THE COUNCIL OF STATE AND TERRITORIAL EPIDEMIOLOGISTS

Occupational Health Surveillance for Tracking Climate Related Health Impacts on Workers: Heat, Wildfires & Floods

Council of State and Territorial Epidemiologists
Occupational Health Surveillance Subcommittee
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Executive Summary

Introduction

Climate -related issues including extreme heat, wildfires, and floods pose substantial risks to occupational health. These climate-related hazards will result in direct and indirect effects on the health and well-being of workers. Understanding which workers will be most affected is critical to public health preparedness and response. The primary goal of this document is to provide guidance for occupational health professionals to explore climate-related hazards, exposures, and outcomes for occupational health surveillance. There is considerable variation in climate-related outcomes in the United States (U.S.); this document serves as a resource for approaches to defining heat, wildfire, and flood-related health outcomes for workers.

Methods

In April of 2023, the CSTE Occupational Health Subcommittee convened a workgroup of epidemiologists, researchers, and public health experts to address the risks to workers that are posed by ongoing and rapidly increasing changes to the earth's climate. These climate-related issues were selected based on the scope and focus area of the 2023 CSTE Occupational Health (OH) Subcommittee spring workgroup meeting. The participants of the spring OH workgroup sought to: 1) identify data sources and reassess public health capacities post-pandemic, 2) capture approaches to surveillance for climate and occupational health using guiding principles from disaster and environmental epidemiology surveillance, and 3) create a framework for CSTE which can be useful to health departments, partners, and local groups who are interested in addressing the issue of worker health risks as they relate to climate .

Findings

Identifying climate-related health outcomes for occupational health surveillance requires considering the types of industries and occupations within a given jurisdiction. Exposures to climate-related hazards will differ by industry, occupation, and region. Worker populations may be impacted both by ongoing incremental changes to the climate and by acute disasters. Since the pandemic, several new tools are available to assist with characterizing worker populations by particular characteristics. Different regions and jurisdictions of the U.S. have different climates and, as such, will experience different anticipated exposures and outcomes from climate impacts. These areas also have different worker populations with different susceptibility and adaptive capacity.

- There is no single source of data that can identify all work-related injuries and illnesses, and multiple data sources are often needed to help provide information on the distribution of these outcomes.[1,2]
- Carrying out successful occupational health surveillance for climate related issues also requires monitoring the health of workers at an appropriate time interval, considering seasonality or time lags, at the extremes of climate impacts– heat waves, wildfires, and floods.

One way to make progress in the climate and occupational health space is to partner with other groups that are involved in this work. Such partnerships can lead to synergies that move the work further along for both parties. Local and state health departments play an important role in disseminating information on climate-change related health impacts for workers, as they are uniquely positioned to tailor recommendations based on the industries and vulnerabilities of their region.

Discussion

This document serves as a resource to accelerate occupational surveillance focused on heat, wildfires, and floods. It is worth noting, impacts of other extreme weather events, such as extreme cold, are beyond the scope of this document but should be considered in future efforts. By offering a framework for occupational health surveillance in the context of climate impacts, this white paper intends to support health departments in developing their own approaches to monitoring climate-related health outcomes among workers.

The following appendices are included as separate files accompanying this document:

Appendix 1. Detailed description of occupational and climate related data sources: health outcome, exposure measures and tools

Appendix 2. List of questions to ask of potential partners for collaboration for working in the occupational health and climate impacts domain

Introduction

Climate change-related issues including extreme heat, wildfires, and floods pose substantial risks to occupational health. These climate-related hazards will result in direct and indirect effects on the health and well-being of workers. Understanding which workers will be most affected is critical to public health preparedness and response.

Occupational health surveillance plays a vital role in identifying, tracking, and understanding the impact of injuries and illnesses among workers. The information derived from occupational health surveillance is important in the development of intervention and prevention strategies. Understanding the potential impact of climate-related hazards on occupational injuries and illnesses is necessary in the face of changing environmental conditions. The workforce is vulnerable to emerging hazards due to environmental changes (e.g., extreme temperatures, air pollution, and infectious diseases) that can impact worker health, including increases in chronic diseases. Existing hazards and occupational injuries and illnesses may also be exacerbated by changing climate conditions. By incorporating climate-related factors into occupational health surveillance, health departments can provide insights into emerging health risks faced by workers and allow for proactive identification of approaches for mitigating impacts of emerging health risks.

The primary goal of this document is to provide guidance for occupational health professionals to explore climate-related hazards, exposures, and outcomes for occupational health surveillance. There is considerable variation in climate-related outcomes in the United States (U.S.); this document serves as a resource for approaches to defining heat, wildfire, and flood-related health outcomes for workers. These climate-related issues were selected based on the scope and focus area of the 2023 CSTE Occupational Health Subcommittee spring workgroup meeting. It is worth noting, impacts of other extreme weather events, such as extreme cold, are beyond the scope of this document but should be considered in future efforts. By offering a framework for occupational health surveillance in the context of climate impacts, this white paper intends to support health departments in developing their own approaches to monitoring climate-related health outcomes among workers.

Prioritizing climate-related hazards for occupational health surveillance in your jurisdiction

Identifying climate-related health outcomes for occupational health surveillance requires considering the types of industries and occupations within a given jurisdiction. Exposures to climate-related hazards will differ by industry, occupation, and region. To understand jurisdiction-specific worker populations, states can utilize the National Institute for Occupational Safety and Health (NIOSH) Employment Labor Force (ELF) Query system to estimate the number of workers within industries or occupations, or use other options described below.[3] This information can be paired with climate exposure data to assess industry- and occupation-specific risks to workers for climate-related outcomes. Moreover, NIOSH ELF enables queries by age, sex, race/ethnicity, and education. This information can provide insight into the magnitude of risk for– and distribution of – potentially impacted workers, enabling tailored interventions, including health equities and disparities between potentially impacted workers.

States should consider integrating social vulnerability indices, which are often available by county or census tract. Examples include the Centers for Disease Control and Prevention (CDC)/Agency for Toxic Substances and Disease Registry (ATSDR) Social Vulnerability Index,[4] the CDC Environmental Justice Index,[5] and County Health Rankings.[6] These indices can help identify where occupational vulnerabilities intersect with broader socioeconomic vulnerabilities, including income and education level, race/ethnicity, health insurance, and housing quality. Work is also a social determinant of health. Occupation not only influences access to resources, including healthcare benefits and income, but also exposures to workplace hazards.

Worker Populations

Worker populations may be impacted both by ongoing incremental changes to the climate and by acute disasters. Climate -related disasters can affect many workers beyond those who quickly respond with first-aid, medical treatment, or response and recovery. NIOSH, labor unions, and volunteer emergency responder groups worked together to develop a framework – the Emergency Responder Health Monitoring and Surveillance™ (ERHMS™) – which addresses first-responders in any emergency.[7] In addition, The Federal Emergency Management Agency (FEMA) has a National Risk Index which factors in Community Resilience.[8]

Workers involved in clean-up or infrastructure restoration continue to work during the weeks – or years – post-disaster which can lead to additional risks of injury. For example, following Hurricane Sandy, New Jersey found an increase in tree-related injuries[9,10] for Utility workers who clear trees from power lines as well as municipal workers who clear trees from roadways – both were at risk of injuries due to response. Insurance adjusters, mental health workers, and social workers,[11] responding to disasters or living in these affected areas may also be impacted. These findings highlight how multiple types of workers can incur injuries or illnesses during the periods following disasters.

Slow-moving changes to the climate, not defined by discrete time periods as during disasters, can upend our preconceptions about which workers may be considered at high-risk. For example, health care support workers and aides often work indoors and are not typically considered at risk from wildfire smoke on the job. Yet, health care support workers acted as first responders evacuating residents from assisted living and skilled nursing facilities during the 2018 California Camp fire.[12] Thus, rapidly enumerating workers employed in each occupation may be critical.

Incremental changes to the climate may increase the frequency and intensity of hot days and heat waves, wildland fires (non-structure and vegetation fires) and wildfires (unplanned fires), and flood events. Knowing which workers may be impacted by these different situations is essential. As an example, consider manufacturing workers who may work indoors, in large urban centers without air conditioning. These workers are vulnerable to heat and wildfire smoke. In addition, warehouses often lie in the rural-urban interface, lack adequate temperature-controlled environments, and face risks of fires

and floods. Finally, outdoor workers such as highway workers and agricultural workers may also face risks of heat, wildfire, and flood exposure.

