



## Agricultural Employer Perspectives on Occupational Wildfire Smoke Rules

Molly Parker, Janessa M. Graves, Lois James & Julie Postma

**To cite this article:** Molly Parker, Janessa M. Graves, Lois James & Julie Postma (2025) Agricultural Employer Perspectives on Occupational Wildfire Smoke Rules, Journal of Agromedicine, 30:3, 577-590, DOI: [10.1080/1059924X.2025.2465639](https://doi.org/10.1080/1059924X.2025.2465639)

**To link to this article:** <https://doi.org/10.1080/1059924X.2025.2465639>



Published online: 18 Feb 2025.



Submit your article to this journal [↗](#)



Article views: 149



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 1 View citing articles [↗](#)



## Agricultural Employer Perspectives on Occupational Wildfire Smoke Rules

Molly Parker<sup>a</sup>, Janessa M. Graves<sup>b</sup>, Lois James<sup>c</sup>, and Julie Postma<sup>c</sup>

<sup>a</sup>Nursing, Gonzaga University School of Health Sciences, Spokane, Washington, USA; <sup>b</sup>Family Medicine, University of Washington School of Medicine, Seattle, Washington, USA; <sup>c</sup>Nursing and Systems Science, Washington State University College of Nursing, Spokane, Washington, USA

### ABSTRACT

**Objectives:** The purpose of the study was to examine the perspectives of agricultural employers and managers regarding wildfire smoke-related occupational health and safety protections. The aims were to (1) explore implementation and evaluation of the Washington (WA) State Department of Labor and Industries Wildfire Smoke Rule, (2) develop a survey to explore perspectives on the rule, and (3) examine the relationship between occupational roles and knowledge and training received related to components of the rule.

**Methods:** We used exploratory sequential mixed methods, including key informant interviews with industry stakeholders, survey design, and online survey administration to agricultural employers and managers. Thematic analysis of interviews informed survey design. Descriptive statistics and logistic regression were used to analyze survey results.

**Results:** Our team interviewed seven agricultural industry stakeholders. Three themes were identified: (1) competing demands and regulation fatigue, (2) workplace attitude and culture, and (3) suggestions for rule implementation and evaluation. Themes and components of the smoke rule were used to develop the survey. Of the 128 survey respondents, almost half (45.1%) reported owner or grower as their role and 39.3% reported supervisors or managers. Over half (51.6%) of respondents reported fewer than 25 employees in their workplace and 17.2% reported 250 or more employees. Respondents were from multiple WA counties and worked with various crops. Most employers and workers they supervise reported wildfire smoke exposure at work and related adverse symptoms. Almost one-third of respondents reported they had not heard of the smoke rule (33.3%). Over half of respondents have not received training on managing workers with smoke-related symptoms (53.9%). About one-third has not received training on air quality monitoring (40.0%), health effects of exposure (36.8%), and implementing protective controls (31.0%). Differences in knowledge and training on rule components by occupational role were insignificant.

**Conclusion:** Findings identify gaps in awareness and training regarding protection from wildfire smoke in the agricultural workplace, especially around symptom recognition and management. Barriers to implementing protective controls in the workplace were identified. Findings will inform targeted outreach and educational toolkits for the agricultural industry and support the development and evaluation of protective occupational health rules.

### KEYWORDS

Agriculture; climate change; occupational health; particulate matter; survey

## Introduction

Wildfires and wildfire smoke are increasing due to climate change.<sup>1</sup> Wildfires have escalated in duration, frequency, and intensity in the Western United States (US), and since at least 2016, have contributed to an increase in smoke exposure in three-quarters of the contiguous US.<sup>2</sup> Wildfire smoke contains fine particulate matter (PM<sub>2.5</sub>), tiny particles known to irritate the eyes, nose, and throat, cause cardiovascular morbidity and mortality, and aggravate existing respiratory conditions.<sup>3,4</sup>

Agricultural workers in the West face heightened exposure to wildfire smoke given their work is outdoors during peak smoke season, and

exertion is required to do the work.<sup>5,6</sup> The increase in frequency and severity of wildfire smoke and heat has led to a recent federal initiative on protecting farmworkers from extreme heat and wildfire smoke directed by the Department of Health and Human Services.<sup>7</sup> This is critical because outside of the general duty clause in the Occupational Health and Safety Act (OSHA), there are no federal standards to protect workers from wildfire smoke. Previous research on agricultural workers in California and Washington stresses their reliance on employers and supervisors to implement protective measures during periods of wildfire smoke<sup>8,9</sup>; however, there is a gap in research

exploring employer and manager perspectives of adopting state standards to protect outdoor workers from wildfire smoke.

The Washington State Department of Labor & Industries (WA L&I) enacted temporary emergency rules for smoke protections for outdoor workers in the summer of 2021 and 2022, a process that involved opportunities for public comment.<sup>10</sup> A permanent “Wildfire Smoke Rule” (WAC 296–820), hereafter referred to as “the smoke rule,” took effect in January 2024 and applies to outdoor workers across multiple industries,<sup>11</sup> with these requirements duplicated within the Safety Standards for Agriculture (WAC 296–307). Rule components include identification of harmful exposures through air quality (AQ) monitoring, hazard communication, information and training, exposure symptom response, exposure controls, and respiratory protection. The final smoke rule was similar to the emergency rules. Notable exceptions include requiring employers to provide respirators (e.g. N95 masks) at lower levels of pollution than what was specified in the 2021 emergency rule and requiring employees to wear respirators above a higher threshold than the 2022 emergency rule.<sup>10</sup> Implementation and evaluation of wildfire smoke-related occupational health and safety protections has yet to occur.

The purpose of this study was to examine the perspectives of agricultural employers regarding wildfire smoke-related occupational health and safety protections. The first aim was to explore implementation and evaluation of the smoke rule among agricultural industry stakeholders. The second aim was to develop a survey instrument to explore perspectives on the smoke rule for agricultural employers and managers. The third aim was to examine the relationship between occupational role and training received related to components of the rule.

## Methods

### Study design

This study used an exploratory sequential mixed method approach.<sup>12</sup> The Centers for Disease Control and Prevention (CDC) framework for policy evaluation was used to guide study

activities.<sup>13</sup> The framework is circular, with six steps beginning and ending with stakeholder engagement. The first phase of the study engaged agricultural industry stakeholders by employing qualitative interviews to obtain insights about their experiences related to wildfire smoke exposure and risk reduction in the workplace. Qualitative findings were integrated into the design of the survey, the second phase of the study. In the third phase, the survey was administered to a large sample of agricultural employers, supervisors, and managers who were on an agriculture-related email list. Qualitative findings and survey results were reviewed and incorporated into a synthesis of findings. The study was deemed exempt from the Washington State University Institutional Review Board in compliance with ethical research policies (Interviews IRB #19444; Survey administration IRB #19995).

### *Interviews: sample, recruitment, data collection, analysis*

We sampled agricultural industry stakeholders to examine implementation and evaluation of the smoke rule. Inclusion criteria included adults working in Washington State, with 3 or more years’ experience in the agricultural industry and a plan to stay in their position for 3 years to understand adaptation to our evolving climate. Our goal was to recruit six to eight stakeholders.

