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POU water filters effectively reduce lead in drinking water: a demonstration field study in flint, Michigan

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ABSTRACT
A field study was conducted to test the effectiveness of faucet-mounted point of use (POU) water filters for removing high concentrations of lead in drinking water from premise plumbing sources and lead service lines (LSL). These filters were concurrently certified for total lead removal under NSF/ANSI Standard 53 (NSF/ANSI-53) and for fine particulate (Class I) reduction under NSF/ANSI Standard 42 (NSF/ANSI-42). In 2016, filtered and unfiltered drinking water samples were collected at over 345 locations in Flint, Michigan. Over 97% of filtered water samples contained lead below 0.5 μg/L. The maximum lead concentration in filtered water was 2.9 μg/L, well below the bottled water standard. The effectiveness of the POU activated carbon block filters in reducing lead concentrations, even above the 150 μg/L NSF/ANSI-53 challenge standard, is likely related to trapping particles due to the small effective pore size of the filters, in addition to ion-exchange or sorption removal of soluble lead. Properly installed and maintained POU filters, certified under both NSF/ANSI-53 (for total lead) and NSF/ANSI-42 (for fine particulate), can protect all populations, including pregnant women and children, by reducing lead in drinking water to levels that would not result in a significant increase in overall lead exposure.

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Lead; drinking water; point of use filtration

Introduction

Filtration of tap drinking water through point-of-use (POU) water treatment devices has gained acceptance and popularity,[1] in part due to concerns regarding lead contamination from service lines and interior premise plumbing materials. Lead is a neurotoxin that can be harmful even at low exposure levels, especially to young children and pregnant women, and the US Centers for Disease Control states that "No safe blood lead level in children has been identified."[2] Minimizing lead exposure, particularly by the removal of lead sources, has been the focus of public health experts and practitioners. Blood lead levels in children are generally declining following implementation of several regulations to remove sources of lead from homes and the environment, prevent the use of lead materials, and improve corrosion control in drinking water systems. Legacy sources of lead, such as leaded paint and lead-containing plumbing, still affect many children.[2,3] The Centers for Disease Control (CDC) blood lead level reference level (5 μg/dL) is set such that 2.5% of children ages 1–5 (i.e., over a half of a million children based on US Census Bureau data) are above this reference level, and even lower levels have been associated with lifetime effects on health and well-being for children[2,4,5] and adults.[6] In June 2016, American Association of Pediatrics issued a policy statement recommending lead levels in water consumed by children do not exceed 1 μg L^{-1}.[5]

Where present, lead service lines (LSL), which connect the water main to the premise (i.e., indoor or household) plumbing, are the largest contributor to waterborne total lead in homes.[7,8] Although use of LSLs was banned in 1986, surveys estimate 6.1 million to 10.2 million lead service lines[9,10] are likely still in use. This number is likely higher because many water systems do not have good records, especially on private property. Based on the experience of the authors, most public water systems historically only removed the public portion of LSLs. Premise plumbing components, including brass fixtures and fittings, lead solder,[7,11–13] flux, water meters, lead goosenecks, and galvanized steel pipes,[14] can also release large amounts of lead to drinking water. Corrosion control water treatment is essential for lowering lead levels in water. Properly optimized corrosion control treatment can significantly reduce water lead levels across the whole system, but many factors can still result in high lead release at individual homes even with properly optimized corrosion control treatment.

Particles originating from corrosion by-product or scale deposits, which can be sporadically released from LSLs and other lead-containing plumbing and may contain very high lead levels, may not be captured with most water sampling

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Figure 1. An example of particulates observed in a faucet aerator, Flint, MI (Photo credit: Peggy Donnelly, EPA).

protocols.[15,16] Physical, hydraulic, and chemical disturbances to these lead pipes and associated galvanized pipes have resulted in measurable and undesirable particulate release.[7,17–20] The size of the "particles" can range from the nanometer scale to naked-eye visibility, and the size and mobility are governed by water chemistry factors.[15,16,21] Figure 1 illustrates an example of granular particulate material in a Flint household, that was large enough to be filtered out by the faucet aerator. When elevated lead is present in tap water used for drinking, cooking, or baby formula preparation, there is a higher risk of detrimentally impacting blood lead levels, especially for infants and young children.[15] Because the inorganic lead in drinking water is not absorbed through the skin,[22,23] washing hands and bathing have a negligible effect on blood lead levels, even if elevated lead is present in tap water.

