A Framework for Experiential Environmental Health Through Theater

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Extreme weather events, including wildfires, are becoming more frequent, intense, and consequential for human health. Scientific advances have improved our ability to characterize hazards and the socioeconomic constraints shaping exposure, but these dimensions are not always integrated throughout the development of environmental health knowledge. Meanwhile, broader publics, although often not directly affected, may shape the socioeconomic conditions under which exposure occurs yet rarely have opportunities to engage experientially with how exposure unfolds or its consequences. We propose an experiential environmental health framework that uses theater to bring scientists, affected communities, and broader publics into a shared process of investigation, interpretation, and action. We illustrate the framework through *Hidden Strawberries*, a play developed from a wildfire-smoke toxicity study among California farmworkers, whose prolonged outdoor labor and limited access to protective resources shape exposure. Through interactive performance, audiences encounter how symptoms, labor demands, information gaps, decision-making, and socioeconomic constraints intersect during smoke events. Audience responses illustrate increased empathy and understanding of farmworker exposure, socioeconomic constraints, and health risks, while motivating action. As more people experience the health impacts of extreme weather, such frameworks can transform individual experiences of exposure into shared public understanding and strengthen collective responses.

We are entering an era in which extreme weather events, such as wildfires, are increasingly shaping human health risks across populations.[1-5] Empirical measurements have transformed our ability to characterize environmental hazards and quantify exposure.[2,6] However, understanding exposure requires more than measuring the physical hazard alone.[7] It also requires understanding how hazards are perceived, experienced, and responded to under various socioeconomic conditions.[7] Although awareness of these issues has increased over the past decades,[8-10] populations that are disproportionately exposed during such events, including first responders, outdoor and agricultural workers, and populations with limited access to economic and protective resources, are still not fully involved in environmental health frameworks.[11,12] As a result, current scientific frameworks only partly capture how exposure is experienced during extreme weather events.[12,13] Addressing the difference between risk measurements and lived experience requires approaches that can integrate empirical measurements with the lived conditions, decisions, and socioeconomic constraints that shape exposure.[14]

Environmental health exposure is shaped not only by physical intensity, but also by where people work and live, whether they can avoid the hazard, what information they receive, and the socioeconomic costs associated with protective actions.[9,15] Many environmental health assessments and regulatory frameworks treat exposure to a given hazard as comparable across populations at a given location or time.[12] However, exposure is highly differentiated.[9,11,12] For example, during wildfire smoke events, one person may remain indoors with filtration, while another may work outside for hours to ensure income and job security.[16-18] Farmworker communities in California illustrate the dilemma of risking exposure compared to loss of income or job: their work often requires prolonged outdoor labor during smoke events, making exposure continuous, cumulative, and difficult to avoid.[19] Public-health tools such as the Air Quality Index (AQI) play an essential role in communicating air-quality conditions and associated health risks.[20,21] However, by necessity, these metrics provide population-level guidance based primarily on pollutant concentrations and cannot fully represent the diverse social, economic, biological, and behavioral contexts that shape how exposure is experienced by different individuals and communities.[12]

Environmental health studies operate across multiple modes of engagement. At one end, data are generated through laboratory, modeling, or observational approaches.[2,22,23] Participatory and community-engaged methods extend outward through surveys, interviews, or outreach, enabling the collection and dissemination of information, but often through passive flow.[8,24] Other approaches, including risk communication and decision science, have increasingly examined how people perceive environmental hazards, interpret risk information, and make protective behavioral decisions under evolving environmental, social, and economic conditions.[8-10] These approaches provide important insights into the physical, behavioral, and social dimensions of environmental health risks. However, because these dimensions are often examined through different disciplinary approaches and forms of engagement, physical measurements of exposure, the lived experience of affected communities, and their behavioral responses often remain disconnected from one another. In particular, the broader public who may not be directly affected by environmental issues (i.e., unaffected communities) are often absent from these processes despite helping shape the economic, social, and political conditions under which exposure occurs.[25,26] The opportunity, therefore, is to develop frameworks that bring scientists and affected and broader publics together, creating opportunities for broader publics to experience, interpret, and reflect upon how environmental health risks emerge in extreme weather conditions.