As the above examples emphasize, it is critical to be able to quantify and understand who makes up subpopulations of workers within a given jurisdiction. We provide some potential *a priori* approaches to understanding the workforce within each jurisdiction.

Approaches to Characterize Worker Populations

Since the pandemic, several new tools are available to assist with characterizing worker populations by particular characteristics. In response to heat and wildfires jurisdictions may want to understand which worker populations are primarily indoor versus outdoor, for example. We provide information about such tools below.

NIOSH Essential Industries Matrix

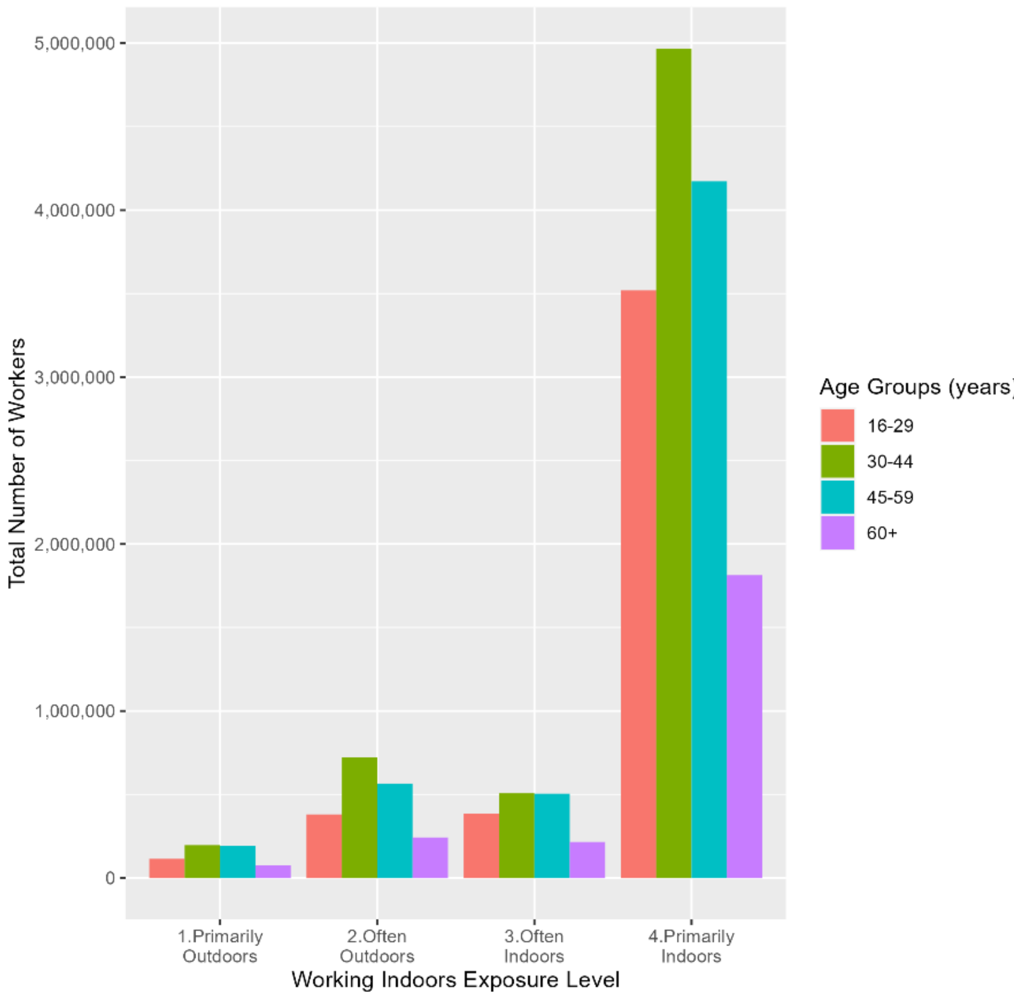
Essential workers have critical jobs that keep society functioning during emergency situations such as a pandemic or natural disaster. NIOSH used the Cybersecurity and Infrastructure Security Agency (CISA) advisory list identifying essential critical infrastructure workers (ECIW) during the coronavirus disease 2019 (COVID-19) response and mapped to U.S. Census industry Codes (CICs) to readily identify these worker populations in public health data sources known as the NIOSH Essential Workers Code Set.[13] New tools, like the NIOSH Essential Workers Code Set, may also be used to identify potentially high-risk industries. The NIOSH Essential Workers Code Set tool allows for flexibility in linking to worker population data such as NIOSH ELF because it is coded to 2017 North American Industry Classification System (NAICS), 2012 NAICS, and 2012 CIC along with industry-occupation pairs coded as 2012 CIC-2010 Census Occupation Codes (COC). For example, when the NIOSH Essential Industries Matrix is coupled to ELF data, states can key in on industries deemed mostly "Essential."

CSTE SARS-CoV-2 Occupational Exposure Matrix

A risk-based approach to identifying occupations in which workers, when present in the workplace, are likely to be at increased risk of exposure to SARS-CoV-2. The CSTE SARS-CoV-2 Occupational Exposure Matrix (SOEM) was developed to offer a systematic approach to characterizing workplace exposure to SARS-Cov-2 in hundreds of non-health care occupations using metrics from the Occupational Information Network (O*NET), a national database with information on occupational characteristics, together with input from experts in occupational safety and health.[14] The SOEM focused on three factors identified as contributing to increased risk of exposure in the workplace: whether an occupation involves routine in-person interaction with the public (Public Facing), working indoors (Working Indoors), and working in close physical proximity to others, either co-workers or the public (Close Proximity). The CSTE SOEM [coded to 2010 Standard Occupational Classification Codes (SOC) and 2010 COC] may be employed to define which groups and how many workers may be potentially at risk of

environmental impacts. For example, states can use NIOSH ELF data,[3] which uses the Current Population Survey (CPS), to understand who may be working indoors versus outdoors using the CSTE SOEM (Figure 1). Jurisdictions can opt to use the American Community Survey (ACS) 5-year data for more stable estimates, but they may need to convert to 2010 COC or 2018 SOC to use with the SOEM.

Figure 1. California worker population (16-60+ years) characterized by the CSTE SARS-CoV-2 Occupational Exposure Matrix[1]



Data sources: NIOSH ELF, 2019 Current Population Survey for California; CSTE SARS-CoV-2 Occupational Exposure Matrix

CSTE SARS-CoV-2 Occupational Exposure Matrix Industry Extension

An expansion to the CSTE SOEM was coupled to the U.S. 2015-2019 Current Population Survey to estimate the number of workplaces with a high risk of SARS-CoV-2 exposure by industry. These data were analyzed using 2021 CIC and 2010 COC. The SOEM-IE provides information about the national variability of occupational exposure within an industry and another mechanism to use the SOEM. This tool may be used when jurisdictions only have data with industry codes. Jurisdictions can opt to use the American Community Survey (ACS) 5-year data[15] for more stable estimates to analyze their industries

and understand jurisdiction-level variability with the SOEM-IE.[14]

Other approaches

Jurisdictions may choose to monitor the emergence of new industries and the decline of existing industries over time. For example, the U.S. has seen a rise in disaster clean-up industries as climate events occur more regularly and with higher severity.[16] These companies may rely on volunteers or workers migrating from other regions or countries – making them challenging to enumerate using traditional national surveys, but possible to capture using rapid needs assessment surveys.[17,18] In addition, the use of traditional surveys may not capture other kinds of workers, including those in other industries such as agriculture. The ongoing assessment of the workforce by industry within a jurisdiction using a survey data source remains a reasonable approach, acknowledging the caveats and explicitly stating the data source limitations (e.g., state which workers or industries are not captured).

Regional Considerations

Different regions and jurisdictions of the U.S. have different climates and, as such, will experience different anticipated exposures and outcomes from these climate impacts. These areas also have different worker populations with different susceptibility and adaptive capacity. In the summer of 2023, the Midwest and East Coast each experienced poor air-quality as a downstream effect of Canadian wildfire smoke.[19] Concurrently, on July 19th of 2023, Arizona broke a record set in 1974 for the most consecutive days above 110°F.[20] National Weather Service forecast offices issue heat advisories, excessive watches, and excessive heat warnings at different thresholds in different parts of the country. For example, Miami issues a heat advisory if the heat index is expected to be at least 105°F[21] while offices in New England will issue a heat advisory for a heat index of at least 95°F.[22] Different experiences and preparedness measures in these regions contribute to the different thresholds. The NWS is also testing a HeatRisk prototype that will assign locations to one of five heat risk categories based on factors such as how unusually hot the temperature is for that location and the time of year to account for acclimatization.[23] Knowing the potential hazards workers in different regions face requires understanding regional climate models, having an awareness of the kinds of work and worker demographics in the area, and knowing where to seek additional information.