Lead contaminated drinking water became a major issue in Flint, Michigan, following the April 2014 transition from drinking water purchased from the City of Detroit to the Flint River as the city's drinking water source,[24–26] resulting in an increased percentage of children with elevated blood lead levels.[27] Federal agencies including EPA and the Department of Health and Human Services (HHS) subsequently recommended that Flint residents use either filtered water (i.e., using NSF/ANSI-53 certified lead-reducing POU filters) or bottled water for drinking and cooking. Federal and state agencies and other organizations distributed Brita® (Brita, LP [part of The Clorox Company family of companies]; Oakland, CA) and PUR® (PUR Water Purification Products, Inc. [Helen of Troy Ltd.], El Paso, TX) brand POU water filters for use in Flint to protect residents against elevated lead. The State of Michigan has been distributing POU filters for use in Flint since January 2016,[28] and this program is expected to continue until one year after all LSLs have been removed in Flint.[29] The filters are certified in accordance with NSF/ANSI-53 as being effective for the removal of particulate and soluble lead at concentrations in water up to 150 μg L^{-1}. Testing of unfiltered water from Flint residences by EPA, MDEQ, and others showed water lead levels exceeded 150 μg L^{-1}, and in extreme circumstances levels above 10,000 μg L^{-1} were measured.[30,31] As a result, there were questions from consumers and the medical community about the ability of distributed POU filters to reduce elevated lead levels found in Flint given the filters were certified using a challenge concentration of 150 μg L^{-1} total lead. In some cases, direct statements were made that caused residents to believe that the filters were not capable of working at levels of lead released in many homes, and in some cases they were advised to only use bottled water for drinking or cooking.[32–35]

The POU filter models included in this study had dual certification in accordance with NSF/ANSI-53 (total lead) [36] and NSF/ANSI-42 (Class I particulate, 0.5 to 1 micron). [37] These standards mutually support each other, and the relative impact of one certification versus the other could not be separated in this study. In fact, the relative impact of each certification would be expected to vary from house to house and city to city, based on the physical and chemical speciation of the lead at that site. The certification of POU filters to both of the noted NSF/ANSI standards is intended to ensure that the device reduces total lead (dissolved and particulate) to below 10 μg L^{-1} during the performance lifetime of the product.

The solubility chemistry and speciation of lead has been widely discussed and reviewed, especially since the early 1980s.[16,38] Because of the complexity of lead chemistry in drinking water and the wide variations of finished water chemistry across the United States, one single test condition was not deemed adequate for lead removal certification testing under NSF/ANSI-53. Peak soluble lead and peak colloidal or particulate lead would normally occur in different background water quality conditions, particularly with different pH, alkalinity and orthophosphate corrosion inhibitor concentrations. Dissolved lead concentrations approaching the NSF/ANSI-53 certification testing challenge level of 150 μg L^{-1} would most often occur at acidic pHs to slightly basic pHs, in the absence of phosphate corrosion inhibitors.

The NSF/ANSI-53 testing protocol challenges POU filter devices with two types of water each containing 150 μg L^{-1} total lead: (1) a low-alkalinity aggressive water (pH 6.5, alkalinity 10–30 mg $CaCO_3$/L) and (2) a more mineralized water (pH 8.5, alkalinity 100 mg $CaCO_3$/L). Revisions to the NSF/ANSI-53 protocol in 2007 added particulate lead by requiring 30 ± 10% of the 150 μg L^{-1} of the total lead in the challenge influent be particulate and upwards of 20% of the total lead content be fine particulate lead (0.1–1.2 microns).[36,39]

Many newly certified POU filters utilize an outer fabric or fiber filter surrounding a solid block composed primarily of activated carbon, made of small particles of activated carbon augmented in some filter cartridges with ion exchange or sorption media for metals removal, fused together to form a block of uniform pore size, typically 0.5–1.0 micron.[39] Solid block activated carbon will be simplistically abbreviated as SBAC for the purposes of this article. Deshommes *et al.* (2010) demonstrated consistent lead removal by tap-mounted POU filters (80–99% removal) and under-the-sink POU filters (82–90% removal), which were NSF/ANSI-53-certified for total lead after 2007 and NSF/ANSI-42-certified for fine particulate (0.5–1 micron), when challenged with two levels of particulate lead (approximately 20 μg L^{-1} or 100 μg L^{-1}) and one level of dissolved lead (approximately 50 μg L^{-1}).[39]

Based on a combination of understanding of the mechanisms of lead removal within the filters, and some field study evidence,[40] the authors expected that POU filters certified in accordance with NSF/ANSI-53 (total lead removal) and NSF/ANSI 42 (Class I particulate reduction, 0.5–1 micron) standards would be effective at providing protection against lead levels much higher than 150 μg L^{-1}. Figure 2 illustrates the components of the commercial POU faucet-mounted filtration devices designed to remove particulate and soluble metals, including lead. At high lead levels (>150 μg L^{-1}) and typical drinking water pH conditions, lead solubility dictates that much or most of the lead present in the water would be in particulate form.[16,38] Thus, elevated lead would be physically trapped and removed by the filters. Consistent with known water filtration performance, the removal effectiveness of particulate lead would become progressively better with more clogging, though for best flow performance, the certified filter capacity (gallons) should not be exceeded.

