Per- and Polyfluoroalkyl Substances (PFAS) Point-of-Use Treatment System Study

FINAL REPORT

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UMass Mobile Water Innovation Laboratory at the Townsend Water Department

MassDEP

UMass Amherst

ACKNOWLEDGEMENTS

This document was developed in collaboration between the MassDEP Drinking Water Program and the University of Massachusetts - Amherst, Department of Civil and Environmental Engineering. The following individuals from the University of Massachusetts - Amherst contributed to this project:

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EXECUTIVE SUMMARY

This report describes the Point of Use (POU) Treatment Study design, methods, results, and future recommendations to evaluate the effectiveness and capacity of commercially available POU water treatment devices to remove per- and polyfluoroalkyl substances (PFAS) from contaminated drinking water in the Commonwealth. The project was carried out under an Inter-Departmental Service Agreement (ISA) with the Massachusetts Department of Environmental Protection (MassDEP) using funds provided by the Massachusetts Clean Water Trust.

Key elements for the study were as follows:

1. **Public Water Systems participation:** MassDEP requested volunteer Public Water Suppliers to participate in the study on July 30th and November 11th, 2021, through its "In The Main" newsletter. MassDEP and UMass wanted to see how effectively POUs functioned in diverse water chemistries, from different sources (surface water or groundwater), and with common co-contaminants. The Town of Burlington, Townsend Water Department, Wayland DPW, and Hanover Water Department all responded to the invitation, but ultimately only the Townsend Water Department participated in the study.
2. **Device selection:** Forty devices were identified in the market using product review websites that recommend POU devices and are commonly frequented by consumers, including Popular Mechanics, Consumer Reports, and Wirecutter. For this study 17 POUs were selected for testing and categorized by installation location, media type (e.g., carbon block, spun fiber, coconut shell fiber, etc.), and whether the device was certified by the National Sanitation Foundation (NSF Standard 53) for the removal of PFOA/PFOS.
3. **The Trailer**: The "Trailer" is the UMass Mobile Water Innovation Laboratory that has the capacity to test up to ten POU units at a time. It is configured to house and operate POU devices to simulate household locations and conditions specific to the use case of each device. In the spring of 2022, the trailer was deployed to Townsend, MA, to evaluate 17 POU devices.
4. **Laboratory analysis**: A total of 51 water samples were analyzed by a commercial MassDEP-certified lab, PACE (formerly Con-test) Analytical Laboratory in East Longmeadow, MA, using U.S. Environmental Protection Agency (EPA) method 537.1 for 18 individual PFAS compounds, including the PFAS6 compounds.
5. **Budget:** The total budget for the project was $164,400. Costs included trailer set up, site deployment, device testing, and staffing.

Results and Conclusions

Five of the 17 filters showed an effluent PFAS6 concentration below the Massachusetts Maximum Contaminant Level (MCL) of 20 nanograms per liter (ng/L) or parts per trillion (ppt) at 100% of the manufacturer recommended volume capacity. Three filters: 3M plumbed-in (Carbon Block), A.O. Smith plumbed-in (GAC), and ZeroWater (GAC), showed no detection (ND) for the samples run at 100% and 200% of the volume capacity. ZeroWater and A. O. Smith are GAC filters and are certified by NSF under standard 53 for the removal of PFOA/PFOS. All other devices had variable concentrations of PFAS6 above the Massachusetts MCL. The results of this analysis show that most of the filters - 12 of the 17 readily available for consumers - are not able to produce water with PFAS6 below the Massachusetts MCL of 20 ng/L at 100% of the manufacturer recommended volume capacity for Townsend Water Department's well water chemistry. However, it is important to note that none of these 12 filters possess NSF 53 certification, which means that they are not certified to remove PFAS. Additional research must be done on these devices, including a thorough breakthrough investigation of various water chemistries. Additionally, the performance of POU devices are dependent on proper maintenance and timely replacement of POU components as specified by the manufacturer.