Climate models

The National Oceanic and Atmospheric Administration (NOAA) provides climate projections on their website and through their Climate Explorer/U.S. Climate Resilience Toolkit on Climate.gov.[24] As an example, data from this Toolkit shows that, if emissions remain high, the average daily temperature in Madison, Wisconsin, in 2050 is projected to increase to a level approximately the same as the average historical temperature of St. Louis (1961-1990). Modeled data like these provide an opportunity for planning and adaptation based on what climatic conditions we can expect the workforce to be facing now and in the future.

Current work and resources

Each jurisdiction has different work being conducted at the local level. It is useful to assess ongoing projects and potential partnerships (also see the "Identifying and engaging potential partners" section of this document). For instance, many universities and colleges have environmental science, atmospheric science, climate science, or conservation degree programs. There also may be ongoing work from federal grants in your jurisdiction. Both the Climate-Ready States & Cities Initiative (CRSCI)[25] and the National Environmental Public Health Tracking (EPHT) Program[26] have state-level grant recipients throughout the country. Some states also have access to a Climate Adaptation Partnership/Regional Integrated Sciences and Assessments (CAP/RISA) Program. These programs are funded through NOAA's Climate Program Office and have regional climate expertise. It is part of the CAP/RISA mission to participate in research and engagement partnerships that can expand regional capacity for adaptation and resiliency.[27] All these groups are involved in ongoing efforts and may also be able to provide expertise in exposure data for any initiatives aimed at worker populations. They might serve as resources that can help public health professionals establish the state of the climate in each region.

State climatologists

Most states have a state climatologist whose job is to study climatic changes and variability and predict the effects of weather and climate for economic and other purposes.[28] The state climatologist is a potential informational resource as well as someone with a vested interest in how climate impacts will affect workers and the economy. Connecting with your state climatologist may provide opportunities to leverage existing resources or collaborate on future initiatives. This individual may also be aware of existing outreach, analysis, or mitigation efforts within other branches of state or local government.

Additional region-specific topics

Understanding regional differences in various factors is crucial to adaptation in the face of climate impacts. For instance, housing stock (e.g., total number of houses and apartments in the area and the historical context of when they were built or remodeled) may be different in different states or regions of the country. This can depend on several factors including when the housing was built and the historical climate of the area. In the northern Midwest, for example, the need for air conditioning was not as prevalent in the past as it is today or is anticipated to be in the future. Considering various region-specific issues like this (e.g., historical industries, flood plains, population centers, etc.) is an important part of understanding the climate -related needs of your jurisdiction.

Data sources to identify work-related health outcomes

There is no single source of data that can identify all work-related injuries and illnesses, and multiple data sources are often needed to help provide information on the distribution of these outcomes.[1,2] Therefore, jurisdictions need to identify the data sources they have access to and what variables are available in those data sources to help recognize work-related health risks. Common data sources

include syndromic surveillance, death record data, emergency discharge and hospitalization data, and workers' compensation claims. The following table (Table 1) lists commonly used data sources for occupational health surveillance along with example variables, and references that may be used to help determine work-relatedness. It should be noted that these variables may differ by state, as states often have access to different data sources; information for similar data sources may be collected differently state-to-state; and data may vary as different regions of the country experience different types of work-related injuries and illnesses.[29] Additional details, including strengths and weaknesses, for these data sources can be found in the CSTE Occupational Health Indicators: A Guide for Tracking Occupational Health Conditions and Their Determinants, Appendix D: Data Sources.[30] Further, a synthesized version of the 2023 CSTE Occupational Health spring workshop participant worksheet with identified data sources related to occupational health outcomes is available in Appendix 1.

Additional tools for coding industry and occupation

- NIOSH Industry and Occupation Computerized Coding System (NIOCCS): https://csams.cdc.gov/nioccs/About.aspx
- North American Industry Classification System (NAICS). US Census Bureau: https://www.census.gov/naics/
- Standard Occupational Classification (SOC). US Bureau of Labor Statistics: https://www.bls.gov/oes/current/oes_stru.htm

Table 1. Health outcome data sources containing work-related variables*

Data Source	Collected By	Available in Near-Realtime	Possible Work Variables	References
Emergency and Hospital Discharge Data	State health department; State Hospital Association	No. Availability depends on jurisdiction	Workers' Compensation as primary payer; ICD-codes in discharge diagnosis (disease conditions or indicating work-relatedness); V- and Z- codes indicating work-relatedness; Y codes (Y92 - Place of occurrence codes, Y93 - Activity codes	CSTE Occupational Health Indicators How-To Guide; Identification of Work-Related Injuries (Bush et al)
Death Certificates	State vital statistics	No. Availability depends on jurisdiction	Industry and occupation free text fields; location of death; place of injury; how injury occurred narrative field (occupational keywords); employer name and address; flag for injury at work	
Workers' Compensation	Data owner/manager of workers' compensation data in your state (e.g., Dept. of Labor)	No. Availability depends on jurisdiction	All accepted claims data is work-related by default; industry and occupation available; ICD-codes; keyword search in narratives	CSTE Occupational Health Indicators How-To Guide
Syndromic Surveillance [Early Notification of Community-based Epidemics (ESSENCE) or in-house system]	Liaison in state health department infectious disease program	Yes.	Chief complaint keyword search; triage notes; ICD-codes (disease conditions or indicating work-relatedness)	CSTE Syndromic Surveillance for Occupational Health Surveillance; Evaluation of State Based Syndromic (Borjan et al)
Survey of Occupational Illnesses (SOII)	Bureau of Labor Statistics	No. One year lag	Industry and occupation; number of days away from work	CSTE Occupational Health Indicators How-To Guide

Census of Occupational Injuries (CFOI)	Bureau of Labor Statistics	No. One year lag	Industry and occupation; incident type; event or exposure	CSTE Occupational Health Indicators How-To Guide
Trauma Registry	State health department	No. Availability depends on jurisdiction	ICD-codes; injury description fields	Work-Related Injuries in State Trauma Registry (Bunn et al); State Trauma Reg Occ Surv (Sears et al)

*Data sources vary by state.

Considerations for climate-related occupational health surveillance

In addition to spatial considerations, carrying out successful occupational health surveillance for climate related issues also requires monitoring the health of workers at an appropriate time interval, considering seasonality or time lags, at the extremes of climate impacts – heat waves, wildfires, and floods.[31]

Environmental health scientists consider temporal aspects such as seasonality. For example, El Niño and La Niña events may recur in a 3-10-year cycle and cause increased precipitation in different areas. Thus, jurisdictions with limited resources could plan targeted surveillance to coincide with the climate cycle. For this approach, the ability to detect any occupational injuries or illnesses relevant to floods would be maximized if the monitoring occurred in specific time periods within a year every 3-10 years, for example, early in the year during an El Niño season. Time lags also need to be considered for successful occupational health surveillance. Time lags as brief as 24 hours might be needed for heat waves and mortality,[32] whereas weeks are needed to detect diarrheal diseases among workers due to precipitation.[33]

Assessing the environmental data is essential after defining an objective for the occupational health and climate surveillance system. When combining health data with environmental data, key questions to ask prior to using the environmental data are:

- *How spatially granular are the geographic data?*
    - Weather stations can provide detailed climatological information at a precise location. If information from one weather station is used due to the limited number of stations available in an area, however, monitoring precipitation may reflect larger geographic areas rather than potential smaller areas where rain falls and require strong spatial pattern assumptions.[34]

- *What timescale is captured?*
    - A heat wave, such as one that occurred in Arizona in the summer of 2023, may last over one month. Hourly or daily temperatures or heat indices may be more meaningful than a monthly average temperature or heat index.

- *What is the basis for the measured data?*
    - Methods used to track changes to the climate can vary over time.
        - Historical data may only contain certain types of measurements that can present challenges to assessing trends over time. For example, historical weather station data may capture temperature but not humidity, which is needed to calculate heat index. In another situation, stations may have data on larger particulate matter (e.g., PM10 rather than PM2.5) for earlier time periods.

        - Projected or modeled data may rely on historical data and use assumptions to assess potential scenarios for the future.