One possible way to address this opportunity is through performing arts.[27,28] Theater, particularly environmentally engaged performance such as eco-theater, is uniquely suited to addressing environmental health challenges by creating an interactive narrative through participation of broader publics. While environmental health, risk-communication, and decision-science research examine how people perceive risks and make decisions under uncertainty, theater allows these processes to be encountered interactively by the audience as they unfold through characters, stories, decision-making, settings, and socioeconomic constraints. These narrative mechanisms have been examined in entertainment-education, where fictional narrative, character identification, and emotional engagement can make health and social issues more personally meaningful and support individual and social change.[29-33] More specifically, eco-theater has

explored ecological themes through artistic practice.[27,28,34,35] Despite these complementary foundations, scientific research, community engagement, artistic development, and public participation often remain only partially integrated. Many environmentally themed performance projects are developed primarily through artistic interpretation, often without sustained collaboration with scientists or affected communities.[27,28,34] In other cases, artists and communities may collaborate directly, but without integrating ongoing scientific discoveries into the development of the work.[34,35] Similarly, environmental scientists and engineers may work in isolation or, in some cases, directly with affected communities while rarely incorporating broader public, artists, or performative development into the environmental monitoring and assessment frameworks.[8,10,36,37] Even when such collaborations occur, many eco-theater and environmental performance efforts primarily emphasize environmental communication and advocacy[27,28,34,35] rather than focusing on how human perception, behavior, and vulnerability are shaped by environmental health risks.[8] Building on these complementary efforts, there is a unique opportunity to extend eco-theater beyond communication and advocacy into a structured experiential environmental health framework that integrates scientific data, lived experience, artistic development, and public participation within a single interactive process.

Here, we propose a structured framework for experiential environmental health that uses interactive eco-theater (Box 1) as its performative form. The framework has two primary objectives: (1) to integrate scientific data, lived experience of affected communities, artistic development, and broader public participation into a collaborative interactive process in which these domains develop simultaneously and inform one another throughout the work; and (2) to allow the broader public to experience how human behavior and environmental health decisions emerge through the interaction of physical hazards, risk information, human decision-making, and socioeconomic constraints under extreme weather conditions. Interactive performances enable the audience to encounter exposure and decision-making as a sequence of conditions and constrained choices. By following characters through this process, audiences may become emotionally invested, making environmental health risks more personal and less abstract.[31] Interactive performance

also encourages audiences to contribute their own interpretations and experiences to the collective understanding of environmental health impacts. Scientific knowledge of environmental hazards, such as wildfire-smoke composition, toxicity, and health effects (Box 2), is developed alongside community-derived knowledge, including farmworkers' accounts of prolonged smoke exposure and limited ability to avoid it (Box 3). Artists synthesize these materials into a performative structure that can be tested, revised, and experienced in real time through audience engagement and feedback. Through audience participation and shared presence, the work becomes a site where environmental health knowledge is not only represented but is collectively generated and experienced. The framework is intended to serve as a catalyst for continued dialogue, collective action, and policy engagement beyond the performance itself by bringing scientists, affected communities, and broader publics into a shared process of understanding and responding to environmental health threats.

Experiential Environmental Health Framework

The framework has five linked stages: elicitation, synthesis and transformation, performance and public engagement, evaluation, and translation, ongoing collaboration and action. Each stage has a distinct epistemic function: elicitation identifies different forms of environmental health knowledge; synthesis organizes scientific and experiential material into a performative narrative structure (e.g., a play); performance makes exposure available as a temporal and embodied experience; evaluation assesses how audiences interpret and respond to that experience; and translation, ongoing collaboration and action extends the framework beyond performance by catalyzing ongoing interaction among scientists, communities, the public, and policymakers (Fig. 1). To illustrate each component of the framework, we developed and performed *Hidden Strawberries* in Stanford Live at Stanford University in October 2024 over four nights, reaching more than 400 audience members. A recording of the full performance is available through the Stanford Digital Repository.[38]

