

Urban Flooding and Worker Health Effects





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Introduction

Urban flooding is the “accumulation of floodwaters that result when the inflow of storm water exceeds the capacity of a drainage system to infiltrate water into the soil or to carry it away”¹ the frequency of which has increased over the past several decades. The Federal Emergency Management Agency (FEMA) defines urban flooding as, “the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems.”² Tidal flooding, the temporary inundation of low-lying areas such as streets, has increased approximately 600 % over the past 50 years.³ Severe weather events have continually increased in the US since 1950.⁴ Two major factors accounting for the increase of urban flooding are population growth and climate change. With regards to the former, much of the increase has occurred in coastal areas already prone to severe weather and tidal flooding. Up to 90% of floodplains in the US are heavily developed⁵ and population growth has resulted in expansion of the built environment, thereby increasing the amount of impervious space. These increases are related to the amount of storm runoff. Projections are for the urban footprint to expand by approximately 5.5% over the next 30 years.⁶ In many urban areas, infrastructure modernization has not kept up with growth. A 2021 report on the status of infrastructure assessed the U.S. stormwater systems as a D, stating that the aging legacy stormwater infrastructure is struggling to keep up with regulations, climate change, and the excessive cost of retrofitting.⁷ Sewer systems have not been kept up to date with backflow mitigation technologies and, consequently, contaminated sewer water backflows into homes and businesses.

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- 1 National Academies of Sciences, Engineering, and Medicine. 2019. Framing the Challenge of Urban Flooding in the United States. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25381>.
 - 2 FEMA
 - 3 Moftakhari, H.R., A. AghaKouchak, B.F. Sanders, D.L. Feldman, W. Sweet, R.A. Matthew, and A. Luke. 2015. Increased nuisance flooding along the coasts of the United States due to sea level rise: Past and future. *Geophysical Research Letters* 42:9846–9852.
 - 4 National Academies of Sciences, Engineering, and Medicine. 2019. Framing the Challenge of Urban Flooding in the United States. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25381>.
 - 5 Tockner, K., and J.A. Stanford. 2002. Riverine flood plains: Present state and future trends. *Environmental Conservation* 29(3):308–330.
 - 6 National Academies of Sciences, Engineering, and Medicine. 2019. Framing the Challenge of Urban Flooding in the United States. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25381>. Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose, and M. Wehner. 2018. Our changing climate. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, D.R. Reidmiller, C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart, eds. Washington, DC: U.S. Global Change Research Program, pp. 72–144.
 - 7 DJ Nowak, JT Walton. 2005. Projected urban growth (2000–2050) and its estimated impact on the US forest resource. *Journal of Forestry*, - academic.oup.com.
 - 7 American Society of Civil Engineers 2021 Report Card for America's Infrastructure Reston VA

Climate change, specifically atmospheric warming, results in severe storms that carry more water vapor which, when released as precipitation, drops substantial amounts of water in short periods of time. Storm water systems designed for less severe storms and more porous landscapes are quickly overwhelmed, resulting in urban flooding. Most systems are designed to manage 1.5 inches of rain per hour. Recent storms in the US have dumped as much as 3.5 inches per hour for several hours, causing extensive flooding.⁸ The nature of these floods results in many occurring outside FEMA defined flood plains.⁹

The combination of more impermeable surface space, more people at risk, and more frequent and severe weather events creates a scenario where health impacts affect greater numbers of people immediately and in the longer term.

The immediate and long-term health impacts of floods have been well-described.^{10,11,12} Table 1 lists the hazards associated with flooding.

Most immediate health impacts are experienced

by those living in the affected area and result from driving through moving water or not being able to evacuate. Contact with energized power lines is the most common cause of electrocution. Longer term health hazards can cause a variety of diseases from a wide host of hazards, many of which are preventable. Diseases can be caused by infectious or vector-borne microorganisms, fungi and molds, and bloodborne pathogens.

“It was dark and hot. You couldn’t tell where anything was. You had to have a mental map in your head to be able to navigate it. There was devastation everywhere; walls were down, items toppled over, things were broken.”

—*UT professor describing below ground lab space*

During tropical storm Allison in 2001, 40 inches of rain fell in Houston, flooding the metro area. UTHealth was among the hardest hit areas. A loading dock in UT was breached, releasing 22 ft of water into the basement and first floor. Thousands of research animals along with the cyclotron, used to make radioactive isotopes, were destroyed. Clean-up started days after and following the pumping out of the basement, it was determined that the air within the basement was “immediately dangerous to life or health”

—*Faith harper UTHealth Houston news June 8, 2021*

8 Severe storm rainfall

9 FEMA floodplain definition

10 Saulnier DD, Brolin Ribacke K, von Schreeb J. No Calm After the Storm: A Systematic Review of Human Health Following Flood and Storm Disasters. *Prehosp Disaster Med.* 2017;32(5):568–579.

11 Nai-Tzu Chen, Mu-Jean Chen, Chih-Da Wu, Yue Leon Guo, Emergency room visits for childhood atopic dermatitis are associated with floods. *Science of The Total Environment*, Volume 773, 2021, 145435, ISSN 0048-9697, <https://doi.org/10.1016/j.scitotenv.2021.145435>.