- *Is the measurement variable relevant to the outcome of interest?*
    - How much lag time should one allow for the measurement variable?
        - In a review[35] of time lag among climate related epidemiologic studies, the authors found the following:
            - For ambient temperatures and infections, the time lag depends on the infection: 1-2 weeks for influenza, 3-6 weeks for diarrheal diseases, 6-7 for malaria and 6-16 weeks for dengue.
            - For hot temperatures and cardiovascular diseases or respiratory diseases, an average of less than 5 days has been documented.
            - For rainfall and diarrheal outcomes lags of 4-10 weeks are used; whereas for vector-borne diseases 8-12 weeks.
            - For wildfire, lag times are shorter for respiratory outcomes (3 – 7 days)[36] rather than cardiovascular outcomes. Multiple lag times might be used since differing subpopulations may be sensitive.[37]
    - Should a cumulative exposure measure be used?
        - Who are the worker populations you are concerned about?
            - For example, workers in many industries may perform long-shifts for consecutive days and could be under exposed to heat for multiple successive days.
        - Are there chronic or long-term effects under surveillance?

Another factor jurisdictions must consider is whether the available climate data are easy to use or require more resources for adequate processing into relevant exposure measures. The following table (Table 2), below, provides a snapshot of potential data sources jurisdictions can use when looking for exposure data relevant to climate, specifically for heat, wildland fires, and floods. Additional data elements for these exposure data sources gathered from the 2023 CSTE Occupational Health spring workshop participant worksheet is available in Appendix 1.

Table 2. Select data sources containing exposure data relevant to climate

Data Source	Collected By	Climate Issues Covered	Strengths	Weaknesses	References
CDC WONDER: Environmental Data	Center for Disease Control and Prevention (CDC)	Heat Wildland fires	Readily available, covers US, straightforward and flexible query interface, supporting documentation available and downloadable	Limited to stationary monitors for heat and wildland fires – not necessarily spatial or temporally relevant	CDC WONDER
National Environmental Public Health Tracking Network Data	Center for Disease Control and Prevention (CDC)	Heat Wildland fires Floods	Readily available, covers US, straightforward query interface, supporting documentation available, and downloadable or API	Limited to stationary monitors for heat and wildland fires – not necessarily spatially or temporally relevant Limited modeled data	National Environmental Public Health Tracking Network Data Explorer (cdc.gov)
Local Climatological Data	National Oceanic and Atmosphere Administration (NOAA)	Heat	Readily available, covers the US, spatial query interface, supporting documentation available and downloadable Accommodates direct data requests	Limited to stationary monitors – not necessarily spatially or temporally relevant	Local Climatological Data (noaa.gov)

Data Source	Collected By	Climate Issues Covered	Strengths	Weaknesses	References
Hazard Mapping System Fire and Smoke	National Oceanic and Atmosphere Administration (NOAA)	Wildland Fires	Close to real-time data	Requires GIS knowledge – maps downloadable as shape files, KML	Office of Satellite and Product Operations - Hazard Mapping System (noaa.gov)
Coastal Flood Exposure Mapper	National Oceanic and Atmosphere Administration (NOAA)	Floods	Excellent visualizations using mapping feature	Downloadable only as maps – requires geographic software	Coastal Flood Exposure Mapper (noaa.gov)
Interactive Snow Information	National Oceanic and Atmosphere Administration (NOAA)	Floods	Covers large areas	Satellite data may not be as well-measured	NOHRSC Interactive Snow Information (noaa.gov)
Inundation Dashboard – NOAA Tides & Currents	National Oceanic and Atmosphere Administration (NOAA)	Floods	Covers coasts and lakes		Inundation Dashboard - NOAA Tides & Currents
Storms Events Database	National Oceanic and Atmosphere Administration (NOAA)	Heat Wildland fires Floods	Readily available, easy to understand and download. Event information reported by NWS, newspapers, emergency services and contains descriptive text	Limited temporal and geographic information. Limited to events considered significant enough to be reported	Storm Events Database | National Centers for Environmental Information (noaa.gov)
Flood Event Viewer	US Geological Survey (USGS)	Floods	Excellent data visualization maps	Retrieval challenging as entry by users – no single method to pull relevant information	Flood Event Viewer (usgs.gov)

Data Source	Collected By	Climate Issues Covered	Strengths	Weaknesses	References
Flood Inundation Maps	US Geological Survey (USGS)	Floods	Covers coasts, lakes, and rivers	Not available for all sites with stream gauges	Flood Inundation Mapper (usgs.gov)
National Water Dashboard	US Geological Survey (USGS)	Floods	Excellent data visualization maps	No downloads. Limited temporal and geographic information. Requires subject matter knowledge	USGS | National Water Dashboard
National Water Information System: Web Interface	US Geological Survey (USGS)	Floods	Contains real-time data useful for floods, droughts plus weather data. Downloadable with tutorials available.		USGS Surface-Water Data for the Nation
Snow and Water Interactive Map	US Department of Agriculture (USDA)	Floods	Provides downloadable data from multiple Snow Telemetry (SNOTEL) networks with geocoding and elevation	Primarily covers western United States	Snow and Water Interactive Map | Natural Resources Conservation Service (usda.gov)
Air Data: Air Quality System Data Collected at Outdoor Monitors Across the US	US Environmental Protection Agency (US EPA)	Wildland fires	Processed files available for download. Validated data. Good for retrospective reports and analyses.	Requires knowledge to make meaningful insights. Lag time of 3-6 months.	Download Files | AirData | US EPA

Data Source	Collected By	Climate Issues Covered	Strengths	Weaknesses	References
AirNow Fire and Smoke Map	US Environmental Protection Agency (US EPA)	Wildland fires	Easy to visualize as maps. Near real-time data with API available. Flat files for daily summaries available until replaced by validated Air Quality System data.	Limited to ozone, PM2.5, and PM10 and to stationary monitors. Preliminary data.	Fire and Smoke Map (airnow.gov)
Water Quality Data	US Environmental Protection Agency (US EPA)	Floods	Data element profiles available for download	Requires subject matter knowledge for selection and use	Water Quality Data | US EPA
Wet Bulb Globe Temperature	National Weather Service (NWS)	Heat	Reliable, consistent data Incorporates more detailed measure of heat stress risk	Limited to specific locations and time periods	WetBulb Globe Temperature (weather.gov)
Weather Query Builder[1]	Subscription services	Heat	Easy to use and get historical and forecast data	Paid service Data sources unclear	Weather Data & Weather API | Visual Crossing
Coastal Emergency Risks Assessment[2]	Subscription services	Floods	Covers all coasts, detailed local flood data	Subscription for downloadable data Limited temporal and geographic information	CERA - Coastal Emergency Risks Assessment (coastalrisk.live)

[1] Visual Crossing

[2] Center for Computation & Technology and Louisiana Sea Grant, Louisiana State University

Assessing climate issues at the jurisdiction level

Heat-related illness

Outdoor workers who are exposed to ambient heat and whose work tasks require physical exertion, such as agricultural, construction, firefighting, and military workers, are at high risk for heat-related illness. While outdoor workers are most likely to be impacted by heat, indoor workers may also be at risk, particularly those in non-climate-controlled settings or exposed to point sources of heat such as workers in foundries and bakeries. In addition, use of nonbreathable personal protective equipment (PPE), e.g., Tyvek suits, can increase the risk of heat stress.

There is a wide range of heat-related health outcomes, including heat exhaustion, heat stroke, dehydration, and exacerbation of cardiovascular and respiratory conditions (Table 3). Many jurisdictions track heat-related deaths and illness from emergency department (ED) or hospitalization data to inform prevention efforts surrounding heat events.

Table 3. Possible Heat-Related Health Outcomes

Acute heat-related conditions	Heat cramps, heat rash, heat syncope, heat exhaustion, heat stroke, dehydration
Other conditions	Acute kidney injury, rhabdomyolysis, exacerbations of cardiovascular or respiratory conditions, chronic kidney disease, permanent impairment following heat-related traumatic injury
Indirect effects	Injuries (e.g., falls), mental health impacts

Measurement options

While diagnosis codes can identify heat-related illness, it is more challenging to determine if a heat-related illness is work-related. The CSTE Occupational Health Indicator (OHI)[30] is a measure of occupational heat-related illness. Heat-related ED visits are classified as work-related if records have the primary payer listed as Workers' Compensation or if they contain an external cause of morbidity code (ICD-10) indicating work as the place of occurrence.[30] Jurisdictions can use this indicator on hospitalization data in addition to ED data.

