Summary

Pacific Northwest Drought and Human Health Workshop
19–20 October, 2022
Portland, Oregon

Prepared by the Oregon Climate Change Research Institute in partnership with the National Integrated Drought Information System and University of Nebraska Medical Center

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Introduction

Drought can have substantial negative effects on human health, creating challenges for public health departments, emergency managers, and healthcare providers. For example, drought can lead to decreased water quantity and quality, increased incidence of illness or disease, increased mortality rates, and adverse mental health outcomes, especially as livelihoods are affected.

On 19–20 October, 2022, the National Integrated Drought Information System (NIDIS; www.drought.gov) and the University of Nebraska Medical Center co-led the Pacific Northwest Drought and Human Health Workshop in Portland, Oregon. The workshop was intended to identify gaps and needs, opportunities for collaboration, and ways to integrate the health sector and existing drought activities.

To provide participants and others with a better understanding of the effects of regional drought on human health, encourage collaboration, and inform strategies for minimizing the negative effects of drought on human health, this summary highlights the major points raised during presentations and panel discussions at the workshop (see Appendix 1). Additionally, three speakers capitalized on the invitation to include an extended abstract of their presentation in this summary.

We thank Nicholas Kimutis for his patient and skillful synthesis of the workshop presentations.

Major Points from Presentations, Panels, and Subsequent Discussion

Points are grouped in chronological order by topic.

Intersection between drought and human health

Jesse Bell, University of Nebraska Medical Center, College of Public Health

Points raised

- The effects of drought can be as severe as those of wildfires, floods, and other hazards, although they tend to accrue more slowly. "Floods kill people, but droughts destroy civilizations." Drought often affects human health indirectly, such as through famine and the increased incidence of infectious, chronic, and vector-borne diseases. Moreover, drought affects both physical and mental health. For example, farmers were four times more likely to report stress during periods of drought. These indirect effects can be difficult to incorporate into estimates of the financial costs of drought.
- Drought is defined in numerous ways and with diverse metrics or indices. Accordingly, selection of drought data for research on the nexus between drought and human health can be challenging. Among the many considerations are whether the data are publicly available, whether the extent of the data is regional or national, and the approximate duration of drought that is applicable to the target human health metric.

Opportunities

- The exposure of human populations to drought is highly variable in space and time, and is not equitable among demographic groups. Improved projections of drought can increase preparedness not only for physical but also for mental health challenges.

Environmental justice and drought

Alida Cantor, Portland State University
Ira Cuello-Martinez, Piñeros y Campesinos Unidos del Noroeste
Melissa Haeffner, Portland State University
Rose Poton, Oregon Water Futures Project
Alai Reyes-Santos, Oregon Water Futures Project

Points raised

- In autumn 2020, farm workers in Oregon, many of whom are Latino or undocumented, were exposed to both COVID-19 and unhealthy air as a result of wildfires. Workers received little to no guidance from the Occupational Safety and Health Administration, air quality monitoring was limited, and few N95 respirators were available. "Regulation without enforcement [and protection from retaliation] is just a suggestion."
- Piñeros y Campesinos Unidos del Noroeste (PCUN; pcun.org) seeks to strengthen a "right to refuse work" statute and to develop federal heat and smoke standards.
- Discussion about environmental justice, including equitable access to water, requires discussion about race and nationalities. Justice means changing societies, not only individuals. Because the effects of drought are not equitable, discussion about drought must begin with climate justice.

Opportunities

- Oregon recently adopted the strongest state-level heat and smoke standards in the country

(osha.oregon.gov/OSHARules/adopted/2022/heat-wildfire-smoke-rule-summary-2022.pdf).

- Enable communities to drive public health research and communication of the research. Latino farmworkers are experts on the health effects of drought.
- Develop accessible information in people's preferred languages.
- Young people and students often are missing from conversations about environmental justice, and could be included in future discussions.
- Groups that are missing from this workshop and could be approached for subsequent discussions include homeowners whose wells are becoming dry, Klamath Basin tribes, U.S. Bureau of Reclamation staff, and salmon managers. These groups have interests that sometimes compete.

Frameworks for drought response

Gary Bahr, Washington Department of Agriculture
Marnie Boardman, Washington Department of Health
Curtis Cude, Oregon Health Authority
Sheryl Howe, Washington Department of Health

Points raised

- Growers are struggling with multiple extremes, such as snow, drought, and extreme heat.
- The effectiveness of pesticides during drought is unclear.
- Some types of agricultural production may shift from California to Washington, Oregon, and Idaho.
- One in three Washington residents are food insecure.
- Emergency response to drought generally has not followed a public health model, but addressing the effects of drought may lead to a transition to public health frameworks.
- The Washington State Department of Health provided a $40,000 grant to Whatcom County to install pressure transducers (devices that measure groundwater well levels). The monitoring data will be used for drought contingency planning and preparedness, long-term sustainable management of regional water supplies, and integration with other agency and public platforms. Data are communicated to the public in real time.
- Public health officials are not always trusted as messengers. Academics and government staff also may not be trusted. It is essential to have relationships with individuals and groups that are trusted messengers in a given community.
- Dry wells reduce property values.