12 Lane K, Charles-Guzman K, Wheeler K, Abid Z, Graber N, and Matte T. Health Effects of Coastal Storms and Flooding in Urban Areas: A Review and Vulnerability Assessment *Journal of Environmental and Public Health* Volume 2013, Article ID 913064, <http://dx.doi.org/10.1155/2013/913064>

Table 1: Flooding Health Hazards

| Hazard | Immediate | Long-term (once floodwaters recede) |
|--------------------------------|-------------------|---------------------------------------------------------------|
| Drowning | Drowning | |
| Electrocution | Death | Death |
| Physical trauma | | Fractures, lacerations, punctures, sprains, contusions, burns |
| Biological contaminants | | Hepatitis, cellulitis, COVID-19, HIV, gastroenteritis |
| Mold | | Asthma, allergic reactions |
| Chemical contaminants | | Dermatitis, CO poisoning |
| Insect bites | | Allergic reactions, cellulitis, encephalitis, Lyme disease |
| Animal bites | | Punctures, lacerations, envenomation, cellulitis, rabies |
| Temperature | Hypo/hyperthermia | Hypo/hyperthermia |

The above information relates to flooding across all terrains and environments. The urban environment has several unique characteristics that may pose special threats to remediation and clean-up workers. Table 2 summarizes those characteristics and links to health impacts.

| Characteristic | Hazard | Health link |
|------------------------------------------|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Population density | More persons using infrastructure (e.g., sewer system) | Increased possibility to exposure to disease in sewage |
| Zoning | Mixed use spaces-Residential, business, industry in proximity | Increased risk to industrial chemical exposure |
| Building design | More stories underground More stories above ground | Underground: Greater chance for trauma, electrocution, CO poisoning, Above ground: greater harm from fall from a height |
| Transportation | Congestion of construction and general population traffic | Greater risk of RTA's and pedestrian-vehicle accidents |
| Universities and Research Centers | Variety of chemicals and biologic agents | Increase risk of exposure to rare biological and chemical agents |
| Subways | Underground systems with poor lighting and ventilation Other utilities run in/near tunnels | Increased risk of trauma, chemical exposures, electrocution |
| Social vulnerability | Repeated flooding of disadvantaged areas Lack of insurance Lack of funds to repair to code | Anxiety, depression, domestic abuse, substance use disorder, PTSD |

Clean-up after floods can be a large scale, lengthy endeavor. Clean-up and remediation workers are exposed to the same long-term hazards noted above. Occupational deaths are most often associated with clean-up activities.¹³ There is scant evidence that describes any unique health risks to workers from the post-flood urban environment. Our investigation considered two issues:

- Do the unique characteristics of the urban/built environment carry unique health risks to remediation and clean-up workers?
- Does training exist that protects workers in this environment?

13 G. M. Fayard, "Fatal work injuries involving natural disasters, 1992–2006," *Disaster Medicine and Public Health Preparedness*, vol. 3, no. 4, pp. 201–209, 2009.

Methodology

Our approach to this investigation was three-fold: a literature search of peer-reviewed journal articles, interviews with subject matter experts (SMEs) and Worker Training Program (WTP) awardees with urban flooding experience; and a focus group meeting with referred SMEs.

Literature Review

A literature search for peer-reviewed publications was completed using PubMed and Web of Science on October 21, 2021, to identify the health effects of urban flooding on workers involved in response, recovery, and remediation. An iterative series of searches was conducted first in PubMed, followed by Web of Science, with unique results imported into an EndNote 20 Library (Clarivate, Philadelphia, PA, USA). A combination of Boolean AND and OR Operators, field designators, wildcards, and order of operations were employed to structure search strings comprised of MeSH (Medical Subject Headings) and keyword terms were searched for in the title and abstract fields using the [tiab] function in PubMed and the TOPIC search in Web of Science. The search strings were not date limited.

In PubMed:

- An initial search of (health effect* AND urban flood* AND workers AND (response OR recovery OR remediation)) returned three unique results which were imported into the EndNote Library.
- (urban flood* AND health effect* AND workers) returned 5 unique results which were imported into the EndNote Library, and three duplicate records which were not imported.
- (health effect* AND urban flood* AND (response OR recovery OR remediation)) returned 30 unique results which were imported, and three duplicates which were not imported.
- (“health effects” OR “health effect” OR Acute Disease [MESH] OR Air Microbiology [MESH] OR Air Pollution, Indoor [MESH] OR Depression [MESH] OR Diarrhea [MESH] OR Drowning [MESH] OR Dust [MESH] OR Environmental Exposure [MESH] OR Environmental Health [MESH] OR Fungi [MESH] OR Health Status [MESH] OR Humidity [MESH] OR Hypersensitivity [MESH] OR Mycoses [MESH] OR Mycotoxins [MESH] OR Pregnancy Outcome [MESH] OR Prenatal Exposure Delayed Effects [MESH] OR Public Health [MESH] OR Urban Health [MESH] OR Quality of Life [MESH] OR Respiratory Tract Infections [MESH] OR Wounds and Injuries [MESH] OR Occupational Diseases [MESH] OR Occupational Exposure [MESH]) AND (“urban flooding” OR “urban flood” OR Floods [MESH]) AND (workers OR Emergency Responders [MESH] OR Rescue Work [MESH] OR Research Personnel [MESH] OR Safety Management [MESH] OR Volunteers [MESH])) returned 70 unique results which were imported, and 2 duplicate records which were not imported.

