CONSIDERATIONS FOR INVESTIGATING VOC CONTAMINATION IN RESIDENTIAL PLUMBING

1. What testing is needed to determine if the COLD water plumbing has VOC contamination?
2. What testing is needed to determine if the HOT water plumbing has VOC contamination?

1. PURPOSE

The purpose of this document is to illustrate the scientific and technical considerations to assess volatile organic compound (VOC) residential plumbing contamination, along with important caveats and knowledge gaps regarding testing protocols. The information in this document may help decision-makers take more informed actions regarding their site-specific needs. However, it is incumbent upon those decision-makers to establish the goals of performing sampling and adapt the considerations herein to those purposes and existing operational parameters at sample sites in order to provide meaningful guidance. This document was developed in response to the Camp Fire and requests from the public to provide county, state, and federal agencies input on factors to consider when characterizing drinking water plumbing components.

2. RECOMMENDATION FOR TESTING AND VALIDATION BEFORE WIDESPREAD ADOPTION

It is recommended that sampling procedures be developed and validated *before* widespread implementation. Certain plumbing components and configurations may be at greater risk to VOC contamination and more difficult to identify when contaminated than others. Understanding the factors that impact contamination is important so appropriate testing plans can be developed. The consequence of inadequately designed or conducted testing could be that contaminated plumbing components are not identified even though they may exist. It is also possible that inadequately designed or conducted water sampling and analysis could also lead to the appearance of contamination, even if it does not actually exist.

3. RELATIONSHIP TO THE JUNE 14, 2019 CALIFORNIA STATE WATER RESOURCES CONTROL BOARD (SWRCB) GUIDANCE[1]

On Friday June 14, 2019 at 4:38 pm the California State Water Resources Control Board (SWRCB) issued new guidance to homeowners about testing residential plumbing for *benzene only* contamination. There are clear and important differences between the SWRCB guidance and scientific opinions provided in this document:

1. The SWRCB has proposed *"evidence strongly suggests that benzene is an appropriate indicator of the presence or absence of other contaminants that could pose adverse health risks."*

   <u>Recommendation herein:</u> As supported by available evidence, including building water testing data in the Camp Fire area, testing is needed for VOCs other than benzene. This evidence includes:

[1] State of California Water Resources Control Board (SWRCB). *Information to Water Customers Regarding Water Quality in Buildings Located in Areas Damaged by Wildfire.* June 14, 2019. Sacramento, CA.

- <u>May 2019 indoor water testing from buildings in the Town of Paradise, California indicates that other VOCs can be present *in the absence of benzene* at levels that exceed their State of California regulated maximum contaminant level (MCL) (e.g., methylene chloride) and/or California notification level (e.g., *tert*-butyl alcohol or TBA).</u> To date, it is unknown if the occurrence of these contaminants is or is not associated with the Camp Fire since barely any credible testing has been conducted in affected buildings. However, only testing benzene would have determined this water to meet California drinking water standards, when in fact methylene chloride and TBA exceeded allowable California limits. [Methylene chloride levels have exceeded California drinking water standards in the Paradise Irrigation District water distribution system after the Camp Fire and City of Santa Rosa water distribution system after the Tubbs Fire.]

- Evidence from water distribution system testing conducted by the Paradise Irrigation District indicates that other VOCs than benzene have been present in their buried piping system and that the levels of these other VOCs have exceeded their 1-day USEPA health advisory level (e.g., naphthalene), California MCL (e.g., methylene chloride, styrene, vinyl chloride), and California notification level (e.g., TBA). This was noted in a March 11, 2019 letter to the SWRCB Division of Drinking Water: https://engineering.purdue.edu/PlumbingSafety/resources/Opinion-About-Drinking-Water-Safety-2019-03-11.pdf.

- Evidence from the City of Santa Rosa's water distribution testing revealed TBA exceeded its California notification level in samples where benzene was not detected. This was noted in a March 11, 2019 letter to the SWRCB Division of Drinking Water: https://engineering.purdue.edu/PlumbingSafety/resources/Opinion-About-Drinking-Water-Safety-2019-03-11.pdf.

