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Two weeks after the 2023 Maui wildfires: drinking water experiences and needs†

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To understand community impacts and needs after the August 2023 Maui wildfires, we conducted a rapid survey-based field investigation two weeks after the incident. During the fires, municipal water customers were warned not to use their water due to potential drinking water contamination. Household displacement and isolation of some impacted areas limited extensive study participation. Households (14) in the affected areas were visited and surveyed about property characteristics, evacuation, water use, and water quality observations. Publicly available test results from Maui County and the University of Hawai'i were also reviewed. Opportunistically, wildfire impacts to agricultural water systems were documented. Half of the households had property damage, and all lost power and used drinking water before being notified that it was potentially contaminated. Nearly all households expressed confusion about allowable water use activities and health risks. Most households noticed water issues after the evacuation order was lifted, and some acquired and used at-home drinking water test kits. None of these kits could find all previously identified fire-related chemicals. Damage to agricultural water systems was similar to damage seen for residential systems. Recommendations to lessen impacts and expedite community response and recovery from wildfires are provided.

Water impact

Wildfires are impacting communities worldwide and prompting water safety challenges. Experiences and needs after the 2023 Maui Hawai'i wildfires were examined through a rapid response effort. This was the deadliest U.S. wildfire incident in more than 100 years. To lessen public confusion and chemical health risks posed to residential and agricultural water users, science and policy recommendations are provided.

1. Introduction

On August 8, four fires ignited in Maui County, Hawai'i, resulting in the deadliest U.S. wildfire incident in more than 100 years. The four wildfires included the Kula Fire, Olinda Fire (both referred to as the Upcountry Fires), Pūlehu/Kihei Fire, and Lāhainā Fire. Fire damage was estimated to be more than \$5.52 billion in Lāhainā, \$434 million in Kula, and more than 100 people were killed.[1–3] During and after the fire, more than 20 000 people were evacuated, and the State of Hawai'i encouraged visitors to leave the island of Maui.

The community impacts of the fire were significant. In a small section of Kula, 20 structures were damaged and destroyed (544 exposed), while more than 2207 structures were damaged and destroyed in Lāhainā, with 86% being homes.[3,4] Lāhainā is unique to Hawai'i as it was the traditional home of Maui royalty dating back to the 1500s. In 1820, Lāhainā became the capital of the Hawaiian Kingdom. Whaling, sugar plantations, and most recently tourism reshaped the landscape and economy of the town and surrounding area. Lāhainā is the economic center of West Maui. The devastation of the fires resulted in more than 58% job loss among a surveyed population of survivors, and racial

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and ethnic minorities also experienced significant hardship.[5–7] Fig. 1 provides a general incident timeline and the ESI† provides a more detailed timeline.

As with prior U.S. wildfires, two public drinking water systems were damaged by the 2023 Maui wildfires. The Upper Kula and Lāhainā systems served 7686 and 20 065 people, respectively. Both systems relied upon surface water and groundwater.[8–10] Author discussions with the system owner and operator, Maui County Department of Water Supply (Maui DWS), revealed that both systems experienced power loss. Customer structures were also destroyed, prompting water leaks and loss of water pressure.

Fig. 1 The Maui fires began August 8, 2023 and Hurricane Dora was off-shore passing to the south. A brief (a) timeline is shown pertaining to public water systems being impacted as well as the (b) general water advisory areas where the unsafe water alerts were issued in and near Lāhainā and Kula. A more detailed timeline can be found in the ESI† file. Acronyms used: POTUS = President of the United States; HI DOH = Hawai'i Department of Health; UH = University of Hawai'i; Louisville = City of Louisville, Colorado public works officials worked with Purdue University to aid the Hawai'i Department of Agriculture.

To warn their customers about potential chemical exposure risks, the Maui DWS issued an "Unsafe Water Advisory" for the Upper Kula and Lāhainā systems on August 11, three days after the fires and evacuations began. The Maui DWS followed guidance from the Hawai'i Department of Health, the *Safe Drinking Water Act* primacy agency. This guidance directed customers to avoid drinking or using the water for cooking, and limit use of the water for showering due to acute chemical exposure concerns.[11] This type of notification was in response to recent U.S. wildfire disasters that have sometimes caused volatile organic compound (VOC) drinking water contamination at levels exceeding hazardous waste limits.[12–14] VOC drinking water contamination caused by past fires has been associated with plastics degradation[15–17] and depressurization of plumbing and utility system components coupled with smoke, vapor, and debris entry.[12,18,19] Wildfire impacts on drinking water systems have been linked to additional household costs, economic hardship, as well as anxiety, stress, and depression.[20]

The present study was initiated to document important ephemeral data two weeks after the fires began. This rapid study was conducted August 19 to 25, 2023 and consisted of multiple components, including (1) household surveys, (2) an assessment of impacted agricultural water systems, and (3) a review and summarization of publicly available drinking water sample data. This study is not statistically representative of the populations impacted due to multiple challenges: many households were still physically displaced two weeks after the incident, some fires were still smoldering aboveground and belowground where evacuation orders had been lifted, isolation of some fire impacted areas by law enforcement inhibited some data gathering, and funding was not available to support an otherwise larger and equally rapid experimental design. While conducting the household survey, the Hawai'i Department of Agriculture requested help inspecting damage to agricultural property water systems, and those results were subsequently included in this project. The authors note that prior wildfires on agricultural properties damaged fencing and structures,[21,22] but no studies have documented their water system damage.

2. Methods

The in-person household surveys were conducted for standing homes in neighborhoods affected by the Kula Fire, Olinda Fire, and the Lāhainā Fire. The 37-question household survey lasting about 30 minutes was approved by the Purdue University Institutional Review Board (IRB-2023-1250, Public Health Support to the August 2023 Wildfires in Maui, Hawai'i, see ESI S3†). Participating households were identified by those who contacted the authors for assistance. Information collected included property characteristics, evacuation experiences, drinking water uses, water quality observations, and drinking water related questions that households wanted answered by officials. Many households remained evacuated from the impacted areas at the time of the study.

The onsite inspections were conducted at both the surveyed households and at two agricultural (non-residential) properties. These inspections involved identifying and examining drinking water sources, the infrastructure (*i.e.*, meter, pipes, tanks), and building plumbing. The two non-residential agricultural properties visited were located in the Kula Fire and Pūlehu/Kihei Fire burn areas. These properties were served by their own private water sources, not the damaged public water systems. The water sources for these sites included a private well and creek used primarily for irrigation and watering animals. At the time of our field investigation, no guidance on post-wildfire agricultural water system inspection protocols were available. As such, the team partly relied upon guidance from the Center for Plumbing Safety for private wells and buildings[23,24] and personal experience from responding to previous wildfire disasters.

