Addressing Contamination of Drinking Water Distribution Systems from Volatile Organic Compounds (VOCs) After Wildfires

After the 2017 Tubbs Fire and the 2018 Camp Fire in California, volatile organic compounds (VOCs) were found in the drinking water of the impacted towns. Tests of the water revealed elevated levels of several VOCs, such as benzene, in water mains, service connections, and building fixtures. If unaddressed, VOC contamination can pose a potential health risk for consumers and result in a loss of consumer confidence.

Addressing VOC contamination can be a potentially long-term problem. Flushing is the primary method for removing VOC contamination; however, flushing may not always be effective or feasible. Infrastructure replacement is another option, but depending on the scale, can take time and be cost-prohibitive. Delays in addressing contamination can impact the return of residents to their homes and the restart of commercial businesses, significantly slowing community recovery. This factsheet examines VOC drinking water contamination from the Tubbs and Camp Fires and recommends practices to assist drinking water utilities in identifying and addressing contamination. While this information is intended for public water systems, it also may benefit private water systems and well owners.

The causes and remediation of VOC contamination in distribution systems is an emerging field of study. The cited research reflects the current understanding of wildfire impacts on drinking water distribution systems as well as the informational gaps. This document is meant to provide a resource for water utilities, communities, and state primacy agencies dealing with wildfire damage and public health concerns. Utilities should contact their state primacy agency or EPA Regional Office for additional technical assistance.

Wildfire VOC Contamination

VOC contamination may occur when water distribution infrastructure (e.g., pipes, valves, meters, etc.) is impacted by a wildfire. VOC contamination has been observed primarily in areas that were damaged during the wildfire and experienced pressure loss in the water system. Research into the exact cause of the VOC contamination is ongoing, but two possible explanations have been proposed that may account for such contamination either alone or in combination.

1. Contamination may be released into the water from infrastructure containing polyvinyl chloride (PVC), high density polyethylene (HDPE), or other plastic materials that degrade when exposed to heat.[1]

2. Contamination may occur when the smoke, hot gases, and chemicals (e.g., VOCs) from burning vegetation and structures are sucked into the water lines. This suction can occur when the water pressure drops due to broken water lines or water demand elsewhere in the system.[2]

Degraded plastic pipe following wildfire
Credit: CA State Water Board Division of Drinking Water

Whatever the source, VOC contaminated water can potentially be moved to parts of the water system unimpacted by the wildfire.

An additional challenge is that VOCs can permeate into some materials (e.g., certain plastics, such as polyethylene, and rubber).[3] The VOCs then can be released back into the water. While the release of VOCs from these materials is slow, VOCs can accumulate in the water, particularly under stagnant conditions when the water remains in contact with contaminated material for an extended period. The potential for recontamination of the water will persist until all the VOC contamination has leached out.

VOC contamination can be present without visible damage, as infrastructure (e.g., pipes, meters) in the impacted area may retain the ability to sustain pressure and flow following a fire. The only way to determine if the water has elevated levels of VOCs is to collect water samples for analysis.

Analytical testing from impacted communities demonstrated that VOC concentrations at service connections can exceed the Safe Drinking Water Act maximum contaminant levels (MCLs). In some cases, residents were advised not to drink, cook, or bathe with the water. [4, 5]

Testing for Contamination – Sampling and Analysis

To determine if contamination is present, water systems should create a sampling plan with their state regulatory agency that identifies target contaminants, sample collection protocols, sampling locations (in the distribution system and surviving buildings), and data quality and management. The plan should account for a potentially large number of samples that could be collected over an extended period (e.g., months) depending on the extent of fire damage and if contamination is found.

Target Contaminants: Multiple VOCs, both regulated and unregulated, may be present in contaminated water. At present, it is unclear which chemicals are of most concern following a wildfire. Benzene was found in many of the samples collected during the Tubbs and Camp Fires[2]; however, it is not a perfect indicator of VOC contamination as some water samples that were free of benzene contained other VOCs. Because knowledge is limited on the types of contaminants that may impact drinking water distribution systems during wildfires, utilities should consider broader methods, such as EPA methods 502.2 or 524.2, that cover a range of contaminants potentially associated with fire impacts. Utilities should also consider that chemicals not covered by these methods may be present. Utilities should contact their state regulatory agency or EPA Regional Office to discuss additional methods for specific contaminants of interest.

Sample Collection Protocols: The protocol for sample collection is critical for determining the presence and extent of contamination. As noted above, because VOCs can leach out of some materials over time, a period of stagnation should be incorporated into the sampling protocol. A stagnation period should be established that best assures the presence or absence of contamination while also taking feasibility into consideration. Stagnation periods of 8, 24, 48, and 72 hours have been suggested during past wildfires, with longer periods allowing larger quantities of the contaminants to enter the water, thus increasing the likelihood of detection during analysis and providing greater confidence in the results. Additionally, the utility should consider multiple samples (e.g., first draw and then a second draw after a brief flush) to determine if potential contamination is localized or systemic. A stagnation period is a deviation from the collection procedures in most standard VOC methods and should be noted to all involved. Samples should be collected by individuals who have been properly trained on the sampling protocol, marked as investigative samples, and analyzed by a certified laboratory that has been informed of the protocol. State drinking water regulatory agencies can provide a list of certified drinking water laboratories. Utilities should discuss with the laboratory whether rapid turn-around for the analytical results is available during emergencies.