Framework inputs. The framework is built on three forms of input. First, scientific knowledge of environmental hazards, including (in this case) information on wildfire smoke composition, toxicity, and health effects. Second, community-derived knowledge, including lived experiences of wildfire smoke exposure among farmworkers and the social and economic conditions that influence decision-making and human response to health risks. Third, theater as an interactive performative form that brings scientific and community-derived knowledge into a shared experiential context, allowing audiences to experience how environmental health risks and human responses unfold under real-world social, economic, and environmental conditions. Scientists, artists, or affected communities may initiate the framework, but its implementation benefits from collaboration among all three groups. The initiating group can therefore convene a team that integrates scientific, artistic, and community knowledge across the framework.

Elicitation. The elicitation stage collects scientific data from scientists and experiential and narrative material from affected communities. Ideally, community engagement begins before scientific data collection so that community and scientist co-develop the research. The goal is not only to document exposure but to understand how environmental health exposure shapes everyday activities, risk interpretation, and decision-making under social and economic constraints. The elicitation process should also gather material needed for performance: places of exposure, objects, characters, conflicts, stories, and moments of decision. In *Hidden Strawberries*, participants described their migration to California, their working environments, and specific moments related to wildfire smoke, including ash settling on crops, difficulty distinguishing ripe strawberries under smoky conditions, and breathing challenges during fieldwork in heavy smoke. These accounts revealed exposure as a practical and temporal process: smoke slowed labor, extended working hours, intensified symptoms, and social and economic constraints made avoiding smoke difficult even when risk was visible.[19] Further information about the community-engagement process and protocol is provided in Box 3. The elicitation stage, therefore, produced three forms of information: scientific information about environmental risks, accounts of how exposure occurs in practice, and narrative materials that could later be transformed into performance.

Synthesis and transformation. The synthesis stage translates scientific and community-derived material into a structured narrative that can be performed. Its function is not simply to dramatize information but to organize environmental health processes into scenes, relationships, and decisions that can be enacted. Community accounts are converted into narrative building blocks, including setting, character, conflict, consequence, and stories. Scientific information is then positioned within the story where it can shape the audience's interpretation of exposure without interrupting the lived trajectory of the characters.

This process is iterative rather than linear. Early narrative versions can be tested through workshops in which participants use the collected inputs to create short, improvised scenes. These settings allow scientists and artists to assess which environmental and social dimensions of exposure are immediately legible through performance and which require additional narrative framing. In our workshops, participants created short scenes that were performed for small audiences. This process helped identify where the story clearly communicated smoke exposure, labor constraint, and health risk, and where the scientific or social context needed to be made more explicit. In addition, affected-community partners can help select stories, review scripts and characterizations, and identify inaccurate or harmful portrayals. In *Hidden Strawberries*, we followed a single character whose life trajectory connected migration, labor, and wildfire-smoke exposure. Environmental and health dimensions were embedded through scenes of work under hazardous conditions rather than presented as separate explanatory material. Although developed around wildfire-smoke exposure among farmworkers, the elicitation-synthesis-performance structure is adaptable across environmental health contexts, community settings, and artistic forms.

Performance and public engagement. The performance stage translates the structured narrative into a live setting where exposure can be encountered as it unfolds. Rehearsals and collaboration among actors, designers, and the production team refine the narrative through pacing, sound, set design, and lighting. Actors do not merely execute a fixed script; they help develop characters, relationships, and stories. Working with artists who have cultural or experiential proximity to the represented community can also strengthen the performance's contextual grounding.