Future Recommendations

Considering the 2022 draft EPA lifetime health advisory levels for PFOA of 0.004 ng/L and PFOS 0.02 ng/L as well as EPA's proposed National Primary Drinking Water Regulation to establish legally enforceable levels of 4 ng/L for PFOA and PFOS, and to regulate the combination of four additional PFAS – GenX, PFBS, PFHxS and PFNA, it is recommended that any future testing prioritize POU devices that maintain a non-detectable PFAS6 concentration in the effluent water at 100% of the manufacturers recommended throughput. Also, given the expected importance of water chemistry and PFAS profile on performance, a few carefully selected devices should also be tested against at least three other sources of PFAS-contaminated water. A full breakthrough analysis should be conducted on these devices across a total of four distinct water chemistries.

While MassDEP recommends that consumers use treatment devices certified to meet the NSF standards for the removal PFOS and PFOA, consumers should recognize that the NSF standard is set at EPA's former health advisory of 70 ng/L for the sum of PFOS and PFOA and is not as protective as MassDEP's drinking water standard of 20 ng/L for the sum of six PFAS (PFAS6) or EPA's proposed drinking water standards. Some of the treatment devices certified to meet NSF standards may be able to reduce PFAS6 levels to well below 70 ng/L, however there are no federal or state testing requirements for these treatment devices. Consumers who choose to install a treatment device should check to see if the manufacturer has independent, verifiable PFAS monitoring results demonstrating that the device can reduce PFAS below the all applicable drinking water standards, including the current Massachusetts PFAS6 MCL of 20 ng/L.

Given the changing scientific, health and regulatory climate for PFAS, MassDEP will share the information from this project and links from similar relevant studies as information sources for interested parties. MassDEP will continue to work with UMass to identify opportunities to utilize the mobile laboratory for further PFAS and other emerging contaminants analysis and evaluation, including a plan to potentially use the mobile laboratory for testing of emerging contaminants and treatment technologies for Small or Disadvantaged Communities with public water systems that have been contaminated by PFAS.

INTRODUCTION

Point of Use (POU) systems provide water treatment at distributed locations where the consumer uses it. A POU system could be installed at an individual tap, faucet, or shower. POU systems include filters that connect to a water line under the sink, attach to a faucet, or are pitchers one fills with water. They can cost several hundred dollars to install which is approximately an order of magnitude lower than the cost of point of entry treatment (POET) systems which are installed on the main water supply line serving a building.

The research question for the study focuses on information for residential consumers: if one installs a POU device and follows the manufacturer's recommendations for maintenance, how effective is that device at reducing the concentration of PFAS? What extent of PFAS removal would occur if a consumer followed the manufacturer's recommendations? These questions were selected as the simplest way for consumers to determine how best to control PFAS in domestic tap water given the rapidly changing regulatory and certification climate.

This report describes the POU Treatment Study design, methods, result, and future recommendations to evaluate the effectiveness and capacity of commercially available POU water treatment devices to remove per- and polyfluoroalkyl substances (PFAS) from contaminated drinking water in the Commonwealth.

DEVELOPMENT OF THE PROJECT

Trailer/apparatus:

POU device performance is dependent on flow, concentration, and environmental conditions. The UMass Mobile Water Innovation Laboratory (the “trailer”) was configured to house and operate multiple POU devices to simulate household location and conditions specific to the use case of each device.

The trailer allows for “plug and play” mode of testing. This means that devices can be quickly removed from and/or added to the trailer for operation and water quality sampling. The initial plan was to evaluate ten new devices each time the trailer was moved to a new location (initial plan for four locations).

The trailer has a capacity of testing up to ten POU units at a time. Water flow through each of ten individual POU devices connected in parallel was monitored and controlled. Flow was maintained in the range of 0.05-1.6 gallons per minute to emulate household flows while staying consistent with the manufacturer-claimed flow rate for optimum performance of the filter. Since each manufacturer sets its own flow rate, the study analyzed how well each device performed relative to the manufacturers’ recommendations. The trailer set-up includes various control valves to obtain consistent and uniform flow through each device. One refrigerator unit was installed to simulate temperature conditions of the refrigerator POU units. The unit was also used to store samples after collection to comply with the sampling protocol.

Device Selection

Forty devices were identified in the market, 17 of which were selected for study based on the process below. They were further divided into four categories: faucet mounted, refrigerator, plumbed-in, which includes filters that can be connected under the sink or placed on the countertop near the sink, and standalone.