- While 8,222 water samples were collected in the City of Santa Rosa's 5.2 mile water distribution system after the Tubbs Fire, limited testing of building plumbing was conducted. Therefore, practically all of the water samples tested by the City of Santa Rosa represent the water quality *in the buried water distribution system*, not plumbing. Previously, Dr. Whelton has recommended that complete reliance on chemical data from the post-fire water distribution system when making decisions related to building plumbing is not advisable due to the differences of the infrastructure and fate of VOCs in plumbing: https://engineering.purdue.edu/PlumbingSafety/resources/Opinion-About-Drinking-Water-Safety-2019-03-11.pdf.

2. The SWRCB has recommended that building owners *"take a cold-water sample at the kitchen faucet, which is typically the primary location where water is obtained for consumption. Note: Do not use a faucet with a filter. Testing at the kitchen faucet should generally provide representative data about the water pipes in the house."*

   <u>Recommendation herein:</u> Due to the complex nature of VOC's adhering to and permeating into and out of residential plastic plumbing components and other materials, possibly to different degrees and in different parts of the plumbing system, it is recommended that

building owners consider testing all outlets where VOC exposures could occur via ingestion, inhalation, and/or dermal contact. Because of these exposure routes, other outlets including but not limited to hot water taps, bathtub spigots and showerheads should be included in testing.

More comprehensive testing at outlets throughout the building is necessary to fully characterize exposure risks from VOCs that have contaminated home plumbing.

- o More comprehensive sampling in post-wildfire situations adheres to precedent established by USEPA through their recent guidance to schools and childcare facilities when testing for distribution system derived contaminants, namely lead and copper. The USEPA guidance document clearly states that "schools and child care facilities *should not* use sample results from one outlet to characterize potential lead exposure from all other outlets in their facility. *This approach could miss localized lead problems that would not be identified*" (see bottom of page 31[2]). Problems with VOC contamination in household plumbing may also be highly localized, such that results from one outlet may improperly characterize potential VOC exposure from other outlets in the building.

3. The SWRCB has postulated that *"If your results come back as "non-detect (ND)," "below quantification limit," or less than 1 ug/L, then the water meets the State standard."*

   Recommendation herein: This interpretation fails to consider the dynamic situation in the affected water piping networks. Specifically, this claim is not supported according to a discussion that Dr. Whelton had in May 2019 with USEPA Region 9 which was informed by numerical modeling by USEPA ORD for benzene sorption into and desorption from plastic water pipe. Dr. Whelton was told that if a building owner only follows an 8 hour stagnation period, and there is 0.4 ppb benzene in water after 8 hours for HDPE piping, at 72 hours the level of benzene would be 1.25 ppb. This would exceed California's benzene 1 ppb MCL. Also noteworthy is that the minimum detection limit for benzene is often 0.5 ppb. Therefore, the individual who found 0.4 ppb would not know benzene was leaching from their plumbing (because they would not be able to detect it), but with a 72 hour stagnation period they would have discovered the plumbing was contaminated. Any detection of benzene during an 8 hour stagnation between 0.5 ppb to 1.0 ppb may indicate plumbing contamination, that the plumbing, if stagnated longer, may also contain unsafe water. The SWRCB guidance does not consider this. In fact, the SWRCB guidance assumes that if benzene does not exceed 1 ppb after 8 hours, the plumbing is safe, when it may or may not be.

   Due to the dynamic processes of chemical desorption and multiple VOCs associated with the wildfire are present, not only benzene, a 72 hour stagnation period is recommended.

4. The basis for of the SWRCB guidance is unclear. The citing of an industry trade magazine [*OPFLOW*] often used for marketing commercial products (not a peer-reviewed publication) as

[2] US Environmental Protection Agency, Office of Water. *3Ts for Reducing Lead in Drinking Water in Schools and Child Care Facilities: A Training, Testing, and Taking Action Approach, Revised Manual.* October 2018. Washington, D.C. https://www.epa.gov/sites/production/files/2018-09/documents/final_revised_3ts_manual_508.pdf

the only authoritative source for plumbing sampling was surprising. Public health recommendations are best based on the peer-review literature. Such an approach provides additional checks on the quality of information provided. Further, a major assumption of the *OPFLOW* commentary is that the contaminant they considered was “nonabsorbing” – a fact that is well-known to be false associated with VOCs and plastic in plumbing post-Camp Fire. The background of the persons who created the SWRCB guidance and their qualifications in post-disaster building water testing remains undefined.