Opportunities

- The National Syndromic Surveillance System (www.cdc.gov/nssp/index.html) can be used to identify clusters of symptoms that are characteristic of drought, which in turn can enable a public health response.
- Washington's 2021 Healthy Environment for All (HEAL) Act (ecology.wa.gov/About-us/Who-we-are/Environmental-Justice/HEAL) requires that state agencies' strategic plans describe how environmental justice will be applied to agency activities. Agencies must create and adopt a plan for engaging with overburdened communities and vulnerable populations as they evaluate new and existing activities and programs, and they must offer tribal consultation for all significant agency actions, programs, and distributions of state funds that affect tribes' rights and interests in their lands. Moreover, agencies must assess

environmental justice when considering significant actions, incorporate environmental justice into financial planning and decisions, and report regularly on their progress with respect to environmental justice.

- Domestic wells are not covered by the Safe Drinking Water Act (www.cdc.gov/healthywater/drinking/public/regulations.html). However, the U.S. Environmental Protection Agency can provide clean drinking water to owners of domestic wells. Public health cannot be used as a mechanism to regulate stream flows.

Air quality

Kyle Chapman, Oregon Institute of Technology
Courtney Farrell, California State University, Chico
Dmitri Kalashnikov, Washington State University, Vancouver
Diana Rohlman, Oregon State University

Points raised

- The effects of fine particulate matter ($PM_{2.5}$) and ambient ozone interact to exacerbate negative consequences on public health.
- Concentrations of $PM_{2.5}$ historically were greatest in winter, but are becoming more prevalent in summer. Larger geographic regions are being exposed to unhealthy concentrations.
- It is critical to set expectations when conducting public-health messaging.
- Jargon is terrible when talking to the public. Be aware of words that have multiple meanings.
- Health literacy and environmental health literacy are not correlated.
- Air quality monitoring is biased towards urban rather than rural areas.

Opportunities

- Prescribed fires tend to burn at lower intensity, and produce lower concentrations of $PM_{2.5}$, than wildfires.
- There is little to no monitoring of many air pollutants, including semi-volatiles. Although monitoring is expensive, awareness is growing that monitoring would be quite useful.

Role of the National Integrated Drought Information System (NIDIS) in drought and health

Britt Parker, NOAA National Integrated Drought Information System and Coooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder

Points raised

- Local weather drives day-to-day wildfire activity, but seasonal weather also plays a role.

Opportunities

- NIDIS is trying to make the links among drought, wildfire, and human health more explicit. Associated activities including convening regional workshops such as this, sponsoring research on these topics, and maintaining related materials on drought.gov.
- Because the effects of drought can manifest slowly, NIDIS is conducting annual impact assessments in some regions.

Observed and projected drought conditions in the Pacific Northwest

Nicholas Bond, Washington State Climatologist, University of Washington
Larry O'Neill, State Climatologist of Oregon, Oregon State University

Points raised

- Spring 2021 was notably dry.
- Summer precipitation in the Pacific Northwest is decreasing over time, and summer temperatures are increasing.
- Drought is expected to become more common, although total precipitation is projected to be stable, in part because air holds more water as it becomes warmer.
- Given a moderate emissions scenario (RCP 4.5), climate models project temperature increases of 2–5°F across the Pacific Northwest by 2100.
- Given a scenario of continued increases in emissions (RCP 8.5), climate models project temperature increases of 5–10°F across the Pacific Northwest by 2100.
- Likely changes include less snow, more rain-on-snow events, and earlier snowmelt. Peak streamflows will shift from May to February.
- Evapotranspiration is projected to increase by 10–20 percent by 2100.
- Hydrological extremes, both drought and flooding, will intensify.

Opportunities

- Stream flows can be a useful way to examine different types of drought.
- Snowpack can be used as a reliable indicator of summer drought.

Drought and mental health

Don McMoran, Washington State University Extension

Points raised

- Farmers are irrigating in October for the first time. Many farmers will say they don't believe that the climate is changing, but recognize that the weather has changed over decades.
- The greatest three stressors to farmers are workload, lack of time, and financial concerns.
- Women attempt suicide more often than men, but men are more successful. Children are thinking about suicide more often. Programs such as 4-H tend to increase children's potential for success.

Opportunities

- Farmers in western Washington may benefit from a warming climate because they can begin growing crops that currently are grown primarily in California.

Drought, groundwater, and river restoration

Adell Amos, University of Oregon

Points raised

- Prior appropriation of water rights in the western United States is different from the land-based system in the eastern United States. Prior appropriation recognizes that water is a public resource rather than a private resource.
- Water rights are subject to public interest review: public welfare, safety, and health. Public interest review is a mechanism by which the public participates in discussion or decisions about water rights.
- Pressures on surface water often lead to groundwater withdrawal. Groundwater is less regulated than surface water.
- In the context of drought, dams are controversial. Many believe that the solution to drought

is more water storage.

- In a permitted system, markets can affect water allocation. Water-market solutions can affect both private and public water sources. Not all populations are included in market operations, or in collaborative processes. There is no single definition of "the public."
- Water resources departments traditionally managed water rights rather than water itself.
- Agencies tend to feel that their authority is relatively narrow, but water issues often transcend the authority of any given agency.

Opportunities

- "While one function of law is to give stability to institutions and predictability to the results of action, often the strength of law will lie not in immutability but in capacity for change and flexibility in the face of new forces." – Frank Trelease
- Agencies and other entities in many basins are observing conflict in the Klamath Basin, don't want to become the next center of conflict, and therefore are more willing to collaborate.