Furthermore, elevated levels of other metals such as iron, copper, and zinc were occasionally reported in unfiltered drinking water samples. Although POU filters used to remove lead from water in Flint were not certified for removal of such metals, the general expectation among drinking water experts, based on the properties of carbon-based and cation exchange media materials, was that the filters would prove capable of removing them as well. An extensive drinking water sampling effort was initiated in Flint to evaluate the effectiveness of POU filters under field conditions in actual residences, including locations with elevated lead above the 150 μg L^{-1} certification level. The objective of this work was to summarize the findings of this filter effectiveness sampling program in Flint, Michigan.

Materials and methods

Filtered and unfiltered grab samples were collected to assess whether the NSF/ANSI-53 and NSF/ANSI-42 certified POU filters being distributed in Flint were effective for the reduction of lead, regardless of influent levels above the certification criteria of 150 μg L^{-1}. Sampling locations were selected by targeting homes with previous lead results above 150 μg L^{-1},[30,41] with a confirmed LSL coming into the home, or at the residents' request. Almost all samples were collected from within the Flint drinking water system service area, with the exception of 9 sampling locations in surrounding areas served by Beecher Metropolitan District (2 sites), Genesee County (6 sites), and a private well (1 site).

Filtered and unfiltered water grab samples were collected at each selected sampling location, generally at the kitchen faucet, as outlined below in accordance with EPA's Quality Assurance Project Plan.[41] Samplers recorded field observations including the filter type/brand, filter indicator status, and the resident's estimate of the time since the filter or cartridge was installed. Samplers were not able to verify the certification status of the filter and cartridge, except for those installed by the sampling team. All samples were collected from the cold water tap, and three types of 1000-mL samples were collected from homes:

1. *Filtered Water, Existing Filter* – One grab water sample was collected through the existing water filter already installed at the home (if present).
2. *Unfiltered Water* – An unfiltered water grab sample was collected after removing the existing filter or turning the by-pass valve on the filter. No cleaning or flushing was conducted prior to the unfiltered water grab sampling.
3. *Filtered Water, New Filter* – Following installation and flushing of a new filter or replacement filter cartridge for approximately 2 min, a grab sample was collected through the newly installed filter or filter cartridge. At some sites that had an existing filter in place that appeared in good condition (including no red or yellow indicator lights), a new filter or filter cartridge was not installed and no 'New Filter' sample was collected.

Only PUR® and Brita® POU filters that have been certified under NSF/ANSI-53 (total lead) and NSF/ANSI-42 (Class I particulate) were approved for distribution to Flint residents. These PUR® and Brita® POU filters use a SBAC matrix, as described above. All POU filters installed by EPA during the study ('New Filter' samples) were certified under NSF/ANSI-53 (total lead) and NSF/ANSI-42 (Class I particulate). Based on their wide, no-cost distribution to Flint residents, it is assumed that all 'existing' PUR® and Brita® POU filters included in this study were certified under NSF/ANSI-53 (total lead) and NSF/ANSI-42 (Class I particulate).