Subsequently, in Web of Science:

- (health effect* AND urban flood* AND workers AND (response OR recovery OR remediation)) returned one unique record which was imported into the EndNote Library
- (health effects OR health effect OR Acute Disease OR Air Microbiology OR Air Pollution, Indoor OR Depression OR Diarrhea OR Drowning OR Dust OR Environmental Exposure OR Environmental Health OR Fungi OR Health Status OR Humidity OR Hypersensitivity OR Mycoses OR Mycotoxins OR Pregnancy Outcome OR Prenatal Exposure Delayed Effects OR Public Health OR Urban

Health OR Quality of Life OR Respiratory Tract Infections OR Wounds and Injuries OR Occupational Diseases OR Occupational Exposure) AND (“urban flooding” OR “urban flood” OR Floods) AND (workers OR Emergency Responders OR Rescue Work OR Research Personnel OR Safety Management OR Volunteers) AND (response OR recovery OR remediation OR Environmental Restoration and Remediation OR Health Services Research OR Risk Mediation OR Disaster Medicine) returned unique 100 records which were imported, and 14 duplicate records which were not imported.

After search results were exported into an EndNote 20 Library (Clarivate, Philadelphia, PA, USA), duplicates were removed, and then screened for relevancy by title, abstract, and keyword. A grey literature search was conducted in Google using a combination of advanced Google searches limited to PDF filetype site type “.gov” intended to capture any after action reports, briefings, or media postings for the same topics from the non-peer-reviewed literature (October 21, 2021). Full text of screened articles and grey literature results were then reviewed for relevance to the search topic based on keyword and systems relevance.

Interviews

The WTP provided us with a list of potential SMEs and WTP awardees who have experienced remediation and clean-up activities following an urban flood. Requests for participation were sent out and 14 stakeholders including academics, disaster and emergency responders, environmental and worker health and safety specialists, and community and worker advocates and trainers, volunteered to participate in a structured interview by 3 investigators. A list of questions was developed to stimulate the discussion and sent to the participants in advance. Participants were also encouraged to provide information beyond what was asked in the standard questions. Interviews lasted between 35 and 60 minutes. All interviews were conducted virtually using the Zoom meeting platform and were non-attributional.

Appendix A lists interview participants’ organizations and questions.

Focus Group Discussion

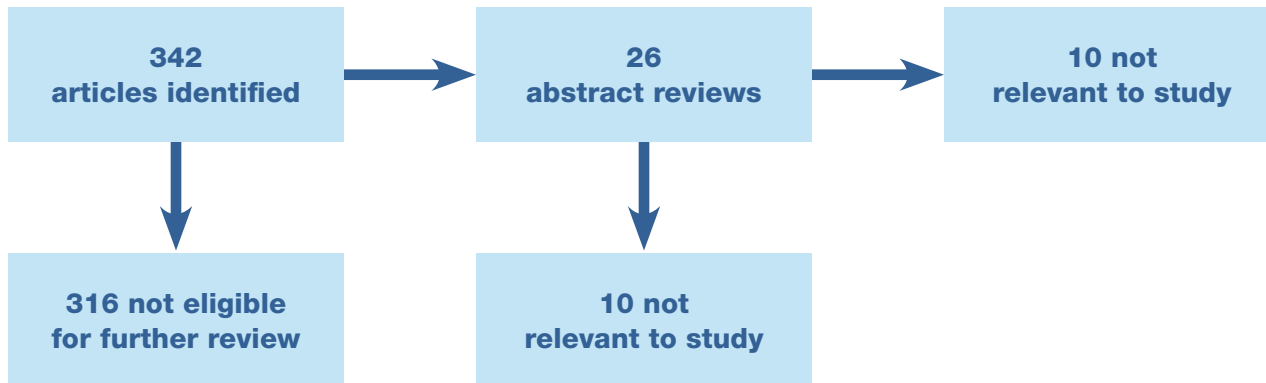
Following the interviews and an analysis of the comments, a focus group of SMEs representing WTP grantees, federal employees, academia, and community and worker organizations participated in a 90-minute group discussion. Participants were selected from recommendations and were approved by WTP. A standardized set of open-ended questions was developed and sent to the participants before the discussion. The discussion was conducted virtually using the Zoom meeting platform. The focus group also responded in real-time to a series of polling questions about urban flooding hazards, challenges to workers, training gaps, and environmental justice. All comments were non-attributional.

Appendix B lists focus group participants’ organizations.

Results

Literature Review

342 articles and 100 after action reports were identified by the literature review. Titles were screened for relevance and those articles deemed by the screener to be non-relevant were removed from consideration. Twenty-six articles underwent further review by reading the abstract for relevance to the investigation. Ten articles were eliminated from a final review, leaving 16 articles for full review.



The same process was conducted for the grey literature/after action reports. 199 documents were identified, and, after a title review, all were removed from consideration. The most common reason for exclusion was that the documents consisted of jurisdictional flood control plans and did not pertain to health issues resulting from urban flooding.

An additional search for articles was conducted using the Google search engine. Twenty-six articles/reports were deemed eligible for review. Twelve documents were determined to be relevant for this study.

Interviews and Focus Group Discussion

We conducted fourteen interviews over several weeks in late 2021 that we followed with a focus group discussion in March 2022. The focus group had similar observations about the health effects of urban flooding and the unique characteristics of the built environment as did the cohort that was interviewed. Appendix C contains polling results from the focus group meeting on the uniqueness of the urban environment, health hazards, training needs, and environmental justice concerns as it relates to urban flooding.