Impact of drought on tribal nations

Gwen Carter, Nez Perce Tribe
Dan Martinez, Warm Springs Tribes
Gillian Mittelstaedt, Tribal Healthy Homes Network
Melodi Wynne, Spokane Tribal Network

Points raised

- Drought and responses to drought have cultural impacts.
- Traditional practices include both farming and gathering, not just farming. Drought affects both practices.
- Drought is both felt and seen.
- The potential for tribes to be exposed to aerosolized tailings from uranium and lithium mining is increasing.

Opportunities

- Capitalize on the wisdom that can emerge from the unfortunate history of trauma.

Air Quality and Hospitalizations in Southern Oregon

Kyle Chapman, Adelaide Clark, and Kerry Farris
Oregon Institute of Technology

Wildfires pose a significant threat to social, economic, and ecological systems. In addition to destroying land and property, wildfires disperse dangerous particulate matter over wide geographic regions, which greatly contribute to air pollution. Wildfire regimes in North America are strongly influenced by climatic controls, especially drought (Swetnam and Baisan 2003, Heyerdahl et al. 2008). In western coniferous forests, drought-stressed trees are more susceptible to mortality by nutrient loss, insect outbreaks, or disease infection (Heyerdahl et al. 2008, Vose et al. 2016). Combined, these stressors can lead to extensive patches of mortality, which significantly increase fuel loads and fire susceptibility (Heyerdahl et al. 2008, Vose et al. 2016), leading to more frequent, severe, and larger wildfires that significantly impact air pollution. In 2012, half of all fine particulates emitted in California were from wildfires, exacerbated by drought (Black et al. 2017). Nationwide, 20% of the total $PM_{2.5}$ emitted during 2014 was attributed to wildfire emissions (Requia et al. 2021). Climate change is projected to worsen these emissions, especially in the western United States, where the frequency, extent, and severity of wildfires are expected to increase (Flannigan et al. 2000, Kinney 2008, Abatzoglou and Williams 2016, Reid et al. 2016, Black et al. 2017, Cascio 2018). In the Pacific Northwest alone, the area burned is expected to increase by 80 percent by 2050 (Kim et al. 2018). Consequently, $PM_{2.5}$ is projected to be 160 percent higher by 2046–2051 (Williamson et al. 2016, Lassman et al. 2017, Sheldon and Sankaran 2017, Alonso-Blanco et al. 2018, Larsen et al. 2018, McClure et al. 2018, Requia et al. 2021, Ye et al. 2021).

Exposure to wildfire-related emission sources is a growing public health concern, not only because it increases healthcare utilization, particularly in the Pacific Northwest, but also because it has direct consequences on human health (Makkonen et al. 2010, Dohrenwend et al. 2013, Urbanski 2013, Kochi et al. 2016, Cascio et al. 2018, Hutchinson et al. 2018, Nelson 2020, Ye et al. 2021). Each year, 339,000 premature fatalities are due to short-term exposures to high concentrations of $PM_{2.5}$ from wildfires, which can lead to severe health effects such asthma, heart attacks, strokes, and impaired lung function (Kinney 2008, Reid et al. 2016, Ye et al. 2021, Borchers Arrigada et al. 2019, Matz et al. 2020, Requia et al. 2021). Patients seeking treatment for a variety of respiratory diseases have a major impact on healthcare operations, including emergency room visits, hospital admissions, and outpatient visits (Künzli et al. 2006, Viswanathan et al. 2006, Johnston et al. 2007, Delfino et al. 2009, Tham et al. 2009, Henderson et al. 2011, Dohrenwend et al. 2013, Dennekamp et al. 2015, Reid et al. 2016, Black et al. 2017, Ye et al. 2021). The burden of treating chronic illnesses and less serious respiratory problems may increase workload for hospitals. Similar to the demands placed on hospitals during COVID-19 waves, individuals with less-serious diseases may not receive the care they require, or hospitals may not have the resources to provide that care. Additionally, the issue of increasing staff requirements and resource distribution during customarily reduced-demand seasons is now raised by wildfires. In the past, hospital systems were ready for increased demand and use of respiratory treatment throughout winter. However, the risk of wildfires drastically rises in summer, when rates of respiratory sickness normally decline.

Before steps can be taken to strengthen health care systems' reaction to wildfires, the potential effects of wildfires on the number of respiratory patients must be better understood. The objective of our research was to quantify the effect of wildfire-generated $PM_{2.5}$ on hospital respiratory

admissions. Such information can be used by hospitals to create contingency plans for wildfires. Here, we present the results from our analysis of one high-fire year (study 1) and a second analysis that examined a four-year period that encompassed both high and low fire years (study 2).