To help the authors better interpret survey and field observations, water quality monitoring data from Maui DWS and the University of Hawai'i for August 16 to December 8, 2023 were analyzed. Drinking water sample chemical analysis results were available from the Maui County website as pdf files and from the University of Hawai'i Maui Post-Fire Community Drinking-Water Information Hub as a Microsoft® Excel files.[11,25] Maui County drinking water test results were representative of the Upper Kula and Lāhainā public water systems. Test results from the University of Hawai'i Water Resources Research Center were representative of private properties that were delivered water from these two public water systems. The authors summarized these two datasets to better understand the distribution of VOCs throughout the impacted community. Survey and water analysis results were not publicly available for the impacted households at the time Maui County held its first community meeting in Kula (August 24, 2023).

3. Results

3.1 Household assessment and responses

3.1.1 Household locations and demographics. During this study, large portions of Lāhainā were closed to both residents and visitors by law enforcement. Further, significant displacement was ongoing, which limited household survey and field reconnaissance results. As a result, study results primarily represent areas impacted by the fires outside Lāhainā. Despite this limitation, the authors were able to include two Lāhainā households in this study.

Fourteen households that participated in the study had been impacted by either the Lāhainā Fire, Kula Fire, or Olinda Fire. All homes were inside an "Unsafe Water Alert" map area issued by Maui County but received drinking water from different sources: the Lāhainā water system (2), Upper Kula water system (11), and one household was served by its own private cistern and was not connected to a Maui County water meter. Households generally consisted of three to four people between the ages of 1 to greater than 65 years of age; no households had children less than 1 year of age. These results were consistent with U.S. Census typical household characteristics in Kula (2.54 per person/household) and Lāhainā (3.93 per person/household) (ESI† Table S1).

All surveyed households had either homeowner or renter insurance for their property. Most households (71%, 10 of 14) owned their home and four rented, more than the 67% and 51% home ownership rates for Kula and Lāhainā, respectively (ESI† Table S1). On average, survey participants had resided in their home for 12 years range, but individual responses ranged from 8 months to 38 years. The average age of each household respondent was 51 with a minimum age of 26 and maximum age of 75.

3.1.2 Wildfire notification, evacuation, power, property damage. More than half of the households were at home when they first learned about the fire threat to their property (9 of 14) (ESI† Video S1). Some households only became aware of the fire threat when they first saw the either the smoke or fire on or from their property, while others were woken up in the middle of the night by family urging them to evacuate. Nearly all households (12 of 14) personally knew someone whose home was damaged or destroyed by the fires. One household reported not receiving an evacuation notice despite seeing flames in the distance and from two sides of their property.

The following results reflect our study's bias toward households affected by the Kula Fire: a majority of households that evacuated (7 of 11) either returned to their

Fig. 2 Two weeks after the wildfire and the evacuation orders had been lifted, some fires were still burning, and various damage and household responses were observed.

home the same day or the following day. All households lost power either the night before the fire associated with high winds or the day of the fire. Power was out for eight households for three days or less, while three households had power out for 5, 7, and 11 day periods. One household had a backup generator so their power was only slightly interrupted, while two households could not recall when power was restored.

Some households (5 of 14) had homes less than 500 feet from multiple destroyed buildings, while other homes were located up to two to five miles away from the nearest damaged or destroyed structure (Fig. 2). Half of the households (7 of 14) reported having some sort of fire damage on their property ranging from destroyed shed buildings, melted fences, burned vegetation (*i.e.*, trees, bushes, grass), ash on the roof, smoke and ash inside the house (*i.e.*, on furniture, in the attic). One household in Kula reported that their high-density polyethylene (HDPE) drinking water service line on their side of the Maui County water meter sprung four different leaks during the fire. Each leak occurred after the prior one was fixed by the homeowner, who stayed at their property. That same homeowner also reported seeing the neighbor's HDPE irrigation system spring leaks during the fire event. After the fire, this homeowner noticed very high water pressure problems at their kitchen faucet, and ultimately replaced their customer service line with a polyvinylchloride (PVC) pipe. The elevation differences of about 2000 ft for some Kula water system assets near the Haleakalā slope, a dormant volcano, may have contributed to pressure fluctuations. Another household in Kula reported that the home across the street caught on fire and firefighters let it burn down because ammunition stored in the home exploded. On this same street, multiple families used buckets of water to fight the fire. The other half of the households surveyed did not report any physical or fire damage to their property, but some did report smoke smells in their homes. After the evacuation order was lifted for Kula, 11 of 12 households returned home and flushed their plumbing, but their actions varied widely (*i.e.*, running a single outdoor spigot for 5 minutes *vs.* every fixture for 1 hour each). These actions were conducted before plumbing flushing guidance was issued by government agencies.

3.1.3 Water use and other challenges. All households indicated that after the evacuation order was lifted, they used the drinking water as they would for everyday use until they learned that Maui DWS issued an "Unsafe Water Advisory" on August 11. One challenge mentioned by multiple households was that because mobile phone and internet communications were down after the fire, face to face meetings were the initial way residents learned about water safety warnings. Once households learned about the Unsafe Water Advisory, most halted tap water use for drinking and cooking. Sometimes occupants in the same household, however, continued to use the potentially contaminated water differently (*i.e.*, husband took hot showers *vs.* wife took warm or cold showers). Noncompliance with drinking water advisories can occur after wildfires for a variety of reasons, even when public water systems have been found to be chemically contaminated.[20] Importantly, many households reported unusual drinking water issues when they returned to their homes (Table 1). No studies were found that reported Maui County customer feedback post-fire, but customer feedback has been found to help identify localized and widespread chemical drinking water contamination incidents.[26]

Households also encountered other challenges when they returned after the evacuation. Because Lāhainā's municipal sewer system was damaged, households returning to their standing homes were advised to limit water use. Sewer damage included debris entry through open sewer laterals, pump station damage, and lack of power. Where sewer restrictions were not in place, some Kula households used water from their lawn sprinklers and hoses to suppress flare up fires (ESI† Video S2). Flare ups in the Upper Kula water system service area were a concern and during the author's site visit. Smoldering was observed near a site visited in Kula and a fire department response was observed (ESI† Video S3). Smoldering combustion is "the slow, low temperature, and flameless burning of porous fuels".[27] It has been reported elsewhere that belowground smoldering and fire can occur for weeks to months after a wildfire.[28–30]