In addition to the use of retrospective ED and hospital data, syndromic surveillance can be used to monitor heat-related illness (HRI) ED visit trends and patterns in near real time. Jurisdictions may choose to monitor specific heat-related outcomes. Affiliated ICD-10 codes for heat-related outcomes can be found in the CSTE Climate, Health, and Equity Subcommittee (formerly the Climate Change

Subcommittee) guidance document entitled *Heat-Related Illness Syndrome Query: A Guidance Document for Implementing Heat-Related Illness Syndromic Surveillance in Public Health Practice*.[38]

It is important to recognize that a worker can develop both acute and long-term heat-related outcomes and that heat exacerbates chronic cardiovascular and respiratory conditions. Longer-term conditions, or exacerbations of chronic conditions, such as respiratory and cardiovascular complications, are more challenging to identify as heat related. Any estimate of heat-related illness using ICD-10 codes and ED or hospitalization data is likely an underestimate,[39] as excess heat may not be explicitly documented as a contributing factor to the visit, hospitalization, or death. Moreover, workers may be undercounted if the heat-related illness is not identified as being work-related at the time of the visit.

To evaluate exposure to heat, jurisdictions can consider various exposure data including dry air temperature, heat index, and wet bulb globe temperature. While dry air temperature may be the easiest exposure measurement variable to interpret, it does not capture other factors that impact the risk of HRI, including humidity, wind, and solar radiation. Temperature measurements often represent localized conditions, specific to the area of the weather station. These measurements may not reflect the conditions where workers are exposed. Previous research has utilized heat waves or extreme heat events as an exposure measure.[40-42] There is no standardized definition of a heat wave. Various criteria for defining a heat wave exist, including a consecutive number of days with temperatures exceeding a certain temperature or historical temperature thresholds, as well as a set of days with heat advisories from the National Weather Service.[43]

Variables that capture the location of an illness or injury will not always be available or specific within all data sources, which makes linking exposure data challenging. Moreover, certain regions will not have adequate coverage of weather stations, meaning that there will be inaccuracies in assessing heat exposure. Details of these measurement variables, including descriptions, strengths and weaknesses, and sources for these data can be found in Table 4 (below).

Table 4. Heat exposure measurement options

Measurement Variable	Description	Strengths of Measure	Weaknesses of Measure	Timescale	Smallest Geographic Unit available	Measured or modeled?	Data Source Options
Temperature (dry air)	Degree or intensity of heat	Easy to understand and measure	Temperature alone does not capture all elements relevant to human heat stress	Hourly, Daily, Weekly, Monthly	Measured at local weather stations, forecasted for any point	Measured (min, max, average); modeled, forecasted	Local Climatological Data (noaa.gov); Online Data Request Submitted | Climate Data Online (CDO) | National Climatic Data Center (NCDC) (noaa.gov) prism.oregonstate.edu/
Heat Index	Combines relative humidity with dry air temperature	Easy to understand	Measured in shade, so does not consider sunlight.	Hourly, Daily	Measured at local weather stations, forecasted for any point	Measured; but can be forecasted	https://ephtracking.cdc.gov/DataExplorer/ https://healthdata.gov/dataset/CDC-WONDER-Daily-Air-Temperatures-and-Heat-Index/etgt-szcw https://www.visualcrossing.com/weather/weather-data-services

Wet Bulb Globe Temperature (WBGT)	Combines temperature, humidity, wind, and solar radiation	Measure has multiple components to better reflect working conditions	Challenging to measure, requires specialized equipment, more challenging to interpret	Hourly, Daily	Measured at location; can be estimated elsewhere using satellite and weather station data	Measured, but can be forecasted	National Weather Service (NWS) https://www.weather.gov/tsa/wbgt Heat - OSHA Outdoor WBGT Calculator | Occupational Safety and Health Administration

Wisconsin example: Heat-related illness analyses

In 2023, a team of epidemiologists in the Wisconsin Occupational Health and Safety Program set out to better understand the burden of heat illness and injury played for workers in the state. Prior analyses of heat illness and injury relied on data from vital records or ambulance runs. Those data made it difficult to connect the outcomes to occupation and industry. To compensate for this problem, the team used data from workers' compensation and unemployment insurance. Wisconsin's workers' compensation program provides financial remuneration for employed individuals who are unable to work due to injuries or illnesses they encountered on the job.

The goal of the Wisconsin analysis[44] was to improve heat-related illness surveillance by examining claim trends and identifying workers at high risk. To that end, the project sought to: 1) describe heat-related workers' compensation claims, 2) identify the most affected industries and occupations by rates and counts, and 3) describe lost work time stemming from heat-related illness claims.

To identify cases of heat-related illness or injury, claims coded as "heat prostration" by nature of injury or "extreme temperature" by cause of injury, as well as specific heat-related terms (e.g., heat stroke, heat rash, etc.) in the injury description were identified. Workers' compensation data were then linked to unemployment insurance data to obtain detailed industry codes for the businesses where the injury or illness occurred. Detailed occupation codes were obtained after coding the industry title and the occupation information using the National Institute for Occupational Safety and Health (NIOSH) Industry and Occupation Computerized Coding System (NIOCCS).

The analysis[44] had several important findings. First, denials of workers' compensation claims for heat-related illness or injury are increasing in Wisconsin from 14.3% in 2008 to 68.8% in 2021. Second, Wholesale Trade and Construction industries had the highest rates of heat illness or injury at the industry sector level and Specialty Trade Contractors had one of the highest rates at the industry subsector level. Third, major occupation groups such as Protective Service, Transportation and Material Moving, and Construction and Extraction had a high rate. But this rate was largely driven by Fire Fighting and Prevention occupations at the minor occupation group level. Finally, the median lost time for all workers was 4 days (range: 1-26 days).

Analyses like these can provide stakeholders with the information they need to create interventions and make decisions. The findings from the Wisconsin team highlighted needs for the state that will be useful in tailoring next steps. For instance, communicating with employers and employees in industries and occupations with high rates of heat-related illness or injury may prevent future negative health outcomes. Additionally, educating relevant parties around claims to prevent inappropriate denials is important, particularly as we anticipate more extreme heat days in the future due to changing climate .

Louisiana example: Using syndromic surveillance to track and report ED visits for heat-related illness

Louisiana's Occupational Heat-Related Illness and Injury (HRI) Program[45] established timely analysis and reporting of syndromic surveillance data for HRI. Data were used to track the impact of heat on Louisiana residents and workers, and to communicate heat-health impacts. In the summer of 2023, Louisiana experienced its hottest temperatures on record. In combination with high humidity, heat indices – or "feels like temperatures" – reached 115-120°F. Night-time highs remained in the 80s which provided little cooling relief. Dangerously hot conditions persisted for most of the summer.

The HRI Program established weekly syndromic surveillance reports. Using the HRI v2 syndrome definition built into ESSENCE that recognizes emergency department (ED) visits based on text or an ICD code associated with heat exhaustion, heat exposure, heat cramps, heat stroke, or hyperthermia as a base, a new free text HRI syndrome definition was created. The new HRI syndrome definition that was used to query ESSENCE includes the original HRI v2 syndrome definition plus the ICD-10 code P81.0 (environmental hyperthermia of a newborn) and includes clinical impression and triage notes in the variables that are searched. The changes to the HRI v2 ESSENCE query improved the number of cases captured. The HRI Program produced weekly reports April-October, which at first, were emailed to stakeholders and posted on the web. Reports included daily number of HRI visits to EDs in Louisiana and cumulative counts by age, sex, race\ethnicity, region, day of the week, and time of day. In August 2023, the HRI Program partnered with the Louisiana Department of Health's Bureau of Health Informatics to develop a public-facing Tableau dashboard and a new webpage for Heat-Related Illness and Deaths.[46]

Syndromic surveillance data for HRI were instrumental in informing state and local policies and practices related to heat and health. The total number of HRI ED visits captured by ESSENCE was three times greater than the annual average number of ED visits for HRI. The data highlighted the high rates among working-age men (75% of HRI visits were men, with the highest number among men ages 20 to 49 years). This finding influenced messaging about heat risks for workers.

HRI Program staff conducted numerous interviews with local and national media, and these findings contributed to the following activities:

1. The Governor of Louisiana declared a state of emergency for extreme heat.
2. Health Alert Network issued to all Louisiana physicians (Extreme Heat Poses Serious Risk of Heat Exhaustion and Heat Stroke).
3. Heat action plan developed by the City of New Orleans.
4. Guidance issued for employers and workers about working in excessive heat.

Washington example: Using workers' compensation data to track occupational heat-related illness

The Washington State (WA) Department of Labor and Industries' (L&I) Safety & Health Assessment & Research for Prevention (SHARP) Program[47] has tracked occupational HRI using workers' compensation claims. These methods have been refined to further characterize HRI claims to inform prevention.