Theater unfolds through the shared presence of performers and audience. Interactive theater, therefore, is particularly useful because it can make several dimensions of exposure visible at once in the presence of the audience and through their engagement and feedback. In *Hidden Strawberries*, audience members were invited onto the stage, directly addressed by the performer, and asked to participate in decision-making (Fig. 2a). The interactive structure transformed audiences from passive observers into participants in the interpretation of exposure, allowing them to confront the social and economic constraints shaping the character's decisions in real time. Direct engagement with the leading character encouraged empathy, while questions to the audience prompted reflection on the structural constraints shaping her decisions. Information asymmetry was also staged: wildfire-smoke information was delivered through radio broadcasts to the audience, while the main character continued working without access to information on the smoke hazards. This allowed audiences to recognize risk while watching a worker with pre-existing respiratory vulnerability continue under hazardous conditions. Set design, lighting, sound, music, and movement shaped the performance environment. Lighting and set design created the atmosphere of smoke days (Fig. 2 b,c), while folkloric dance and music provided a cultural context (Fig. 2d). In addition, exposure was presented as cumulative rather than instantaneous: coughing, difficulty breathing, and slower work intensified over multiple acts. Symptoms were initially minor, and then eased, returned, and worsened, while the character continued to work because stopping was economically and socially constrained. The performance thus made exposure legible as an embodied process unfolding over time, under unequal access to information and limited choices.

Evaluation. The evaluation stage assesses how the performance changes the audience, the depth of connection to the topics, and the willingness to continue acting and engaging with the issue. Further, the evaluation provides a gauge of how the audience feels and thinks about the topics pre- and post-performance. Evaluation can include post-show conversations, structured surveys, facilitated discussions, or panels.[39]

For *Hidden Strawberries*, anonymous pre- and post-performance surveys provided descriptive feedback on this particular implementation of the framework. Pre-show responses indicated limited and uneven understanding of wildfire smoke and its impacts. Some participants reported general familiarity with smoke toxicity, but awareness of farmworkers' conditions was low. Nearly half of the participants out of 263 respondents reported being not at all familiar with the socioeconomic impacts of wildfires on farmworker communities, and more than half were not familiar with the extent to which farmworkers continue working during smoke events. These results suggest that audiences may recognize the general toxicity of wildfire smoke while lacking a clear understanding of how exposure unfolds through labor conditions, economic pressure, and limited job options.

Post-show responses showed shifts in self-reported understanding. A majority of participants reported that the performance improved their understanding of environmental injustice related to wildfire smoke, with 70% indicating high or very high levels of increased understanding. Similar increases were reported for socioeconomic conditions (77%) and work conditions, including job security and lack of protection (69%). Improvements in understanding of health risks associated with wildfire smoke were also reported, with 37% indicating "somewhat" improvement and 40% reporting "high" or "very high" levels of increased understanding. The performance also produced strong affective responses: 83% of participants reported feeling highly or very highly connected to the farmworker experiences portrayed in the play. A majority of the audience indicated that they were likely to discuss or share these issues with others (72%), and more than half reported a high or very high likelihood of taking action or learning more (53%). These responses suggest that the framework did more than increase audience awareness of wildfire smoke toxicity and farmworker conditions. By placing audiences within an unfolding and participatory interpretation of exposure, the performance enabled environmental health risks to be encountered as lived social, emotional, and bodily conditions rather than as abstract scientific information.

Translation, ongoing collaboration and action. Data from the post-performance responses illustrate a profound change in the audience's comprehension of the issues facing farmworkers. The largest shifts in

opinions (thoughts and feelings) occurred in areas where audiences initially had the least awareness, particularly the structural and labor conditions shaping farmworker exposure to wildfire smoke. Combining scientific data with interactive performative storytelling can make the structural and lived dimensions of environmental exposure more accessible to audiences. The responses also indicate that the framework can extend beyond the performance itself. Audience members not only reported increased understanding but also a willingness to continue engaging with these issues through discussion, reflection, learning, and action. As part of the translation stage, affected-community representatives, policymakers, public-health practitioners, advocacy organizations, employers and other relevant stakeholders and decision-makers can be invited to attend the performance together, creating a shared experiential point of reference. Following the performance, facilitated talkbacks and workshops can enable participants to hear one another's perspectives, identify shared priorities and points of disagreement, and develop concrete next steps for continued collaboration and community, organizational or policy action. Within this process, the performance serves as a catalyst linking shared experience to continued dialogue, collaborative decision-making, collective action and policy engagement beyond the stage.