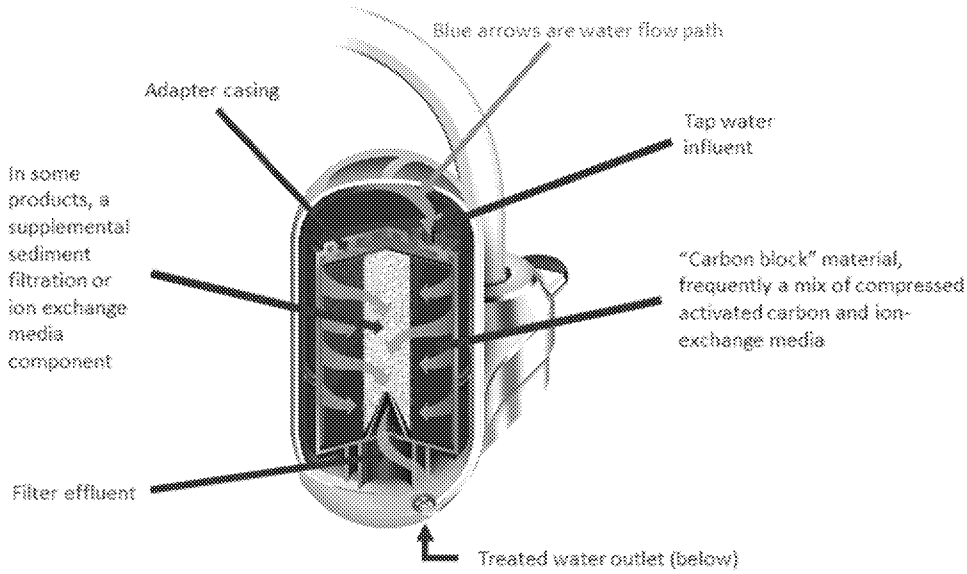

Figure 2. Schematic diagram of the internal structure of a typical faucet-mounted POU water filter, representative of the models tested by this study in Flint, MI.

There were slight modifications in the sampling protocol during the course of the study, including elimination of the "Filtered Water, New Filter" at most locations, unless a replacement filter was needed. According to the respective manufacturers [42–45], the PUR® and Brita® POU filters are designed with a warning light to come on when the filter should be changed soon (e.g., approximately 25% of the rated volumetric capacity or estimated useful lifetime remaining) and turn red after the filter reaches end of life (e.g., rated volumetric capacity or estimated useful lifetime).

Each grab water sample consisted of filling one 1,000-mL HDPE bottle, which was then field preserved (HNO_3 to pH < 2) for analysis of total metals (including lead). EPA regional laboratories or a contract laboratory analyzed samples by EPA Methods 200.8 (Pb, Cu, Zn) and 200.7 (Fe, Mn, Al, Ni, Cd, Cr, Ca, Mg, K, Na), after acid digestion. Lead levels were reported down to levels between 0.11 and 0.5 μg L^{-1} among the analytical laboratories used in this study, and method detection and reporting limits also varied among the laboratories for some of the other metals of interest (see Table S2). Final analytical results were evaluated, and 2 sites were resampled due to apparent sampling errors; the resampling results are included in the subsequent analysis. Residents were provided all sampling results from sampling locations at their homes.

Lead sources in the plumbing are highly variable along the water flow pathway, the amount of water used at any given time varies, the volume of the sample represents different lengths of pipes, and the stagnation time between water uses varies greatly; for all these reasons, the lead (and other metal) filter influent concentration constantly varies [12,17,46] at each site. Thus, there was no way to do a simple "before and after" filtration impact sampling when the "before" sample is never constant, as could be done in a certification laboratory setting. Because the distribution system water quality was shown by water quality sampling to be generally consistent with respect to the best estimation of the parameters affecting lead release, the study design was to pool unfiltered grab samples as representing "before" lead sample concentrations, and to compare the pools of post filtration grab sample results for the "existing" filters and the newly-replaced filters.

Results and discussion

Given the nature of the filtered and unfiltered water sampling, and the varying reporting limits amongst the analytical laboratories, an effective way to present and evaluate the data visually is by using percentile distribution versus concentration plots, with a logarithmic scale on the concentration axis (Figures 3 through 7). The concentrations of any chosen percentile, and even individual values, can be simply obtained by the intersection of projecting lines from each axis. Table S3 summarizes the metals results for grab unfiltered water samples as well as the post filtration grab sample results for the "existing" filters and the newly-replaced filters.

Removal of lead

High lead levels, in some cases above the 150 μg L^{-1} NSF/ANSI-53 challenge concentration and as high as 10,000 μg L^{-1}, had been detected in unfiltered water samples collected in Flint, both as part of this study and other sampling efforts.[30,31] The unfiltered water samples represented a wide range of stagnation times, typical of normal household use conditions, with less than 20% of the samples in this study representing a confirmed stagnation period of 6 h or more. The maximum lead concentration in the unfiltered water at the 345 sampling locations in this study was 4,080 μg L^{-1}, with approximately 4% of the unfiltered water samples above 150 μg L^{-1} and over 37% above the Food & Drug Administration (FDA) standard for bottled water (5 μg L^{-1}). Approximately 20% of the unfiltered water samples contained lead below the laboratory reporting limit of