Table 1 Households reported unusual drinking water taste, odor, color, and clarity issues when they returned to their homes after evacuating

Description of drinking water observations by each household that reported
1. Discolored water at kitchen sink and toilet – brown color
2. Odor had a weird scent like an acrid, acid, potpourri odor
3. The water smelled bad
4. The water had a clarity issue, it looked dirty
5. The water had a strong chlorine odor
6. When we first turned on water, water pouring into the bathtub was a dirty color
7. The water smelled like gasoline; the water smelled a lot when we did dishes with hot water; water was discolored too when we turned on faucet after getting home
8. The water smelled, looked brown
9. The water smelled like eggs at the kitchen faucet
10. The water had a strong odor, didn't smell like gas but something similar; last night water smelled funny; because of [the] water smell we slept in a different room in the house away from that fixture

3.1.4 Field observations. Field reconnaissance revealed that water system and structure damage was similar to wildfires observed elsewhere by the authors.[13,14,19] Damages observed included burned and destroyed structures, open (metal) plumbing pipes in the home footprint near where the water heater had fallen over, melted and burned plastic pipes, and water meter box damage. Heat damaged plastic service lines were sometimes observed on the customer side of the water meter. Particulate was also observed on and inside some standing homes likely associated with smoke and wind. Smoke odors were also detected by the authors inside some homes. Some households were operating newly acquired indoor air purifiers.

Discussions with Maui DWS officials indicated that all water meters to properties with destroyed structures had initially been shutoff and then were removed. During the authors Kula household investigations two weeks after the fires, some inconsistencies were found; some water meters serving destroyed structures had been removed while one was not. One property owner with a destroyed home had turned on his shutoff water meter to water his plants (Fig. 2). This water meter did not have a backflow prevention device. Another nearby property owner with a destroyed home told the authors that he would resist allowing the Maui DWS to shutoff his water or take the meter because he needed the water to clean his property. After the 2023 Marshall Fire in Colorado, when water meters were not removed from destroyed properties at one utility, a property owner turned it on without utility consent thereby enabling a potential cross-connection.[14] Backflow prevention devices are not common for residential properties but have been recommended for wildfire vulnerable communities to protect water systems from wildfire caused contamination.[14,31] Property inspections in Lāhainā were limited to areas outside the main burn area due to access controls.[32]

Unlike some communities previously investigated after wildfires, on Maui the authors observed a noticeable amount of water treatment equipment and domestic plumbing located outside buildings. For example, inline sediment filters, water meters, valves, and piping such as copper, PVC, chlorinated PVC (CPVC), and HDPE, and crosslinked polyethylene (PEX) were located aboveground and outside buildings. Burial depths of some pipes and water meter boxes were shallow, less than 6 inches. In some cases, property owner service lines were partially exposed. Shallow public water system or aboveground water main and service lines and property owner service lines have been observed in prior fires.[30] Plastic, metal, and concrete water meter boxes were common in Maui like elsewhere. Water meter boxes were located next to or surrounded by concrete (recessed in a sidewalk), while others were surrounded by vegetation and underbrush. The amount of aboveground water system infrastructure and plumbing observed in Maui is likely because air temperature rarely decreases below 14 °C, and freezing is not a risk.

3.1.5 Household emergency drinking water: bottled water and buffalos. Bottled water was the most popular emergency household drinking water source. Most households (12 of 14) purchased bottled water or used in-store dispensers, whereas seven also received bottled water from donations. One household obtained and transported drinking water from a family home outside the unsafe water alert area to their home within the advisory area.

Most households had concerns with the safety of water from water buffalos provided by Maui DWS (ESI† Video S4). Only 4 of 14 households obtained drinking water from the water buffalos located in the community. Many households (7 of 10) chose not to use water buffalos because they were unclear how the water buffalos were cleaned and made safe. One household claimed to have never seen a water buffalo, one stated the water tasted bad, and another said they had enough emergency drinking water so they did not need that water.

3.1.6 Trust in drinking water safety and testing at home. When households were asked about which organization that they trusted most about drinking water safety, most (10 of 14) chose not to select a provided option. The options were: county agency, state agency, in-home water treatment company or water testing laboratory. Instead, five households listed Purdue University and others also cited community members, fire-fighters, and private water testing companies as the most trusted groups. Households that mentioned Purdue University as trustworthy stated that this was because representatives were at their home asking them questions about their drinking water safety questions and needs. Of the 14 households, four expressed prior distrust with Maui County. Several households also cited that they did not trust government agencies because they were not warned to evacuate before the fire was visible on their property nor were they warned to avoid the potentially contaminated water before they had used it.

As of two weeks after the fire, 3 of 14 households had conducted their own drinking water testing, though two more households were actively searching for drinking water quality tests to conduct themselves. Two households conducted testing at their homes using swimming pool and spa test kits. One household had found several at-home drinking water sampling kits available online that claimed to screen for VOCs. These kits ranged from approximately $300 to $700 each.

When households were asked to identify the most important questions they had about their drinking water, they provided the authors 47 questions. The authors include them here (Box 1), verbatim, in the order in which they were received. Question 1 is the first question asked by a household and question 5 is the last; some households did not ask the authors five questions. The question topics ranged from the chemicals present in the drinking water, protective actions, vulnerability of household plumbing to contamination, the safety of emergency drinking water sources, and how water system damage was being identified and resolved.

Box 1 Two weeks after the wildfires, households located in the unsafe water alert area listed 47 different questions that they wanted answered by health officials as well as by Maui County. Questions are listed in the order they were received from each household (a to f) by the order of the household's response Q1 to Q5. No households submitted more than five questions.