The categories maintain the distinction between different types of filters while still encompassing the devices available on the market, including those found in hardware and home improvement stores. Several factors were considered when selecting the 40 devices, including certification, claims by the manufacturer to remove PFAS, and cost to the consumer. The first step was to identify generally used consumer review businesses that recommend POU devices. Three websites were selected: Popular Mechanics, Consumer Reports, and The Wirecutter.

Once the recommended POUs (Table 1) were identified, those certified under the National Sanitation Foundation’s Standard 53, “Drinking Water Treatment Units – Health Effects” were selected for this study. Additional POUs where the manufacturer’s advertising included a claim to remove PFOA and PFOS were also included in the study. These were included in order to provide information about the effectiveness of recommended POU devices, regardless of certification status. The POU filter models, media type (carbon block, spun fiber, coconut shell fiber, etc.), along with the manufacturer-claimed throughput volume (total gallons that can be treated before the filter has to be replaced) and replacement frequency were noted to aid in designing the sampling matrix.

Sampling protocol

The volume of water treated and the collection of samples for each filter was based on the manufacturer-rated throughput volume capacity. This information is available to the POU consumer. Samples were collected at 100% and 200% of the throughput volume capacity. Triplicate samples of treated water from each device at each selected capacity point were collected along with samples of raw water (to establish the influent PFAS6 concentration), resulting in three unique samples for each device. All samples were collected in certified pre-cleaned polypropylene 250-mL containers preserved with Trizma and were kept refrigerated.

The study was designed to evaluate the performance of POU device in removing PFAS6 (PFHxS, PFHpA, PFOA, PFOS, PFNA, PFDA) compounds from water. The treated water goal is to produce water with PFAS6 levels below the Massachusetts MCL of 20 ng/L. The results for the study are generated based on analysis of raw water and the 100% and 200% manufacturer-rated throughput capacity samples. Raw water was sampled for PFAS6 at uniform intervals and testing revealed a deviation of approximately 15% for all samples from the reported value of 122.6 ng/L.

Table 1. List of point of use devices and the ones included in this study highlighted.

	Brand	**Model**	**Category**	**Media Type**	NSF 53
1	GE	GXK185KBL	Plumbed-in	Spun Fiber	NO
2	Whirpool	WHKF-DUF	Plumbed-in	Carbon Block	NO
3	Samsung	HAF-CIN	Refrigerator	Carbon Block	NO
4	GE	RPWFE	Refrigerator	Carbon Block	YES
5	PUR	RF9999	Faucet	Carbon Block	NO
6	Brita	SAFF-100	Faucet	Carbon Block	NO
7	Zero Water	ZD018	Standalone	GAC	YES
8	HDX		Standalone		NO
9	Ispring		Plumbed-in	GAC	NO
10	PUR	DS1800ZV5	Standalone	GAC	NO
11	AO Smith	AOMFB	Plumbed-in	GAC	YES
12	LG		Refrigerator	Carbon Block	NO
13	Clear Choice	CLCH105 DA29-00020B	Refrigerator	Carbon Block	NO
14	WaterDrop	WD-FC-01	Faucet	Carbon Block	NO
15	Culligan	FM-15RA	Faucet	Carbon Block	NO
16	Brita	OB03	Standalone	GAC	NO
17	Clear2o	GRP200	Standalone	Carbon Block	NO
18	3M Aqua-Pure	AP-DWS1000LF	Plumbed-in	Carbon Block	NO
19	DrinkPod		Standalone	Carbon Block	NO
20	WaterDrop	WD-CTF-01	Plumbed-in	Carbon Block	No
21	Brondell	UC100	Plumbed-in	Carbon Block	YES
22	CuZn	UC-200	Plumbed-in	GAC	NO
23	Home Master	TMJRF2E	Plumbed-in	GAC	NO
24	HDX	FMS-2	Refrigerator	Carbon Block	NO
25	Brita	WFRF104	Refrigerator	GAC	NO
26	Ispring	DF2	Faucet	GAC	NO
27	DuPont	WFFM350CH	Faucet	Carbon Block	NO
28	Vitapur		Standalone	Carbon Block	NO
29	LifeStraw		Standalone	GAC	NO
30	Naki		Standalone	GAC	NO
31	IVO	B08KSH2QQ3	Faucet	GAC	NO
32	Wingsol	6.54070892364E+11	Faucet	Spun Fiber	NO
33	Apec Water Syste	CS-2500	Plumbed-in	GAC	NO
34	Kohler	77686-NA	Plumbed-in	GAC	YES
35	EveryDrop	W10295370A	Refrigerator	Carbon Block	NO
36	AquaFresh	WF3CB	Refrigerator	Carbon Block	NO
37	Epic Water		Standalone	Carbon Block	NO
38	PUR	CR1100CV	Standalone	Carbon Block	NO
39	Brita	36261	Standalone	Carbon Block	NO
40	Apec Water Syste	WD-CTF-01	Plumbed-in	Carbon Block	NO