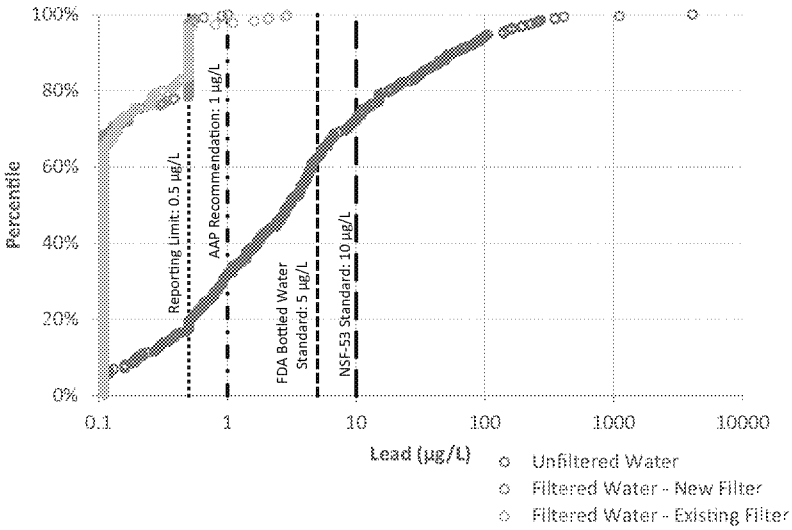

Figure 3. Percentile versus concentration distribution of lead levels in filtered and unfiltered drinking water samples. Note logarithmic scale for lead concentration. Laboratory results presented include some estimated values between the Method Detection Limit (0.11 µg L^{-1}) and the Reporting Limit (0.5 µg L^{-1}).

0.5 µg L^{-1}. Variability in lead levels at individual sampling locations can be attributed to many factors, including site-specific plumbing and service line materials, low water usage, long stagnation time, as well as particulate lead release caused by physical, hydraulic, and chemical disturbances to lead and associated galvanized pipes.[12,14,16,17,20]

Although a detailed characterization of particulate versus soluble lead was not conducted, the indirect evidence and theoretical lead solubility modeling support the conclusion that a significant portion of the lead at the highest concentrations is present as particles. This statement is supported by field observations of heavy loading of faucet aerators with particulate material, which was confirmed by laboratory testing to have a high lead content (see Figure 1 and Table S4). The particulate lead is likely to be scale material that has been released from the interior of water service lines and interior pipes. Previous EPA investigation of 91 lead pipe scale samples from 26 different drinking water systems revealed that the lead concentration ranged from approximately 3% to over 90% by weight, depending on the nature of the treatment and water chemistry.[47]

Filtered water lead levels were very low for cartridges in use for days or weeks (existing filter), as well as those sampled on the same day as the cartridge was installed (new filter) (Figure 3). As shown in Figure 3, 97 and 98% of the filtered water lead levels were lower than the laboratory reporting limit of 0.5 µg L^{-1} for existing and new filters, respectively. Lead levels in all but 6 filtered water samples (99%) were below the AAP recommendation of 1 µg L^{-1}. [5] and the maximum lead level in filtered water observed was 2.9 µg L^{-1}. Lead levels in all filtered water samples were below the FDA bottled water standard of 5 µg L^{-1} and the NSF/ANSI-53 standard for certification of 10 µg L^{-1}.

A limited number of filtered water samples were collected through a filter which was due to be changed (red light observed), but they are not included in the graphical removal analysis. Of these 12 filtered water samples, lead levels ranged from <0.11 to 0.56 µg L^{-1}. However, these results should not suggest that consumers should use their water filters longer than recommended by the manufacturer, because additional important complications could arise, as discussed elsewhere in this article.

Further statistical analyses were performed, making different assumptions about the data below the laboratory reporting limit and the distribution of the lead concentrations. These are summarized in the Supplemental Information.

Removal of other metals

Although tap-mounted filters certified under NSF/ANSI-53 for total lead removal are not jointly certified for their removal, the sampling results showed incidental removal of copper, zinc, iron, and manganese. The co-occurrence of other metals in unfiltered water, and the removal of the other metals along with removal of lead, provide further evidence that high lead removal is by physical removal of particles. Figures 4 through 7 illustrate, in the same fashion as Figure 3, the comparisons of filter performance for the common corrosion or scale release byproduct metals copper, zinc, iron, and manganese.

1. *Copper.* 98% of filtered water samples contained copper below the higher laboratory reporting limit of 5 µg L^{-1}, and the maximum copper concentration in filtered water was 120 µg L^{-1} (see Figure 4), well below the Maximum Contaminant Level Goal (MCL Goal) of 1,300 µg L^{-1}. By comparison, unfiltered water samples had higher copper as high as 4,700 µg L^{-1}, with 2% above the MCL Goal of 1,300 µg L^{-1}.
2. *Zinc.* 97% of filtered water samples contained zinc below the higher laboratory reporting limit of 50 µg L^{-1}, and the maximum zinc concentration in filtered water was 540 µg L^{-1} (see Figure 5), well below the MCL Goal of 5,000 µg L^{-1}. By comparison, unfiltered water samples had higher zinc, with 1% above the