1st question	a. What is the benzene level now compared to after the fire? b. What are the chemicals evident in the (drinking) water? c. Will all homeowners need to filter their home? d. What chemicals are in the (drinking) water? e. Is the (drinking) water safe for family to bathe in? Just want it to be safe f. Can you (Maui County) send a regular water quality report (monthly) to be transparent? g. Why does (drinking) water have a problem? h. What chemicals are being found in the (drinking) water and what quantities? i. Where is the water meter? j. What is in the (drinking) water? k. Is the (drinking) water at a safe level to drink and bathe in? l. Is the (drinking) water unsafe? m. What's the range of scope of (drinking water) testing? n. Is the (drinking) water coming from the street potable, safe to use? o. Can you explain what caused the (drinking) water problem in layman's terms?	2nd question	a. How do I get the chemicals out of the drinking water? b. Why would the chemicals be in the (drinking) water system? c. Are the chemicals in the (drinking) water trace or particulate? d. Can I brush my teeth with the (drinking) water? e. How are water buffalos prepared or made sanitary before distribution? f. Does a private well near a property impact the (drinking) water supply? g. Shouldn't they (Maui County) have a hearing before they decide to do things? h. What was the source of contamination? i. Will someone remove the fire danger posed by the gulch? j. Is it (the drinking water) safe to drink? k. Should I get trucked in (drinking) water and tanks? l. What's in the (drinking) water making it unsafe? m. Are you testing for benzene only or running wider tests? n. Why is the pressure oscillating so much?
3rd question	a. If a neighbor test shows chemicals in their (drinking) water, would it come to my house? b. Were the chemicals in the (drinking) water system before? Never heard of it before c. How do chemicals affect health now and in the future? d. Should we install our own well or cistern because the disaster made it clear water is important? e. Is it (the drinking water in the unsafe water alert area) dangerous for gardens and plants? f. Can I trust Maui County to be responsible for (drinking) water safety? g. Can we remedy the situation like using an in-home drinking water filter? h. What scientific paper gives advice about what chemicals to test for? i. Should I install my own pressure valve device at home?	4th question	a. What would the effect of the chemicals be on elderly and children? b. Where does Maui County (drinking) water come from? c. When will we know it is safe? d. How is it that people backwash dirty water into clean (drinking) water? e. How would we provide our own samples to another group to be tested and blinded? f. Can we have regular updates about the whole situation?
		5th question	a. When your (drinking) water is said to be safe what does that mean? b. How could this be avoided in the future? c. If there was a false alarm about a missile attack and Maui County issued an island-wide alarm, why didn't they send an alarm about the wildfire? Before the disaster communication was low

3.2 Concerns and damage to agricultural water systems

The authors visited two agricultural properties to identify potential water system damage. At both properties, the water systems inspected relied on onsite wells. Water was pumped to either aboveground steel or plastic tanks primarily using PVC and HDPE pipes and fittings. Finished water storage tanks had vents like municipal water storage tanks making them vulnerable to smoke entry like observed for depressurized municipal drinking water storage tanks in other fires.[14] Pipes that conveyed this water to the usage points were sometimes located on the ground surface for long distances (1000s of ft). At both properties, water was provided to animals using plastic and metal troughs and livestock tubs. The larger operation also utilized tire waterers. Both operations utilized their own fire-fighting equipment such as sprayers and water tenders to fight the fire, smoldering, and hot spots. Having onsite fire-fighting equipment is not unusual for livestock and farm properties vulnerable to fire risk.[33] In general, agricultural water systems had a more decentralized approach to water storage and distribution than households and public water systems.

Of the agricultural properties visited, one had extensive damage to their water system while the other property did not. On the property that experienced fire damage, the wildfire damaged and destroyed an estimated 50 000 ft of HDPE pipe used for irrigation and animal watering. Most of this pipe was observed along burned and destroyed fences (Fig. 3). Interestingly, an HDPE pipe on the ground surface seemingly ruptured due to plastic softening and water boiling/pressure build up. For this property, the property manager shared that when pipes were repressurized new water leaks were discovered at many joints. Underground smoldering was observed (with smoke) during the author's inspection (ESI† Video S5) and at a different location on the same property by a property representative a day earlier (ESI†

Video S6). For the most damaged agricultural property, some assets were surrounded by burned vegetation, leaving a coat of particulates on their exteriors. Field observations indicated that contamination might enter these fire damaged water systems by the (1) thermal degradation of plastic pipes and tanks, and (2) depressurized pipes and tanks thereby enabling entry of smoke, particulates, vapors, and debris. Although the authors did not conduct chemical water testing, the owners of both agricultural properties subsequently conducted VOC water testing and did not find fire-related VOCs. At the second agricultural property where no fire-related water system damage was observed, the fire destroyed structures on an adjacent property located less than 500 ft away.

3.3 VOC contamination was discovered in the public water distribution systems and private property plumbing

Following the conclusion of the field investigation, Maui DWS reported finding VOC contamination in the Upper Kula and Lāhainā public water systems.[34] Those first Maui County drinking water samples provided a snapshot in time for the infrastructure dynamically recovering from the wildfire impacts. Those discoveries also underscored the importance of warning the population about potential contaminated water even when no drinking water sampling data had previously been available.

As of December 2023, Maui DWS had screened water samples from storage tanks, hydrants, and service lines for 24 of the 51 fire-related VOCs (Table 2). The most common chemicals and maximum concentrations detected by Maui DWS in Lāhainā were benzene (40 ppb), methylene chloride (3 ppb), ethyl benzene (2.5 ppb), total xylenes (2.4 ppb), and bis(2-ethylhexyl)phthalate (1.4 ppb), and toluene (1.3 ppb). For several samples, benzene exceeded the 5 ppb federal safe drinking water limit. In Kula, the most common detections and maximum concentrations found were benzene (3.8 ppb), methylene chloride (3.8 ppb), styrene (1.8 ppb), and toluene (1.6 ppb), and no chemicals exceeded federal drinking water

Fig. 3 Some agricultural water system assets were thermally damaged, destroyed, or impacted by particulate.

exposure limits. This difference is unsurprising as fewer structures were damaged and destroyed in suburban Kula (16) compared to more urban Lāhainā (2207).[1] The likelihood of post-fire drinking water contamination has been shown to be related to the density of destroyed buildings.[35] Also, the water pipes in Kula were rapidly repressurized after the fire, but sections of the Lāhainā water distribution system remained depressurized and unused for weeks or longer after the fire.