Analysis Protocol

Raw water samples as well as treated samples collected after each device was in service for a period resulting in 100% of the manufacturer's recommended throughput volume, and a second treated sample at twice that throughput volume (i.e., 200%). Each of these samples were sent to a commercial lab for PFAS analysis. These volume capacities were analyzed to understand the performance of the filter at the recommended throughput volume and at twice that volume in recognition that some consumers may not perform required maintenance according to manufacturers' recommendations. Samples were analyzed by a commercial MassDEP-certified lab, PACE (formerly Con-test) Analytical Laboratory in East Longmeadow, MA by EPA method 537.1 for 18 individual PFAS compounds, including the PFAS6 compounds.

PROJECT FINDINGS

In the spring of 2022, the mobile water innovation laboratory (the "trailer", designed and built by UMass) was deployed to Townsend, MA where it was placed adjacent to the Harbor Trace well house for access to this PFAS-contaminated groundwater supply. The initial study design was to evaluate 10 separate POU devices with this well water. When the other PWS volunteers dropped out of the project, the decision was made to keep the trailer in Townsend and evaluate the performance of 20 different POU devices using Townsend raw water. Samples of raw water (device influent) and treated water (device effluent) were collected for subsequent PFAS laboratory analyses. Water samples were collected at various percentages of the manufacturers' recommended capacity for the device.

Results

In total, 17 point of use (POU) devices were examined; these included four faucet-mounted filters, five plumbed-in filters (including under-sink and countertop filters), three refrigerator filters and five stand-alone filters. The filters were operated in a mobile laboratory with influent water coming from Harbor Trace well in Townsend, MA.

Triplicate water samples were collected after treatment of specified volumes of water. Volumes were based on selected fractions or percentages of the manufacturers' stated volume capacity for each device. The flow rate was set to mimic a household flowrate and was kept between 0.05-1.6 gallons per minute (gpm). The effluent concentrations of PFAS6 (in ng/L) for each filter are illustrated in Figure 1, which also indicates the MassDEP PFAS public drinking water standard, or the Massachusetts MCL of 20 ng/L.

The six PFAS comprising the PFAS6 MCL are: perfluorooctane sulfonic acid (PFOS); perfluorooctanoic acid (PFOA); perfluorohexane sulfonic acid (PFHxS); perfluorononanoic acid (PFNA); perfluoroheptanoic acid (PFHpA); and perfluorodecanoic acid (PFDA).