Recommendation herein: Disclose the information used to justify decisions. Reconsider the recommendations that were applied from this non-peer reviewed magazine. We are happy to talk with you about this. As Dr. Whelton recommended in March to CalOES, SWRCB, USEPA, and the health department, the public would benefit from having an evidence-based plan for testing plumbing. There are many experts who can assist you and have been offering support. The Purdue University and Manhattan College contributors to this document again offer their assistance. The additional contributors to this document also offer their assistance.

4. TUBBS FIRE AND CAMP FIRE: BRIEF INTRODUCTION TO VOCs FOUND IN DRINKING WATER DISTRIBUTION SYSTEMS

Multiple VOCs (benzene, naphthalene, styrene, toluene, xylenes, and others) have been detected in drinking water in public water system buried distribution systems affected by recent wildfires (Table 1). Private wells have also become contaminated due to fire damage. Individual VOCs have different acute and chronic health-based drinking water exposure limits. These compounds also have different physicochemical properties, and thus likely have different degrees of interactions with plumbing materials, including plastics.

Table 1. Some VOC drinking water distribution system concentrations (ppb) reported by the City of Santa Rosa after the 2017 Tubbs Fire as well as the Paradise Irrigation District (PID), California State Water Resources Control Board (SWRCB), and Del Oro Water Company (DOWC) after the 2018 Camp Fire.

Chemical	Drinking Water Limits		Tubbs Fire (11 mo.)				Camp Fire (6 mo. post-fire)						
			Testing in Santa Rosa 5.2 miles				Testing in PID 172 miles			Testing in DOWC (3 systems)		Exceedance for at least 1 system	
	CA Drinking Water Limit, ppb	USEPA 1 day Health Advisory (HA), ppb	*n*	Max, ppb	Exceeded CA Limit	Exceeded USEPA HA	*n*	Max, ppb	SWRCB Testing in PID, *n*=1	*n*	Max, ppb	Exceeded CA Limit	Exceeded USEPA HA
Benzene	1^{MCL}	200	8,222	40,000	**Yes**	**Yes**	509	923	>2,217	41-26-82	8.1-0-46	**Yes**	**Yes**
Methylene chloride	5^{MCL}	10,000	6,089	41	**Yes**	No	p	15	-	p	p	**Yes**	No
Naphthalene	17^{NL}	500	661	6,800	**Yes**	**Yes**	p	278	693	p	p	**Yes**	**Yes**
Styrene	100^{MCL}	20,000	6,062	460	**Yes**	No	p	100	378	p	p	**Yes**	No
Tert-butyl alcohol	12^{NL}	-	339	29	**Yes**	-	p	13	-	p	p	**Yes**	-
Toluene	150^{MCL}	20,000	8,222	1,130	**Yes**	No	p	100	676	p	p	**Yes**	No
Vinyl chloride	5^{MCL}	40,000	6,062	16	**Yes**	No	p	1	-	p	p	**Yes**	No

Adapted from Whelton, Proctor, Lee, Shah, Yu, Sabbaghi. *Implications for health: Responding to and recovering from wildfire caused drinking water system contamination.* Presentation at The National Academies of Science, Engineering, and Medicine Workshop: Implications of the California Wildfires on Health, Communities, and Preparedness. June 4, 2019. Sacramento, CA; *n* = number of samples collected; Max = highest concentration detected; PID = Paradise Irrigation District; SWRCB = California State Water Resources Control Board; TBA = *Tert*-butyl alcohol; NL = Notification level; Under short-term USEPA 1 day – Health Advisory Exceeded "No" means the health advisory was not exceeded for the Camp Fire; "p" symbol indicates the total number of samples not yet confirmed; not all VOCs detected by the organizations listed were included in this table.