Urban environment

One of the most consistent themes from those interviewed and participants of the focus group discussion was the urban environment's building and population densities poses the greatest challenge to workers. This relates to the concentration of hazards, specifically biological and chemical contaminants in floodwaters, debris, and sediments that require handling in remediation and clean-up. Retrograde sewage contamination of facilities was noted specifically as a significant hazard, as are compound mixtures from household chemicals, gas stations, and local industry or chemical facilities,

especially in areas with less restrictive zoning laws. Contamination or hazards from storage areas, electrical units, or parking garages located underground and old buildings and houses (with asbestos) were also mentioned as sources of contamination. Another call out related to density in the built environment was the spaces shared by motor vehicles, construction vehicles, and pedestrians in the remediated/clean-up space, thus increasing the risk of workers being struck by a vehicle or difficulty navigation in the crowded environment. Utility access holes and other confined spaces also pose risks for workers in urban environment.

Health hazards

In terms of health hazards faced by workers, participants of the interviews and focus group meeting mentioned health hazards that are already associated with flooding in general. Mold and water contamination were universally noted as common hazards faced by workers and residents. Working at heights, sharp and cutting objects, and energized wires were also commonly mentioned as hazards. In the urban setting, the risk of falls from multi-story buildings was noted. Lacerations and puncture wounds are also risks to unprotected workers, as are contaminated debris. Ergonomics can also be a health concern for workers as wet objects can be heavier. Carbon monoxide was also listed by participants as a hazard as homeowners, business owners, and workers often use generators in poorly ventilated spaces.

Electrocution was singled out by some as a high consequence risk, especially around standing water. Energized wires mistakenly thought to be de-energized were described as a low frequency/high consequence exposure of the most serious nature to urban environment workers. Wild animals and insects were also cited as concerns for some urban areas such as New Orleans. As in many disaster worksites, in many urban areas, there is not a comprehensive disaster communication plan for those who are conducting recovery and rebuilding work. For instance, private businesses can run generators without informing anyone. This can become a major concern for urban environment to the density and close proximity of buildings and populations.

Table 3 depicts the relative health risks across a spectrum of remediation workers based on several mitigating factors noted in the table. The table describes only general worker categories. Employers and individual workers should determine their risk based on the specifics of their workplace and existing conditions.

Table 3. Urban Flooding Worker Risk Stratification*

| | Understanding of work site risks | Knowledge of health effects | Availability of PPE | Availability of Job Training | Access to health care upon injury | Overall health risk |
|----------------------------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------------------------------------------------|----------------------------------------------------------------------------------|------------------------|
| Homeowner | Low | Low | Low-must purchase | Minimal | None—only private health insurance | HIGH |
| Day laborer/ immigrant worker | Low | Low | Low-often times must purchase | Minimal to moderate-mostly just-in-time, on-site minimal | None – only private insurance | HIGH |
| Unpaid volunteer under small NGO or by self | Low | Low | Low- often times must purchase | Moderate-mostly just-in-time, on-site minimal | None – only private insurance | HIGH |
| Unpaid volunteer under large NGOs | | Some NGOs/ CBOs provide | Moderate - Large NGOs provide | Moderate - Large NGOs provide CBOs provide | None – only private insurance | MODERATE |
| Paid laborer | | Some contractors provide basics | Many contractors provide | Many contractors provide basics | May receive health benefits from work or able to apply for workers' compensation | MODERATE |
| Paid professional | | Good | Provided by employer | Advance training and JIT | Employer/union provided health benefits or via workers comp | LOW TO MODERATE |

* Exceptions may occur.

Training needs

All participants mentioned training disparities. Participants related that advanced training was preferred with just-in-time training needed to provide details specific to the worksite. Almost all noted that minimal training should be required before being allowed to work in the impacted areas. The current NIEHS WTP disaster training tools have been used by many to conduct trainings and were highly praised to be comprehensive, covering a variety of topics.

Participants discussed that professional workers and volunteers from organized NGOs, such as the National Voluntary Organizations Active in Disaster (VOAD), were better trained and equipped to work in the post-flood environment. Day laborers and volunteers from smaller NGO groups were described to be poorly trained and poorly equipped to work safely in the same environment. Of importance is also ensuring that the training is conducted in the language and manner that is easily understood by the workers.

Impacts on socially and economically disadvantaged populations

All participants of the interviews and focus groups stressed the devastating impacts flooding has on the disadvantaged, underserved, and overburdened communities. They noted that low-lying neighborhoods in many urban areas are subject to repeated flooding. Impacted neighborhoods often also have aged infrastructure and homes that have not been maintained, making clean-up and remediation more expensive and difficult, especially when there are building codes that must be met through upgrades during remediation. The expense of remediation may cause homeowners to conduct remediation and clean-up work themselves, which results in repairs done incorrectly and/or not to code. It may also cause delay in timely remediation increasing the risk of exposures to mold and other disease causing microorganisms that propagate in wet and damp environments or exposures to displaced insects or animals that can cause infectious disease in humans. Equally important, homeowners and other workers may not understand the need for protection from the various threats mentioned above, resulting in adverse health consequences. In Houston, a city that experienced repeated large urban floods, 83% of the 1.4 million buildings in Harris County lacked flood insurance at the time of Hurricane Harvey.¹⁴

Importance of Training

Our goal is really to translate the basic knowledge that we have to the most vulnerable workers out there, so that they have a means of identifying and address the hazards and find ways of advocating if they're being unjustly treated.