Study 1

The year 2018 was a particularly high fire year, with over 90 calendar days of smoke exposure. For this initial study, daily regional hospital burden (the dependent variable) was estimated by summing the number of respiratory patients admitted to each of the three hospitals from 1 July through 30 September. These dates corresponded to elevated $PM_{2.5}$ concentrations from wildfires. The daily respiratory patient burden was considered excessive if it surpassed the 80th percentile of the observed 92-day distribution. A generalized linear model with a binomial error structure was used to estimate the probability of exceeding respiratory hospital burden as a function of same-day, 3-, 5-, 7-, 9-, and 11-day $PM_{2.5}$ concentration averages. The probability of exceeding patient burden increased as $PM_{2.5}$ and the duration of poor air quality increased. For example, a single-day mean $PM_{2.5}$ concentration of 24 $\mu g\ m^{-3}$ (midpoint of the yellow or moderate category) resulted in a 37 percent probability of exceeding hospital burden, but the probability jumped to 47 percent if the single-day $PM_{2.5}$ concentration was 201 (midpoint of the purple or very unhealthy category). Similarly, poor air quality that persisted beyond a single day increased the probability of exceeding burden. For example, a single-day mean $PM_{2.5}$ concentration of 103 $\mu g\ m^{-3}$ (midpoint of the red or unhealthy category) resulted in a 41 percent probability of exceeding patient burden, but a three-day to five-day mean concentration of 103 $\mu g\ m^{-3}$ resulted in a 46 percent and 47 percent probability of excessive burden, respectively. Similarly, if these mean $PM_{2.5}$ concentrations persisted for 7, 9, or 11 days, the probability of excessive burden increased to 49, 52, and 53 percent, respectively.

Study 2

Although the 2018 analysis is helpful for understanding the relation between a high fire season and respiratory hospitalizations, additional analysis was needed to better understand the relationin less severe years. A second analysis was conducted with data that included $PM_{2.5}$ concentrations and respiratory hospitalization records for the years 2016–2018. Again, a generalized linear model with a binomial error structure was used to estimate the probability of exceeding respiratory hospital burden as a function of same-day, 3-, 5-, 7-, 9-, and 11-day $PM_{2.5}$ concentration averages.

Lag periods from 3 to 11 days had the highest correlations between mean $PM_{2.5}$ concentrations and hospital burden, and were used to construct predictive curves representing varying durations of mean $PM_{2.5}$ intensities (Figure 1). At $PM_{2.5}$ concentrations greater than 55.5 $\mu g\ m^{-3}$, which correspond to the lower bound of red, or unhealthy on the air quality index, probabilities of regional hospitals exceeding the 80th percentile of respiratory patients sharply increase, regardless of the duration (Figure 1). However, as the duration of poor air quality (e.g., lag period) increased, so did the probability of reaching the 80th percentile threshold (Figure 1). Therefore, a single day mean $PM_{2.5}$ concentration of 125 $ug\ m^{-3}$ (midpoint of the red or unhealthy category) resulted in a 54 percent chance of meeting or exceeding 10 respiratory patients. If this same mean concentration persisted for 11 days, the probability of exceeding the burden threshold increased to 64 percent (Figure 1).

Overall, the likelihood of hospitals in Southern Oregon meeting or exceeding their capacity for respiratory patients during wildfire smoke events is high. Even a single day of smoke in the purple

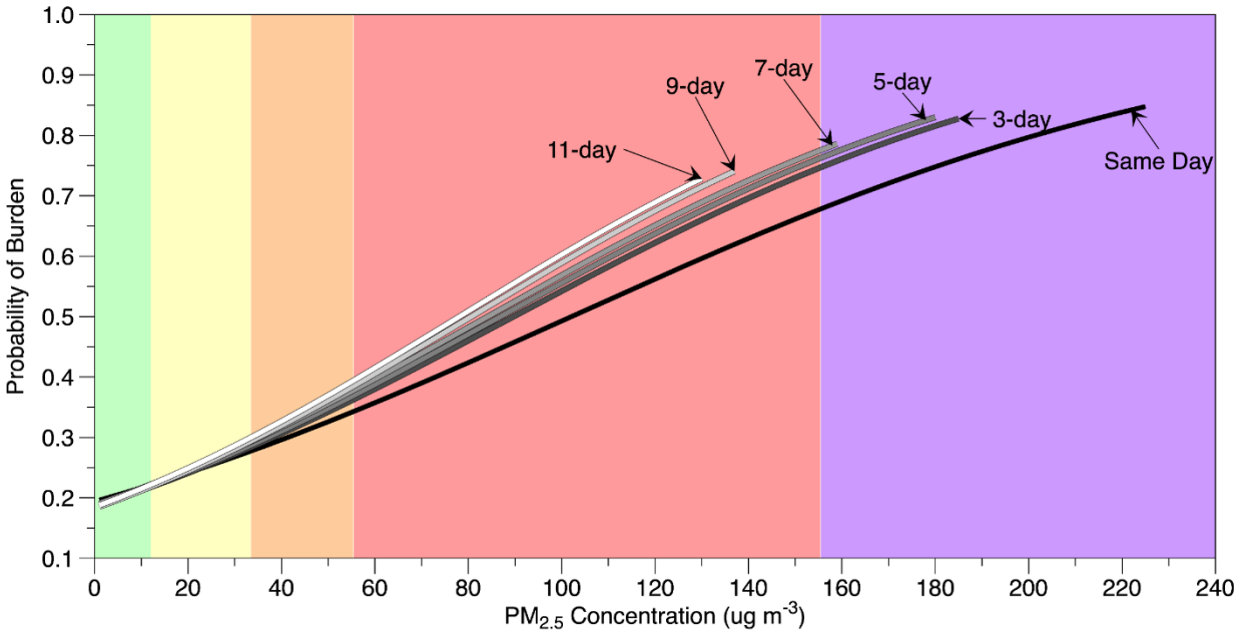

Figure 1. Logistic regression of the probability of hospitals exceeding a respiratory patient threshold (80th percentile) given averaged lagged $PM_{2.5}$ concentrations over various durations. Colored regions indicate U.S. Environmental Protection Agency Air Quality Index categories (green = good; yellow = moderate; orange = unhealthy for sensitive groups; red = unhealthy; purple = very unhealthy).