Implementing and evaluating the framework nevertheless presents some challenges. Bringing together scientists, artists, and affected communities and sustaining their collaboration across the framework's stages can be challenging and may require careful coordination. Because the framework has so far been illustrated through one project, *Hidden Strawberries*, its application across other environmental health contexts, community settings, and performative forms has yet to be demonstrated. *Hidden Strawberries,* developed as a medium- to large-scale production, represents one possible implementation; other applications do not necessarily need to involve a production of this size or scope. Likewise, its audience evaluation provides evidence about this particular implementation, not the framework as a whole. For *Hidden Strawberries*, the evaluation captured self-reported responses, including intentions to continue learning or take action, but did not assess whether these intentions resulted in sustained behavioral change, continued collaboration, collective action, or policy impact. Future applications should examine whether

such outcomes develop and persist over time. The framework's modular design can provide flexibility in responding to these implementation challenges: its components can be adapted to different goals, resources, communities, and environmental health issues. Applications may involve professional artists, students, community members, or hybrid teams and may range from workshops, staged readings, and community forums to full theatrical productions.

The framework complements scientific research by transforming scientific data and lived experience into shared and participatory encounters with exposure beyond traditional academic pathways. Instead of receiving scientific facts, lived experience, and socioeconomic conditions as separate forms of information, audiences encounter them within a single unfolding and interactive narrative. This integrated narrative allows audiences to understand constraints: continuing to work despite symptoms is shown not as an individual choice but as a condition shaped by economic pressure, job insecurity, immigration-related vulnerability, and limited alternatives. Through interactive performance, audiences (i.e., the unaffected community) can actively engage with the environmental health issue, participate in decision-making, and reflect on their shared role within the larger economic and social systems that shape environmental health impacts. In a single performance, people with different levels of prior knowledge can engage with complex environmental and social processes without technical expertise.

As extreme weather increasingly shapes human health, environmental health frameworks must connect the characterization of hazards with the lived social and economic conditions through which exposure unfolds. Bringing scientific evidence, community knowledge, and interactive performance into a shared experiential process can transform individual experiences of exposure into shared public understanding. We hope this framework will encourage scientists, artists, and affected communities to form collaborative teams, adapt its components to their own contexts, and examine whether experiential engagement can support sustained dialogue, collective action, and more responsive environmental health policy.