—Focus group participant

Vulnerable Populations

In Houston, TX one solution to urban flooding has been the use of buyouts of repeatedly flooded homes. In some cases, the solution has perpetuated the problem. Private developers often offer buyouts much quicker than the government. Some of them have saved expenses by cutting corners on the building code and then rent the properties to low-income residents, which worsens the problem.

—Lisa Song, Al Shaw, Neena Satija
(Texas Tribune and Reveal, November 1, 2017)

14 ISET International, Zurich, and Global Disaster Preparedness Center Houston and Hurricane Harvey: a call-to-action June 21, 2018

Day laborers were noted as facing disparity issues related to their involvement in flood clean-up and remediation. Day laborers, and some volunteers, are often hired to do the most dangerous work, often without the safety protection needed. For example, a participant shared that following Hurricane Sandy, volunteers were hired to enter contaminated houses to do remediation work because the employer did not want his employees to work in the hazardous environment. Many day laborers and some volunteers lack safety training and those who do receive training are most likely to have received an abbreviated discussion at the site where they are picked up by contractors (often in parking lots of a home building stores). Day laborers and some volunteers also rarely receive the necessary personal protective equipment (PPE) and associated training from employers to perform their jobs. Several day labor advocacy groups recognize the important need for this training and provide it, but their reach is limited, and their training does not provide the protective equipment necessary to mitigate the hazards they face. These workers often do not have the safety net protections of health care insurance or workers compensation benefits, so health issues and injuries go untreated or are treated after illnesses and injuries become acute. Many of the day laborers also live in the impacted neighborhoods and get additional exposure from their own contaminated homes and neighborhoods.

Discussion

We explored the health effects of urban floods on recovery and remediation workers, acknowledging that urbanization is, as Friel et al.¹⁵ note, both a cause of and potential solution to global climate change. What we continue to experience, and learn, from the deleterious impacts of climate change are innumerable across frontier, rural, suburban, and urban settings. Unsurprisingly, specific to our urban-centric study's participants, broader health determinants and inequities are exacerbating already hazardous work environments. In 2004, Holness, et al, noted a scarcity in understanding occupational health and safety concerns and programs in inner city working settings, calling for further research for both paid and volunteer workers.¹⁶ More recently, research has shown that urban health inequities commonly follow cities' geographic inequality patterns in social, economic, and environmental conditions.¹⁷ Evidence from this work can support environmental justice and equity-focused policymaking and resource allocations, a main area of importance for our projects.

The good news is that we can get ahead of this. Significant momentum exists to bolster the consistent and painstaking efforts by community members to influence policymakers on urban worker health and safety issues. For example, WTP's efforts include the Environmental Career Worker Training Program (ECWTP) that collaboratively develops and disseminates grantee-specific training resources on technical skills, life skills, and environmental justice, all of which WTP could tailor to urban flooding worker safety and health. Local, state, and federal partners, with the invaluable support of academics to craft an

15 Friel S, Hancock T, Kjellstrom T, McGranahan G, Monge P, Roy J. Urban health inequities and the added pressure of climate change: an action-oriented research agenda. *J Urban Health*. 2011 Oct;88(5):886-95. doi: 10.1007/s11524-011-9607-0. PMID: 21861210; PMCID: PMC3191212.

16 Holness DL, Somerville S, Kosny A, Gadeski J, Mastandrea JJ, Sinclair GM. Workplace health and safety concerns in service organizations in the inner city. *J Urban Health*. 2004 Sep;81(3):489-97. doi: 10.1093/jurban/jth132. PMID: 15273270; PMCID: PMC3455950.

17 Freitas Â, Rodrigues TC, Santana P. Assessing Urban Health Inequities through a Multidimensional and Participatory Framework: Evidence from the EURO-HEALTHY Project. *J Urban Health*. 2020 Dec;97(6):857-875. doi: 10.1007/s11524-020-00471-5. PMID: 32860097; PMCID: PMC7454139.

evidence-base, must continue to highlight the pressing need for consistent urban worker health and safety resources, such as those that WTP provides. They must collectively empower those that need these materials and trainings most, such as the NYCOSH Sewage Protection pamphlet,¹⁸ so they can readily access, and use them.

WTP has developed various [training tools](#) aimed at protecting the health and safety of those responding to the aftermath of a hurricane or a flood, including emergency responders, skilled support personnel, homeowners, and business owners. These training tools provide awareness-level health and safety guidance to those involved in disaster response and cleanup activities. The Hurricane, Flood, and Debris training tools were reviewed as part of this study to determine its applicability to a response of an urban flooding. Overall, these three training tools are a good resource for those participating in disaster response and cleanup activities following flooding in any environment. That said, each of the resources could benefit from a review and refresh to identify new content on post-flood urban environment lessons learned. For instance, the Hurricane training tool focuses mostly on outdoor hazards and risks, but could be improved with a section on indoor hazards, such as carbon monoxide, hidden electric components, exposures to biological (e.g., bacteria, viruses, sewage, etc.) and chemical hazards (e.g., household cleaners, petroleum, etc.) as it relates to flood water. While a bit more comprehensive, the Flood training tool could include sections on tidal surge and indoor flood hazards. The Debris training tool is comprehensive and covers the major risks and hazards that were noted by the participants, such as ergonomics and contaminated debris.

