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Publication Date

2024-11-01

DOI

10.1016/j.scitotenv.2024.176067

Peer reviewed

Per- and polyfluoroalkyl substances (PFAS) in Drinking Water in Southeast Los Angeles: Industrial Legacy and Environmental Justice

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are persistent chemicals of increasing concern to human health. PFAS contamination in water systems has been linked to a variety of sources including hydrocarbon fire suppression activities, industrial and military land uses, agricultural applications of biosolids, and consumer products. To assess PFAS in California tap water, we collected 60 water samples from inside homes in four different geographic regions, both urban and rural. We selected mostly small water systems with known history of industrial chemical or pesticide contamination and that served socioeconomically disadvantaged communities. Thirty percent of the tap water samples (18) had a detection of at least one of the 32 targeted PFAS and most detections (89 percent) occurred in heavily industrialized Southeast Los Angeles (SELA). The residents of SELA are predominately Latino and low-income. Concentrations of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) ranged from 6.8-13.6 ng/L and 9.4-17.8 ng/L, respectively in SELA and were higher than State (PFOA: 0.007 ng/L; PFOS: 1.0 ng/L) and national health-based goals (zero). To look for geographic patterns, we mapped potential sources of PFAS contamination, such as chrome plating facilities, airports, landfills, and refineries, located near the SELA water systems; consistent with the multiple potential sources in the area, no clear spatial associations were observed. The results indicate the importance of systematic testing of PFAS in tap water, continued development of PFAS regulatory standards and advisories for a greater number of compounds, improved drinking-water treatments to mitigate potential health threats to communities, especially in socioeconomically disadvantaged and industrialized areas.

Key Words: PFAS, drinking water, California, environmental justice

1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are a class of over 12,000 synthetic chemicals that are highly persistent and mobile in the environment [1, 2] and represent one of the most pervasive classes of global contaminants. These chemicals have been used for decades and are found in a plethora of products including firefighting foams, grease-proof coatings, water-repellents, fume suppressants, personal care products, and building materials. PFAS compounds are linked to a wide range of adverse human health impacts, including lower birth weights, interference with hormones, liver and kidney toxicity, reduced immune response, reproductive harm, and increased cholesterol levels [3]. One common PFAS, perfluorooctanoic acid (PFOA), has been classified as a human carcinogen (Group 1) by the International Agency for Research on Cancer, based on carcinogenesis in animals and some human evidence for testicular cancer [4]. Another abundant compound, perfluorooctanesulfonic acid (PFOS), was recently classified as a possible human carcinogen (Group 2B). PFAS have also been linked to increased risk of kidney and pancreatic cancers [4]. The possible link between PFAS compounds and breast cancer is less well characterized, but they may influence this cancer risk though endocrine disruption pathways [5-9] . Elevated rates of breast cancer in urban areas and increasing rates of breast cancer associated with industrialization have suggested the potential etiologic importance of environmental contaminants [10-14]. However, the findings from epidemiological studies on PFAS and breast cancer risk have been inconsistent [5, 9]. The PFAS analysis described in this paper was conducted as part of a larger investigation into chemical contaminants in California tap water that could play in role in the development of breast cancer.

The same properties, that make PFAS useful for consumer and industrial applications (e.g., oil and water repellency, temperature and acid resistance, friction reduction), make them persistent and mobile in the environment. PFAS may enter both surface and groundwater through a variety of environmental pathways including direct industrial discharges, water recycling, wastewater, stormwater, soil contamination and air deposition[15]. The full extent of PFAS contamination in US drinking water is not well characterized, but an estimated 45% of US drinking water supplies contain at least one PFAS [16]. A recent analysis estimated that over 200 million Americans receive drinking water with combined PFOS and PFOA concentrations of at least 1 nanogram per liter (ng/L) [17].

Californians are served by 2,900 different community water systems [18] and as of 2023, only about 9% of these systems had been tested for PFAS by the State Division of Drinking Water [19]. This testing has focused on large public systems that serve a majority (64%) of the State's population. However, many smaller water systems have not been tested for PFAS. In addition, while PFAS contamination in California appears to be widespread, it is more common in communities that are already burdened by high environmental pollution [19]. There is very limited information on PFAS in point-of-use tap water in the United States, with most studies focusing testing efforts on source water and community water before distribution to homes [16]. We undertook this investigation to evaluate PFAS in California drinking water collected at point-of-use in socioeconomically disadvantaged neighborhoods primarily served by small municipal water systems in areas with known history of water contamination issues. In addition, we included tap water from homes served by private wells, which are not subject to State testing. We included geographically diverse regions of the State to include samples from rural, urban, suburban, and agricultural areas because these places could have different potential sources or occurrences of PFAS.