5. CONCERNS

5.1 Health risk

Exposure pathways for VOC contaminated drinking water can include ingestion, inhalation, and dermal routes. VOC exposure may prompt acute and chronic adverse health effects, depending on the VOC in question, concentration, exposure duration, and a person's age and health condition. Young children, the elderly, and people with respiratory problems (e.g., asthma) may be more susceptible to adverse effects from VOCs.

5.2 Sources and fate of VOCs in building plumbing

Not all VOCs are regulated. However, certain groups of VOCs are regulated and routinely measured in the main distribution system, and must be maintained below a maximum contaminant level (MCL). Health advisories (HA) are not legally enforceable, but pertain to the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for up to one day of exposure for a 10-kg child consuming 1 liter of water per day.

Some VOCs are present in drinking water when chlorine-based disinfectants are used. These compounds are formed in the water system during transport from water treatment plant to point-of-use. These are formed due to unintended and unavoidable reactions between natural organic matter (NOM) and chlorine-based disinfectants commonly used in many US public water systems. These VOCs are called disinfection byproducts. Changes in water treatment processes, and source water quality, such as increased NOM after wildfires, or water age, may increase the formation of some VOCs in drinking water systems. For example, continued reactions of the disinfectant with NOM inside plumbing can generate an increase in VOC concentration.

VOCs can also leach from certain plumbing materials, typically at low levels. Under some circumstances, high levels of VOCs can leach from excess glue for polyvinylchloride (PVC)/chlorinated PVC (CPVC) pipe connections. VOCs can also leach from certain plastic pipe materials, such as cross-linked polyethene (PEX). The rate and amount of VOCs that leach from these components is dependent on many factors, including type of plastic, age of pipe, water temperature, period that water is stagnant in the pipe, among others. The amount of VOC leaching to water is typically considered to be low. VOCs may also be introduced into plumbing from in-building backflow incidents.

VOCs can be introduced to building plumbing if chemically contaminated water enters the plumbing after a wildfire from a contaminated water distribution system or private well line. If VOC contaminated water enters plumbing, the VOCs may adsorb, or for lack of a better term, stick to plumbing material surfaces, biofilm, sediment, and corrosion- or hardness-related scales. Under certain conditions, the adsorbed VOCs may reenter the bulk water.

VOCs that enter building plumbing may also diffuse (i.e., penetrate) into and out of plastic plumbing components such as plumbing fixture and pipe gaskets, interior pipe coatings, liners, and the pipes themselves – where these components essentially act like a sponge. More mass of VOCs can diffuse *into* the plastic with a longer exposure duration, a greater VOC concentration in the water, and at higher temperature, among other factors. VOCs can then leach from inside the plastic back into the water under certain circumstances. How quickly VOCs leach back into the water is dependent on various factors, including, but not limited to: the specific VOCs present in the plumbing component, the amount of VOCs present in the plumbing component (i.e., the amount of VOCs that diffused into the pipe during contamination), the concentration of VOC in bulk water during the leaching process, water temperature, turbulence of flow, the type of plastic, and surface characteristics of the plastic.

5.3 Sample collection procedure considerations

VOCs, by their nature, can rapidly partition from water into air. They are volatile. The volatilization rate is increased at greater water temperature and turbulence. Little information is available about faucet aeration impact on VOC loss. Therefore, care must be taken to minimize VOC loss into air during sample collection.

USEPA sampling and analysis procedures are applied to detect and quantify some VOCs in drinking water. However, for disaster response chemical contamination incidents, VOC compounds not included in the standard USEPA methods may also be present and pose acute and chronic health risks. For these reasons, the development of new analytical procedures or the modification of existing USEPA procedures may be necessary.

Care must be taken to understand the impact of sample collection, sample dechlorination, and preservation agents on sample integrity. If a person collects a sample and allows headspace in the bottle, partitioning of the VOC from the water into air (headspace) will occur and make the analysis prone to error. This may result in underestimating the amount of VOC present in the water. In some cases, dechlorinating agent can react with VOCs and alter their final distribution and concentration. A consequence can be that chemicals not present in the water sampled can be created as the water travels to the laboratory and is stored before analysis. USEPA analytical methods provide some guidance on the appropriate perseveration agent depending on target analyte. Multiple samples may be required if different dechlorination and preservation strategies are needed to quantify numerous compounds in a particular water.