Several preventable occupational HRI deaths occurred in 1997, 2004, 2005, & 2006.[48] In 2007, SHARP developed a surveillance system for HRI, and in 2008, L&I put into place a permanent occupational outdoor heat exposure rule. During the Pacific Northwest 'heat dome' event in 2021, temperatures reached 120°F in WA, and the number of claims for HRI increased, underscoring the dangers faced by outdoor workers and the importance of occupational HRI prevention. Extreme events such as the 'heat dome' are more likely to continue occurring.[49]

SHARP has conducted several recent retrospective descriptive analyses of workers' compensation claims for HRI to inform prevention efforts.[50] The HRI case definition currently uses the Occupational Injury and Illness Classification System (OIICS) codes, ICD-10 codes, and claim review. WA L&I also linked HRI claims to weather data at the location of illness on the illness day and prior days and described HRIs by industry, occupation, and imputed race/ethnicity. HRI rates have been estimated per full time employees (FTE) and systematically manually categorized by likelihood of occurring indoor versus outdoor using free text claim fields.[47]

Data from 2006-2017 indicate Public Administration had the highest third quarter (July-Sept) accepted HRI workers' compensation claims rate (131.3 per 100,000 FTE), followed by Agriculture, Forestry, Fishing, and Hunting (102.6 per 100,000 FTE). Farmworkers and Laborers had the highest numbers of HRI claims. The median maximum daytime temperature was below 89°F for 45% of HRI claims. Latino workers were estimated to be overrepresented among HRI cases. Days when ten or more WC claims occurred ('clusters') from 2006-2021 were characterized by both high maximum temperatures on the day of illness and also high proportions of maximum temperature increases of ten degrees Fahrenheit or more than the average over the past five days. Different geographical patterns were noted for proportions of claims exceeding temperature thresholds versus proportions of 'cluster' claims. The majority of claims occurred outdoors.

These findings have informed occupational heat policymaking efforts. In July 2023, WA L&I updated its permanent outdoor exposure heat rule with enhanced worker protections, and SHARP now updates HRI claims yearly to inform prevention efforts.

Wildfires

Key terms, and definitions, commonly used when discussing fires[51,52]

Wildland Fire: Overarching term that describes any non-structure fire occurring in vegetation and natural fuels and encompasses both prescribed fires and wildfires.

Wildfire: Unplanned fire that can be caused by natural causes such as lightning, by accidental (or arson-caused) human ignition, or by an escaped prescribed fire.

Prescribed Fire or Prescribed Burn: Planned fire that has been intentionally ignited by management actions to meet specific objectives, such as restoring health to an ecosystem, and is controlled by a team of fire experts.

Fuels: Living and dead plant material that can be ignited. Can strongly influence fire behavior and the resulting effects.

Due to human behavior and changes in climate , wildfires are becoming more frequent and lasting longer, especially during dry conditions.[53,54] Individuals who spend most of their time working outdoors, in industries such as construction, agriculture, landscaping, etc., are at increased risk of health effects due to wildfires. Smoke from these fires can also affect indoor air quality for workers. It is important to also note that many states, especially those normally not affected by wildfires, do not have guidelines for working in poor air quality conditions due to wildfire smoke. Therefore, additional actions to protect those worker populations at greatest risk are likely not taken, highlighting the importance of surveillance of worker health during wildfire events.

Wildfire-Related Health Outcomes to Consider

Individuals who must work outside for extended periods of time are more likely to be exposed to higher concentrations of smoke from wildfires. Working outdoors during periods of wildfire smoke could result in a range of health effects depending on the underlying health status of the worker. The effects of wildfire smoke exposure could range from coughing and throat irritation to asthma attacks and cardiovascular issues.[55] Effects of wildfire smoke can be acute in nature or can have a longer-term effect when an individual has an exacerbation of an existing health condition. Below (Table 5) are possible health outcomes to consider with regards to wildfire smoke exposure. Additional information is available from the Environmental Protection Agency (EPA) Health Effects Attributed to Wildfire Smoke.[56]

It has been shown that asthma cases presenting to the ED increase during wildfire smoke events and increased exposure to PM2.5 can greatly impact respiratory health.[57-59] Therefore, conducting surveillance of asthma cases presenting to the ED through near-real time data systems, such as syndromic surveillance, can be an effective early indicator that actions may need to be taken to protect individuals at risk for health effects due to poor air quality days as a result of wildfire smoke.

Table 5. Possible wildfire and wildfire smoke outcomes

Acute Symptoms	Coughing, burning eyes, scratchy throat, runny nose.
Respiratory conditions	Exacerbation of asthma and chronic obstructive pulmonary disease (COPD), upper respiratory infections, respiratory failure, and aggravation of other lung diseases.
Cardiovascular Conditions	Hypertension, ischemic heart disease, acute myocardial infarction, cardiac dysrhythmias, heart failure, cerebrovascular diseases which include intracranial hemorrhage or occlusion, chronic rheumatic heart diseases, and hypertrophic cardiomyopathy.

Injuries	Motor vehicle crashes and other traffic-related incidents, burns or electrocutions from downed powerlines, and ‘struck-by’ or ‘caught in between’ falling objects such as trees or homes collapsing.

Environmental Exposures to Consider

Smoke from wildfires is composed of mixtures of harmful substances such as chemicals, gases, and tiny particles that can cause harm to a person’s health. When there is a wildfire event it is important to keep track of your jurisdiction’s air quality. Smoke levels can change frequently, and it is important to track air quality and plan for poor air quality days to keep outdoor employees from getting sick from smoke during wildfire season.[60] Particulate matter (PM2.5) is one of the main pollutants of concern in wildfire smoke. Exposure to these fine particles can cause a range of health effects, as previously discussed, even in healthy individuals (Table 6).

Table 6. Measurement of Particulate Matter 2.5 (PM2.5)

Measurement Variable	Description	Timescale	Smallest Geographic Unit available	Measured or modeled?	Measure Variable Strengths/ Weaknesses	Data Source Strengths/ Weaknesses	Data Source Options
PM2.5	Main pollutant of concern; fine inhalable particles, diameters generally 2.5 micrometers and smaller	Hourly; daily; 24-hour average; annually	County; monitor level	Measured	Easy to understand and measure. May be gaps in monitoring data when using monitor-based measurements. Monitors may not cover all populated areas.	Readily available. Limited temporal components and limited geography; monitor data may not reflect area of interest.	Air Data: Air Quality Data Collected at Outdoor Monitors Across the US | US EPA; NOAA Hazard Mapping System Fire and Smoke; National Environmental Public Health Tracking Network Data Explorer; EPA AirNow

Additional wildfire exposure tools

- EPA AirNow Fire and Smoke map: https://fire.airnow.gov/
- FEMA National Risk Index: https://hazards.fema.gov/nri/wildfire
- U.S. Forest Service Wildland Fire / Air Quality Tools: https://portal.airfire.org/home
- EPA Climate Change Indicator: Wildfires: https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires

New Jersey Example: Use of syndromic surveillance during Canadian wildfire smoke event

New Jersey's (NJ) Environmental and Occupational Health Surveillance Program utilized syndromic surveillance data to track individuals presenting to NJ emergency departments with respiratory symptoms consistent with asthma when NJ was impacted by the smoke from the 2023 Canadian wildfires. Based on data collected during this event a wildfire smoke syndrome definition was also created to monitor future events in near-real time.

In June of 2023 widespread wildfires throughout southern portions of Quebec and Ontario caused air quality alerts in the Northeast United States, including NJ. Numerous air quality monitoring sites throughout NJ exceeded the National Ambient Air Quality Standard (NAAQS) for PM2.5, registering between 201 and 300, which corresponds to "Very unhealthy" (the risk of health effects is increased for everyone).

Staff began using the established asthma syndrome definition in the state syndromic surveillance system, EpiCenter, to track ED visits during poor air quality days and developed daily internal reports for decision making. Inclusion keywords for the Respiratory illness - Asthma syndrome definition included "asthma", "ashma", "asth", "aths", "athsma", "wheez", and "whz". There were increased asthma-related ED visits compared with the daily average seen before the event. In response to the event a fact sheet "Actions to protect health on poor air quality days" was developed in English[61] and Spanish[62] and distributed to public health professionals through the NJ Local Information and Communication System (NJLINCS).