Figures

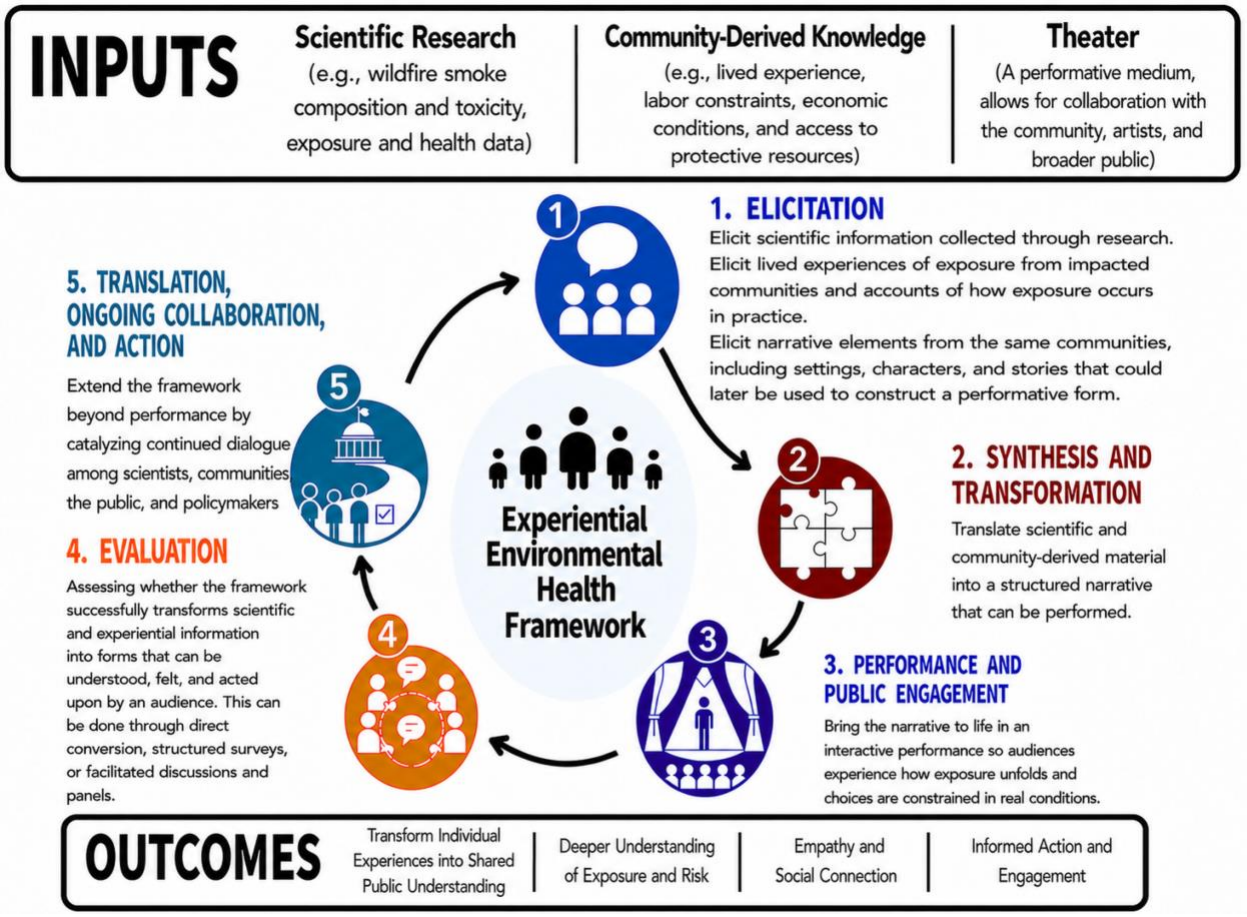

Figure 1. Experiential environmental health framework. The framework integrates scientific data, community-derived knowledge and theater to transform individual experiences into shared public understanding

Figure 2. a) Audience members participating in a group dance with the lead actor (Luna Lau), creating an interactive and shared performance space. b) The lead actor picking strawberries during a non-smoke day. c) Strawberry picking during a smoke day under darker and denser stage lighting designed to evoke wildfire smoke exposure. d) Dance and traditional costume incorporated to reflect cultural identity and community context. The dancer shown in panel d is Jesús Cortés. Photo credit: panel a, Harrison Truong; panels b, c, and d, Franc Chen.

Boxes

Box 1

Terminology and definitions

Eco-theater: Eco-theater is a theatrical practice that uses participatory performance to center people in environmental discourse, revealing how environmental conditions and degradation are experienced across populations. Eco-theater emerges from a recognition that theater has played a limited role in environmental discourse, particularly compared to literature and visual arts. This marginal position is partly rooted in the anthropocentric orientation of traditional theater, which has historically centered human conflict and narrative, constraining its ability to engage with broader ecological relationships.[27] In response, eco-theater repositions performance as a space for engaging with the environment not as background or metaphor, but as a material and relational presence. Through live, embodied encounters, it brings attention to interactions among people, environments, and more-than-human systems, shifting from symbolic representation toward lived and material relations.[27,28] This shift is also reflected in an expanded understanding of environment, one that includes everyday spaces of labor and exposure, connecting ecological conditions to social inequality and environmental justice.[34]

Eco-theater is built on community participation. Within this broader approach, eco-theater is often grounded in community-based and participatory practices, where environmental understanding is developed collectively rather than delivered to audiences.[34,35] These processes bring together scientific knowledge and the experiences of people directly affected by environmental conditions, allowing knowledge to emerge through dialogue, storytelling, and performance.[22] In this sense, eco-theater functions not only as a form of expression but as a way of producing environmental understanding that reflects lived realities and social context. It also creates space for voices that are often underrepresented in environmental research and policy, particularly communities facing disproportionate exposure and limited resources.[34,35] By centering participation, eco-theater becomes a way to connect environmental conditions to people's daily lives while shaping how those conditions are understood and communicated.