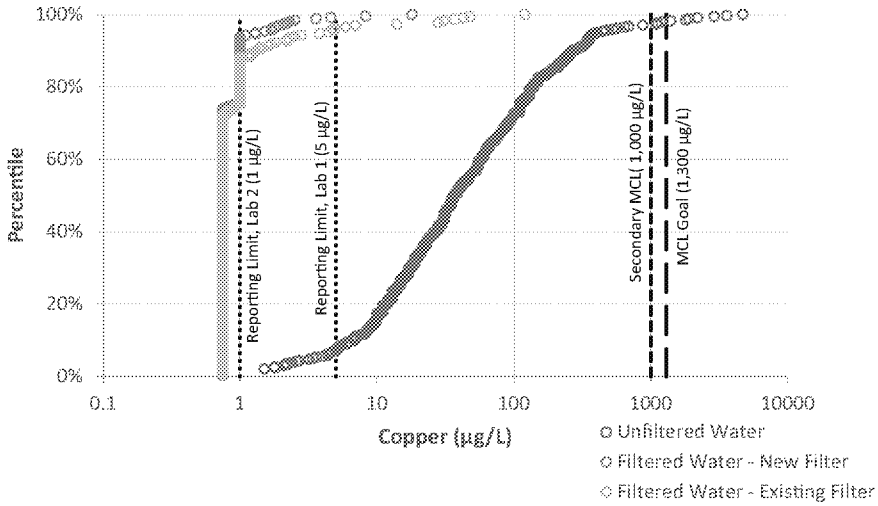

Figure 4. Distribution of copper levels in filtered and unfiltered drinking water samples. Note logarithmic scale for lead concentration. Laboratory results presented include some estimated values between the Method Detection Limit (0.75 µg L^{-1}) and the Reporting Limit (5 µg L^{-1}).

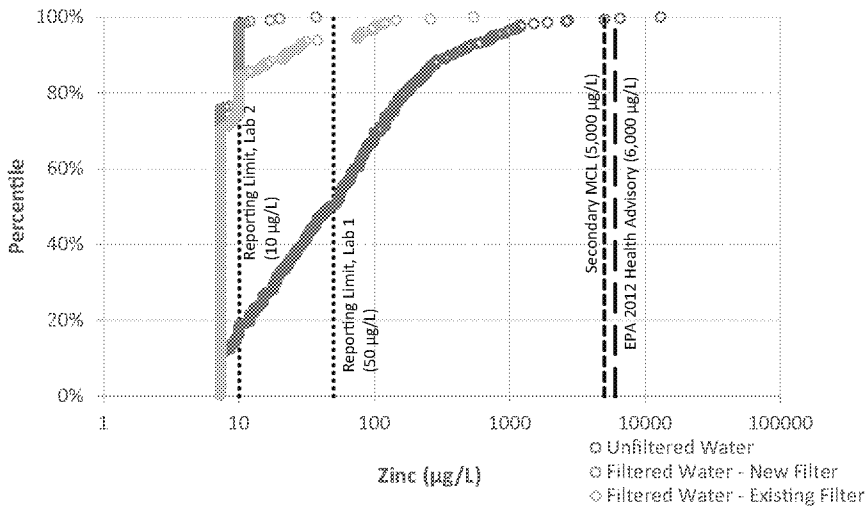

Figure 5. Distribution of zinc levels in filtered and unfiltered drinking water samples. Note logarithmic scale for lead concentration. Laboratory results presented include some estimated values between the Method Detection Limit (7.3 µg L^{-1}) and the Reporting Limit (50 µg L^{-1}).

MCL Goal of 5,000 µg L^{-1} and a maximum of 13,000 µg L^{-1}.

3. *Iron.* 99% of filtered water samples contained iron below the higher laboratory reporting limit of 100 µg L^{-1}, and only two filtered water samples (0.4%) were above the Secondary MCL of 300 µg L^{-1} (see Figure 6). By comparison, unfiltered water samples had higher iron, with 19% above the Secondary MCL of 300 µg L^{-1} and a maximum of 110,000 µg L^{-1} (110 mg L^{-1}).
4. *Manganese.* 98% of filtered water samples contained manganese below the maximum laboratory reporting limit of 15 µg L^{-1}, and only three filtered water samples (0.6%) were above the Secondary MCL of 50 µg L^{-1} (see Figure 7). By comparison, unfiltered water samples had higher manganese, with 4% above the Secondary MCL of 50 µg L^{-1} and a maximum of 4,020 µg L^{-1}.