Our mixed methods study has limitations. First, we sought participant recruitment to those organizations with whom we have established, professional relationships, thereby reducing the sampling breadth of participants. This is of little concern as our work centers on amplifying the voices of those with direct knowledge of and experience with worker safety – in this case, in cities. Second, our real-time polling questions, conducted during the focus group, were organically driven by themes derived from the interview results, not peer-reviewed literature. That said, the focus group provided the chance to have key stakeholders rank the relative importance of these themes, thereby allaying issues of thematic applicability or relevance.

Our study offers valuable information to urban worker health and safety at-large and, to WTP, specifically. Most importantly, we highlight that recovery and remediation workers and the organizations that represent them must continue their tireless advocacy efforts. We identified the subtle, but significant, differentiators between the impacts of floods on workers, and those specific to urban environs.

Specifically, we suggest that WTP:

1. Review and revise safety informational materials to include specific guidance for workers in the post flooded urban environment and develop and issue an urban flooding remediation worker safety and health fact sheet.
2. Review and revise training for workers in the post-flood environment, adding information on urban flooding hazards and mitigation practices.

18 New York Committee for Occupational Safety and Health Protecting Worker & Occupational Health from Sewage in Floodwaters NY, NY

3. Consider actively monitoring urban flooding and worker safety and health, especially in high-risk groups in Table 3.

Additionally, our work can inform future efforts to help decrease the risks to these vital workers – many of whom are members of minority and low-income communities themselves. For example, day laborers, who often tirelessly serve with little to no protections, can serve as key communicators in exemplifying the needs of such workers.

Further, understanding the workforce necessary to accomplish the strategic and tactical goals of urban flooding workers and their organizations requires precise analysis and planning. We propose a thorough environmental justice-oriented workforce analysis comprising a worker composition assessment, a gap analysis and a recruitment, training, and retention program evaluation to understand actionable steps necessary to close gaps. Doing so can offer a framework of recommendations to meet the long-standing needs of these workers.

Friel et al,¹⁹ summarize our context well, emphasizing that equity-oriented climate change and its wide-reaching impacts demands attention to the greater social conditions in which urban populations live, including urban planning and design initiatives and worker health and safety, amongst others, can aid in mitigating future and adapting to current climate change impacts. Advancing health equity is, to Freitas, et al, a place-based issue that demands the context-specific details (e.g., urban environs) to advocate, resource and improve urban worker safety and health.²⁰ We must continue to diligently prepare workers for climate changes' adverse impacts through consistent, comprehensive, and accessible training driven by a contemporary, evidence-based workforce analysis, that WTP is well-suited to undertake.

19 Friel S, Hancock T, Kjellstrom T, McGranahan G, Monge P, Roy J. Urban health inequities and the added pressure of climate change: an action-oriented research agenda. *J Urban Health*. 2011 Oct;88(5):886-95. doi: 10.1007/s11524-011-9607-0. PMID: 21861210; PMCID: PMC3191212.

20 Freitas Â, Rodrigues TC, Santana P. Assessing Urban Health Inequities through a Multidimensional and Participatory Framework: Evidence from the EURO-HEALTHY Project. *J Urban Health*. 2020 Dec;97(6):857-875. doi: 10.1007/s11524-020-00471-5. PMID: 32860097; PMCID: PMC7454139.

Appendix A. Interview Participant Organizations and Questions

- Greater Cincinnati Occupational Health Center
- Green Door Initiative
- International Chemical Workers Union Council
- Laborers' International Union of North America
- National Day Laborer Organizing Network
- NYU-Atlantic Center for Occupational Health and Safety
- OAI, Inc.
- Sustainable Worker Alliance
- The New England Consortium
- United Steelworkers Tony Mazzocchi Center
- University of Tennessee, Center for Industrial Services
- University of Texas Health Science Center

Interview Questions:

1. What are the most unique challenges for urban flooding clean-up and remediation workers?
 - a. What are the unique hazards in flooded urban environments?
2. What is unique about urban environment flood clean up and remediation efforts?
3. What health effects have you observed in these groups?
 - a. Are any of them unique to this type of work?
4. In your experience with flooding, what are the main lessons learned regarding:
 - a. Health effects
 - b. Training
 - c. Work force
5. Is there training for urban flooding workers? If so, please describe.
6. Can urban planning address any challenges associated with working in this environment? If so, how?
7. What are the environmental justice issues associated with urban flooding and workers?
 - a. Housing disrepair?
 - b. Utility infrastructure?
 - c. Other?
8. Are there workforce differences characteristic of urban flooding workers?
 - a. Use of Volunteers?
 - b. Experience?
 - c. Training?
9. Do you have experience with work in a post-flood urban setting?
 - a. If so, which events?
 - b. If so, what were your challenges?
 - c. How did you train for that experience?
10. Are there any other questions we should be asking?
11. Do you have any colleagues who have experience with/expertise in urban flooding who would be interested in participating in a stakeholder listening session?