Participants were recruited using purposive and snowball sampling from a network of industry contacts including growers, trade associations, regulatory and government agencies, and state universities. Potential interviewees were asked to participate in a 30-min interview and review the draft survey. Interviews were recorded and transcribed using Zoom software. Transcripts were reviewed and compared with recordings for accuracy. The thematic analysis was conducted iteratively by a single researcher throughout data collection.<sup>14</sup> Using an inductive, reflexive approach to analysis, along with debriefing sessions with other research team members, common themes emerged. Data saturation was met after seven interviews, in that new data were redundant from data already collected.<sup>15</sup>

## Survey design

The 55-item online survey was designed around smoke rule components with additional items responsive to interview themes (e.g. workplace culture). Previously validated survey items were from the Environmental Protection Agency's (EPA) *Smoke Sense* study (wildfire smoke exposure, health and symptoms), the Centers for Disease Control and Prevention's (CDC) *National Healthy Workplace Program Health and Safety Climate Survey* (workplace culture), and a previously published survey on risk factors for heat-related illness in WA crop workers (workplace characteristics, roles, demographics).<sup>16–18</sup>

The survey included questions in the following 11 categories: *Your Workplace & Role*, *Wildfire Smoke Exposure*, *Health & Hazards of Smoke Exposure*, *Occupational Health & Safety Regulations*, *Air Quality Monitoring*, *Hazard Communication*, *Symptom Recognition & Management*, *Protective Controls & Equipment*, *Education & Training*, *Culture of Safety*, and lastly, *Demographic Data*.

Interviewees were invited to evaluate content validity using a structured guide to assess individual survey items, survey sections, and whether the survey adequately covered the content as intended. Face validity was assessed by asking the stakeholders if, overall, they think that the survey was relevant and appropriate for characterizing factors that may be associated with implementing risk reduction activities in the agricultural workplace.

Two of seven interviewees provided feedback on the draft survey. Based on their feedback, we identified multiple-choice questions that contained options that were similar in meaning and collapsed these options to reduce redundancy and simplify choices, aiming for a 10–15-min time commitment. Readability was enhanced by using terms commonly used in the agricultural industry (e.g., occupational role). Sections were re-organized by style of response options for ease of administration. Interviewees who assisted in the survey design component of this study received a \$50 gift card.

## Survey administration: sample, recruitment, data collection, analysis

The target population for survey administration included agricultural employers, managers, and

supervisors. Inclusion criteria included: adults aged 18 and older, employed within Washington State, and holding a supervisory role of employees who spend more than 50% of their workweek outdoors. We reached potential participants through an email subscription list called AgWeatherNet (AWN). Managed by the Washington State University's College of Agricultural, Human, and Natural Resource Sciences, AWN provides weather data and weather-related support tools to agricultural producers throughout the Pacific Northwest region and maintains a database, including email addresses of its subscribers.

We filtered the AWN database to include only entries that had a Washington State ZIP Code, a valid email address, and showed to be an active user of AWN since 2020. The survey was sent out to 3,815 email addresses via Qualtrics on April 17, 2023, with three reminder emails and closed after 7 weeks. The email text had an introductory description of the survey and a request for participation. The opening screens provided consent and screening criteria questions followed by the survey. The survey data were collected anonymously. Participants could enter their email for a drawing to win one of 18 \$50 gift cards.

We conducted an exploratory data analysis of the survey data using SPSS. We used descriptive statistics to understand the features of our dataset and participant characteristics.<sup>19</sup> Descriptive statistics were also used to look at responses to questions about smoke exposure and reported symptoms, as well as AQ monitoring and hazard communication.

The third aim of our study was to examine the relationship between occupational roles and training received related to components of the WA L&I smoke rule. Our hypothesis was that occupational role was a predictor of the likelihood of having heard of the rule and having received training on components of the rule. We used logistic regression to compare responses to various binary (yes/no) questions by role. Our logistic regression analysis looked at whether our independent variable (role) was predictive of our binary outcome, to see if certain roles had more probability of reported knowledge of the rule or receiving training.

## Results

### Themes from interviews

Thirty-five contacts were made, and seven interviews were conducted in English between June and August 2022 (Table 1). Interview participants included two representatives from trade organizations representing multiple crops, three extension/outreach specialists from two state universities, and two industry stakeholders whose business facilitates onboarding and training for agricultural employees. Three overarching themes provided contextual considerations for implementation of the smoke rule, including (1)

competing demands and regulation fatigue, (2) workplace attitude and culture, and (3) suggestions for rule implementation and evaluation. Themes with supportive quotes are in Table 2.

### Competing demands and regulation fatigue

Interviewees noted employers have become fatigued from so many regulatory changes, noting that the smoke rule comes after multiple changes in safety requirements during COVID-19. Interviewees shared that competing demands challenge compliance with providing workplace protections. Interviewees reported supervisors and foremen are trained on what to do in case of

**Table 1.** Interview Guide.

| Chapter 296–820 Washington Administrative Code (WAC)<br>WILDFIRE SMOKE, relevant rule section                                                      | Question                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WAC 296-820-805                                                                                                                                    | 1) Have you heard of the Labor & Industries Smoke rule?                                                                                                                                                                                                      |
| WAC 296-820-815 Identification of harmful exposures<br>& WAC 296-820-845 Measuring particulate matter (PM <sub>2.5</sub> ) levels at the worksite. | 2) Which sources for air quality monitoring appeal to you/your stakeholders and why?                                                                                                                                                                         |
| WAC 296-820-820 hazard communication                                                                                                               | 3) How do you/your stakeholders plan to communicate wildfire smoke hazards to agricultural employees?                                                                                                                                                        |
| WAC 296-820-825 Information and training                                                                                                           | 4) How do you/your stakeholders plan to train supervisors, field crew chiefs and workers?                                                                                                                                                                    |
| WAC 296-820-830 Exposure symptom response                                                                                                          | 5) How will you/your stakeholders know if an employee is showing signs of injury or illness?                                                                                                                                                                 |
| WAC 296-820-835 Exposure controls & WAC 296-820-840 Respiratory protection                                                                         | 6) Which of these exposure controls do you think is most realistic to implement in an agricultural work setting (i.e., enclosed structure w/filtered air, portable HEPA filters, relocation, changing schedule, reducing work intensity, more rest periods)? |
| Rule evaluation                                                                                                                                    | 7) How would you recommend we evaluate if the rule is working for employers and employees in the agricultural industry?                                                                                                                                      |