In some cases, multiple samples will also be required to appropriately sample for all VOCs of concern. VOCs in drinking water present three possible exposure pathways: ingestion, inhalation, and dermal. Multiple locations will be required to appropriately sample VOCs of concern across all three pathways. For example, while kitchen sink cold water is commonly used for cooking and drinking (ingestion), VOCs in hot water used for showering must be sampled due to potential inhalation and dermal exposure hazards. Inhalation exposure will inherently be a function of site-specific characteristics such as ventilation rate, room volume, among other factors. Hot water requires scrutiny in emergency response and risk assessment scenarios. Prior studies by Dr. Whelton and others investigating VOC contamination of plumbing have involved sampling multiple locations in a home, and sometimes different VOC concentrations were found at different fixture locations.

Useful guidance on where samples should be collected in a home can be adopted from recently established USEPA guidance to schools for lead testing:

> *"schools and child care facilities should not use sample results from one outlet to characterize potential lead exposure from all other outlets in their facility. This approach could miss localized lead problems that would not be identified."*

A similar, comprehensive sampling plan that includes all likely outlets where exposure could occur is best for accurately charactering the extent of VOC contamination in a home. It is important to note that differences in the same water samples analyzed by the California Surface Water Resources Control Board for benzene have varied by 287% (3.1 ppb vs 12 ppb). Therefore, variability between duplicate samples must be considered when interpreting laboratory results. Finally, water sample replicates, trip, and field blanks are critically important to identify sources of contamination and ensure sample integrity.

5.4 Concerns with Directions Issued to the Public Prior to June 14, 2019

During the Camp Fire response, some citizens have taken it upon themselves, at the direction of commercial laboratories and the California State Water Resources Control Board, to collect their own plumbing water samples. At least one laboratory has directed people with plumbing water contamination concerns to flush their faucet for 10 minutes before collecting a water sample in the Camp Fire area. This action likely purges all of the plumbing water out and draws in fresh water from the utility water main, utility service line, customer service line, or, for homes on a private well, from the service line or well column that conveys water from the well to the home. This procedure would therefore likely decrease the chance to detect contamination of the home plumbing.

Prior to June 14, 2019 the California State Water Resources Control Board had directed people to collect only a cold water, kitchen sink water sample (stagnation not needed), and analyze it only for benzene. As discussed above, this strategy would not detect contamination at other outlets or in hot water supplies, may miss contamination at the kitchen outlet depending on stagnation time prior to sampling, and does not assess contamination of any VOC other than benzene.

6. PLUMBING VOC EXPOSURE SCENARIO AND SAMPLING PLAN

The following sections outline an example sampling plan that could be designed to assess the presence of VOC contamination in hot and cold water building plumbing systems. This section demonstrates important sampling considerations and requirements to fully assess home plumbing for VOC contamination and leaching potential. In order to do this, a contamination scenario and assumptions are defined:

- VOC contaminated water has entered residential plumbing and may or may not have fully passed through;
- The water contained a mixture of VOCs to include benzene, ethyl benzene, styrene, toluene, methylene chloride, naphthalene, vinyl chloride, xylenes, among others;
- Concertation of these contaminants in the contaminated water may have ranges from < 0.5 ppb to 40,000 ppb concentration;
- Concentrations of these contaminants entering the plumbing may have varied with time over several months;
- The duration that the contaminated water was in contact with the plumbing is conservatively assumed to have occurred over 5 months; and
- The plumbing is aged and contains some biofilm, scales, and sediment.
- The residence has an external water tank that pumps water directly into the plumbing and bypasses the customer service line for a well or utility service connection

There are many other assumptions and items not considered in this scenario listed below the protocol.

6.1 Sampling approach and logic. The following section is a sampling plan that aims to assess if building plumbing is contaminated with VOCs. To accomplish this goal, water is flushed from the plumbing system and replaced with uncontaminated water from the house's external water tank. Water is then allowed to remain stagnant within the plumbing. After 72 hours stagnation, sampling is conducted. VOCs that leached into the uncontaminated water during stagnation are quantified.