Sampling Locations in Distribution System: Deciding where to sample in the system can be difficult. Potential areas for contamination are within or near the burned area served by the distribution system. Research suggests a correlation between the density of burned structures and VOC contamination.[6] One utility found that over 50% of service connections at burned lots contained fire-related contamination. Areas that lost pressure (e.g., pipe break, leaks, higher elevations) should also be prioritized for sampling since contamination has been associated with a loss of pressure. Areas that were exposed to heat, especially if they contain plastic materials, should be considered for sampling since VOCs can be released without direct damage and failure of the system. However, all types of pipe materials (e.g., metal), not only plastic, should be considered for sampling, as elevated VOC concentrations have been detected in water from metal piping following wildfires.[2] Drinking water utilities should use a systematic approach to assessing the system. For example, initial sampling locations could include the entry point to the distribution system and service mains to determine the location of any contamination across the distribution system. Sampling should also occur at service connections that are preparing for re-occupation to determine if there is any potential contamination for returning consumers. Service connections at burned structures should be sampled and confirmed to be unimpacted before the connections are returned to service.

Sampling Locations at Surviving Buildings: In addition to the distribution system, sampling in surviving buildings and homes should also be considered. Individual property owners are typically responsible for their own plumbing (i.e., service connection from the meter to the building and indoor plumbing). Utilities are usually not required to collect samples from inside structures; however, public health agencies, utilities, and state drinking water regulatory agencies can provide property owners with a list of certified drinking water laboratories and advice on sample collection and handling. There are currently no standards or accepted protocols for sampling buildings or homes for VOCs. As a general guide, sample collection in a building should focus on the points of greatest concern for the building occupant/owner. For example, sampling from the kitchen sink will provide information about the water used for drinking and cooking. Additionally, showers/bath spouts and bathroom faucets can be sampled given the potential for inhalation or dermal contact. Certified laboratories often provide protocols for sample collection but concerned property owners will likely need to collect the sample on their own.

Data Quality and Management: For sampling the distribution system, there should be consistency in sampling locations, sampling and analytical procedures, and laboratories used. Appropriate quality assurance/quality control procedures should be included in the sampling and laboratory procedures to ensure data collected and analyzed by multiple sources are comparable. To review the data, it can be useful to develop a spreadsheet of sampling locations. Mapping the data can be especially useful because it can highlight geographic patterns of VOC levels (and MCL exceedances). When sharing data with the public, private contact information and potentially the results themselves may be considered sensitive information, and therefore utilities may want to consult with the state regulatory agency before disclosure.

Addressing the VOC Issue

Addressing VOC contamination requires immediate as well as long-term actions. Utilities should utilize their risk and resilience assessments and emergency response plans as well as work with their state regulatory agency to identify the most appropriate options for their situation.

Advice on Drinking Water Advisories: Following a loss of pressure, "Boil Water" advisories are commonly issued to protect against microbial contamination; however, until VOC contamination is ruled out, boiling the water or hot water use (e.g., showering) could create an inhalation risk. If there is suspected or confirmed VOC contamination, the utility and the state regulatory agency should consider issuing public health advisories such as "Do Not Drink", "Do Not Drink – Do Not Boil", or in extreme cases, "Do Not Use."

Alternative Water: Because addressing VOC contamination takes time, the immediate need of the utility may be to provide alternative water (e.g., bottles) after wildfires, even for structures that appeared unimpacted. This need could persist due to the initial effort to determine the existence and extent of contamination and then due to any remediation efforts. State drinking water regulatory agencies have Emergency Drinking Water Supply Plans to address drinking water needs during an incident/disaster.[7] Utilities should work with their state regulatory agency to select and implement alternative water strategies, such as points of distribution for bottled water, water storage tank installations at homes and businesses, and water deliveries.

Flushing Protocols: Following both the Tubbs and Camp wildfires, flushing was used to decrease VOC contamination. It is important to conduct unidirectional flushing as soon as possible to completely replace the VOC contaminated water with fresh water. Flushing immediately minimizes permeation of the VOCs into infrastructure. If permeation has occurred, multiple flush cycles may be necessary to account for VOCs slowly re-entering the water. Flushing should begin at the water source and proceed downstream throughout the distribution system. Samples collected after flushing typically contain lower levels of contamination than initial samples. However, because flushing may not always reduce the VOCs to the desired levels even after repeated applications, it should be coupled with sampling after a period of stagnation to assess effectiveness. After utility water mains have been flushed, customers should be instructed to flush their building plumbing in a manner similar to that of water systems, i.e., from a tap (sink, spigot, etc.) closest to the service connection to the tap farthest from the service connection.

Isolation: Isolating, or valving off, areas of the system into zones can be an effective way to prevent contaminated water from flowing into unimpacted areas as well as progressively returning the system to operation. When coupled with flushing and sampling, areas can be cleared of VOC contamination and returned to service in stages while other areas are still being addressed. Isolation should be evaluated carefully due to the potential for negative impacts, such as loss of pressure in portions of the system.