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Box 2

Composition, toxicity and health impact of wildfire smoke

Sample collection. We collected and analyzed wildfire smoke from more than 10 major fires across the Western US in 2024 using size-selective air samplers.

Particle size and composition. Ultrafine particles accounted for more than 60% of the associated mass of particles across different wildfire smoke samples. Toxic metals, including Cr, Fe, Ni, Mn, and Ti, are present in this fraction and extend to sizes below 5 nm. More information about our scientific findings can be seen at Namayandeh et al.[40]

Wildfire smoke toxicity and health impacts. Ultrafine and nanoscale particles (<0.10 μm) can penetrate deep into the lungs, enter the bloodstream, and in some cases cross the blood–brain barrier, while their high surface area enhances tissue interaction and limits clearance, contributing to systemic effects including associations with neurodegenerative diseases.[41-44] Particle size and metal content define multiple pathways for biological reactivity, with size influencing deposition and translocation and metals contributing to oxidative and cellular stress.[41,45-48]

Wildfire smoke mortality. Wildfire smoke exposure is already a major contributor to mortality and is projected to increase substantially in coming decades.[6] In the United States, smoke-related exposure is associated with ~41,000 excess deaths per year.[2] In addition, wildfire smoke is expected to contribute on the order of millions of premature deaths over the coming decades, underscoring its growing role in public health burden.[2]

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Box 3

Community engagement

We conducted formative interviews and conversations with farmworkers in Watsonville, California, from November 2023 to February 2024, while the wildfire-smoke research described in Box 2 was also underway. The engagement was designed not only to understand how wildfire-smoke exposure is experienced, but also to involve farmworkers and community partners as contributors whose knowledge helped shape the framework and performance. Conducting the scientific research and community engagement in parallel allowed scientific and community-derived knowledge to develop simultaneously and jointly inform the project. Farmworkers' perspectives informed how labor conditions, access to information, protective practices, housing conditions and the economic constraints surrounding decisions to continue working were interpreted and represented. The engagement was conducted under a protocol approved by the Stanford University Institutional Review Board (protocol no. 72288), with recruitment, informed consent and compensation conducted in accordance with the approved protocol.

Participant background. Many participants described crossing the desert during their migration to the United States and identified work as a primary reason for migrating. Participants also described family histories closely connected to agriculture, including relatives who worked as farmers or farmworkers.

Living conditions and structural context. Participants described living in single rooms or trailers shared with family members or co-workers. These conditions indicated economic dependence on continuous employment and a limited ability to stop working during wildfire-smoke events.

Exposure and protection. Participants frequently described continuing to work during wildfires while relying on surgical masks or bandanas, which provide limited protection from fine particulate matter in wildfire smoke. Participants also reported little or no prior knowledge about the toxicity of wildfire smoke.

Constraints and continuity of exposure. Participants described exposure continuing over multiple days, even under visibly hazardous conditions, because work could not easily be paused and income depended

on continued labor. Although many characterized their decisions to work as voluntary, their accounts revealed conditions in which stopping work was not a practical option.

Participants' accounts informed the settings, characters, conflicts and moments of decision represented in *Hidden Strawberries*. No character represented a specific participant or other real person; instead, the characters and narrative combined themes and experiences shared across the engagement. These accounts were presented as formative material for this implementation of the framework rather than as a representative assessment of California farmworkers.

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Author contributions A.N. conceptualized the project and framework, developed the methodology, and wrote the original draft. S.N. contributed to the conceptual development of the framework, produced the theatrical work, and led project administration, community engagement, and personnel recruitment. J.H.

coordinated technical production and personnel recruitment. J.L.S. led community engagement and interviews and provided translation. R.K. analyzed the audience-response data. C.M. contributed to production design. A.L. contributed to community engagement and interviews. E.P. contributed to community engagement and personnel recruitment and reviewed and edited the manuscript. R.D. and S.F. contributed to the conceptual development of the framework, funding acquisition, and reviewed and edited the manuscript.

Competing interests The authors declare no competing interests.

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