**Table 2.** Themes and supportive quotes.

| Themes                                             | Supportive Quotes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Competing demands and regulation fatigue           | <p>"It's easy to overload employers. There's been a lot of change in the last few years, a lot of new kinds of regulations. Obviously, COVID was a source of a lot of new regulations. And then on top of that, the new smoke rules and emergency rules and heat related emergency rules. So, education and providing compliance assistance has been a big task."</p> <p>"We deal in everything related to employing human beings. So, it's from health care to immigration ... discrimination and health and safety, labor relations, wage, and hour, all those sorts of things are in our purview, and that's a lot."</p>                                                                                                                                                      |
| Workplace attitude and culture                     | <p>"... the key to addressing smoke and heat problems successfully, and minimizing the risk to employees, is to have very aware supervisors and people who are encouraged to ... engage employees and say, 'hey, are you sure you're doing okay?'"</p> <p>"Nobody wants to appear weak."</p> <p>"And [on the] one hand, there's an incentive for them [foremen and crew leads] to produce as much as possible with the crews they have. On the other hand, they're charged with keeping people safe. And so that training for foremen is a critical part of success."</p>                                                                                                                                                                                                        |
| Suggestions for rule implementation and evaluation | <p>"These farms are run by smart people, and they may suspect that their particular microclimate, in a valley or on a ridge, may differ from where the EPA reading is taking place."</p> <p>"... tailgate training, that safety meeting in the morning, is the place where it's [training] most effective."</p> <p>"Given that it is a fairly new rule, I think people are still on the learning curve of figuring out not only what this rule requires, but how best to be on the lookout for the symptoms."</p> <p>"When you talk about different thresholds [in WA and OR] and how they're based, they should be based on the science of what we know about exposure and health outcomes. And clearly the science isn't different across state lines, but the rules are."</p> |

smoke, but until they are experiencing it, it is not always a priority given competing demands.

### **Workplace attitude and culture**

Interviewees discussed employers' responsibilities to provide a safe work environment while simultaneously noting that maintaining a culture of safety is the mutual responsibility of both employers and employees. An interviewee noted that the personal values of employers and supervisors can dictate how workers are treated. For example, supervisors and managers train the foremen and crew chiefs who then are responsible for managing the working conditions in the field. This was described as "the weak point in the agriculture industry because again, you're relying on someone to really adopt the values that you have."

### **Suggestions for rule implementation and evaluation**

Interviewees made multiple suggestions regarding rule implementation and evaluation. Suggestions included improving access to accurate AQ readings, encouraging symptom reporting from smoke exposure, training opportunities, and continued evaluation of the health impacts of the rule. Interviewees shared that some employers would prefer to use their best judgement on AQ given the distance between a monitor and their workers. Use of direct reading instruments (e.g. PurpleAir monitors) offers another option; however, interviewees noted it can be "hard to trust the value."

Interviewees suggested asynchronous online training to stay abreast of new rules. Others emphasized that training should be motivating and interactive, verifying comprehension. Reviewing AQ forecasts in the morning huddles was offered as a strategy to stay current in dynamic conditions, and using visual resources and checklists was recommended to help with symptom monitoring. More novel approaches to rule compliance were suggested, including the use of software that automates the process of assessing AQ hazards and, if applicable, alerting the supervisor and employee. Text notifications would inform protective measures.

Interviewees recommend tracking illnesses from wildfire smoke to evaluate rule implementation.

Lastly, interviewees noted challenges in providing protective controls such as relocation of work, change in shift times, or providing enclosed areas with high efficiency particulate air (HEPA) filtration. Most said these approaches were not feasible due to a loss of production or a cost to employers to provide power and protective resources to remote areas.

## **Survey results**

### **Characteristics of sample**

Of the 3,692 deliverable emails (123 bounced back), we had 128 responses who partially completed or completed the survey for a response rate of 3.5%. The mean age of our respondents was 48-years-old, with ages ranging from 23 to 86 years (standard deviation: 15.1). Most respondents identified as male (77.7%) and reported speaking English as their primary language (93.8%) (Table 3). Over half (64.1%) identified as white and 10.2% identified as Hispanic or Latino. Almost half of the sample (45.1%) reported their role as an owner or grower and 39.3% self-identified as a supervisor or manager. Many (49.2%) held a previous role as a laborer/farmworker.

Over half (51.6%) of respondents reported fewer than 25 employees in their workplace, and 17.2% reported 250 or more employees. Survey respondents worked with multiple crop types in 23 of Washington State's 39 counties, with the most working in Central Washington. The majority (83.8%) reported working with that crop for more than 5 years.

### **Health conditions, smoke exposure and symptoms**

Respondents were asked about conditions that currently impact their health (Table 4). Hypertension was reported by 16.4% of respondents and asthma by 10.9%. Almost all (95.0%) respondents reported having been exposed to wildfire smoke at work, and 85.9% of the respondents reported that the workers they supervise have been exposed to wildfire smoke at work (data not shown).

Over half (54.7%) agreed that 2 or 3 hours of exposure to wildfire smoke can cause or worsen

**Table 3.** Characteristics of the survey sample.

|                                                                         | N   | %     | Valid %* |
|-------------------------------------------------------------------------|-----|-------|----------|
| <b>Gender</b>                                                           |     |       |          |
| Male                                                                    | 87  | 68.0  | 77.7     |
| Female                                                                  | 22  | 17.2  | 19.6     |
| Prefer not to answer                                                    | 3   | 2.3   | 2.7      |
| Total                                                                   | 112 | 87.5  | 100.0    |
| Missing                                                                 | 16  | 12.5  |          |
| Total                                                                   | 128 | 100.0 |          |
| <b>Race/Ethnicity</b>                                                   |     |       |          |
| American Indian or Alaskan Native                                       | 3   | 2.3   |          |
| Asian                                                                   | 2   | 1.6   |          |
| Black                                                                   | 0   | 0     |          |
| Hispanic or Latino                                                      | 13  | 10.2  |          |
| Mixteco                                                                 | 0   | 0     |          |
| Native Hawaiian or Other Pacific Islander                               | 0   | 0     |          |
| White                                                                   | 82  | 64.1  |          |
| Multiracial                                                             | 3   | 2.3   |          |
| Other                                                                   | 6   | 4.8   |          |
| Total                                                                   | 109 | 85.3  |          |
| Missing                                                                 | 19  | 14.7  |          |
| Total                                                                   | 128 | 100   |          |
| <b>Primary Language</b>                                                 |     |       |          |
| English                                                                 | 106 | 82.8  | 93.8     |
| Spanish                                                                 | 6   | 4.7   | 5.3      |
| Other                                                                   | 1   | .8    | 0.9      |
| Total                                                                   | 113 | 88.3  | 100.0    |
| Missing                                                                 | 15  | 11.7  |          |
| Total                                                                   | 128 | 100   |          |
| <b>Primary Role at Work</b>                                             |     |       |          |
| Owner or Grower                                                         | 55  | 43.0  | 45.1     |
| Supervisor or Manager                                                   | 48  | 37.5  | 39.3     |
| Crew Chief or Foreman                                                   | 2   | 1.6   | 1.6      |
| Technical Professional                                                  | 7   | 5.5   | 5.7      |
| Safety Officer                                                          | 5   | 3.9   | 4.1      |
| Other (write in)                                                        | 5   | 3.9   | 4.1      |
| Total                                                                   | 122 | 95.3  | 100.0    |
| Missing                                                                 | 6   | 4.7   |          |
| Total                                                                   | 128 | 100.0 |          |
| <b>Number of Employees in your workplace</b>                            |     |       |          |
| Less than 25                                                            | 63  | 49.2  | 51.6     |
| 25–49                                                                   | 13  | 10.2  | 10.7     |
| 50–99                                                                   | 14  | 10.9  | 11.5     |
| 100–249                                                                 | 11  | 8.6   | 9.0      |
| 250 or more                                                             | 21  | 16.4  | 17.2     |
| Total                                                                   | 122 | 95.3  | 100.0    |
| Missing                                                                 | 6   | 4.7   |          |
| Total                                                                   | 128 | 100.0 |          |
| <b>Percentage of workweek that workers you supervise spend outdoors</b> |     |       |          |
| 50–74%                                                                  | 25  | 19.5  | 20.7     |
| 75–100%                                                                 | 92  | 71.9  | 76.0     |
| Total                                                                   | 121 | 94.5  | 100.0    |
| Missing                                                                 | 7   | 5.5   |          |
| Total                                                                   | 128 | 100.0 |          |
| <b>Primary Crop Type</b>                                                |     |       |          |
| Tree Fruit or Orchards (e.g. Apples, Cherries, Peaches)                 | 37  | 28.9  | 30.6     |
| Wine or Grapes                                                          | 17  | 13.3  | 14.0     |
| Potato or Row Crops                                                     | 18  | 14.1  | 14.9     |
| Berries                                                                 | 6   | 4.7   | 5.0      |
| Hops                                                                    | 5   | 3.9   | 4.1      |
| Wheat or Grains                                                         | 9   | 7.0   | 7.4      |
| Other (write in)                                                        | 28  | 21.9  | 23.1     |
| None during that time                                                   | 1   | .8    | 0.8      |
| Total                                                                   | 121 | 94.5  | 100.0    |
| Missing                                                                 | 7   | 5.5   |          |
| Total                                                                   | 128 | 100.0 |          |