<u>The pre-sampling flushing procedure:</u>

1. The volume of the external tank was not considered in developing this procedure.
2. Collect a water sample directly from your flushing tank (clean water) that will be used to confirm your flushing water is not contaminated.
3. Remove all faucet aerators and showerheads.
4. Flush out all plumbing and replace it with the clean water
    a. Cold water:
        i. Starting at the cold water outlet closest to the point where water enters the house, sequentially turn on and allow cold water outlets to continuously run for at least 20 minutes. [Note: If more than 1 outlet is opened at the same time, the flows may decrease. If too many outlets are opened at the same time, no water may exit some faucets. It is important that the plumbing is completely flushed out. This may require you to flush a few outlets at time for 20 minutes each, instead of all outlets simultaneously].
            1. If a bathtub has a spout and shower head, direct flow through the bathtub spout.
        ii. Next, flush each toilet at least once.
        iii. Next, flush all outside spigots for 10 minutes simultaneously [You may need to flush one at a time if flow decreases].
        iv. After flushing all cold water taps, direct the flow from the bathtub spout to the shower head, if applicable, for at least 2 minutes.
    b. Hot water:
        i. Turn off the water heater. [This is intended to reduce the temperature of the water being sampled and thereby limit VOC volatilization when water samples are being collected]
        ii. Starting at the hot water outlet closest to the water heater, sequentially turn on and allow hot water outlets to continuously run for at least 90 minutes. [Note: If more than 1 outlet is opened at the same time, the flows may decrease. If too many outlets are opened at the same time, no water may exit some faucets. It is important that the plumbing is completely flushed out. This may require you to flush a few outlets at time for 90 minutes each, instead of all outlets simultaneously. The 90 minute flushing duration is designed to empty the water heater for this building.].
            1. If a bathtub has a spout and shower head, direct flow through the bath tub spout.
            2. At the end of the hot water flush, water temperature should be the same as the cold water, indicating you've flushed all hot water from the tank.

   iii. After flushing all hot water outlets, direct the flow from the bathtub spout to the shower head, if applicable, for at least 2 minutes.
   iv. Turn the water heater back on.
5. Stagnate plumbing to allow for chemical desorption for 72 hours.

Sample collection procedure:

1. It is recommended that at least two people conduct sampling because one will sample and the other one will immediately cap the sample to reduce potential for VOC loss. The aerators and showerheads should be off during sample collection. Vials should be filled completely, headspace free, in accordance with proper VOC water sample collection practices.
2. Collect:
   a. First draw from Location #1 cold sample.
      i. Open the faucet slowly to get a slow, steady stream of water (approximately a pencil width flow).
      ii. Sequentially fill five 40 milliliter (mL) volatile organics analysis (VOA) vials, one after another, starting with the very first volume of water that exists the outlet. Minimize water splashing and overflow from the vials; the flow rate may need to be adjusted if the flow is too rapid.
   b. First draw from Location #2 cold sample
      i. Using procedure above, five 40 mL VOA vials.
   c. First draw Location #1 hot sample
      i. Using procedure above, five 40 mL VOA vials.
   d. First draw Location #2 hot sample
      i. Using procedure above, five 40 mL VOA vials.
   e. Return to Location #1, turn on the tap to a similar flow rate as before, and allow water to continue to run for 5 minutes.
      i. Water should be a constant hot temperature, indicating it is water directly from the water heater tank.
      ii. Collect another series of five 40 mL VOA vials, in the same manner as before.
   f. Return to the Location #2, turn on the tap to a similar flow rate as before, and allow water to continue to run for 5 minutes.
      i. Water should be a constant hot temperature, indicating it is water directly from the water heater tank.
      ii. Collect another series of five 40 mL VOA vials, in the same manner as before.
   g. Continue this process for all outlets where exposures can occur to include ingestion, inhalation, and skin contact.
   h. Fill your five trip blank 40 mL VOA vials with the VOC-free water, such as water provided to you by the laboratory. Open it up in the same physical location as the bathroom sink sampling location, transfer into 40 mL vials with similar procedure as above.
3. Reinstall all faucet aerators.
4. Appropriately package and transport sampling vials according to laboratory instructions.
5. End