The University of Hawai'i tap water testing also revealed drinking water contamination at private properties on the Upper Kula and Lāhainā water systems. Data reviewed in the present study included 239 samples collected between August and December 2023. Private property water testing in Lāhainā was limited because, as of December 2023, portions of the Lāhainā remained inaccessible. Thus, the following results are primarily representative of the Upper Kula water system. Water samples were collected from household plumbing, including kitchen faucets, outdoor spigots, and bathroom faucets at homes occupied or being visited by residents. Samples were primarily taken from undamaged homes, though some damaged and destroyed structures were sampled. Water samples were screened for 78 VOCs including and 43 of 51 fire-related VOCs (Table 2). Eleven chemicals exceeded a Federal or State drinking water maximum contaminant level at least once,[36,37] and 13 chemicals were detected in more than 51% of all drinking water samples, including several chlorinated compounds. Chloramines were used as the residual disinfectant for both water systems at the time this sampling was conducted.[8,9] It remains unclear if some of the chlorinated chemicals detected were solely due to drinking water disinfectant organic carbon interactions or from the fire. Chlorinated compounds have been detected in drinking water elsewhere after fires when no chlorine disinfectant was used and have been attributed to PVC water system asset thermal degradation.[30]

Table 2 Private property drinking water sampling results were compared against Federal and State of Hawai'i drinking water standards and prior wildfires that damaged drinking water systems

Chemicals exceeded a drinking water exposure limit for at least 1 sample, maximum concentration in ppb		Percentage of water samples where a chemical was detected greater than 50% of the time, maximum concentration in ppb			The top 5 chemicals detected at the highest concentrations found, in ppb	
Trichloromethane* (Federal MCL, 80 ppb TTHMs)	195	$^{\Delta}$Acetone*	84%	178	$^{\Delta}$Methyl ethyl ketone (MEK)*	293
1,2,3-Trichloropropane (TCP) (HI MCL 0.6 ppb)	11.2	Trichloromethane*	80%	195	Tetrahydrofuran*	217
1,2-Dibromoethane (EDB) (HI MCL = 0.04 ppb)	10.3	Bromodichloromethane*	71%	19.3	Trichloromethane*	195
Carbon tetrachloride* (Federal MCL, 5 ppb)	10.0	Dibromochloromethane*	68%	23.0	$^{\Delta}$Acetone*	178
1,2-Dichloropropane* (Federal MCL, 5 ppb)	10.0	Bromoform*	68%	33.9	Bromoform*	33.9
Vinyl chloride* (Federal MCL, 2 ppb)	9.80	1,2-Dichlorobenzene*	67%	10	Other notable chemicals detected for at least 1 sample, maximum concentration in ppb	
$^{\Delta}$Methylene chloride* (Federal MCL, 5 ppb)	9.72	$^{\Delta}$Methylene chloride*	63%	9.72		
1,1-Dichloroethane* (Federal MCL, 5 ppb)	9.73	Bromomethane	57%	10.4	Bromoform* (Federal MCL, 80 ppb TTHMs)	33.9
1,2-Dibromo-3-chloropropane (DBCP) (HI MCL, 0.04 ppb)	9.62	1,3-Dichlorobenzene	56%	9.79	Dibromochloromethane* (Federal MCL, 100 ppb)	23.0
1,2-Dichloroethane* (Federal MCL, 5 ppb)	9.50	Iodomethane*	56%	8.50	*cis*-1,2-Dichloroethene* (Federal MCL, 70 ppb)	18.0
$^{\Delta}$Benzene* (Federal MCL, 5 ppb)	8.56	$^{\Delta}$Toluene*	56%	7.99	Bromomethane (Federal MCL, 80 ppb TTHMs)	10.4
		1,2,4-Trichlorobenzene*	55%	8.73	1,1,2,2-Tetrachloroethane (Federal HA, 2500 ppb)	10.3
		$^{\Delta}$*m*-/*p*-Xylene*	54%	9.30	1,1,2-Trichloroethane* (HI MCL, 200 ppb)	9.48
					trans-1,3-Dichloropropene (1,3-D) (Federal RSL, 60 ppb)	9.39

Asterisk (*) symbol indicates the chemical was found by others in wildfire damaged drinking water systems prior to the 2023 wildfires in Maui. Delta (Δ) symbol indicates the chemical was discovered by drawing contaminated air into stainless steel tubing during a structure fire by Horn *et al.* (2023).[18] Federal MCL = *Safe Drinking Water Act* maximum contaminant level; HI MCL = State of Hawai'i maximum contaminant level; RSL = USEPA regional screening level ingestion for a 10 kg child was used because there was no Federal or state regulated drinking water limits or health advisory levels for this compound; HA = Federal one-day USEPA health advisory for a 10 kg child. EDB, TCP, and DBCP are known soil fumigants monitored by the Lāhainā public water system for state drinking water regulatory purposes. Their maximum detections reported by the 2023 CCR were 0.004 ppb, 0.430 ppb, and 0.098 ppb, respectively. The maximum total trihalomethane (TTHM) levels detected in Lāhainā and Upper Kula public water systems for the 2023 state regulatory monitoring period were 63 ppb and 43 ppb, respectively. TTHMs are a summation of four different compounds: trichloromethane, bromodichloromethane, dibromochloromethane, and bromoform.

4. Discussion

4.1 Household challenges

4.1.1 Household drinking water safety notification and uncertainty. Two weeks after the fire, all surveyed households expressed concerns or confusion about drinking water safety. Their concerns are consistent with customers of fire damaged water systems elsewhere.[19,20] The limited information households had about drinking water safety affected their perceptions regarding its safety and use. Some households in Lāhainā had not heard from any government agency two weeks after the fire and were relying on word-of-mouth from family, friends, and neighbors for information. This communication deficiency was later confirmed by others.[38] Nearly all households surveyed in Kula, Olinda, and Lāhainā used water from the contaminated drinking water systems before receiving notification about it being potentially contaminated.

The lack of information reaching impacted households was due to several factors. First, the water system staff experienced significant impacts to their own safety, that of their families, and friends.[39] In several cases, their own homes were destroyed, they knew other families and friends who had lost their homes, businesses, pets, and even experienced the fire firsthand. This prompted less people to be available to respond to the fire-caused water system issues. Second, water systems are not designed to continuously deliver drinking water to all customers at unlimited demand for the scale of wildfires experienced in Maui and elsewhere.[12,14] To date, no water systems have been able to fully navigate the initial communication challenges associated with such a large-scale disaster. Cascading consequences such as pipe breaks, low pressure, no power, and active fire areas placed additional labor burdens on water system staff. Water system staff are also drawn to support fire-fighting activities by keeping water flowing when and where they can.[31] Finally, some households in the burn areas were unable to gain information because formal communication systems were down for more than one week and the only road to Western Maui was closed.[40] The challenge of rapidly getting information to drinking water customers after large disasters is not new.[14,20,41,42]

While federal law directs public water systems to create and issue their own drinking water advisories within 24 h,[43] under extreme circumstances like witnessed in Maui, better active support by more resourced and trained state drinking water agencies is recommended. Regulators should consider taking a more active role in creating and issuing unsafe water alert orders and helping disseminate that initial information. During the 2021 Marshall Fire, the State of Colorado *Safe Drinking Water Act* primacy agency rapidly assisted in creating and issuing advisories to help the City of Louisville. This enabled Louisville public works staff more time to focus on protecting their families, minimizing system damage, and supporting the delivery of water for fire-fighting activities. Second, as recommended by some households in Maui, when communication systems are down, an array of different public notification approaches should be applied. Helpful activities could include physical visits to the area, provision of hardcopy leaflets, and other information items about drinking water safety. This could also be coupled with information regarding the status of evacuation routes, emergency supply distribution sites, and emergency contact information.