(Continued)

Table 3. (Continued).

|                                                       | N   | %     | Valid %* |
|-------------------------------------------------------|-----|-------|----------|
| <b>Number of years working with this crop</b>         |     |       |          |
| Less than 2 years                                     | 5   | 3.9   | 4.1      |
| 2 to 4 years                                          | 15  | 11.7  | 12.3     |
| 5 to 7 years                                          | 14  | 10.9  | 11.5     |
| 8 to 10 years                                         | 12  | 9.4   | 9.8      |
| More than 10 years                                    | 76  | 59.4  | 62.3     |
| Total                                                 | 122 | 95.3  | 100.0    |
| Missing                                               | 6   | 4.7   |          |
| Total                                                 | 128 | 100.0 |          |
| <b>Previous roles held in the agricultural sector</b> |     |       |          |
| Owner or Grower                                       | 43  | 33.6  |          |
| Supervisor or Manager                                 | 59  | 46.1  |          |
| Crew Chief or Foreman                                 | 30  | 23.4  |          |
| Technical Professional                                | 31  | 24.2  |          |
| Safety Officer                                        | 22  | 17.2  |          |
| Training/Education                                    | 30  | 23.4  |          |
| Laborer/Farmworker                                    | 63  | 49.2  |          |
| Other (write in)                                      | 7   | 5.5   |          |
| Total                                                 | 128 | 100   |          |
| Missing                                               | 0   | 0     |          |
| Total                                                 | 128 | 100   |          |

\*Valid percent excludes missing data. Values may not sum to 100% due to missing responses or rounding. Variables without a valid percent are "select all that apply".

Table 4. Health conditions and symptoms.

|                                                                                                                | N  | %    |
|----------------------------------------------------------------------------------------------------------------|----|------|
| <b>Health conditions that currently impact the respondent's own health</b>                                     |    |      |
| Asthma                                                                                                         | 14 | 10.9 |
| Chronic Obstructive Pulmonary Disease                                                                          | 1  | 0.8  |
| Cardiovascular Disease                                                                                         | 3  | 2.3  |
| Hypertension                                                                                                   | 21 | 16.4 |
| Other Respiratory Disease (write in)                                                                           | 2  | 1.6  |
| Other relevant health concern or diagnosis (write in)                                                          | 4  | 3.1  |
| <b>Symptoms experienced by the respondents after exposure to wildfire smoke at work</b>                        |    |      |
| Headache, fatigue, or similar                                                                                  | 30 | 23.4 |
| Irritation of the eyes, nose, throat, or similar                                                               | 65 | 50.8 |
| Chest pain, irregular heart rate, or similar cardiovascular symptoms                                           | 5  | 3.9  |
| Asthma, shortness of breath, difficulty breathing, or similar respiratory symptoms                             | 15 | 11.7 |
| Other (write in)                                                                                               | 1  | 0.8  |
| None of the above                                                                                              | 40 | 31.3 |
| <b>Symptoms that workers have shown, mentioned, or reported as a result of wildfire smoke exposure at work</b> |    |      |
| Headache, fatigue, or similar                                                                                  | 31 | 24.2 |
| Irritation of the eyes, nose, throat, or similar                                                               | 61 | 47.7 |
| Chest pain, irregular heart rate, or similar cardiovascular symptoms                                           | 7  | 5.5  |
| Asthma, shortness of breath, difficulty breathing, or similar respiratory symptoms                             | 19 | 14.8 |
| Other (write in)                                                                                               | 5  | 3.9  |
| None of the above                                                                                              | 0  | 0    |

Variables without a valid percent are "select all that apply".

health problems, while 20.3% were neutral, and 16.4% disagreed with that statement. However, a considerable proportion reported experiencing symptoms after exposure to wildfire smoke at work (Table 4), including irritation of the eyes, nose, throat, or similar (50.8%); Headache, fatigue, or similar (23.4%); Asthma, shortness of breath, difficulty breathing, or similar respiratory symptoms (11.7%). Some (3.9%) reported experiencing

chest pain, irregular heart rate, or similar cardiovascular symptoms after smoke exposure at work.

Respondents also reported symptoms *workers* they supervise have shown, mentioned, or reported as a result of wildfire smoke exposure at work, including irritation of the eyes, nose, throat, or similar (47.7%); headache, fatigue, or similar (24.2%); asthma, shortness of breath, difficulty breathing, or similar respiratory

symptoms (14.8%); chest pain, irregular heart rate, or similar cardiovascular symptoms (5.5%). Of respondents, 68.8% agreed they were concerned about the health of *workers* under their supervision as it relates to smoke exposure at work, whereas 48.4% reported being concerned about *their own* health in relation to smoke exposure at work.

### **Air quality monitoring and hazard communication**

Respondents reported the resource they found most accurate for checking the air quality index

(AQI) or identifying harmful levels of smoke (Table 5). Almost 40% (38.8%) reported a government website or app (e.g. airnow.gov, enviwa.ecology.wa.gov) followed by a smartphone weather app (25.0%) and local news/radio (8.6%). Some (7.8%) reported using local AQ sensors. Notably, 7.0% reported not knowing where to find an accurate AQ measurement, and 6.9% reported estimating the AQI based on sight or smell as the most accurate resource.

