis methods for persistent biological agents or biotoxins in solid wastes, including decontaminated wastes Development of sample collection and analysis methods for drinking water contaminants of interest. (CBR contaminants and biotoxins)	
	Need for continuance of systematic development of sampling and analytical methods for analysis of priority chemical agents (for example CWAs, precursors, degradates, TICs) and their degradation products for all environmental matrices (this includes waste matrices) Development of Rapid and High-Throughput Methods for Analysis of Pathogens in Characterization and Post-Decontamination Samples	HS.2.2269) FY22 - Environmental Sampling and Analytical Methods (ESAM) Tool
	Development of methods and tools to identify sampling locations and strategies within water infrastructure	HS.2.2268) FY21 - Sampling strategies for water distribution systems
	Assessment of emerging technologies to enhance surveying/detection/monitoring capabilities for wide-area incident response application	HS.2.3346) FY21 - Indoor mapping technologies to support remediation decision making
	Need for an adaptive framework that encompasses a series of tools and systems for acquiring, storing, communicating, and visualizing data, and standardizes a process for evaluating new data management technologies	HS.2.4486) FY22 - Data management tools for wide-area biological incidents
Topic 2: Environmental Cleanup and Infrastructure Remediation		
3. Wide-Area Decontamination	Need data on wide-area, outdoor decontamination efficacy and application parameters for B. anthracis, including the effectiveness of various types of washdown and rain in reducing spore concentrations on surfaces, vegetation, and soil, and research supporting strategies for remediating urban environments including the exterior of high-rise buildings	HS.3.5002) FY22 - *B. anthracis* decontamination approaches for wide-area incidents

<table>
<tr><th>Research Area</th><th>Program, Regional, State and/or Tribal Need</th><th>Output Title</th></tr>
<tr><td rowspan="8"></td><td>Persistence, fate and transport, and methods to prevent the transport of spore-forming biological agents in natural environments (including waterways) and in/on built infrastructure

Self-help and low-tech approaches applicable for indoor and outdoor areas, supporting remediation of multiple facilities

Decontamination methods suitable for critical infrastructure</td><td></td></tr>
<tr><td>Decontamination methods for surfaces contaminated with biotoxins (e.g. ricin and abrin), including impacts on decontamination of sensitive equipment</td><td>HS.3.2284) FY22 - Summary of decontamination methods for biotoxins</td></tr>
<tr><td rowspan="2">Need data on wide-area, outdoor decontamination efficacy and application parameters for non-anthrax biological agents, including the effectiveness of various types of washdown and rain in reducing concentrations on surfaces, vegetation, and soil, and research supporting strategies for remediating urban environments including the exterior of high-rise buildings</td><td>HS.3.5064) FY22 - Summary of methods and considerations for wide-area outdoor remediation involving non-spore-forming agent incidents</td></tr>
<tr><td>HS.3.5060) FY22 - Decontamination methods for sensitive equipment and materials contaminated with biological agents</td></tr>
<tr><td rowspan="2">Decontamination and Waste Volume Reduction Methods for Wide-Area Remediation

Self-Help Decontamination and/or Risk Reduction Measures/Tools/Practices</td><td>HS.3.641) FY20 - Compendium of radiological decontamination methods for surfaces and environmental media</td></tr>
<tr><td>HS.3.5006) FY22 - Best practices for gross decontamination and containment during radiological and nuclear incident response</td></tr>
<tr><td rowspan="2">Effective decontamination methods for porous or permeable materials for CWA and other HS chemicals of concern.

Nondestructive and operational decontamination methods for CWAs and TICs on sensitive equipment, rolling stock, valuable items, and records</td><td>HS.3.5004) FY22 - Decontamination technologies for indoor permeable surfaces contaminated with persistent chemicals</td></tr>
<tr><td>HS.3.1165) FY22 - In-situ decontamination options for persistent chemicals on sensitive and valuable surfaces</td></tr>
</table>

Research Area	Program, Regional, State and/or Tribal Need	Output Title
4. Water Treatment and Infrastructure Decontamination	Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service Treatment and disposal options for large volumes of chemical agent-contaminated drinking water and wastewater – this includes decontamination of wash water Water infrastructure systems (drinking water, wastewater, stormwater, source water, and water reuse) need to be resilient to man-made and natural disasters, with the ability for rapid response	HS.4.470) FY22 - Compendium of water infrastructure decontamination research
	Application of tools and techniques in operational technology demonstrations and exercises	HS.4.663) FY21 - The effectiveness of automated and intelligent water meters, valves, and fire hydrants to flush contaminants
	Development of methods and tools for incident detection (including evaluation of on-line monitoring sensors, sensor placement and event detection) for water infrastructure (drinking water, wastewater, storm water and source water)	HS.4.662) FY21 - Update of sensors handbook for water security
5. Oil Spill Response Support	Emergency Response to Oil Spills: Some products on the NCPPS are not intended to be recovered from the environment (e.g., dispersants, herding agents). However, little information exists on certain fate processes (e.g., biodegradation) Emergency Response to Oil Spills: Evaluate additional new species for toxicity testing beyond M. beryllina and A. bahia for dispersants and dispersants mixed with oil	HS.5.5048) FY22 - Behavior, fate and effects of oil and spill-treating agents
	Develop efficacy test protocol for surface washing agents, solidifiers, and oil herding agents, as well as determine fate of these agents in salt and fresh waters	HS.5.5047) FY22 - National Contingency Plan regulatory support