4.1.2 Drinking water testing. At-home drinking water sampling kits under consideration by interviewed households could screen for some VOCs, but none considered all 51 fire-related contaminants of concern (Table 3). The initial 20 compound testing approach used by the Maui DWS and State of Hawai'i, did not screen drinking water for all fire-related chemicals. As the Maui DWS learned about fire-related drinking water contamination potential, this chemical list was expanded. In-home drinking water testing conducted by the University of Hawai'i at standing homes and destroyed homes (spigots, *etc.*) included 43 of 51 VOCs.[25] Household in-home drinking water test kits did not screen for 18, 21, and 27 of these chemicals, depending on the kit. This is notable because after the 2020 Oregon wildfires, methyl ethyl ketone (MEK) was found exceeding the short-term USEPA health advisory level,[19] but would have been missed by initial Hawai'i government agency testing and one of the three test kits evaluated here. Similarly, a recent structure fire pilot study found 11 VOCs drawn into plumbing,[18] including some VOCs not screened for by initial drinking water testing or with at-home drinking water test kits (*i.e.*, MEK, ethanol, acetone, styrene). Responding organizations should adopt the best available science when deciding which specific chemicals to test for in drinking water systems post-fire (Fig. 4). No testing kits screened water for semi-volatile organic compounds (SVOC). Initial water sampling by Maui County and the University of Hawai'i did not include SVOCs, though wildfires can cause drinking water contamination with SVOCs.[14]

4.1.3 Need for public education. The discovery that households engaged in normal drinking water use activities, and in some cases, flushed their plumbing, before learning that an unsafe water alert was issued underscores a need for public education. Due to the uncertainty surrounding wildfire impacts and safety, households acting after a fire is understandable. After the 2018 Camp Fire in California, households that received water testing results felt less worried.[44] Though, here the authors learned that not all households could afford testing, highlighting potential inequities between who could afford private testing and who could not. In Maui, household testing also did not screen for all fire-related chemicals of concern.

To increase public understanding about health risks and empower households to limit their potential exposures, local and state agencies can contribute by more rapidly sharing information. Water testing results of the impacted water distribution systems were not publicly shared until August 24, 2023, 16 days after the fires. Maps denoting the testing, a

Table 3 Comparison of fire-related volatile organic compounds that were listed on the County and State of Hawai'i drinking water testing list and those that were screened by different at-home drinking water sampling test kits

VOCs found in drinking water samples collected after wildfires (Δ exceeded health limit at wildfire damaged water system outside Hawai'i)	Chemical screened for by the organization		Home test kit name, cost, and minimum detection limit for chemical in ppb		
	Maui County and State of Hawai'i	University of Hawai'i	Safe home ULTIMATE drinking water test kit, $379	City check deluxe, $329	Extended city water test, $675
Acetonitrile			50		
[X]Acetone		Yes	50	10	
Acrolein			50		
[X,*,Δ]Benzene	Yes	Yes	1		1
Bromochloromethane		Yes	1		0.5
Bromodichloromethane		Yes	1	2	1
Bromoform		Yes	1	4	1
n-Butylbenzene		Yes			0.5
sec-Butylbenzene		Yes			0.5
tert-Butylbenzene		Yes			0.5
Carbon disulfide		Yes	5		
*Carbon tetrachloride	Yes	Yes	1	1	0.5
*Chlorobenzene	Yes	Yes	1	1	0.5
Chlorodibromomethane			1		
[X]Chloromethane		Yes	1	2	0.5
4-Chlorotoluene		Yes		1	0.5
Dibromochloromethane		Yes	1	4	0.5
*1,2-Dichlorobenzene	Yes	Yes		1	
*1,4-Dichlorobenzene	Yes	Yes		1	0.5
1,1-Dichloroethane	Yes		1		0.5
*1,2-Dichloroethane	Yes	Yes	1	1	0.5
1,1-Dichloroethene	Yes	Yes			0.5
1,2-Dichloroethylene		Yes	*Not screened by any kit*		
*1,2-Dichloropropane	Yes	Yes	1	2	0.5
[X]Ethanol					
[X,*]Ethyl benzene	Yes	Yes	1	1	0.5
Ethyl-*tert*-butyl ether (ETBE)			*Not screened by any kit*		
Iodomethane		Yes	1		
Isopropylbenzene		Yes	1		
[*,Δ]Methylene chloride	Yes	Yes	1		
[X,Δ]Methyl ethyl ketone (MEK)		Yes	50	10	
Methyl-iso-butyl ketone (MIBK)[Δ]		Yes	50		
[Δ]Methyl-*tert*-butyl ether (MTBE)		Yes	1	4	0.5
[X,Δ]Naphthalene		Yes	1		0.5
[X,*,Δ]Styrene	Yes	Yes	1	1	0.5
[Δ]*tert*-Butyl alcohol (TBA)			*Not screened by any kit*		
*Tetrachloroethylene	Yes	Yes			0.5
[Δ]Tetrahydrofuran (THF)		Yes		10	
[X,*,Δ]Toluene	Yes	Yes	1	1	0.5
1,2,3-Trichlorobenzene		Yes		2	0.5
[X,*]1,2,4-Trichlorobenzene	Yes	Yes	1		
1,1,1-Trichloroethane	Yes	Yes	1	1	0.5
1,1,2-Trichloromethane			*Not screened by any kit*		
Trichloroethylene		Yes	*Not screened by any kit*		
Trichloromethane		Yes	*Not screened by any kit*		
1,2,4-Trimethylbenzene		Yes	1		0.5
1,3,5-Trimethylbenzene		Yes			0.5
[*,Δ]Vinyl chloride	Yes	Yes	1	1	
[X,*]*ortho*-Xylene	Yes	Yes	1	1	0.5
[X,*]*meta*-Xylene	Yes	Yes	1	1	1.35
[X,*]*para*-Xylene	Yes	Yes	1	1	1.35