In contrast to identifying the most accurate resource used to check the AQI, respondents were asked to identify what resources they most

**Table 5.** Air quality monitoring and hazard communication.

|                                                                                                                                               | N   | %     | VALID %* |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----|-------|----------|
| <b>Which resource do you FIND MOST ACCURATE for checking the air quality index (AQI) or identifying harmful levels of smoke? (select one)</b> |     |       |          |
| Government website or app (e.g. airnow.gov, nowcast AQI, enviwa.ecology.wa.gov, or similar)                                                   | 45  | 35.2  | 38.8     |
| Local AQ sensors                                                                                                                              | 9   | 7.0   | 7.8      |
| Text Notifications                                                                                                                            | 0   | 0     |          |
| Smartphone Weather App                                                                                                                        | 29  | 22.7  | 25       |
| Local news or radio                                                                                                                           | 10  | 7.8   | 8.6      |
| Estimate based on sight/smell                                                                                                                 | 8   | 6.3   | 6.9      |
| Supervisor or co-worker                                                                                                                       | 3   | 2.3   | 2.6      |
| Other (write in: e.g., none)                                                                                                                  | 3   | 2.3   | 2.6      |
| I don't know where to find an accurate air quality measurement                                                                                | 9   | 7.0   | 7.8      |
| Total                                                                                                                                         | 116 | 90.6  |          |
| Missing                                                                                                                                       | 12  | 9.4   |          |
| Total                                                                                                                                         | 128 | 100.0 |          |
| <b>Which resources do you MOST COMMONLY USE to check AQI or identify harmful levels of smoke? (select all that apply)</b>                     |     |       |          |
| Government website or app (e.g. airnow.gov, nowcast AQI, enviwa.ecology.wa.gov, or similar)                                                   | 75  | 58.6  |          |
| Local AQ sensors                                                                                                                              | 20  | 15.6  |          |
| Text Notifications                                                                                                                            | 16  | 12.5  |          |
| Smartphone Weather App                                                                                                                        | 76  | 59.4  |          |
| Local news or radio                                                                                                                           | 32  | 25.0  |          |
| Estimate based on sight/smell                                                                                                                 | 28  | 21.9  |          |
| Supervisor or co-worker                                                                                                                       | 11  | 8.6   |          |
| Other (write in)                                                                                                                              | 0   | 0     |          |
| I don't know where to find an accurate air quality measurement                                                                                | 5   | 3.9   |          |
| <b>The best way for me to NOTIFY THE WORKERS that I supervise if the air quality reaches a hazardous level is by...</b>                       |     |       |          |
| Text message                                                                                                                                  | 30  | 23.4  | 25.9     |
| Cell phone call                                                                                                                               | 42  | 32.8  | 36.2     |
| Radio or walkie talkie                                                                                                                        | 2   | 1.6   | 1.7      |
| Face to face                                                                                                                                  | 41  | 32.0  | 35.3     |
| Other                                                                                                                                         | 1   | 0.8   | 0.9      |
| Total                                                                                                                                         | 116 | 90.6  | 100      |
| Missing                                                                                                                                       | 12  | 9.4   |          |
| Total                                                                                                                                         | 128 | 100.0 |          |
| <b>The best way for me to RECEIVE NOTIFICATIONS if the air quality reaches a hazardous level is by...</b>                                     |     |       |          |
| Text message                                                                                                                                  | 85  | 66.4  | 74.6     |
| Cell phone call                                                                                                                               | 19  | 14.8  | 16.7     |
| Radio or walkie talkie                                                                                                                        | 2   | 1.6   | 1.8      |
| Face to face                                                                                                                                  | 4   | 3.1   | 3.5      |
| Other (write-in: e.g. weather service)                                                                                                        | 4   | 3.1   | 3.5      |
| Total                                                                                                                                         | 114 | 89.1  | 100      |
| Missing                                                                                                                                       | 14  | 10.9  |          |
| Total                                                                                                                                         | 128 | 100.0 |          |

\*Valid percent excludes missing data. Values may not sum to 100% due to missing responses or rounding. Variables without a valid percent are "select all that apply".

commonly use to check the AQI. Although only 7.8% responded that use of local AQ sensors was the most accurate resource, 15.6% commonly use AQ sensors. Likewise, 21.9% indicated they commonly estimate AQI based on sight/smell, while only 6.3% reported that estimating AQ based on sight and smell was the most accurate resource. When asked if the AQI reading that participants have access to accurately reflects the AQ condition workers they supervise are in, 57.8% agreed, while 20.3% were neutral, and 13.3% disagreed.

In terms of communicating AQ hazards to workers, most respondents (89.1%) agreed they can reach the workers they supervise at any time in the workday, and the workers can reach them (88.3%). Respondents reported the following on the best way to *notify workers they supervise* if the AQ reaches a hazardous level (Table 5): 36.2% selected a cell phone call and 35.3% selected face-to-face, and 25.9% indicated text message as their preference. Three-quarters (74.6%) of respondents identified text messaging as the best way for *them to receive notifications* if the AQ reaches a hazardous level.

Most respondents (83.6%) agreed the workers they supervise will tell them if they are not feeling well due to smoke exposure, and the majority (69.5%) agreed they can recognize the signs and symptoms when a worker is not feeling well due to smoke exposure.

### Knowledge of rule and training needs

Approximately one-third of respondents (33.3%) reported they had not heard of the Smoke Rule

(Table 6). Respondents reported they have not received training on the four key components of the smoke rule: health effects of exposure (36.8%), checking AQI (40.0%), managing workers with smoke-related symptoms (53.9%), and implementing protective controls (31.0%). That said, 65% of respondents agreed the workplace provided workers with education and training to comply with the rule, and 61% agreed it provided them with education and training to comply. Over a third (36.5%) of respondents stated they primarily had heard of the rule or received training at their workplace, and about a fifth (19.1%) reported receiving training at an L&I sponsored event. Differences in knowledge of the smoke rule and training on rule components by occupational role were not significant (Table 7).

### Implementing protective controls

Employers were asked about implementing protective controls at certain AQ thresholds. Over two-thirds of respondents (68.0%) agreed their workplace has the necessary tools and supplies to comply with the smoke rule. However, less than one-third (28.9%) of respondents agreed the rule, if implemented as designed, will reduce worker exposure to hazardous levels of smoke. Respondents identified the most realistic steps to reduce or control smoke exposure. In rank order respondents identified: provide a fitted N95 mask (67.2%), reduce shift length (46.1%), reschedule work for a time with less smoke