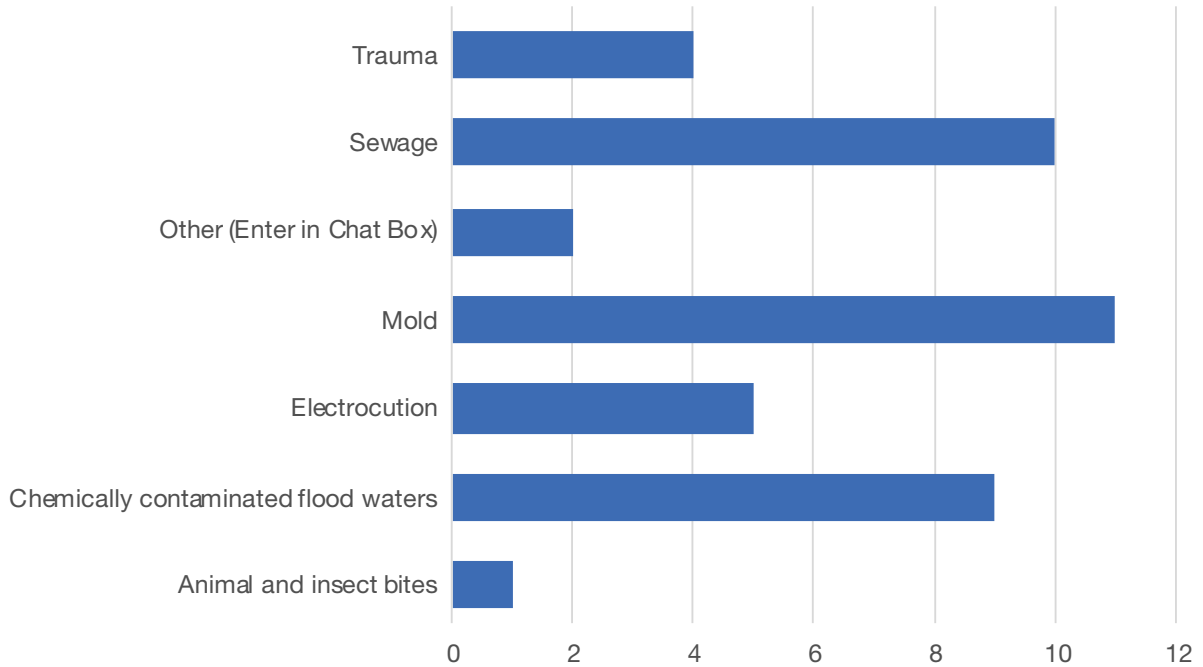
Appendix B. Focus Group Participant Organizations

- Fifteen stakeholders, representing the following organizations, participated in the March 3, 2022, focus group meeting:
- CPWR - The Center for Construction Research and Training
- Deep South Center for Environmental Justice
- Federal Emergency Management Agency
- National Electrical Contractors Association
- National Institute of Environmental Health Sciences, Worker Training Program
- OAI, Inc.
- Occupational Safety and Health Administration
- United Steelworkers
- World Cares

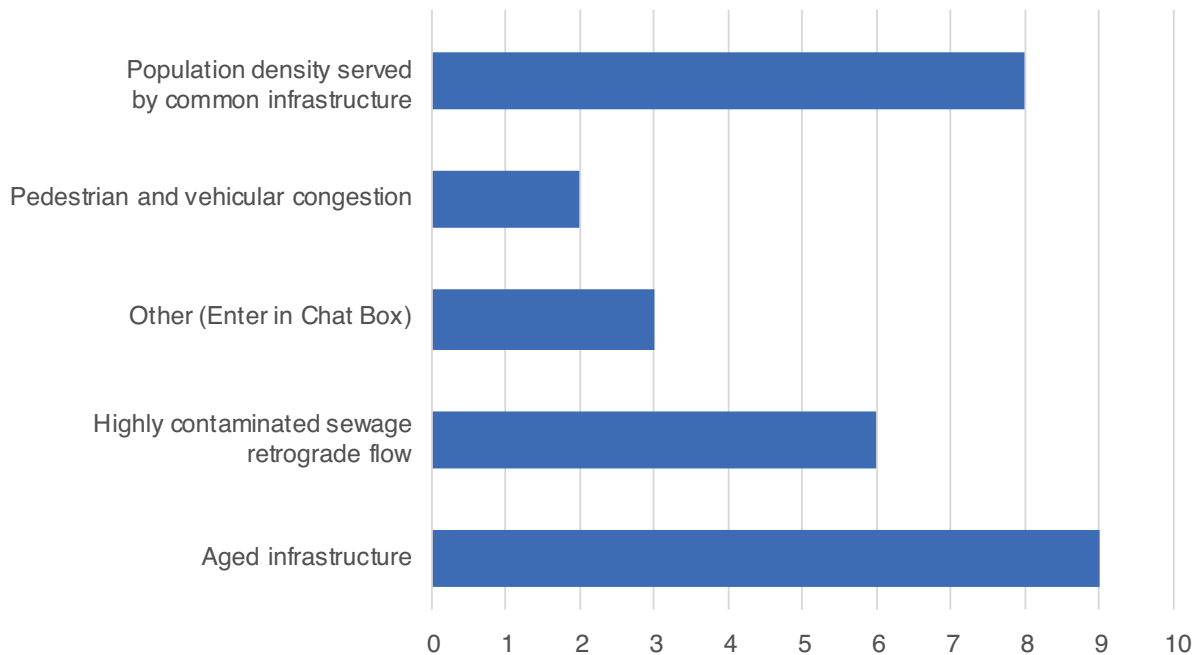
Appendix C. Focus Group Meeting Poll Results

During the focus group meeting, participants were asked to rank urban flooding hazards, challenges to workers, training gaps, and environmental justice issues, as follows:

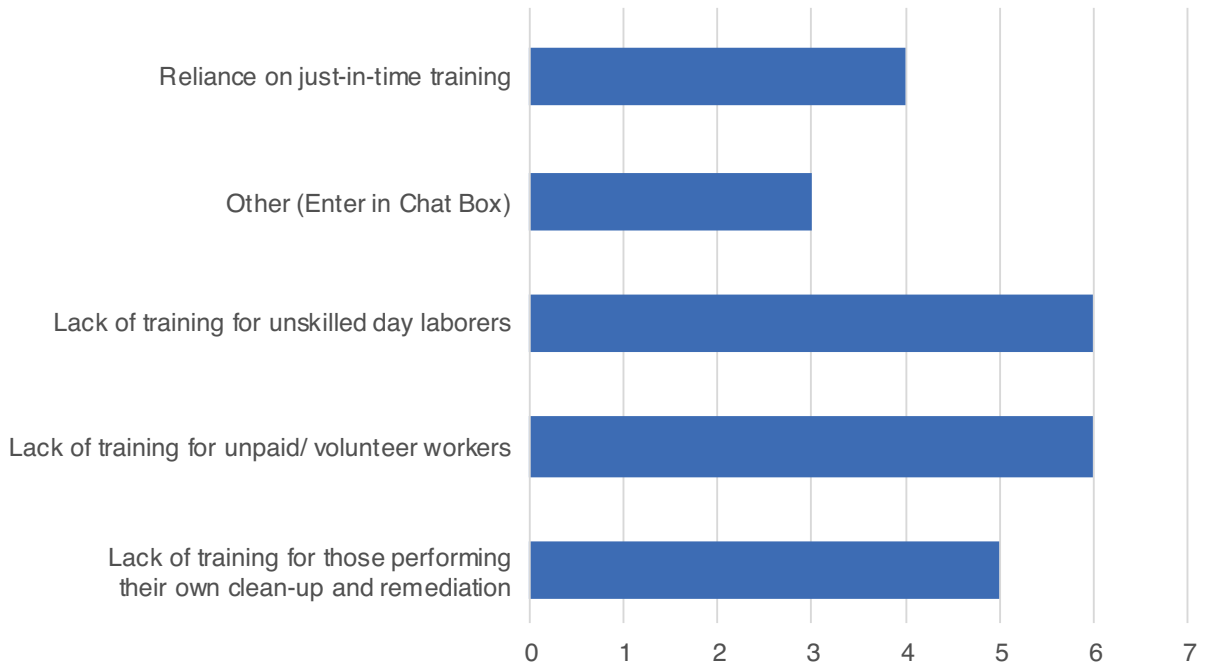
Top Hazards Present in Post-Flooded Urban Environment



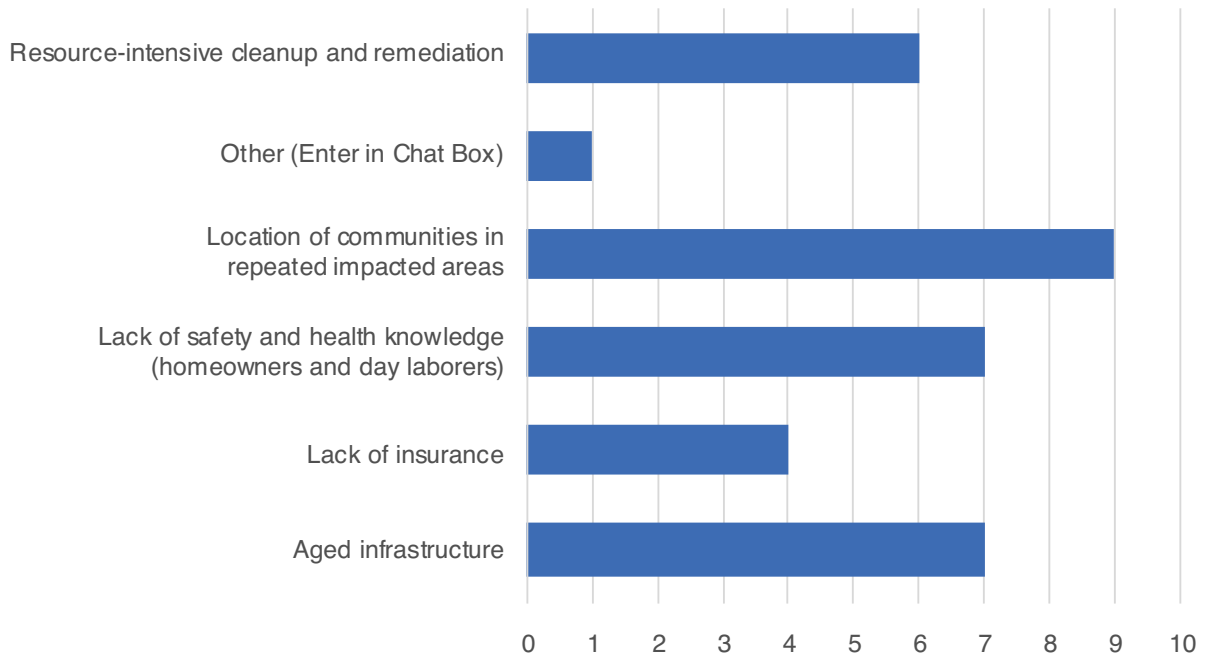
Top Challenges of Working in the Post-Flood Urban Environment



Top Training Gaps for Urban Flooding Workers



Top Issues Related to Environmental Justice and Urban Flooded Areas





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