Asterisk (*) denotes a chemical was initially recommended for testing by the Hawai'i Department of Health and those minimum reporting limits, concentrations that could be quantified, were near 1 ppb; fire-related chemicals associated with drinking water contamination have been identified in Jankowski *et al.* (2023),[19] Whelton *et al.* (2023),[14] and Proctor *et al.* (2020).[12] Symbol (X) denotes structure fire-related chemicals identified by Horn *et al.* (2023)[18] that were drawing into stainless steel tubing. The water testing list of the county and state was in place during the conduct of the survey, and several non-fire related compounds such as 1,2,3-trichloropropane and 1,1,2-trichloroethane were included. The UH WRRC analytical lab detected the following other chemicals: methyl bromide, chloroethane, trichlorofluoromethane, diethyl ether, 3-chloropropene, 2,2-dichloropropane, methyl acrylate, methylacrylonitrile, 1-chlorobutane, 1,1-dichloropropene, dibromomethane, methyl methacrylate, 2-nitropropane, *cis*-1,3-dichloropropene, *trans*-1,3-dichloropropene, ethyl methacrylate, 1,1,2-trichloroethane, 1,3-dichloropropane, 2-hexanone, 1,1,1,2-tetrachloroethane, bromobenzene, 1,1,2,2-tetrachloroethane, 1,2,3-trichloropropane, *trans*-1,4-dichloro-2-butnene, *n*-propylbenzene, 2-chlorotoluene, pentachloroethane, 1,3-dichlorobenzene, isopropyltoluene, hexachloroethane, 1,2-dibromo-3-chloropropane, nitrobenzene, and hexachloro-1,3-butadiene.

Acetonitrile	Chlorodibromomethane	Ethyl benzene	**ΔToluene***
ΔAcetone	Chloromethane	**Ethylene dibromide (EDB)***	1,2,3-Trichlorobenzene
Acrolein	4-Chlorotoluene	Ethyl-*tert*-butyl ether (ETBE)	1,2,4-Trichlorobenzene
Acrylonitrile	Dibromochloromethane	Iodomethane	1,1,1-Trichloroethane
ΔBenzene*	**1,2-Dibromo-3-chloropropane (DBCP)***	Isopropylbenzene	1,1,2-Trichloroethane
Bromochloromethane	1,2-Dichlorobenzene	**Methylene chloride***	Trichloroethylene
Bromodichloromethane	1,4-Dichlorobenzene	**ΔMethyl ethyl ketone (MEK)***	**Trichloromethane***
Bromoform	1,1-Dichloroethane	Methyl iso butyl ketone (MIBK)	**1,2,3-Trichloropropane (TCP)***
n-Butylbenzene	**1,2-Dichloroethane***	**Methyl-*tert*-butyl ether (MTBE)***	1,2,4-Trimethylbenzene
sec-Butylbenzene	1,1-Dichloroethene	**ΔNaphthalene***	1,3,5-Trimethylbenzene
tert-Butylbenzene	*cis*-1,2-Dichloroethene	**ΔStyrene***	**Vinyl chloride***
Carbon disulfide	*trans*-1,2-Dichloroethylene	***tert*-Butyl alcohol (TBA)***	Δ*ortho*-Xylene
Carbon tetrachloride*	**1,2-Dichloropropane***	Tetrachloroethylene	Δ*meta*-Xylene
Chlorobenzene	ΔEthanol	**Tetrahydrofuran (THF)***	Δ*para*-Xylene

Fig. 4 List of VOCs detected in previous drinking water distribution system water samples after wildfires and chemicals that were drawn into stainless steel plumbing from the air during a structure fire. Asterisk (*) symbol and bold font indicates the chemical exceeded a short- or long-term drinking water exposure level after a prior wildfire or as found during the present study. Delta (Δ) symbol indicates that the chemical was drawn from air during a structure fire into stainless steel tubing by Horn *et al.* (2023).[18] At present, there is limited understanding of the most common chemicals associated with wildfire caused drinking water contamination. Chemicals reported above have been those most looked for, not necessarily the ones of greatest frequency or concern. Different laboratories sometimes choose to look for different VOCs using USEPA method 524.2; some of the USEPA method 524.2 VOCs that laboratories commonly report would not necessarily be detected post-wildfire, but are chemicals that the laboratory automatically includes anyways, so they are reported. The following post-fire drinking water quality studies were used to prepare this table: Proctor *et al.* (2020),[12] Jankowski *et al.* (2023),[19] and Whelton *et al.* (2023).[14]

frequently asked question webpage on the Maui County website, and a State of Hawai'i VOC info sheet (in a variety of languages) were made public and then revised around this date[4] (ESI† file). Professional training of water system, county, and state agency staff could also better prepare these professionals for educating their impacted community.[45] Health officials should provide a list of fire-related chemicals to test for based on best available science (Fig. 4). Chemical water testing results should be made publicly available so the public can understand the quality of water being delivered to their faucets.

4.1.4 An unaddressed challenge: households with a cistern as a drinking water source. Wildfires are known to prompt debris deposition onto rainwater catchment roofs. Contaminants of concern include VOCs, SVOCs, and heavy metals. No guidance was found in or outside Hawai'i for private rainwater cistern owners about how to address water safety concerns post-fire. As a result, the cistern owner who participated in the present study followed the advice for Maui DWS public water systems despite not using their drinking water. This system involved metal roof rainwater catchment, an inline cartridge filter, and ultraviolet light disinfection system and it was not fire damaged. Though, fire-debris was present on their metal roof, with potential to enter their cistern (Fig. 2). A first flush diversion system was present pre-fire, so this could have potentially prevented some debris during a rain event from entering the cistern. Given the prevalence of rainwater catchment systems for drinking water use worldwide, guidance for cistern owners on how to inspect and investigate drinking water safety after wildfires should be developed.

4.1.5 Formal support for household water and plumbing safety decisions. As found in Hawai'i, and previously in California and Colorado, households impacted by wildfires often lack guidance about water and plumbing safety decisions. As investigators found previously,[20] household information about drinking water safety can help lessen mental health impacts, which are expected for the Maui communities impacted.[46] After a wildfire, public confidence about drinking water safety can be reduced.[47] To date, most technical support and resources for wildfire drinking water challenges focus on public water systems, not households. In absence of household specific efforts, some public health, university, and insurance organizations have begun creating their own guidance.[23,24,48–53] Though, none of these documents address all questions posed by households in the present study or raised in prior studies. A formal study to better understand and improve household level post-fire guidance is recommended.