**Table 6.** Knowledge of rule and training on rule components by occupational role.

|                    | Have you heard of the Washington State Department of Labor and Industries Wildfire Smoke Rule? |           |              | Have you received training or education on*... |           |                                           |           |                                               |           |                                                                                 |           |
|--------------------|------------------------------------------------------------------------------------------------|-----------|--------------|------------------------------------------------|-----------|-------------------------------------------|-----------|-----------------------------------------------|-----------|---------------------------------------------------------------------------------|-----------|
|                    | Have you heard of the Washington State Department of Labor and Industries Wildfire Smoke Rule? |           |              | Health effects of wildfire smoke exposure?     |           | How to check the air quality index (AQI)? |           | Managing workers with smoke-related symptoms? |           | Implementing protective controls (providing masks, respirators, or relocation)? |           |
|                    | N (%)                                                                                          |           |              | N (%)                                          |           | N (%)                                     |           | N (%)                                         |           | N (%)                                                                           |           |
|                    | Yes                                                                                            | No        | I Don't Know | Yes                                            | No        | Yes                                       | No        | Yes                                           | No        | Yes                                                                             | No        |
| Owner/Grower       | 31 (59.6)                                                                                      | 15 (28.8) | 6 (11.5)     | 29 (55.8)                                      | 23 (44.2) | 27 (54.0)                                 | 23 (46.0) | 22 (43.1)                                     | 29 (56.9) | 32 (65.3)                                                                       | 17 (34.7) |
| Manager/Supervisor | 30 (65.2)                                                                                      | 15 (32.6) | 1 (2.2)      | 34 (73.9)                                      | 12 (26.1) | 29 (63.0)                                 | 17 (37.0) | 22 (48.9)                                     | 23 (51.1) | 35 (77.8)                                                                       | 10 (22.2) |
| Foreman/Crew Chief | 0                                                                                              | 2 (100)   | 0            | 0                                              | 2 (100)   | 1 (50.0)                                  | 1 (50.0)  | 0                                             | 2 (100)   | 1 (50)                                                                          | 1 (50.0)  |
| Tech Professional  | 2 (28.6)                                                                                       | 4 (57.1)  | 1 (14.3)     | 3 (42.9)                                       | 4 (57.1)  | 4 (57.1)                                  | 3 (42.9)  | 2 (28.6)                                      | 5 (71.4)  | 2 (28.6)                                                                        | 5 (71.4)  |
| Safety Officer     | 5 (100)                                                                                        | 0         | 0            | 5 (100)                                        | 0         | 5 (100)                                   | 0         | 5 (100)                                       | 0         | 5 (100)                                                                         | 0         |
| Other (write in)   | 2 (40.0)                                                                                       | 3 (60.0)  |              | 3 (60.0)                                       | 2 (40.0)  | 3 (60.0)                                  | 2 (40.0)  | 2 (40.0)                                      | 3 (60.0)  | 3 (60.0)                                                                        | 2 (40.0)  |
| Total              | 70 (59.8)                                                                                      | 39 (33.3) | 8 (6.8)      | 74 (63.2)                                      | 43 (36.8) | 69 (60.0)                                 | 46 (40.0) | 53 (46.1)                                     | 62 (53.9) | 78 (69.0)                                                                       | 35 (31.0) |

\*Valid percent reported, missing data excluded.

**Table 7.** Occupational role as a predictor of knowledge of rule and training on rule components.

|                        | Heard of Smoke Rule |                | Health Effects |                | Checking air quality index (AQI) |                | Symptom Management |                | Protective Controls |                |
|------------------------|---------------------|----------------|----------------|----------------|----------------------------------|----------------|--------------------|----------------|---------------------|----------------|
|                        | Sig                 | Exp(B)         | Sig            | Exp(B)         | Sig                              | Exp(B)         | Sig                | Exp(B)         | Sig                 | Exp(B)         |
| <b>Primary Role</b>    |                     |                |                |                |                                  |                |                    |                |                     |                |
| Owner/Grower           | .405                | 2.214          | .856           | .841           | .798                             | .783           | .892               | 1.138          | .813                | 1.255          |
| Supervisor/Manager     | .283                | 2.831          | .513           | 1.889          | .894                             | 1.137          | .707               | 1.435          | .388                | 2.333          |
| Foreman/Crew Chief     | .999                | .000           | .999           | .000           | .810                             | .667           | .999               | .000           | .810                | .667           |
| Technical Professional | .680                | .600           | .560           | .500           | .921                             | .889           | .680               | .600           | .286                | .267           |
| Safety Officer         | .999                | 2423212264.277 | .999           | 1076983228.567 | .999                             | 1076983228.567 | .999               | 2423212264.277 | .999                | 1076983228.567 |

(40.6%), reduce work intensity (28.1%), and relocate work to an area with less smoke (22.7%).

Most (72.7%) reported they have access to clean, unused N95 masks, but only 13.3% reported access to regular fit testing for employees. Findings reflect that less than half of respondents (39.1%) have access to an employer-provided vehicle with air conditioning, about one-third (34.4%) have access to an enclosed break area, and few (10.9%) have access to an enclosed break area with a HEPA purifier. Notably, while 78.9% of the respondents agreed their employer considers rule and regulatory compliance to be important, only 64.8% agreed that the workers they supervise consider this compliance to be important.

## Discussion

Agricultural workers in the U.S. face multiple health risks related to heat and smoke, suggesting the nature and social structure of the occupation generate complex factors that contribute to their overall health status.<sup>5,6</sup> In their article, “Deepening the Divide: Health Inequities and Climate Change among Farmworkers” Pagán-Santana, Liebman, and Seda present a framework that reflects how climate change acts as a threat multiplier that perpetuates existing inequities.<sup>20</sup> They note that policies and systems, such as occupational health laws and emergency management systems, limit society’s preparation for, and response to, climate crises in agricultural communities. We interviewed agricultural stakeholders and surveyed agricultural employers and managers to assess their perspectives on wildfire smoke-related health and safety protections in the context of a new occupational

health rule aimed at protecting outdoor workers from health effects related to smoke exposure.

Themes identified in the interviews offer insights into the survey findings. Interview findings suggest “competing demands and regulation fatigue” may be a reason for gaps identified in awareness of the rule and training on the core rule elements. Prioritizing training on an intermittent exposure such as wildfire smoke is challenging given the breadth of regulations agricultural employers face. One interviewee, for example, noted the “learning curve” of identifying the rule requirements and how to identify smoke-related symptoms. This sentiment reflects the area where training is needed most, that of managing workers with smoke-related symptoms. The statement “No one wants to appear weak,” evidence supporting the second theme, “workplace attitude and culture,” reflects the quantitative finding that awareness of the rule and training gaps was not associated with occupational role. Rather, employers and employees all need training related to this new workplace hazard and the rule. Interviewees provided actionable recommendations for agricultural employers, reflecting the third qualitative theme and the training gaps identified in the survey. They noted that multiple types of training modalities would be beneficial, from asynchronous online training to interactive in-person training to safety huddles before each shift.

More respondents agreed that their employer, versus workers they supervise, considered rules and regulatory compliance to be important. These findings contrast with related literature from the employee and employer perspective on wildfire smoke exposure in the agricultural workplace. In a 2023 qualitative study, agricultural workers identified regulations and enforcement of regulations as critical solutions to climate-

related hazards<sup>8</sup> while in a 2020 study, agricultural employers were concerned about wildfire smoke hazards but unclear about solutions.<sup>9</sup>

Findings suggest that respondents are using resources to monitor AQ that they do not necessarily trust as accurate. This could relate to the lack of regulatory AQ monitors in rural areas and speaks to the potential for local AQ sensors as a way to increase access to real-time AQ information.<sup>21</sup> However, researchers note that the performance characteristics of sensors need to be understood before use to ensure accuracy in monitoring.<sup>21</sup> In contrast to OR's regulation, WA State does not permit estimating AQ via sight or smell. OR allows an approach referred to as the 5-3-1 Visibility Index to estimate AQ if employers indicate that other methods to monitor AQ are not available at their worksite.<sup>22</sup>

Marlier et al.<sup>23</sup> recommend three strategies to protect agricultural worker health under future wildfire smoke scenarios. These strategies include distribution of AQ monitors to employers, use of modeling-based forecasts and local alert systems in English and Spanish to warn workers of unhealthy air, and when to wear a mask.<sup>23</sup> The latter reflects solutions posed by our interviewees, including a need for improved training and clear hazard identification and communication.