To better capture future events in near-real time, a retrospective analysis was done of ED visits during the wildfire smoke event in June. A Wildfire Smoke syndrome definition based on the CSTE Wildfire and Smoke Syndromic Surveillance: An Implementation Guide for Public Health Practice guidance document,[63] an analysis of the EpiCenter data, was developed using inclusion keywords such as "smoke", "wildfire", and "wild fire" along with exclusion keywords such as "grill", "detector", "blunt", "joint", and "cooking" to search chief complaint fields for cases presenting to the ED due to exposure to wildfire smoke. It should be noted that this syndrome definition is intended to capture exposures due to smoke from wildfires and not injuries that may occur when responding to a fire such as burns.

Asthma can be used as an early indicator during wildfire smoke events. Combining the asthma syndrome definition with the newly developed wildfire smoke syndrome definition can help provide a baseline for reporting, help determine the effect on the population, identify the population-specific vulnerability, inform lifestyle guidelines, and calculate resources needed for the general and working population.

Note: If using ESSENCE for syndromic surveillance these same events can be monitored using the Air Quality-Related Respiratory Illness CCDD and Fire and Smoke Inhalation CCDD queries. Please refer to the CSTE Wildfire and Smoke Syndromic Surveillance: An Implementation Guide for Public Health Practice.[63]

Strengths and Limitations

Although there are numerous tools to measure PM2.5 available, some monitoring stations may not be available in all areas of a jurisdiction, or some may not provide readings at ground level. However, monitoring PM2.5 is the standard when trying to understand the air quality during wildfire smoke events. It provides useful information needed to help protect the public.[64] It is also important to remember that monitoring respiratory illnesses presenting at the ED can also be a good indicator that an event is occurring, and public health action needs to be taken. Access to these types of data sources is sometimes limited to certain programs such as infectious disease therefore it is important to collaborate with other groups in your jurisdiction.

Additional strengths and limitations to data and monitoring stations during wildfire smoke events have also been extensively written about in the CSTE guidance document Wildfire and Smoke Syndromic Surveillance: An Implementation Guide for Public Health Practice.[63]

Additional Wildfire Resources

- Wildfire and Smoke Syndromic Surveillance: An Implementation Guide for Public Health Practice. Council of State and Territorial Epidemiologists. June 2021. Access report: https://knowledgerepository.syndromicsurveillance.org/wildfire-and-smoke-syndromic-surveillance-implementation-guide-public-heath-practice
- EPA Smoke Sense Study: A Citizen Science Project Using a Mobile App: https://www.epa.gov/air-research/smoke-sense-study-citizen-science-project-using-mobile-app
- Wildfires in California: A Critical Use Case for Expanding State Capacity and Sharing Information Across Public Health Jurisdictions. Syndromic Surveillance Success Story. CDC National Syndromic Surveillance Program.: https://www.cdc.gov/nssp/success-stories/pdfs/nssp-success-stories-ca-wildfires.pdf
- CSTE Environmental Health Indicators: Climate Change: https://www.cste.org/members/group.aspx?id=106445
- McArdle, C.E., et al. Asthma-Associated Emergency Department Visits During the Canadian Wildfire Smoke Episodes — United States, April– August 2023. CDC Morbidity and Mortality Weekly (MMWR) August 25, 2023 / 72(34);926–932. https://www.cdc.gov/mmwr/volumes/72/wr/mm7234a5.htm

Floods

Floods happen when intense precipitation occurs within a short time period, when precipitation occurs over long periods of time, when debris obstructs the natural flow of rivers or streams, or when excessive snowmelt overpowers waterways and floods nearby areas. Flash floods are characterized by a sudden onset of water. These occur with excessive rainfall in a short timeframe, typically within hours.[65] Areas that have suffered from wildland fires are susceptible to flash floods. Coastal floods occur when there is a higher-than-average high tide or heavy rainfall with onshore winds. Whereas storm surges, usually

caused by the wind, waves, and low atmospheric pressure, are abnormal rises in coastal sea levels over and above the tide.

Flood Health Outcomes to Consider

A review of the health consequences of floods identified both direct and indirect impacts.[66] Direct consequences occur from the water and flood environments resulting in drowning, injury from debris, hypothermia, and chemical exposures (Table 7). Most of the worker fatalities occurred while operating motor vehicles during flood events.[67] Fatalities due to floods could potentially affect a wide swath of industries that operate motor vehicles, ships, or equipment – health care services, material moving, and farms.

Indirect health outcomes arise from water damage or events after the flood, including exposure to infectious diseases or mold. Mold growth was documented in homes after Hurricanes Katrina and Rita.[68] Workers involved in remediation, construction, disaster recovery and response, or workers returning to workplaces can be exposed to mold after flooding events. Subsequently, workers may suffer from a host of respiratory conditions (Table 7).

Table 7. Possible flood-related health outcomes

Acute Symptoms	Cough, nasal congestion, throat irritation, skin rash, and wheezing
Respiratory conditions	Asthma, chronic obstructive pulmonary disease (COPD), upper respiratory infections, and respiratory failure
Injuries	Motor vehicle crashes and other traffic-related incidents, electrocutions from downed powerlines, "struck-by" or caught in between" falling objects such as trees or homes collapsing, drowning, hypothermia, chemical burns, and animal bites

Sources of drinking water may also pose risks for workers within areas impacted by floods. Microbial risks may occur after flooding if workers ingest drinking water at work from private wells. As a result, workers could be exposed to intestinal bacteria and experience health effects that are not listed on Table 7.[69]

In general, many health outcomes can occur due to flooding. Due to urban population growth and changes in climate , organizations have begun to explore the impacts to workers arising from urban flooding. Jurisdictions may need to assess whether the floods are occurring in rural or urban areas.[70]

Environmental Exposures to Consider

Overall, floods can be characterized by events, flood hazard composite index, designated flood areas, inundation depth, precipitation, quality, streamflow, water elevation, or water equivalent depending on the outcome of interest and/or data and resources available. There were ten data sources identified for

flood exposure measures. Some applied researchers have integrated social vulnerability indices with Federal Emergency Management Agency (FEMA) flood hazard maps and new contiguous, high-resolution inland flood maps that incorporate pluvial hazards.[71] However, we have not included social vulnerability indices in the exposure table (Table 8).

Strengths and Limitations

Despite the existence of ten exposure measures, most depend on data that are measured and processed, not in real-time; hence, the extent of the lag may be a limitation for surveillance. Nearly all the measures are based on limited temporal and geographic information. Each specific measure must be assessed with the outcome to be evaluated e.g., streamflow and discharge data above a specific threshold may be used for occupational injuries.

Table 8. Measures of flood-related exposures

Measurement Variable	Description	Strengths of Measures	Weaknesses of Measures	Timescale	Smallest Geographic Unit available	Measured or modeled?	Data Source Options
Events	Discrete time capture of particular floods or hurricanes	Discrete time period – requires defining a time period for the outcome High water mark surrogate for water level.	Limited temporal and geographic information May be challenging to “detect” health outcomes Challenging to reduce relevant data e.g., high-water marks at specific locations	Event periods	Area	Measured	Storm Events Database | National Centers for Environmental Information (noaa.gov); Flood Event Viewer (usgs.gov)
Flood hazard composite index	Maps of combined flood hazard data sets	Summarized index if used as continuous measure can be combined with a threshold		N/A	State; County: City	Based on modeled flood zones	Coastal Flood Exposure Mapper (noaa.gov)

Measurement Variable	Description	Strengths of Measures	Weaknesses of Measures	Timescale	Smallest Geographic Unit available	Measured or modeled?	Data Source Options
Designated flood area, as number of people, housing units or square miles within	Maps of areas with likelihoods of floods	Areas defined by spatial variable e.g., county FIPS Available by square mile	Limited years and geographic information Measures flood vulnerability rather than direct exposure	N/A	State; County	Based on modeled flood zones	National Environmental Public Health Tracking Network Data Explorer (cdcgov);
Inundation depth, for coastal areas and lakes	Total water that occurs on normally dry ground as a result of storm tide	Easy to conceptualize	Limited to coastal areas, in general.	Daily	Geographic specific along water body	Modeled	CERA - Coastal Emergency Risks Assessment (coastalrisk.live); Inundation Dashboard - NOAA Tides & Currents; Flood Inundation Mapper (usgs.gov)
Precipitation amount	Precipitation totals measured	Can be coupled with NWS flash flood warnings	Temporal selection dependent on outcome	Daily; Monthly; Annual ranges	State; County	Measured; Historic; Modeled	National Environmental Public Health Tracking Network Data Explorer (cdc.gov)
Quality or water quality (WQ)	Physical /chemical measurements, fish tissue concentration;	Specific per WQ attributes turbidity, temperature, or total dissolved solids	Requires some biological plausibility Dependent on sampling time	Minutes; Daily	State; monitoring sites	Measured; Historic; Modeled	USGS | National Water Dashboard; Water Quality Data Home