Additional metals (e.g., aluminum, nickel, cadmium, chromium) were analyzed; however, because most results were at or below the laboratory reporting limit, the authors were not able to evaluate whether or not the metals were being removed by the POU filters (see Tables S2 and S3 in Supplemental Information).

Previous tap water sampling efforts[31] indicated correlations between lead and other metals (e.g., aluminum) were present in Flint tap water. Lead and galvanized iron pipe scales from water systems using alum as a coagulant have contained high levels of aluminum, zinc, iron, and manganese.[7,48] Iron corrosion scales have an affinity to bind other metals, such as lead, from drinking water,[14,49] so particles can often contain elevated levels of multiple metals. Although no correlations could be found between lead and other metals (copper, zinc, iron, manganese) in unfiltered water samples, there are some examples of high lead co-occurring with higher levels of other metals. For example, in this work, one unfiltered sample, which contained 1,100 µg L^{-1} lead, also contained 1,000 µg L^{-1} aluminum, 2,200 µg L^{-1} copper, 110,000 µg L^{-1} iron, 430 µg L^{-1} manganese, and 1,900 µg L^{-1} zinc. The filtered water sample subsequently collected at this site contained much lower

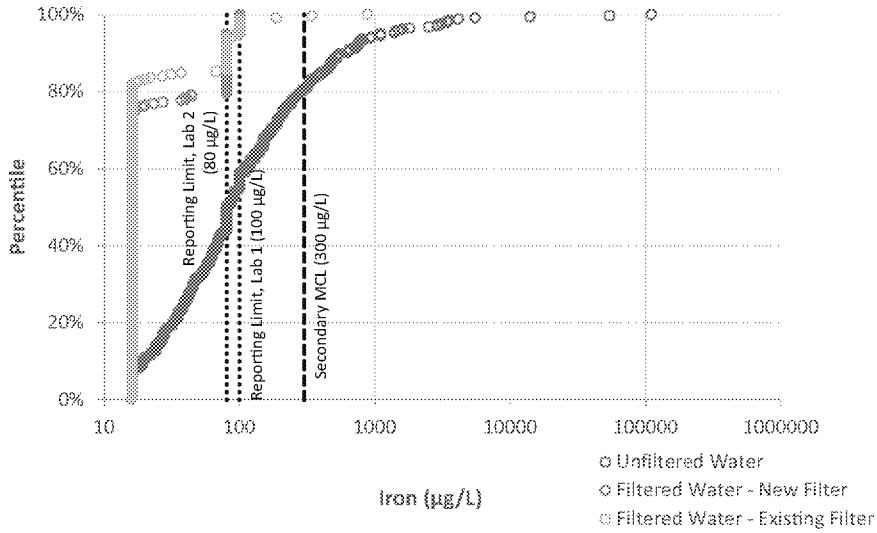

Figure 6. Distribution of iron levels in filtered and unfiltered drinking water samples. Note logarithmic scale for lead concentration. Laboratory results presented include some estimated values between the Method Detection Limit (16 µg L^{-1}) and the Reporting Limit (100 µg L^{-1}).

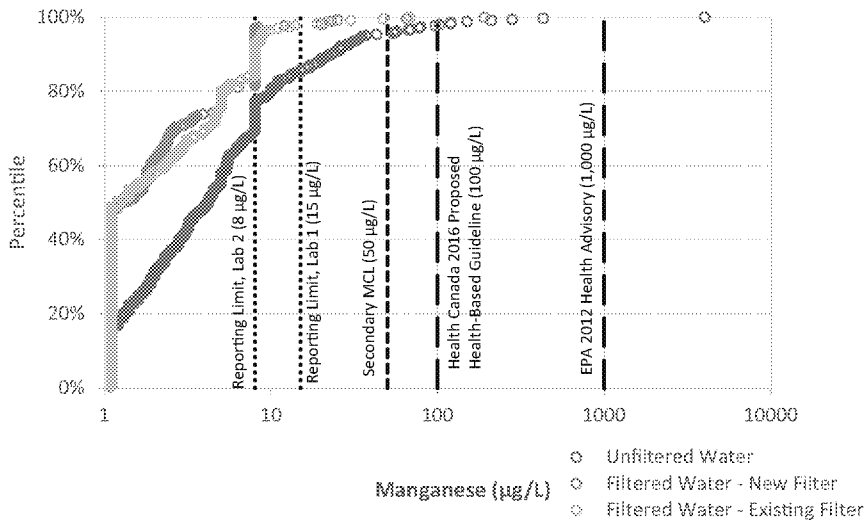

Figure 7. Distribution of manganese levels in filtered and unfiltered drinking water samples. Note logarithmic scale for lead concentration. Laboratory results presented include some estimated values between the Method Detection Limit (1.1 µg L^{-1}) and the Reporting Limit (15 µg L^{-1}).

levels of lead (<0.5 µg L^{-1}) and other metals including aluminum (<200 µg L^{-1}), copper (<5 µg L^{-1}), iron (<100 µg L^{-1}), manganese (<15 µg L^{-1}), and zinc (<50 µg L^{-1}).