7. ASSUMPTIONS AND CALCULATIONS

There are many assumptions, which will impact the ability of the sampling approach to detect VOC contamination. They include, but are not limited to:

1. Building characteristics
    - Two story, single–family residential building
    - 3 bedroom, 1.5 bath home that is 2,800 square feet (1st floor: kitchen sink, dishwasher, refrigerator (no water filter, no ice maker), water heater, 0.5 bath [sink, toilet], laundry washing machine; 2nd floor: bedrooms and full-bath [shower, tub, showerwand, his and her sinks, toilet]; outdoor: 2 hose spigots; no hot water recirculation system)
    - 1 in diameter HDPE customer service line, which is bypassed by the external tank
    - 75 gallon conventional storage tank water heater
    - Trunk-and-branch design with ¾" diameter copper pipe
    - All faucets have aerators that can be removed
    - No water filters installed on any fixture location

2. Building plumbing component characteristics
    - Fixture flow rate was assumed to be 1 gallon per minute.
    - COLD water pipe 140 ft of 0.75 in diameter holds 3.2 gallons
    - HOT water pipe 140 ft of 0.75 in diameter holds 3.2 gallons
    - Water heater holds 75 gallons
    - Each faucet connector [0.5 in FIP x 20 in length] holds 0.2 gallons (3.2 cups)
    - Time to flush water heater
        - Theoretically, 75 gallon water heater flushed at 1 gallon per minute should take 75 minutes to turn over. If multiple fixtures are opened water heater flushing *may* occur faster. The time needed to completely flush out the water heater will also be determined by the pressure at the service line, fixture type and fixture use.
        - Assume 25% margin of safety (divide water heater volume by 4, then add that to the water heater volume). That will indicate you should flush for at least 90 minutes, not 75 minutes. This is why the pre-sample flushing protocol indicates to flush from every fixture.
    - This scenario does not include a water service line.
    - This scenario assumes if there is a metal or plastic water meter it is located outside the building, not inside the building. This document only pertains to plumbing inside the building and not a meter.
    - There is sufficient volume and pressure supplied by the external tank to conduct the pre-flushing protocol and have enough water left over to sample and for regular domestic use if the house is occupied.
    - Current configuration is not connected to service line. So, pressure at the service line should be omitted. It is regulated by available tank volume/ pressure, among other factors.

8. OTHER FACTORS TO CONSIDER

This document does not include a number of scenarios. Deviations from the approach outlined above may result in no, minor, or significant changes in the chemical testing considerations for determining the safety of the plumbing. Under certain scenarios, removal and replacement of components may be warranted. Not included in the approach described above are:

- Septic systems are susceptible to damage due to high flows and volumes of water. Before flushing, building owners should determine what volumes are appropriate for their septic system and not exceed that limit.
- The act of flushing and resulting VOC exposures may pose a health risk. Proper personal protective equipment and practices are needed to best ensure the safety of the individuals who conduct flushing.
- A comparison of trunk-and-branch and manifold plumbing systems
- The presence of whole house filters, point-of-use filters, or filters within appliances
- On-demand water heaters and water heaters of different size.
- Faucet connector contamination, ice maker lines, shower wands, and other related items
- Variability in results over time
- The degree biofilms, scales, and sediment influence VOC fate in plumbing
- The consequence, if any, that when hot water cools in the vial and headspace may form, VOCs to partition out of the water into that headspace.
- The consequence, if any, of VOC loss due to shutting the water heater off and allowing the water in the tank to cool before sampling.
- The consequence, if any, of collecting a sample without removing aerators
- Fire-damage to exterior plumbing components that contain plastic or are entirely plastic may be sources of VOCs, including spigots, tanks, and pipes.
- Irrigation systems
- Volume of the external tank supplying uncontaminated water
- Pressure capabilities of the external tank supplying uncontaminated water
- Price of or time required for sampling

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The findings and conclusions in this report should not be construed to represent any agency determination or policy. Institutions listed funded some information described here.

10. DATE FINALIZED

June 16, 2019