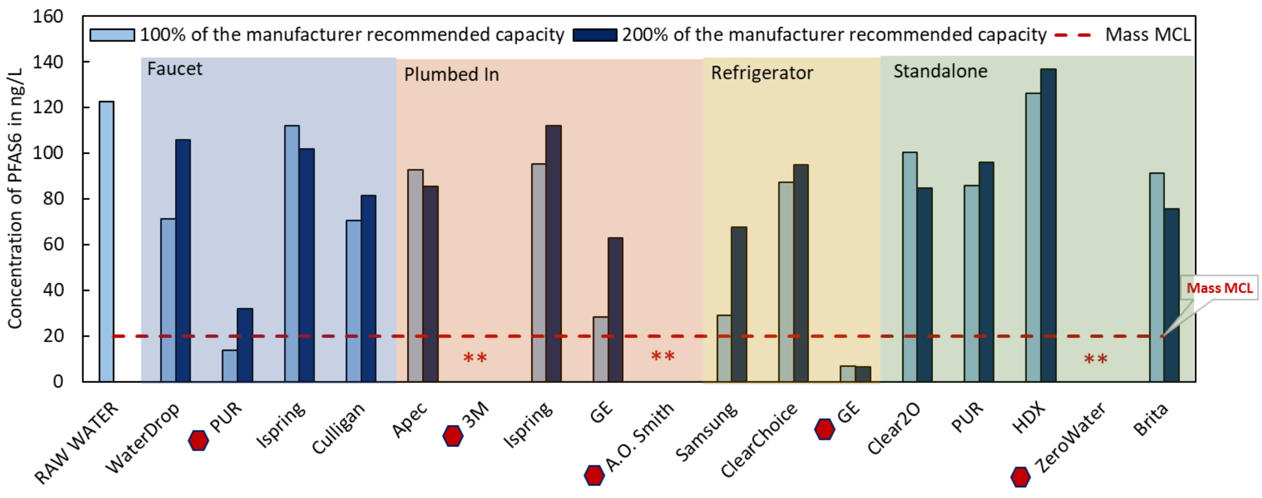

Figure 1. *PFAS6 concentrations in effluent of tested filters at 100% (light blue) and 200% (dark blue) volume capacity based on manufacturer recommendations. Devices are divided by category. Asterisk (*) denotes no PFAS6 was detected in the sample. Devices marked with ⬣ had less than 20 ng/L PFAS6 detected in the effluent sample at 100% volume capacity based on manufacturer recommendations for the water tested in this study.*

Five of the 17 filters showed an effluent PFAS6 concentration below the Massachusetts MCL of 20 ng/L at 100% of the manufacturer recommended volume capacity. The effluent concentrations of samples collected from the PUR faucet and GE refrigerator were 13.8 and 6.8 ng/L, respectively. There was no concentration detected (ND) for the samples run at 100% and 200% of the volume capacity for the 3M plumbed-in, A.O. Smith plumbed-in, and ZeroWater standalone filters.

The detection limits for EPA method 537.1 are different for each analyte and range from 0.71 to 2.8 ng/L. All other devices had concentrations of PFAS6 above the Massachusetts MCL. At 200% of the manufacturer recommended volume capacity, the GE refrigerator, 3M plumbed-in, A. O. Smith plumbed-in and ZeroWater standalone had effluent concentrations below the MCL and comparable to levels at 100% of their volume capacities with concentrations at 6.4 ng/L, ND, ND, and ND, respectively. However, the effluent concentration of the PUR faucet increased above the MCL to 32 ng/L. In this case, the device effluent reached levels above 20 ng between the 100% and 200% of the PUR faucet volume capacity. The study demonstrated that most of the filters – 12 of the 17 readily available for consumers – are not able to produce water with PFAS6 below the Massachusetts MCL of 20 ng/L at 100% the recommended volume throughput capacity for the Harbor Trace well water chemistry. It is important to note that none of these devices has an NSF 53 approval and therefore is not been certified to remove PFAS.

Two of the devices that maintained an effluent concentration below 20 ng/L limit were dual stage filters (3M plumbed-in and A.O. Smith plumbed-in). The 3M plumbed-in device contains a multi-composite media filter followed by a solid pressed powdered activated carbon block. The A.O. Smith dual stage filtration includes two Claryum® carbon block filters. Three of the five filters that maintained an effluent concentration below the Massachusetts MCL for the 100% recommended throughput are certified by NSF under NSF certification 53 for the removal of PFOA/PFOS. POU devices that comply with NSF 53 are able to maintain PFOS and PFOA levels below the prior EPA health advisory level of 70 ng/L (for the sum of PFOS and PFOA) under standard NSF water quality conditions. These filters include A.O Smith plumbed-in, G.E. refrigerator, and Zero Water standalone filter. The 3M plumbed-in filter was the only non-NSF certified filter to maintain a non-detect PFAS6 concentration at 200% of the recommended throughput.