Measurement Variable	Description	Strengths of Measures	Weaknesses of Measures	Timescale	Smallest Geographic Unit available	Measured or modeled?	Data Source Options
	biological and habitat data		and area and type of analytic methods				
Streamflow or discharge	Volume of water passing through a given cross-section per (area) unit time	Might be coupled with injury outcomes at higher thresholds Low streamflow may indicate droughts	Dependent on sampling time and area and type of analytic methods	Minutes; daily; monthly; annually	County; station/monitor level	Measured	USGS | National Water Dashboard; National Environmental Public Health Tracking Network Data Explorer (cdc.gov)
Water elevation or water level	Height, in relation to mean sea level, of floods of various magnitudes and frequencies in the floodplains of coastal or riverine areas or height reached by the water (also	Continuous measure for which threshold can be used	Comparisons to mean sea level may be difficult to understand Dependent upon measurement method – brackish waters may yield inconsistent	Daily; Monthly	Station/monitor level	Measured; Historic;	CERA - Coastal Emergency Risks Assessment (coastalrisk.live); USGS Water Data for the Nation; USGS | National Water Dashboard

Measurement Variable	Description	Strengths of Measures	Weaknesses of Measures	Timescale	Smallest Geographic Unit available	Measured or modeled?	Data Source Options
	known as gage or stage)		measurements with sensors[72]				
Water equivalent	The depth of water that would theoretically result if you melted the entire snowpack instantaneously.	May be a better indicator of severe floods[73]	Limited time and geographic availability	Daily; Monthly	Station/monitor levels	Measured; Modeled (satellite)	Interactive Map (usda.gov); NOHRSC Interactive Snow Information (noaa.gov)

Data sources accessed: October 5, 2023

Kentucky example: Fatalities occurring in Southeastern Kentucky flood remediation efforts

As the climate continues to create stronger and more frequent extreme rainfall events, it is likely that Kentucky workers will be subjected to dangerous flooding with increased regularity. The unique topography of Appalachian Kentucky combined with the region's socioeconomic vulnerability creates a high risk of injury and fatality during these events. The July 2022 flood highlights a need for increased worker safety and organization during disaster cleanup efforts.

Beginning on July 24th, 2022, a massive rainfall event covered a large area of the United States ranging from the Las Vegas Valley to Central Appalachia. Residents of more than 20 states were affected with parts of Las Vegas, Saint Louis, Phoenix, Dallas, Fort Worth, and Huntington, WV, seeing significant flooding. No state, however, matched the destruction seen in Southeastern Kentucky which accompanied the thunderstorms which settled over the region on July 27th and 28th. It was estimated that 14-16 inches of rain fell over two days in this extremely mountainous region creating floods of 15-20 feet in roughly 12 hours with peak crests of 43 feet in some regions.

All deaths that the state officially attributed to flooding were reviewed for this analysis. Of the deaths, the analysis was restricted to those which occurred during or after cleanup operations. Because of the timing of the flooding, most initial victims were at home or attempting to evacuate and were not considered occupational fatalities. Specifically, deaths caused by environmental exposures such as mold or mildew or deaths caused by injuries that occurred during the cleanup process were reviewed.

There were two fatalities which occurred during cleanup operations. An 18-year-old male athlete suffered a fatal heart attack following cleanup operations. It is unclear whether exposures that occurred during cleanup were a contributing factor as the family declined an autopsy to enable donation of organs. After three days of volunteer cleanup work, he complained of feeling unwell. The young man was transported to intensive care and spent four days on a ventilator before dying. The official cause of death was anoxic brain damage with cardiac arrest being a contributing cause. The second fatality occurred when a 76-year-old male fell into a creek from a crossbeam while attempting to repair a bridge damaged by flooding. This gentleman was the owner and operator of a local trucking and construction company. The official cause of death was blunt force trauma to the torso.

This investigation highlights a clear need for observation and organization of volunteer cleanup work. As it stands now, independent volunteers conducting cleanup are not considered workers – except those who are volunteering under the aegis of a larger organization such as The Red Cross or The Salvation Army. Thus, it is unclear how informal groups such as churches or high school groups would be counted under these standards. Kentucky is one of a limited number of states which employs a full-time Emergency Management Volunteer Coordinator. Working with this coordinator and the Kentucky Emergency Management office to create standards for volunteering as well as the collection of volunteer information was a logical first step towards the protection of cleanup workers.

Identifying partners

One way to make progress in the climate and occupational health space is to partner with other groups that are involved in this work. Such partnerships can lead to synergies that move the work further along for both parties. Non-traditional partners (e.g., those your jurisdiction does not typically partner with) may be particularly valuable as they might have alternative data sources, additional networks, and diverse perspectives. We encourage you to consider groups outside of your usual partner set for this work and to expand your networks, where possible (see Appendix 2 for a list of questions to ask potential partners).

Partners could be groups working on equity, environmental justice, or labor issues. Unions (e.g., The American Federation of Labor and Congress of Industrial Organizations [AFL-CIO] , The International Association of Fire Fighters [IAFF], etc.), non-profits (e.g., National Resource Defense Council [NRDC]), Total Worker Health Centers, Federally Qualified Health Centers (FQHCs) – especially those that do outreach with farm worker populations – and state climatologists are examples of potential partners that share the priorities of protecting workers from the effects of climate . Local employers with at-risk workers might also be interested in partnering on these topics.

Many data providers are potential partners. These might include your state poison control center, local preparedness organizations, and your state-level EPHT, CRSCI, or CAP/RISA program.[1] Departments of workforce development, the National Guard, and the Army Corps of Engineers are all potential partners as well. Give some thought to the needs of your region when considering where to look for partnerships. Table 9 (below) provides some examples of partnerships categorized by their level (i.e., national and state). Please note that this table is intended to be suggestive, not exhaustive.

Dissemination

Local and state health departments play an important role in disseminating information on climate-change related health impacts for workers, as they are uniquely positioned to tailor recommendations based on the industries and vulnerabilities of their region. Examples of meaningful collaboration with different sectors can be found in the CDC's Climate and Health Guide for Cross-Sector Collaboration.[74]

Surveillance data can inform emergency preparedness and response efforts, as indicated in the heat case example from Louisiana (above). Publishing manuscripts or reports can be valuable for policymakers but are insufficient as a dissemination strategy for worker groups. Translating surveillance data for other audiences will require data visualization, plain language, and storytelling. Local and state health departments should actively communicate this information through accessible channels, including partnerships with labor organizations, advocacy groups, and employers.

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[1] Details of these programs are provided in the "Current work and resources" section of this document.

Table 9. Examples of partnerships categorized by their level (i.e., national and state)

	National	State
Organizations	• Bureau of Labor Statistics (BLS) • National Institute for Occupational Safety & Health (NIOSH) • Occupational Health and Safety Administration (OSHA) • Environmental Protection Agency (EPA) • The Centers for Disease Control and Prevention (CDC) • National Oceanic and Atmospheric Administration (NOAA) • The National Weather Service (NWS) • United States Department of Labor (USDOL) • Federal Emergency Management Agency (FEMA) • National Environmental Public Health Tracking (EPHT) • Climate-Ready States & Cities Initiative (CRSCI) • Army Corps of engineers • National Guard • National Poison Data System • Agency for Toxic Substance and Disease Registry (ATSDR) • Center for Protection of Workers Rights (CPWR) • Unions (e.g., AFL/CIO, IAFF, UFCW, etc.) • Migrant Clinicians Network • National Resources Defense Council (NRDC) • Climate Adaptation Partnership/Regional Integrated Sciences and Assessments (CAP/RISA) Programs National Fire Protection Association (NFPA) • Other national NGOs (e.g.,ISeeChange) Public Health Extreme Events Research (PHEER) network	• Health interview systems • State OSHA offices • Departments of natural resources • Departments of workforce development/labor • Departments of agriculture • State climatologists • Emergency management Public Health Emergency Preparedness programs within STLT health departments Public Works • Poison control centers • University environmental programs • University occupational safety programs • Energy or weatherization groups • Local labor programs (e.g., Worksafe in CA) • Total Worker Health Centers • Federally Qualified Health Centers (FQHCs) • Local National Guard • Physician groups

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