2. Materials and Methods

2.1 Selection of Geographic Areas for Water Sampling

We collected tap water samples from 60 private residences in California based on three criteria: areas with history of drinking water-contamination concerns, low household income, and elevated regional breast cancer incidence rates.

To select systems with a history of industrial chemical and pesticide contamination, we used CalEnviroScreen version 3.0 [20] to identify water systems. CalEnviroScreen is a publicly available resource developed by the California Office of Environmental Health Hazard Assessment. All census tracts in California were scored and ranked using a combination of data sources on health outcomes, socioeconomic factors, and environmental contamination, including drinking water. The CalEnviroScreen drinking water scores were based on average contaminant concentrations in public water systems. We selected systems with any maximum contaminant level (MCL) violation; any detection of hexavalent chromium, cadmium, 1,2-dibromo-3-chloropropane (DBCP), perchlorate, perchloroethylene (PCE), trichloroethylene (TCE), 1,2,3-trichloropropane (TCP), or any value for nitrate, arsenic, uranium or radium above ½ the MCL during 2005-2013. We also included water systems that detected any PFAS from US EPA's Third Unregulated Contaminant Monitoring Rule (UCMR 3) (2013-2015) or the California State Water Resources Control Board Division of Drinking Water testing (2019) [21]. Non-community water systems, non-transient non-community water systems (e.g., businesses and schools) and water systems with only total coliform or total trihalomethanes MCL violations were not included.

The second inclusion criterion focused on census tracts where the age-adjusted incidence of invasive breast cancer was 10-20% higher than the rest of California during 2000-2008 based on a previous mapping project using California Cancer Registry data [22, 23]. Lastly, to address poverty and environmental justice considerations, we identified socioeconomically disadvantaged census tracts that had greater than or equal to 20% of the population with household incomes less than $25,000 (2017 American Community Survey 5-Year Estimates). Environmental justice is the concept that all people, regardless of income, race, or national origin, should have equal protection from environmental hazards and have meaningful engagement in decisions that impact the environments where they live, work, and play [24]. The California Environmental Protection Agency (Cal EPA) has an Environmental Justice Program that works to implement environmental justice principles in all areas of their work [25]. The CalEnviroScreen tool that we used to identify areas with drinking water contamination was developed by Cal EPA to identify communities that are disproportionately burdened by multiple pollution sources and socioeconomically disadvantaged.

Areas where census tracts with elevated breast cancer rates and/or low-income neighborhoods intersected with potentially contaminated public water systems or township boundaries (for private wells in rural areas where there were no public water systems) were prioritized for potential sampling. We then selected public water systems in areas meeting the above criteria across three geographic regions of California: the Central Valley (Fresno, Madera, Merced and Kern Counties), the San Francisco Bay Area (Alameda, Santa Clara and San Mateo Counties), and Southeast Los Angeles (SELA). We also selected a combination of water systems and private wells in Gold Country (Nevada County) that also met the selection criteria.

SELA is an unusual urban area because it has multiple small groundwater-supplied public water systems, most serving only a few thousand people. This area was developed from the 1920s through the 1960s as a mixed residential-industrial zone of independent small cities and unincorporated areas built to house workers for nearby automobile and tire factories, steel plants, and during the later 1960s for aerospace facilities [26] . In the late 1970s, most of the larger factories closed, but small-scale industry, such as chrome plating, continued in the area [27]. Currently, over 90% of the approximately 400,000 residents of SELA are Latino, nearly half are first generation immigrants, and the median household income is significantly below the rest of Los Angeles County [28]. The Central Valley is an agricultural region with intensive pesticide use, many oil and gas extraction sites, heavy reliance on groundwater and many areas with high socioeconomic disadvantage. Gold Country is groundwater-dependent and has potential water contamination from historical gold mining and recent wildfires. The San Francisco Bay Area sample collection was focused mostly in the southern part of the region, which has shallow ground water sources and a history of contamination from industrial use. None of these locations or communities were selected specifically to assess PFAS exposure, but they were part of a larger study designed to understand exposures to contaminant mixtures, including PFAS, in tap water.