Figure 2 illustrates the gallons of water filtered through each device at 100% of the manufacturer recommended throughput, or the amount of water the manufacturer states the device can filter before the filter needs replacement. These values range from 20 gallons for the ZeroWater standalone to 1000 gallons for the Apec plumbed-in device. Of the devices that maintained PFAS6 levels below the Massachusetts MCL for the tested water source, the 3M plumbed-in had the largest throughput at 650 gallons followed by the A.O. Smith plumbed-in (500 gallons), the GE refrigerator (170 gal), the PUR faucet (100 gal) and the ZeroWater standalone (20 gallons). In general, standalone devices have the lowest recommended throughput capacity ranging from 20 – 60 gallons. Figure 3 illustrates the concentration of PFAS6 against the gallons passed through the filter at 100% and 200% of the manufacturer rated capacity. This information helps the consumer visualize device performance with water consumption. Figure 4 shows images of each of the five devices that maintained an effluent concentration below the Massachusetts MCL at the recommended throughput. Devices outlined in green maintained non-detect PFAS6 effluent concentrations for both the 100% and 200% throughput samples.

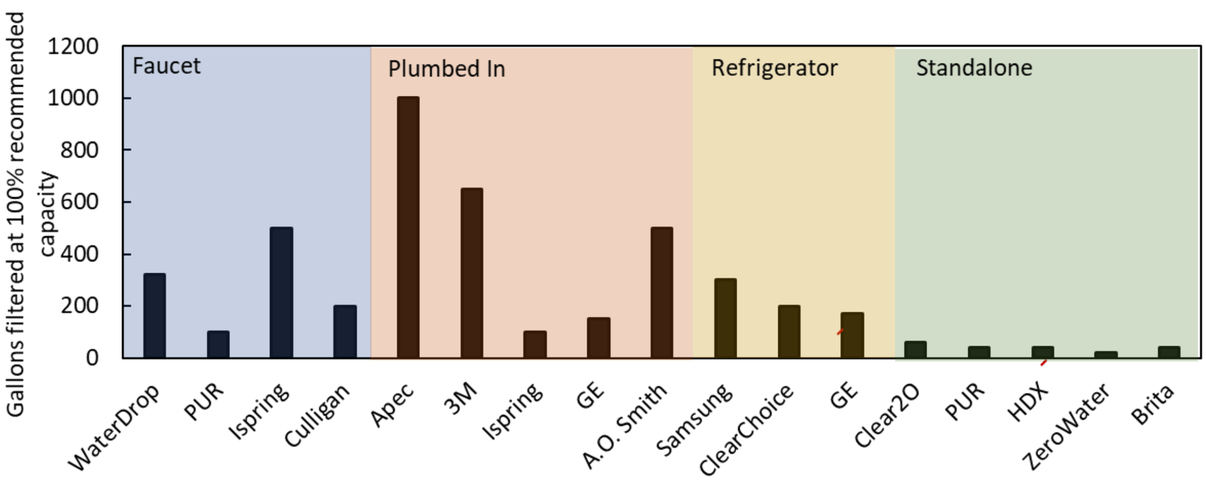

Figure 2. *Manufacturer recommended volume capacity (gallons).*

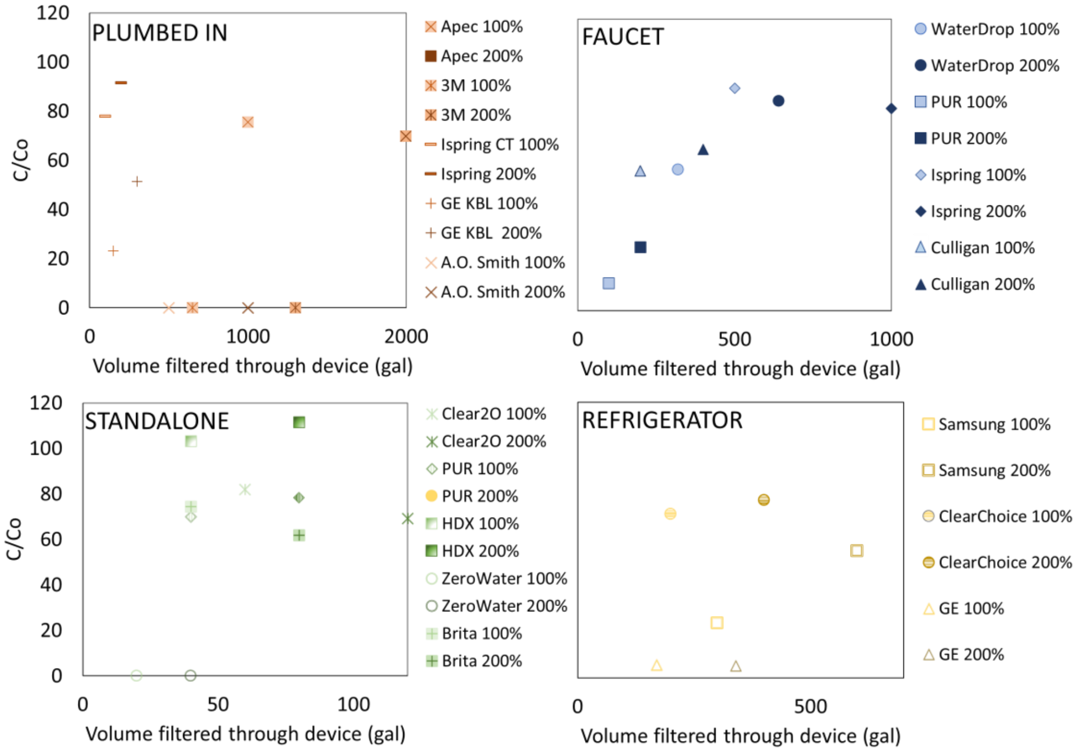

Figure 3. *PFAS6 effluent concentrations as percent of influent concentration versus volume of water filtered at 100% and 200% recommended throughput volume for each device.*

Figure 4. *Devices that maintained effluent concentration below the MassDEP MCL at 100% throughput.*

Cost Considerations