(very unhealthy) category presents a three-fold increase compared to a day in the green (good). The longer the duration of the smoke event, the lower the concentration must be to have the same effect on hospital capacity. This effect is most notable when the $PM_{2.5}$ concentration rises above 100 μg m^{-3}. In the study, there were as many as 32 days in one year on which the PM2.5 concentration exceeded 100 μg m^{-3}. These results are consistent with some aspects of previous research. For example, studies in Australia, Brazil, and California (USA) found significant increases in respiratory hospitalizations when $PM_{2.5}$ increased (Viswanathan et al. 2006, Johnston et al. 2007, Tham et al. 2009, Dennekamp et al. 2015, Hutchinson et al. 2018, Requia et al. 2021, Ye et al. 2021). Although studies in Australia and Brazil found that the effects either dissipated or decreased after two days (Johnston et al. 2007, Tham et al. 2009, Abatzoglou and Williams 2016, Requia et al. 2021), a study in California found a significant three-day lag (Viswanathan et al. 2006, Hutchinson et al. 2018). The results of study 2 provided evidence of both same-day surges and multiple-day surges in respiratory hospitalizations. This presents a major problem for health care systems. As drought conditions continue to worsen, the likelihood of more years with more days at or exceeding the observed conditions in this study increases. For a variety of reasons, including the effects of wildfires on human health, ecological health, and healthcare systems, preparation and intervention are needed immediately to lessen the effects of the drought on the Pacific Northwest. Institutions involved in public health and health care can use this information to educate the public, develop and evaluate programs, and guide business decisions.

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Applying Environmental Health Literacy to Air Quality During Wildfires

Diana Rohlman, Pacific Northwest Center for Translational Environmental Health, Oregon State University, Corvallis, Oregon
Katherine Duarte, Klamath County Public Health, Klamath Falls, Oregon
Lynda Crocker Daniel, Oregon Health & Sciences University, Klamath Falls, Oregon
Kim Brown, Pacific Northwest Center for Translational Environmental Health, Oregon State University, Corvallis, Oregon

Environmental health literacy (EHL) is fundamentally defined as the ability to understand how the environment can impact health (Hoover 2019). EHL builds from basic concepts of health literacy and recognizing and understanding environmental health concepts, applying and analyzing data to reduce exposures and engage in health-protective behaviors (Finn and O'Fallon 2017). These skills mimic those in health literacy, which begin with functional literacy, progress to interactive literacy, and expand into critical literacy (Nutbeam 2000).

Environmental health literacy is one method for addressing impacts of environmental hazards on human health. Messaging developed with tenets of EHL can build from progress made in basic research that connects environmental risk factors to human health; EHL leads to understanding of how individuals and communities can make informed decisions to reduce their risk (Finn and O'Fallon 2017).

Wildfire smoke is a complex mixture of pollutants that people are exposed to through the air they breathe, and even through touching ash and wildfire debris. When surveyed, Oregon residents identified outdoor and indoor air quality as the major way in which wildfires had impacted them (Oregon Department of Land Conservation and Development 2022). A second survey identified needs regarding access to information during smoke events and a need for additional health protective behaviors and risk reduction methods (Coughlan et al. 2022). Although methods to reduce exposure to wildfire smoke are available, people continue to face challenges of finding accessible, understandable, trustworthy, accurate, and appropriate information. EHL can address some of these challenges by ensuring the language used in messaging is understandable, a range of options are available to ensure accessibility, and sufficient information is provided to help people make informed decisions about which methods are appropriate for reducing their exposure to wildfire smoke.

Messaging around wildfire smoke exposure and other environmental health hazards is difficult given the words often chosen. Educational attainment is not always associated with concurrent environmental health literacy, as is typically the case with health literacy. One reason for this may be the way in which language is used in the field of environmental health. For example, one tool to measure EHL, the Short Assessment of Environmental Health Literacy, uses word recognition (Rohlman et al. 2022). In a survey of 869 adults, the SA-EHL revealed that several words commonly used in environmental health and wildfire smoke messaging, including risk, error, and response, had different definitions in the public than in the scientific literature (Rohlman et al. 2022). For example, about 80 percent of participants defined risk as a hazard rather than as the possibility of an adverse outcome. As a result, use of these words may render messaging less effective (Rohlman et al. 2022).

Klamath County, Oregon, has high rates of infant mortality, preterm birth, and low birthweight compared to the rest of the state. Additionally, the county is subject to an increasing number of days where air quality is considered unhealthy, or worse, due to wildfire smoke (Oregon Department of

Environmental Quality 2021). Preliminary studies in the United States and other countries identified correlations between exposure to wildfire smoke and poor infant health outcomes, to include preterm birth and low birthweight (Amjad et al. 2021). Klamath County Public Health partnered with Oregon State University to develop an online infographic to highlight methods to reduce exposure to wildfire smoke during and after pregnancy (Figure 1). The infographic was designed to be accessible, understandable, and appropriate, and relied on trustworthy sources to ensure accuracy. This infographic, which was built on principles of EHL, is available in English and Spanish and has been widely distributed through Klamath County and elsewhere in Oregon.