Confirmation that Service Connections are Clear: Undamaged structures are less likely to have a VOC contaminated service connection; however, they can become contaminated when the system repressurizes and, therefore, should be sampled prior to restarting service. Based on experiences during the Camp Fire, utilities should be able to confirm that the connection is ready for service after tests reveal that VOC concentrations are at levels deemed safe for use. Connections that have contamination should be addressed with other measures as described in this section. Utilities should use care when asserting which parts of the system (e.g., from a service line to a group of homes) are cleared of VOCs, because a system without backflow prevention can potentially spread contamination from service connections to water mains. Water mains should be fully pressurized and confirmed to be clear of VOCs before attempting to confirm service connections are clear.

Treatment Devices: Pitcher filters, point-of-use devices (e.g., under-counter filters), and/or whole building treatment devices can be effective at treating VOC contamination when designed and maintained properly; however, these devices have limitations. Where VOC concentrations exceed the treatment abilities of these devices, VOCs will pass through the devices untreated. Drinking water utilities that elect to utilize localized treatment devices should do so in consultation with their state regulatory agency. Utilities should advise individual customers who are considering installing such devices independent of a recommendation from the utility or state regulatory agency to adopt a cautious approach. Safe use of these devices requires knowledge of the contaminants present and their concentrations in the drinking water, other water quality characteristics, the manufacturer-specified and independently certified treatment capabilities, and the design life of the treatment device.

Replacement: For pipes and other system infrastructure that are damaged or cannot be flushed effectively, replacement should be considered. The cost of water pipe repair and replacement varies widely depending on the extent of the damage. Utilities should consider prioritizing the replacement of water lines in locations that coincide with rebuilding (e.g., after building permits are issued). Also, physical examination (e.g., camera inspection, destructive sampling) of the pipes may be useful to prioritize replacement. It is important to document VOC contamination and the physical characteristics of damage to qualify for federal disaster assistance to replace infrastructure.

Service Line Replacement
Credit: Paradise Irrigation District

Mitigation: Measures to prevent VOC contamination in water utility infrastructure after wildfires have not yet been proven. However, reasonable countermeasures against VOC contamination could include backflow prevention on all service connections, fireproof concrete meter boxes, and brass meters.[8]

Concrete Meter Boxes
Credit: Paradise Irrigation District

Long-term Monitoring: After VOC contamination has been addressed, utilities should consider if a long-term monitoring program for VOCs is appropriate. Such a program can confirm that contamination no longer remains in the system over an extended period and serve to boost consumer confidence. While no standard exists for a monitoring program, it should include the same considerations described in the “Testing for Contamination” section.

Mutual Aid and Funding for VOC Sampling, Analysis, and Remedies

Following a wildfire, a utility can face many challenges returning the system to operation including, but not limited to: damage to facilities and service connections, lack of needed equipment or materials, and limited personnel who are themselves facing wildfire impacts to their homes and community. The Water and Wastewater Agency Response Network (WARN) and other mutual aid and assistance programs exist to provide utilities with the resources they need during an emergency. Through mutual aid agreements, utilities can provide equipment, generators, supplies, or personnel to support recovery activities at impacted utilities. Utilities can work with nearby utilities to foster mutual aid agreements and engage with larger programs, like WARN, to ensure they have a support system in place. If there is justification for emergency drinking water, the utility can coordinate with their local emergency management agency.

After a wildfire, costs of utility infrastructure damage and lost revenue, as well as the costs to identify and address VOCs in drinking water distribution systems, may be of concern. Public funding may be available for utilities to address VOC contamination. If the wildfire has received a Presidential Disaster Declaration, funding may be available from FEMA for public and private non-profit utilities under the Public Assistance Program. Possible eligible expenses include costs for increased analytical testing to determine contamination immediately after the incident, costs for obtaining water from an alternate source, and costs for damage to infrastructure and VOCs in the distribution system. Utilities may also receive financial assistance for measures to protect public health and for permanent repairs. Mitigation grants to retrofit water systems (e.g., replace water systems that have been burned and are contaminated) may be available through FEMA's Fire Mitigation Assistance Grants and FEMA's Hazard Mitigation Grant Program.[9] EPA Drinking Water State Revolving Funds (DWSRF) can be used in limited cases for sampling and analysis as part of rebuilding utility assets with additional resilience measures to better withstand future disasters. Also, the revolved portion of the DWSRF can be used as the state and local match for FEMA funds (see Memorandum of Understanding). For small utilities serving populations less than 10,000 people, the U.S. Department of Agriculture has grants and loans to address water quality issues, which could include VOCs in water supplies after wildfires. Technical assistance for infrastructure recovery may also be available if the state requests federal help under the Federal Disaster Recovery Framework.

For many of these programs, documentation of the infrastructure damage and the steps taken to recover from the wildfire are critical for securing financial assistance. It is recommended that all actions be documented, even before applying for financial assistance. For home and building owners, financial support may come from FEMA's Individual Assistance Program or homeowner/building insurance.

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