### ***Implications for practice and policy***

Study findings highlight education and training needs for agricultural employers and workers. Findings depict specific gaps in knowledge and awareness, which can inform training and outreach offered by WA State L&I and trade organizations that support industry stakeholders, such as the WA State Tree Fruit Association. Given the proportion of respondents that worked with fewer than 25 employees, targeted outreach is also occurring through the university's county-level extension program, and particularly the regional small farm program, both of whom share a commitment to building a more resilient agricultural industry in the face of climate change.<sup>24</sup> Both qualitative and quantitative findings allude to the newness of the rule and the need for industry-wide orientation to the rule requirements.

Training priorities include addressing short- and long-term risks to health from smoke exposure, symptom recognition and management, and monitoring AQ accurately and legally per the smoke rule. For example, most respondents reported experiencing irritation of the eyes, nose, throat or similar after smoke exposure. Trainings should emphasize the frequency of this symptom expression and identify the importance of mucosal membranes in preventing infection.<sup>25</sup> Training materials (e.g., poster, infographic, training discussion guide, worksite checklist, pocket respirator pocket guide) are available in English and Spanish on symptom recognition and management of smoke-related symptoms from the Western Center for Agricultural Health and Safety.<sup>26</sup> WA L & I has a wildfire smoke response plan template for employers and a training kit with presentation materials and an instructor's guide that includes how to find AQ information.<sup>27</sup> Training should emphasize the industrious culture of the agricultural workforce and the importance of maintaining a safe environment.

Findings from this study inform the development of similar smoke rules in other states or at a national level. Results will be shared with the National Institute of Occupational Safety and Health via their request for public comment on their draft hazard review "Wildland fire smoke exposure among farmworkers and other outdoor workers."<sup>28</sup> This is important, because wildfires and smoke exposure are no longer health threats unique to the Western states of California, Oregon, and Washington. Although these are the only three states with an occupational health and safety rule for wildfire smoke exposure, wildfire trends are impacting AQ across the US. Wildfire smoke has stalled AQ improvements across most of the US as long-range atmospheric circulation can transport smoke particles up to thousands of miles from active fires.<sup>2</sup>

### ***Recommendations for further research***

Future research will examine the perspectives of Spanish-speaking employers, managers, crew chiefs, and foremen regarding wildfire smoke-related occupational health and safety protection.<sup>8,9</sup> Leveraging existing agricultural

safety training events for in-person data collection is one way to capture more diverse perspectives. For example, WA State has “Agricultural Safety Days,” a training event with sessions in Spanish and English offered in different regions of the State.<sup>29</sup> Evaluations of different training modalities under various working conditions, as has been done with participatory heat education and training, would also benefit the field.<sup>30</sup>

Feasible interventions need to be developed and tested for temporary agricultural workers who perform seasonal farm labor, also called H-2A workers, due to their visa classification. This worker population has increased more than sevenfold in the past 17 years<sup>31</sup> and face unique challenges in understanding their rights and responsibilities in the workplace.<sup>31</sup> They are onboarded in rural communities by the thousands in a short-time frame and have little time to orient to local regulations and conditions, including evacuation routes.<sup>32</sup>

Evaluation of the health impacts of the smoke rule, as recommended by interviewees, would complement our study findings. For example, a study of the impact of wildfire smoke on workers compensation claims in Oregon found that agricultural and construction workers had an 11% greater risk of traumatic injury claims (incidence ratio: 1.11; 95% CI: 1.06–1.16) when wildfire smoke was present. However, in joint models with heat, wildfire smoke was not associated with a higher risk for injury.<sup>33</sup> Future research should explicate associations between concurrent climate-related hazards such as smoke and heat with health outcomes.

### Limitations

Two (of seven) of our key informant interviewees reviewed the draft survey. However, other subject matter experts and experts in survey design reviewed the survey and made recommendations. Our survey response rate was low; therefore, results may be subject to nonresponse bias affecting generalizability.<sup>34</sup> Respondents with strong opinions may be more likely to respond, leading to a biased sample. Online surveys with invitation via email are known to typically have a lower response rate than multi-modal approaches with phone, and/or in-person outreach.<sup>35</sup> However, this approach was the most feasible for this study and

recommended by our stakeholders. Shortening the survey will likely increase the response rate in future studies by decreasing participant burden. Survey respondents were primarily white employers or managers whose primary language was English. The lack of representation by crew chiefs or foremen and Spanish-speaking respondents is a limitation of the study. Finally, the survey may have lacked the power to detect effect sizes that seem notable in descriptive statistics.

### Conclusion

This study identifies gaps in awareness and training regarding protection from wildfire smoke in the agricultural workplace, especially around symptom recognition and management. Participants suggested multiple types of training be made available. Trainings may include asynchronous online training to better understand the elements of the rule, interactive in-person training to teach employers and managers how to manage workers with smoke-related symptoms, and safety huddles before each shift to update on AQ conditions and protective controls needed. Stressing the industrious culture of the agricultural workforce while acknowledging a balance between productivity and safety may be beneficial to maintaining a safe work environment. Findings will inform targeted outreach and educational toolkits for the agricultural industry and support the development and evaluation of protective occupational health rules.

### Acknowledgments

Anna Zamora Kapoor, PhD, Department of Sociology, IREACH, Washington State University; Lav Khot, Director, Washington State University AgWeatherNet; Washington State University Survey Design Clinic; Mary Jo Ybarra Vega, Outreach & Behavioral Health, Moses Lake Community Health Center; Farmworker Health Coalition; University of Washington Pacific Northwest Agricultural Safety and Health Center

### Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

The research reported in this publication was supported in part by The Institute for Research and Education to Advance Community Health (IREACH), Washington State University; The Professional Training Opportunities Program through the Northwest Center for Occupational Health and Safety (NWCOHS), University of Washington; The National Institute of Environmental Health Sciences of the National Institutes of Health under award number R25ES033452 (PI: Castner). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