For comparison purposes, an equivalent uniform annual cost was computed for each POU device. This cost incorporated the annualized value of purchasing the device housing and the recurring cost of replacing the filter cartridge following the manufacturer's time-based recommendations (*e.g.*, every three months). On average, the cartridge replacement costs comprise 65% of the overall equivalent uniform annual cost. Changing the cartridges more frequently than recommended (due to increased consumption) will increase the costs.

Figure 5 presents these costs by category of device. The costs range from \$46 – \$176 per year. The least expensive device that met the Massachusetts PFAS6 MCL costs \$62 per year. Within this set of devices, there was not a strong association between cost and either category of device or ability to remove PFOA/PFOS to the MMCL of 20 ng/L. Higher cost did not correlate with removal for the set of devices analyzed.

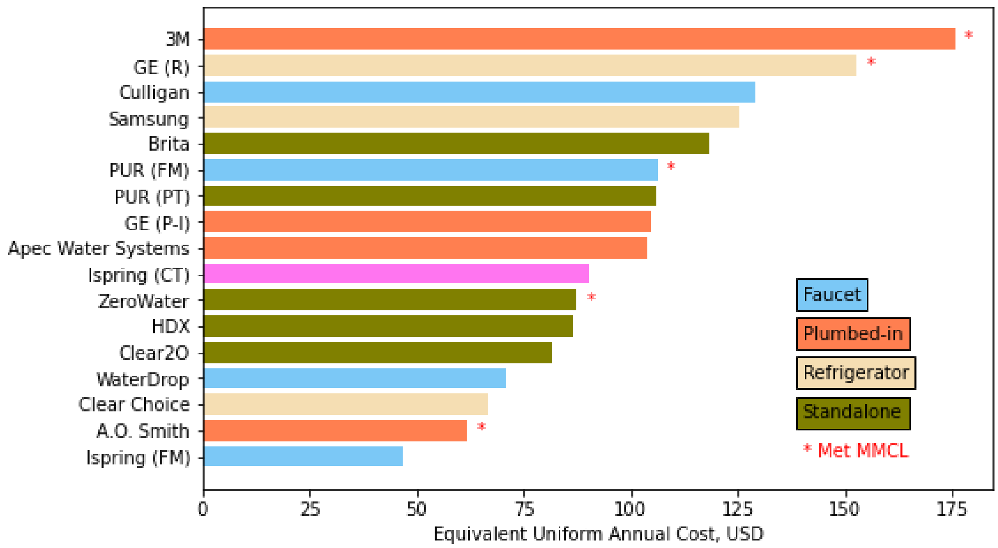

Figure 5 *Illustrates the annualized cost of the POU devices in this study when filter cartridge changes occur at manufacturer-recommended intervals. Bar colors indicate the device category; asterisks denote devices that meet the MMCL at the 100% recommended throughput.*

OTHER CONSIDERATIONS:

The original project design was to develop and build a mobile laboratory that would process samples from up to 10 POU devices at a time, deploy that mobile laboratory at 4 different MA communities with drinking water exceeding the Massachusetts PFAS6 standard of 20 ng/L for the sum of six PFAS, gather multiple samples from each device as the PFAS contaminated drinking water flowed through the devices, use newly installed "in-house" analytical equipment at UMass Amherst to analyze the samples based on EPA method 537.1, and then publish the results for consumers.