County and state public health organizations responsible for property and building water system safety should be better resourced to assist households. Public water systems issue post-wildfire drinking water advisories, but do not advise on property drinking water safety and plumbing issues. Regulated water systems often develop emergency response plans and water safety plans, but these do not typically address post-disaster in-building plumbing issues. The public water system may be able to repair its own infrastructure rapidly and again deliver safe water to the property, but the property plumbing may still be contaminated. Once drinking water enters the private property, water quality and plumbing is the responsibility of the property owner. Property water testing, onsite water treatment, and plumbing repair decisions would be the property owner's responsibility. Testing and repair actions taken on the property may be influenced by the property owner's insurance company's opinion. Some households impacted by wildfires also rely on their own water sources (*i.e.*, wells, cisterns), not a public water system.

4.2 An unaddressed challenge: water system damage and safety for agriculture

No guidance on how agricultural operations should respond to post-wildfire water system damage was found in the literature or available from government agencies. Further, no guidance was found for assessing these operations after other disasters like chemical spills and other natural disasters. Considering this gap, observations of the present study, and confirmed damage to water systems after other wildfires, evidence-based guidance should be developed. That work should include post-fire inspection and testing practices, possibly supported by agricultural government agencies including extension offices. Due to the lack of any guidance, a one page information sheet was developed here.[49] Case studies could also help establish evidence about the frequency and magnitude of potential impacts and actions taken to limit potential water system damage. Unlike residential communities, it may be unreasonable to expect animals or crops to be moved out of the disaster area until the water systems can be repaired. For that reason, rapid investigation and testing would be urgent for agricultural water systems as well as identifying alternate safe water sources. Compared to residential and commercial buildings where pipes are often buried or indoors, agricultural water system assets are often aboveground and thus more vulnerable to fire. Further, livestock tubs, troughs, and tire waterers are open to the atmosphere and could be impacted by smoke. For a single agricultural property multiple small water systems of different sources (*i.e.*, well, creek), configurations, and materials (*i.e.*, metal, plastic, concrete) may exist. In the absence of guidance, agricultural properties should consider flushing and aeration to remove VOCs and conduct testing that involves stagnation to accurately identify VOCs leaching from assets into water.

5. Conclusion and recommendations

Wildfires are increasingly damaging water systems and actions are needed to reduce vulnerability and improve the response to these incidents.[54] An onsite survey and inspections of residential and agricultural water systems were conducted in the present study two weeks after the Maui wildfires. During this time, the Kula and Lāhainā water system customers were under drinking water advisories and no chemical testing results had been released by government agencies for the damaged drinking water systems.

Three weeks after the fires, drinking water testing by Maui County and the University of Hawai'i revealed chemical contamination of two public water systems and private property plumbing. Most households noticed water quality and pressure issues after the evacuation order was lifted. All households served by public water systems lost power and used the potentially contaminated drinking water before learning that the water system and state recommended against its use. Due to the lack of information after the fire, nearly all households expressed confusion and concern about allowable water use activities and health risks. In response to their own concerns, some households flushed their plumbing, used water in ways they believed were protective, and conducted their own plumbing water sampling and analysis. At-home drinking water VOC sampling kits found by households were not capable of testing for all the fire-related chemicals. A household that did not rely on public water systems for drinking water, but instead a rainwater cistern, also lacked post-wildfire drinking water safety guidance. Damage to agricultural water systems was like that seen for residential systems.

Local, county, and state officials seeking to improve their own preparation and response to these disasters should consider the following recommendations:

1. Before fires occur, state drinking water agencies should make publicly available the list of fire-related chemicals they would test for as well as the methods. Of specific note, not all laboratories screen for all VOCs listed in a single USEPA water testing method. For that reason, water testing recommendations should be explicit and should follow best available science.

2. Before fires occur, state agencies responsible for commercial laboratory water testing certification should notify laboratories about exactly which fire-related chemicals, at a minimum, should be considered, should they be contacted by households and businesses for post-fire assistance.

3. Before fires occur, water system and state agency staff should prepare answers to frequently asked questions about drinking water safety after wildfires. This information can be made publicly available. In response to a fire, the public can

be directed to this information. Information can also be distributed on hardcopy material in the affected communities at public meetings, emergency supply distribution centers, and community organization events.

4. To lessen the chance that households use contaminated drinking water, under extreme incidents, state agencies should consider taking a more active role on preparing and distributing initial drinking water advisories. These actions could help local water utility staff focus on their families impacted and dedicate resources to support firefighting, stop water loss, contain damage, and lessen the drinking water contamination potential.

5. To support household decisions, health departments responsible for providing water safety advice to building owners should notify households that current commercial drinking water testing kits do not screen for all fire-related chemicals.

6. Once a wildfire impacts a public water system, the water system and state agency should consider weekly updates about drinking water safety and recovery actions such as test results, and the expected next steps. In-person community meetings can also be helpful.

7. State agencies responsible for drinking water safety on private property should develop and issue post-wildfire inspection and testing guidance for cistern systems.

8. Case studies of wildfire impacted agricultural water systems should be conducted. State agencies responsible for supporting agricultural businesses should prepare and issue post-wildfire guidance for ranches, farms, and other agricultural enterprises that have water systems threatened or damaged by fire.

9. A larger post-fire rapid response household study is recommended following future wildfires to better identify representative household experiences and needs. Without such an effort, knowledge about community needs and experiences will continue to remain ill defined.

Data availability

The data is reported in the manuscript and in the electronic ESI† file.

Author contributions

AW and PC designed and conducted the field survey, interacted with government agencies; AW conducted agricultural water system inspections; AW, PC, SS and SH completed the survey data analysis; CS, KC, and AK contributed to the Maui Hub water sampling program development, data analysis, as well as context associated with community response and recovery. AW led the writing with support from other co-authors.

Conflicts of interest

After the household surveys began, AW and PC were contracted by and helped Maui County assess their Lāhainā and Upper Kula drinking water systems after the Maui Wildfires starting August 22, 2023. KC and CS live in the fire impacted areas and receive drinking water from Maui DWS. During support provided to Maui County, the authors interacted with professionals working for the county, Hawai'i Department of Health, Hawai'i Department of Agriculture, U.S. Environmental Protection Agency, U.S. Department of Agriculture, as well as elected leaders and their representatives.

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