Conclusion

Given the sporadic nature of lead release, especially from LSLs and associated galvanized iron pipes, a reliable means of reducing lead in drinking water is needed by homeowners, especially for susceptible populations such as bottle-fed infants, young children, and pregnant women.

In this field investigation in Flint, MI, faucet-mounted POU filters concurrently certified under NSF/ANSI-53 (total lead) and NSF/ANSI 42 (Class I particulate) were shown by this study under particularly challenging lead and scale release conditions to be a robust approach that consistently achieved lead levels at or below the 1 µg L^{-1} concentration in tap water that was recommended by AAP (2016).[5] This study demonstrated the removal of a combination of soluble and particulate lead from concentrations much greater than the 150 µg L^{-1} certification challenge concentration, to well below the current 10 µg L^{-1} certification acceptance criterion. Therefore, properly certified, installed, and maintained filters can be expected to reliably reduce lead exposure from drinking water, even when high lead levels (in excess of 1,000 µg L^{-1}) are present in unfiltered water. The City of Washington, D.C. has also reported that testing of POU filters indicated consistent lead levels at or below 1 µg L^{-1} in filtered tap water.[50]

Faucet-mounted POU devices can be an important and reliable barrier against unpredictable lead release from LSLs and interior plumbing materials by reducing lead in drinking water to levels that would not result in a significant increase in overall lead exposure.[51] Other state and local agencies beyond Flint have recommended the use of NSF/ANSI-53 certified lead-removal POU filters in certain cases, especially by bottle-fed infants, young children, and pregnant women.[39,52–54]

To ensure effectiveness and safety, POU filters should be maintained and replaced in accordance with manufacturer recommendations. For example, only cold water should be run through the POU filter media.[55] Recent attention to bacterial growth on POU filters[56] has cast doubts in Flint and elsewhere regarding POU filter usage. However, previous studies demonstrated regrowth of heterotrophic bacteria in building plumbing, including POU devices, and that drinking this water does not constitute a significant health risk to healthy adults and children when the entry water meets acceptable water microbial quality norms.[57–63] Manufacturers recommend running water through the POU filter for 5 s before using the water for drinking or cooking; and several studies have confirmed that flushing the water for 30 s or more can significantly decrease bacterial counts in the filter effluent.[56,60]

The findings of this study only apply to the use of an appropriate POU filter that is certified to remove the contaminant of concern (e.g., lead).[64] Using "whole house" or point-of-entry devices for lead removal rather than certified POU devices, can cause problematic water quality changes, including removal of chlorine, that can increase bacteriological risk and increase lead release from premise plumbing after the 'whole house' or point-of-entry filter.[40,65–67] Specific required package labeling and literature, required for certified products, can help the consumer select a product that will meet their needs. For a lead reducing filter, the certification seal and conformance statement on the packaging should indicate that the product was tested and certified against NSF/ANSI Standard 53 and NSF/ANSI Standard 42 for the claims specified on the performance data sheet. The performance data sheet, which is inside the package but also available online or by contacting the company, should be reviewed to check the product removes lead and fine particulate material (Class I, 0.5 to 1 micron), as well as any other specific contaminants of concern.

While this study verified the ability of some appropriately certified commercially-available POU devices to effectively remove lead to very low concentrations under challenging water chemistry conditions, some additional research seems to be warranted. This study tested devices only with a tap water using free chlorine as a secondary disinfectant. Many of the faucet-mounted POU devices for which this study is applicable contain some form of activated carbon, and many devices are also certified to concurrently remove both free and combined chlorine along with the lead. Reduction of chloramine by GAC is well-known.[68] As a result, the acclimation of nitrifying bacteria with time in some waters creates the potential for nitrite generation. Recently, this phenomenon has been reported in another study of tap water POU filters that have some similarities to the devices tested in this study.[69] In that study reported by Alfredo and Lin (2018), larger filters were used that stay in place for one year, unlike the smaller filter cartridges containing some form of GAC that homeowners might install on a faucet and change every few months.

We have not located any published research reports showing nitrite formation occurring in residential end-of-tap carbon block or mixed media POU filters in chloraminating systems. But, it is definitely an important public health question, and more research needs to be done to confirm or discount this potential complication for different devices in general usage across all water chemistries.

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