Research Area	Program, Regional, State and/or Tribal Need	Output Title
	Subpart J Regulatory Support: Evaluate new reference oils testing for Dispersant Effectiveness, Chemical Characterization, and Toxicity Subpart J Regulatory Support: Need LC50s for crude oils.	
	Improving oil slick thickness estimates for decision making on skimming and burning. Emergency Response to Oil Spills: Evaluation of oil spill detection assets	HS.5.5049) FY22 - Oil Spill planning, response and technical support
6. Waste Management	Treatment and disposal options for large volumes of biological agent-contaminated water Treatment and disposal options for large volumes of chemical agent-contaminated drinking water and wastewater– this includes decontamination wash water Develop and evaluate tools and methodologies to inform decontamination of water infrastructure (drinking water, premise plumbing, wastewater, stormwater, source water, and reuse), management of the contaminated water, and return to service	HS.6.5009) FY21 - Management of contaminated water and associated waste streams HS.6.5010) FY22 - On-site and portable treatment methods for chemical and biological waste streams
	Best management practices for staging, segregating, and transporting waste contaminated with biological agents Comprehensive resource which enables efficient, fast, and accurate decision making regarding sustainable waste and debris management	HS.6.5008) FY21 - Decision making tools to support waste management of chemical, biological, radiological contaminated waste

Research Area	Program, Regional, State and/or Tribal Need	Output Title
Topic 3: System Approaches to Preparedness and Response		
7. Tools to Support Systems-based Decision Making	Centralized and routinely maintained database for monitoring, surveying, decontamination, mitigation, and waste treatment technologies/methods Assessment of emerging technologies to enhance surveying/detection/monitoring capabilities for wide-area incident response application Need for a user-friendly decision-support tool that assists in the prioritization of remediation activities Water infrastructure systems (drinking water, wastewater, stormwater, source water and water reuse) need to be resilient to man-made and natural disasters with the ability to respond rapidly	HS.7.5039) FY22 - HSRP integrated decision-support tools to enhance resiliency, response and recovery
	Systems measures for communities to assess resilience as part of pre-incident planning or post-incident recovery	HS.7.5041) FY22 - Tools and training to assess community resilience and to understand social aspects of remediation

Appendix 2: Homeland Security Research Program Supports Decisions Mandated by Legislation and Executive Actions

Legislation	Acronym	Website
Clean Air Act (1970)	CAA	https://www.govinfo.gov/app/details/STATUTE-84/STATUTE-84-Pg1676
Clean Water Act (1972)	CWA	https://www.govinfo.gov/app/details/STATUTE-86/STATUTE-86-Pg816
Safe Drinking Water Act (1974)	SDWA	https://www.govinfo.gov/app/details/STATUTE-88/STATUTE-88-Pg1660-2
Resource Conservation and Recovery Act (1976)	RCRA	https://www.govinfo.gov/app/details/STATUTE-90/STATUTE-90-Pg2795
Comprehensive Environmental Response, Compensation and Liability Act (1980)	CERCLA	https://www.govinfo.gov/app/details/STATUTE-94/STATUTE-94-Pg2767
Emergency Planning and Community Right-to-Know Act (1986)	EPCRA	https://www.govinfo.gov/app/details/STATUTE-100/STATUTE-100-Pg1613
Robert T. Stafford Disaster Relief and Emergency Assistance Act (1988)		https://www.govinfo.gov/content/pkg/USCODE-2015-title42/pdf/USCODE-2015-title42-chap68.pdf
Oil Pollution Act (1990)	OPA	https://www.govinfo.gov/app/details/STATUTE-104/STATUTE-104-Pg484
Federal Insecticide, Fungicide, and Rodenticide Act (1996)	FIFRA	https://www.govinfo.gov/app/details/STATUTE-110/STATUTE-110-Pg1489
Homeland Security Act (2002)	HSA	https://www.govinfo.gov/app/details/PLAW-107publ296
Public Health Security and Bioterrorism Preparedness and Response Act (2002)		https://www.govinfo.gov/app/details/STATUTE-116/STATUTE-116-Pg594
Post-Katrina Emergency Management Reform Act (2006)		https://www.govinfo.gov/app/details/PLAW-109publ295
Food Safety Modernization Act (2011)	FSMA	https://www.govinfo.gov/app/details/PLAW-111publ353
Executive Action	**Acronym**	**Website**
Homeland Security Presidential Directive-4 *National Strategy to Combat Weapons of Mass Destruction* (2002)	HSPD-4	https://www.hsdl.org/?abstract&did=860
Homeland Security Presidential Directive-5 *Management of Domestic Incidents* (2003)	HSPD-5	https://www.govinfo.gov/app/details/PPP-2003-book1/PPP-2003-book1-doc-pg229
Homeland Security Presidential Directive-9 *Defense of United States Agriculture and Food* (2004)	HSPD-9	https://www.govinfo.gov/app/details/PPP-2004-book1/PPP-2004-book1-doc-pg173
Homeland Security Presidential Directive-18 *Medical Countermeasures Against Weapons of Mass Destruction* (2017)	HSPD-18	https://www.hsdl.org/?abstract&did=456436
Presidential Policy Directive-22 *Domestic Chemical Defense*	HSPD-22	Classified

Presidential Policy Directive-8 *National Preparedness* (2011)	PPD-8	https://www.hsdl.org/?abstract&did=7423
Presidential Policy Directive-21 *Critical Infrastructure Security and Resilience* (2013)	PPD-21	https://www.govinfo.gov/app/details/DCPD-201300092
National Security Presidential Memorandum-14 *Support for National Biodefense* (2018)	NSPM-14	https://www.whitehouse.gov/presidential-actions/presidential-memorandum-support-national-biodefense/
Executive Order-13636 *Improving Critical Infrastructure Cybersecurity* (2013)	EO-13636	https://www.govinfo.gov/app/details/DCPD-201300091