Figure 1. Excerpt from the Wildfire smoke and your baby infographic. Available in English (https://beav.es/iN4) and Spanish (https://beav.es/53W).

With warming temperatures and reduced rainfall occurring in the Pacific Northwest, wildfire season has lengthened, and the magnitude of wildfires has increased, leading to poor air quality throughout the region. Environmental health literacy is one approach to increase access to information and inform health-protective behaviors.

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Drought, Groundwater, and River Restoration: Connecting Water Law and Policy to Human Health Impacts of Drought

Adell L. Amos, University of Oregon
Michelle Smith, Environmental and Natural Resources Law Center, University of Oregon School of Law

Background

Drought is a normal part of most climates and a particular feature of arid climates, such as those that characterize the western United States. However, climate change is increasing the frequency, severity, and length of droughts. In 2022, 40 percent of the United States experienced drought and 93 percent of the western United States experienced abnormally dry conditions. In the Pacific Northwest, the timing and type of precipitation is changing. Warmer winters and springs are resulting in less snowpack and earlier snowmelt, longer and drier summers, and more intense precipitation in winter. These changes necessitate a shift in how society views and manages water.

Drought has significant economic and public health costs. The federal government identifies drought as the second costliest type of natural disaster. Combined, the last 27 major drought events have cost over $200 billion (Lookadoo and Bell 2020). However, understanding of drought's impacts and its management has been less developed than that of other natural disasters. Drought is slow to arise and persists over long periods, with no clear end point (Wilhite et al. 2007), and the impacts of drought are typically secondary. For example, droughts increase the severity and incidence of wildfires, but the impacts of wildfires, such as poor air quality, loss of human life, and property damage, are typically not linked with drought.

Although these characteristics make it difficult to correlate drought with its impacts, the ecosystem impacts of drought have been well documented, and drought has been linked to a variety of public health impacts (Lookadoo and Bell 2020). These human health-related impacts encompass the full range of public health concerns, including but not limited to water insecurity (Lombard et al. 2021, Rizutto and Magill 2022), power production changes (Irfan 2022), air quality issues, mental health impacts, infectious disease; food insecurity, migration patterns, and land subsidence. The connections between drought and the health impacts associated with less-discussed water law concepts, such as conjunctive management of surface and groundwater sources and the impact of drought on river restoration efforts, are often tied to human health impacts (Van Wing 2021).

Vulnerability to the public health impacts of drought is tied to social determinants (Bell et al. 2016). Among the social determinants that can impact vulnerability to drought are age, economic status, profession (e.g., farmers and professions that are reliant on water availability), and demographics. Rural communities that often have less infrastructure investment, and typically have smaller and often unsupported water systems, are also more vulnerable to drought (Lookadoo and Bell 2020).

Drought Policies

Despite being a normal and predictable part of most region's climate, drought is principally managed as an emergency. Drought conditions are largely ignored by policy makers and resource managers until their impacts are most acute, at which point policy interventions focus on managing impacts until drought subsides (Wilhite 1997). As one article noted, current drought policies are reactive and not proactive (Neuman 2003).

In the western United States, drought policy has largely centered on managing water resources within existing legal frameworks—the state's management of water is a primary lever for addressing water scarcity associated with drought (Wilhite 1997, Neuman 2003). These interventions seek to ameliorate drought through the reallocation of water with the goal of helping water users to access water in times of water shortage. Prior to a drought declaration, these approaches act within existing laws to manage water scarcity—curtailing water users based on priority (Neuman 2003). After a drought declaration is issued, drought policies focus on temporary measures that provide regulatory flexibility to respond to water scarcity and, when water is not sufficient to meet existing needs, reduce demand and provide financial assistance to communities impacted by drought (Neuman 2003). Oregon's drought management policies exemplify this approach: the governor's drought declaration triggers a suite of regulatory authorities to address immediate water shortage, including flexibility in water allocation, conservation measures, and financial assistance (Neuman 2003).

Under this crisis approach, after drought conditions subside, water management reverts to the ordinary water management frameworks. This approach creates a seesaw of management policies—where responses occur only during acute conditions and then fade away until the next drought occurs. This cycle has been aptly described as the "hydro-illogical" cycle (Wilhite 1997). As a result, water management approaches to drought generally deal directly with water scarcity and do not expressly address public health impacts of drought. There is a need to shift drought response from an emergency-focused reaction to proactive planning and preparation built into existing water management (Neuman 2003, Mount et al. 2015).

Alternatives to Existing Policy Responses

To address the disconnect between drought management and public health concerns there are mechanisms discussed above that pull from public health authorities discussed below. In addition, mechanisms that pull from existing water law and policy try to achieve this kind of integration.

Public Health Authority Interventions

The literature identifies a need to enhance policies to prepare for and address these health impacts. Public health and drought-related policy interventions to explore include declarations of public health emergencies associated with drought, incorporating drought and climate into public health planning (CDC 2018), classifying drought as a public health threat, and building a network of professionals to support drought response. All state health departments complete hazard vulnerability assessments, which identify threats that might impact the state. The identification of hazards then triggers preparedness planning requirements. Integrating drought experts and stakeholders into these processes can support recognition of drought as a public health hazard. The Centers for Disease Control and Prevention's Community Assessments for Public Health Emergency Response can support drought planning efforts. This tool provides data on a community's preparedness for an emergency and has been used to assess drought preparedness in California and in Oregon.