However, the project ran into three problems which delayed progress. First, the budget estimate developed in 2019 for designing and building this unique mobile testing laboratory did not anticipate the added time, expense, and difficulty of doing this work in COVID times. Second, the analytical equipment installed at UMass in 2020 that UMass intended to use for analysis of samples for this project encountered a series of problems that rendered it unusable for low-level PFAS analysis. Third, as the project timeline stretched into 2021 and as Massachusetts Public Water Systems (PWS) began constructing PFAS treatment, only one

PWS remained available to host the trailer. These considerations resulted in a more scaled down study than originally anticipated.

CONCLUSIONS AND RECOMMENDATIONS

Seventeen point of use (POU) devices were examined. Five of them showed an effluent PFAS6 concentration below the Massachusetts MCL of 20 ng/L at 100% of the manufacturer recommended volume capacity and of these five, three showed no detection (ND). Out of the 12 devices that exhibited PFAS6 concentrations in their effluents, none possesses NSF 53 approval, which indicates that they have not been certified to be able to remove PFAS to 70 ng/L.

The on-site mobile laboratory approach demonstrated the proof-of-concept at one source of contaminated drinking water to simultaneously evaluate multiple POU devices. Once the mobile laboratory was outfitted with its POU devices and controls, it was used to collect treated water samples from 17 POU devices with; laboratory analyses completed for selected samples.

Considering the recent update to the EPA lifetime health advisory levels for PFAS compounds, including a health advisory level for PFOS of 0.004 ng/L and PFOA 0.02 ng/L as well as EPA's proposed National Primary Drinking Water Regulation to establish legally enforceable levels of 4 ng/L for PFOA and PFOS, and to regulate the combination of four additional PFAS – GenX, PFBS, PFHxS and PFNA, it is recommended that future testing prioritize POU devices that maintain a non-detectable PFAS6 concentration in the effluent water at 100% of the manufacturers recommended throughput. Also, given the expected importance of water chemistry and PFAS profile on performance, the devices should also be tested against at least three other types of PFAS-contaminated water. A full breakthrough analysis would be conducted on these devices at a total of four distinct water chemistries.

While MassDEP recommends that consumers use treatment devices certified to meet the NSF standards for the removal PFOS and PFOA, consumers should recognize that the NSF standard is set at EPA's former health advisory of 70 ng/L for the sum of PFOS and PFOA and is not as protective as MassDEP's drinking water standard of 20 ng/L for the sum of six PFAS (PFAS6) or EPA's proposed drinking water standards. Some of the treatment devices certified to meet NSF standards may be able to reduce PFAS6 levels to well below 70 ng/L, however there are no federal or state testing requirements for these treatment devices. Consumers who choose to install a treatment device should check to see if the manufacturer has independently verifiable PFAS6 monitoring results demonstrating that the device can reduce PFAS below the Massachusetts PFAS6 MCL of 20 ng/L. In addition, to verify that the device achieves PFAS6 levels less than 20 ng/L, consumers may need to resample their water after the treatment device has been installed. For more information see MassDEP's PFAS POU information here: https://www.mass.gov/info-details/pfas-in-private-well-drinking-water-supplies-faq.

Given the changing scientific, health and regulatory climate for PFAS, MassDEP will share the information from this project and links from similar relevant studies as information sources for interested parties. MassDEP will continue to work with UMass to identify opportunities to utilize the mobile laboratory for further PFAS and other emerging contaminants analysis and evaluation, including a plan to potentially include use of the mobile laboratory for testing of emerging contaminants and treatment technologies for Small or Disadvantaged Communities.

For information on this project please contact:

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