## References

- West JJ, Nolte CG, Bell ML, et al. Ch. 14. Air quality. In: Crimmins AR, Avery CW, Easterling DR, Kunkel KE, Stewart BC, Maycock T, eds. *Fifth National Climate Assessment*. Washington, DC: Global Change Research Program; 2023:p. 14.
- Burke M, Childs ML, de la Cuesta B, et al. The contribution of wildfire to PM<sub>2.5</sub> trends in the USA. *Nature*. 2023;622(7984):761–766. doi:10.1038/s41586-023-06522-6.
- Environmental Protection Agency. Integrated science assessment (ISA) for particulate matter. 2019. Washington D.C.: U.S. Environmental Protection Agency. <https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter>. Accessed February 8, 2025.
- U.S. EPA. Supplement to the 2019 integrated science assessment for particulate matter (final report, 2022). U.S. Environmental Protection Agency, Washington, 765 DC, EPA/635/R-22/028. 2022. <https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=354490>. Accessed February 8, 2025.
- Fenske RA, Pinkerton KE. Climate change and the amplification of agricultural worker health risks. *J Agromedicine*. 2021;26(1):15–17. doi:10.1080/1059924X.2021.1849211.
- Austin E, Kasner E, Seto E, Spector J. Combined burden of heat and particulate matter air quality in WA agriculture. *J Agromedicine*. 2021;26(1):18–27. doi:10.1080/1059924X.2020.1795032.
- Wittenberg A. E&E news. As extreme heat and smoke threaten U.S. Farmworkers, federal health leaders evaluate protections. *Scientific American*. <https://www.scientificamerican.com/article/as-extreme-heat-and-smoke-threaten-u-s-farmworkers-federal-health-leaders/>. 2024. Accessed February 8, 2025.
- Parker M, Ybarra-Vega MJ, Postma J. Agricultural worker perspectives on climate hazards and risk reduction strategies. *J Agromedicine*. 2024;29(3):333–343. doi:10.1080/1059924X.2023.2299378.
- Riden HE, Giacinto R, Wadsworth G, Rainwater J, Andrews T, Pinkerton KE. Wildfire smoke exposure: awareness and safety responses in the agricultural workplace. *J Agromedicine*. 2020;25(3):330–338. doi:10.1080/1059924X.2020.1725699.
- WA State Department of Labor and Industries. Wildfire Smoke Workplace Safety & Health Rulemaking. <https://lni.wa.gov/safety-health/safety-rules/rulemaking-stakeholder-information/wildfire-smoke>. 2023. Accessed February 8, 2025.
- KP Fletcher WA *Administrative Code, Chapter 296-820 WAC Wildfire Smoke WA State Department of Labor and Industries*. 2024.
- Creswell JW, Creswell JD. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 5th ed. Thousand Oaks, CA: Sage Publications; 2018.
- Centers for Disease Control and Prevention. Framework for program evaluation in public health. *Morb Mortal Wkly Rep*. 1999;48:RR-11. <https://www.cdc.gov/mmwr/preview/mmwrhtml/rr4811a1.htm>.
- Braun V, Clarke V. *Thematic Analysis: A Practical Guide*. Thousand Oaks, CA: Sage Publications; 2022.
- Saunders B, Sim J, Kingstone T, et al. Saturation in qualitative research: exploring its conceptualization and operationalization. *Qual Quant*. 2018;52(4):1893–1907. doi:10.1007/s11335-017-0574-8.
- Rappold AG, Hano MC, Prince S, et al. Smoke sense initiative leverages citizen science to address the growing wildfire-related public health problem. *Geohealth*. 2019;3(12):443–457. doi:10.1029/2019GH000199. Accessed December 10, 2019.
- Centers for Disease Control and Prevention. CDC National Healthy Workplace Program Health and Safety Climate Survey (INPUTS™). [https://www.cdc.gov/workplacehealthpromotion/tools-resources/pdfs/nhwp\\_inputs\\_survey.pdf](https://www.cdc.gov/workplacehealthpromotion/tools-resources/pdfs/nhwp_inputs_survey.pdf). n.d. Accessed January 1, 2022.
- Spector JT, Krenz J, Blank KN. Risk factors for heat-related illness in Washington crop workers. *J Agromedicine*. 2015;20(3):349–359. doi:10.1080/1059924X.2015.1047107.
- Pallant J. *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS*. London: Routledge; 2020.
- Pagán-Santana M, Liebman AK, Seda CH. Deepening the divide: health inequities and climate change among farmworkers. *J Agromedicine*. 2023;28(1):57–60. doi:10.1080/1059924X.2022.2148034.
- Schollaert C, Austin E, Seto E, Spector J, Waller S, Kasner E. Wildfire smoke monitoring for agricultural safety and health in rural Washington. *J Agromedicine*. 2023;28(3):595–608. doi:10.1080/1059924X.2023.2213232.
- Oregon Occupational Safety and Health Division. Oregon OSHA's permanent rules for protection from wildfire smoke. <https://osha.oregon.gov/OSHAPubs/factsheets/fs92.pdf>. 2024. Accessed October 24, 2024.
- Marlier M, Brenner K, Coco Liu J, et al. Exposure of agricultural workers in California to wildfire smoke under past and future climate conditions. *Environ*

- Res Lett.* 2022;17(9):094045. doi:10.1088/1748-9326/ac8c58.
24. The Russell Family Foundation. WSU Regional Small Farms Program. November 26, 2024 Available from: <https://trff.org/updates/ws-u-regional-small-farms-program-qa-with-the-russell-family-foundation/>. Accessed December 10, 2024.
  25. Dwivedy A, Aich P. Importance of innate mucosal immunity and the promises it holds. *Int J Gen Med.* 2011;4:299–311. doi:10.2147/IJGM.S17525.
  26. Western Center for Agricultural Health and Safety. Wildfire Smoke Exposure. <https://aghealth.ucdavis.edu/wildfires>. 2023. Accessed May 20, 2024.
  27. WA State Department of Labor and Industries. Wildfire Smoke & Workplace Safety and Health. <https://lni.wa.gov/safety-health/safety-topics/topics/wildfire-smoke#training-and-resources>. 2024 Accessed May 20, 2024.
  28. Centers for Disease Control and Prevention. Draft hazard review: wildland fire smoke exposure among farmworkers and other outdoor workers. In: *Department of Health and Human Services, Editor*. National Institute of Occupational Health and Safety, Washington D.C.: Federal Register; 2024:p. 86805.
  29. WA state department of labor and industries. Governor's Safety and Health Conference; 2024 <https://lni.wa.gov/safety-health/safety-training-materials/workshops-events/governors-industrial-safety-health-conference>. Accessed December 10, 2024.
  30. Chavez Santos E, Spector JT, Egbert J, et al. The effect of the participatory heat education and awareness tools (HEAT) intervention on agricultural worker physiological heat strain: results from a parallel, comparison, group randomized study. *BMC Public Health.* 2022;22(1):1746. doi:10.1186/s12889-022-14144-2.
  31. U.S. Department of Agriculture. Farm Labor. <https://www.ers.usda.gov/topics/farm-economy/farm-labor>. 2023. August 7, 2023, Accessed May 20, 2024
  32. Kneeder R. *Fleeing from Fires, Evacuees Slept in a Brewster Park Until Shelter Arrived. The Wenatchee World.* Wenatchee: WA; World Publishing; 2020.
  33. Evoy R, Hystad P, Bae H, Kincl L. The impact of wildfire smoke and temperature on traumatic worker injury claims, Oregon 2009-2018. *Health Sci Rep.* 2022;5(5):e820. doi:10.1002/hsr2.820.
  34. Shi L, Zhang D, Martin E, et al. Racial discrimination, mental health and behavioral health during the COVID-19 pandemic: a National survey in the United States. *J Gen Intern Med.* 2022;37(10):2496–2504. doi:10.1007/s11606-022-07540-2.
  35. Elliott MN, Brown JA, Hambarsoomian K, et al. Survey protocols, response rates, and representation of underserved patients: a randomized clinical trial [published correction appears in. *JAMA Health Forum.* 2024;5(1):e240186. doi:10.1001/jamahealthforum.2024.0186.