Water Law and Policy Interventions

Water law and policy contains a suite of pathways that can better align water management with current and projected drought conditions and minimize impacts of water shortages. Increasing communities' ability to plan for and manage water within drought conditions will help alleviate

public health risks associated with drought. These pathways also provide opportunities for the broader public to engage with water management.

Existing water planning frameworks provide a process for states to align ongoing water management with drought and plan for drought's associated public health components. For example, Washington recently authorized the state's water management agency to support water users in developing resilience to drought before drought conditions emerge. The state also expanded its tools to address water shortages during drought, including increasing the amount of available water through long-term leasing and contracts (Sessions and Marti 2020).

In addition to water planning under state water codes, nearly every western state has a public interest review as part of its water rights permitting process (Bell and Johnson 1991). These reviews reflect an understanding of water as a public resource. The reviews also recognize that granting appropriations of water rights impacts the entire public and that the state, as the trustee for the water resources, carries an obligation to evaluate the appropriations considering the overall public interest. These standards look at whether a proposed water use preserves the public welfare, safety, and health—a direct tie to the human health impacts of drought (Bastastch 2006).

Existing drought management also amplifies inequities embedded within water policy. For example, conjunctive management of surface and groundwater supplies is often used to augment surface water supplies with groundwater sources during drought (Petersen-Perlman et al. 2022). Frequently, non-water rights holding communities rely on unpermitted groundwater rights as a source of freshwater. Therefore, as reliance on groundwater supplies increases during drought, there can be direct impacts to human health in communities that rely on those groundwater sources. Use of existing tools in the groundwater management governance provisions of state water law could create opportunity to address public health concerns in water management. Enforcement of tribal water rights also provides a pathway to address public health impacts faced by indigenous communities.

Federal Responses to Drought and Human Health Impacts

Drought is typically managed at the state level. However, there are several federal roles in drought policy, including monitoring, increasing water availability through water storage projects, monetary payments for losses tied to drought, and, more recently, supporting planning and preparedness (Congressional Research Service 2022).

As with states, federal approaches focus on responding to drought conditions and offsetting their effects. However, more recently, federal efforts have invested in building long-term water resilience. The White House Action Plan on Global Water prioritizes "achiev[ing] universal access to sustainable, climate-resilient, safe water effectively" and "promoting sustainable management and protection of water resources and associated ecosystems to support economic growth, build resilience, mitigate the risk of instability or conflict, and increase cooperation" (Touton 2022).

Conclusion

State policies must catch up with existing drought realities. Drought is increasing in severity and frequency, but current policies treat drought as an emergency water management problem to be endured until so-called normal conditions return. These policies are costly and unsustainable, and in many cases fail to address drought's myriad impacts. State and federal agencies must begin to utilize existing water law authorities to pair emergency policies with more systemic shifts in water

management that make communities more resilient to drought. As two researchers noted, drought response must shift from "quick-fix approaches" to "consistent long-term tactics" (Lookadoo and Bell 2020). Increasing community water resilience by stabilizing water supply can help reduce drought's public health impacts by making communities less susceptible to water shortages (Lawton 2021). Moreover, expanding the scope of existing tools to include mechanisms in water management and policy will support this more integrated approach to drought and human health.

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Appendix 1. Workshop Agenda

Pacific Northwest Region Drought and Human Health Workshop

October 19-20, 2022
Queen Marie Ballroom
Embassy Suites by Hilton Portland Downtown
319 SW Pine Street
Portland, OR

Meeting Goals

- Provide participants with a better understanding of the health impacts of drought in the Pacific Northwest
- Engage participants across academic, healthcare, public health, and other sectors to encourage cross-sector collaboration
- Showcase best practices on how to reduce health impacts from observed and projected increases in the frequency, duration, and severity of drought
- Discuss strategies for further addressing and minimizing the health impacts of drought

Agenda: Day 1, Wednesday, October 19, 2022

(all times are in Pacific Standard Time)

8:30 AM – 9:00 AM **Breakfast (Continental Breakfast Provided)**

9:00 AM – 9:30 AM **Welcome and Introductions**
Land Acknowledgement Statement by Ryan Sealy, Northwest Portland Area Indian Health Board

9:30 AM – 10:20 AM **Intersection between Drought and Human Health**
Jesse Bell, University of Nebraska Medical Center College of Public Health

10:20 AM – 10:30 AM **Break (Coffee/Tea Provided)**

10:30 AM –12:00 PM **Environmental Justice and Drought**
Alida Cantor, Portland State University
Ira Cuello-Martinez, Pineros y Campesinos Unidos del Noroeste (PCUN)
Melissa Haeffner, Portland State University

Rose Poton, Oregon Water Futures Project
Alai Reyes-Santos, Oregon Water Futures Project

12:00 PM - 1:00 PM **Lunch (Provided)**

1:00 PM – 2:20 PM **Drought Response Frameworks Panel**
Gary Bahr, Washington Department of Agriculture
Marnie Boardman, Washington Department of Health
Curtis Cude, Oregon Health Authority
Sheryl Howe, Washington Department of Health

2:20 PM – 2:30 PM **Break (Snacks provided)**

2:30 PM – 4:00 PM **Air Quality Panel**
Kyle Chapman, Oregon Institute of Technology
Courtney Farrell, California State University – Chico
Dmitri Kalashnikov, Washington State University - Vancouver
Diana Rohlman, Oregon State University

4:00 PM – 4:50 PM **Facilitated Discussion (Identifying Issues and Challenges)**
Tamara Wall, Desert Research Institute

4:50 PM - 5:00 PM **Closing Thoughts and Adjourn**

Agenda: Day 2, Thursday, October 20, 2022

8:30 AM – 9:00 AM **Breakfast (Continental Breakfast Provided)**

9:00 AM – 9:15 AM **Welcome Back & Day 2 Overview**

9:15 AM – 9:45 AM **Role of NIDIS in Drought and Health**
Britt Parker, NOAA National Integrated Drought Information System/Cooperative Institute for Research in Environmental Sciences, CU-Boulder

9:45 AM – 10:40 AM **Observed and Projected Drought Conditions in the Pacific Northwest**
Nicholas Bond, Washington State Climatologist, University of Washington
Larry O'Neill, Oregon State Climatologist, Oregon State University

10:40 AM – 10:50 AM **Break (Coffee/Tea Provided)**

10:50 AM - 11:30 AM **Drought and Mental Health**
Don McMoran, Washington State University Extension

11:30 AM – 12:00 PM **Drought, Groundwater, and River Restoration**
Adell Amos, University of Oregon

12:00 PM – 1:00 PM **Lunch (Provided)**

1:00 PM – 2:30 PM **Impacts of Drought on Tribal Nations**
Gwen Carter, Nez Perce Tribe
David Close, University of British Columbia
Dan Martinez, Warm Springs Tribes
Gillian Mittelstaedt, Tribal Healthy Homes Network
Melodi Wynne, Spokane Tribal Network

2:30 PM – 2:40 PM **Break (Snacks Provided)**

2:40 PM – 4:30 PM **Facilitated Discussion (Focus on next steps, solutions, additional activities)**
Keith Hansen & Rachel Lookadoo, University of Nebraska Medical Center College of Public Health

4:30 PM **Closing Thoughts and Adjourn**

Appendix 2. Participant Affiliations

Affiliated Tribes of Northwest Indians
Benton County Health Department
California Environmental Protection Agency, Office of Environmental Health Hazard Assessment
California State University, Chico
Coalition of Communities of Color
Confederated Tribes of Warm Springs, Oregon
Deschutes County Health Services
Desert Research Institute, Western Regional Climate Center
Nez Perce Tribe
NOAA National Integrated Drought Information System
North State Planning and Development Collective
Northwest Portland Area Indian Health Board
Office of the Washington State Climatologist
Oregon Health & Science University–Portland State University School of Public Health
Oregon Department of Human Services, Office of Resilience and Emergency Managenment
Oregon Environmental Council
Oregon Health Authority
Oregon Institute of Technology
Oregon State University
Oregon Watershed Enhancement Board
Piñeros y Campesinos Unidos del Noroeste (PCUN)
PNW Just Futures Institute for Climate and Racial Justice
Portland State University
Portland State University, Institute for Sustainable Solutions
Scripps Institution of Oceanography
Spokane Tribal Network
State of Oregon, Department of Land Conservation and Development
Tribal Healthy Homes Network / Partnership for Air Matters
U.S. Geological Survey
University of Nebraska Medical Center
University of Oregon
University of Oregon School of Law, Environmental and Natural Resources Law Center
UrbanKind Institute
Verde
Washington Department of Health
Washington State Department of Agriculture
Washington State University
Washington State University, Skagit County Extension
Washington State University Vancouver
Willamette Partnership

Appendix 3. Steering Committee

Adell Amos, University of Oregon
Gary Bahr, Washington Department of Agriculture
Jesse Bell, University of Nebraska Medical Center
Marnie Boardman, Washington Department of Health
Nick Bond, Office of the Washington State Climatologist
Lynny Brown, Willamette Partnership
Karin Bumbaco, Office of the Washington State Climatologist
Polet Campos-Melchor, University of Oregon
Heejun Chang, Portland State University
Dar Crammond, U.S. Geological Survey, Oregon Water Science Center
Curtis Cude, Oregon Health Authority
Celeste Davis, Northwest Portland Area Indian Health Board
Jill Elizabeth, University of Oregon
Erica Fleishman, Oregon Climate Change Research Institute and Oregon State University
Keith Hansen, University of Nebraska Medical Center
Alison Hopcroft, Portland State University
Sheryl Howe, Washington Department of Health
Chas Jones, Affiliated Tribes of Northwest Indians
Molly Baer Kramer, Portland State University
Rachel Lookadoo, University of Nebraska Medical Center
Amelia Marchand, Affiliated Tribes of Northwest Indians
Jeff Marti, Washington Department of Ecology
Alyssa McClean, Oregon Health Authority
Joseph Needoba, Oregon Health and Science University
Craig Nolte, Federal Reserve Bank of San Francisco
Larry O'Neill, Oregon Climate Service and Oregon State University
Britt Parker, National Integrated Drought Information System
Rose Poton, Oregon Water Futures Project
Alai Reyes-Santos, Oregon Water Futures Project
Antoinette Ruiz, Northwest Portland Area Indian Health Board
Ryan Sealy, Northwest Portland Area Indian Health Board
Chantal Wikstrom, Oregon Health Authority