2.2 Participant Recruitment and Community Engagement

The project team included local community-based organizations in each of the study areas, enabling the team to conduct recruitment and sampling during the early phase of the pandemic in 2020-2021. Our partners included Clean Water Fund in the Central Valley, Communities for a Better Environment in Los Angeles, and Sierra Streams Institute in Gold Country. Partner community groups used the maps generated according to the criteria described above to identify and recruit 1-2 households within each eligible water system or geographic area of interest in their region. Because the focus was on drinking water systems, the selection of households was not randomized. After the completion of laboratory testing, individual results were provided to study participants in packets with explanatory information, and community-level results were presented at multiple community meetings.

2.3 Water Sample Collection and Analyses

Tap water samples were collected in phases by region from October 2020 through July 2021. Apart from the 5 private wells in Gold Country, for the remaining 55 samples we collected water samples from 1 - 2 households within each water system. Ten homes relied on drinking water sourced from surface waters, 18 relied on groundwater, while 27 locations relied on mixed sources. One set of tap water samples was collected at each participating home, with sampling times varying throughout the day and without precleaning, screen removal or flushing of the tap. Tap water samples for PFAS were collected in three 2-mL polypropylene centrifuge tubes that were rinsed three times with tap water prior to sample collection. Sample tubes were filled half full with tap water, placed in a whirl pack bag and shipped on ice to the U.S. Geological Survey National Water Quality Laboratory, Denver, Colorado, where they were stored frozen prior to analysis [29, 30]. Due to COVID-19 restrictions, study staff stayed outside the participant home and coached the study participants to self-collect the sample.

Concentrations of 32 PFAS compounds, including 11 perfluoroalkane carboxylates (PFCAs), nine perfluoroalkanesulfonates (PFSAs), four PFOS/PFOA replacements, and 10 PFSA/PFCA precursors, were analyzed based on previously published methods [30] and are listed in **Supplemental Table 1**. Briefly, tap water samples were analyzed by direct aqueous injection-liquid chromatography/tandem mass spectrometry (DAI-LC/MS/MS) with isotope-dilution quantification. Method detection limits for the targeted PFAS ranged from 0.1 to 50.4 ng/L. Quantitative ($\geq$ limit of quantitation, $\geq$ LOQ) and semi-quantitative (<LOQ) results were treated as detections [31-33]. Any concentration reported in Supplemental Table 3 below the LOQ was coded as estimated (“E”). Quality-assurance/quality-control included analyses of 10 field blanks and stable isotope surrogates (N=20 compounds; Supplemental Table 2). Similar to another citizen science efforts designed to assess PFAS broadly across the US (Smalling et al., 2023), no PFAS were detected in blank samples and the median surrogate recovery across all samples was 102% (interquartile range 92-111%; Supplemental Table 2) [34].

2.4 State Well Water Testing Data and Geographic Information on Industrial Sites

We obtained public water system well water PFAS data from the State Water Resources Control Board (SWRCB) [21]. Potential sources of PFAS contamination located in or near the water systems were identified from the SWRCB’s Geotracker Database [35], including locations of chrome plating facilities, bulk fuel terminals, airports, landfills, refineries, and usages that could potentially affect groundwater. These were defined from CalEnviroScreen as any cleanup sites, land disposal sites, leaking underground storage tanks, and produced water ponds from oil and gas production. Locations of federal and state cleanup sites, including military sites, were identified from the EnviroStor Cleanup Sites

Database maintained by the California Department of Toxic Substances Control [36]. As a mapping and visualization exercise, we totaled the sites in and within one km of each water system boundary. We computed Spearman rank correlation coefficients to examine the relationship between the number of PFAS detections and the number of contamination hazards (chrome plating facilities, refineries, ground water threats, and clean-up site).

3. Results

We collected 22 tap water samples from SELA, 12 from Gold Country, six from the San Francisco Bay area, and 20 from the Central Valley (**Table 1**). Most tap water samples were collected from public water systems (55 out of 60 samples). There were five samples from private wells, all located in the Gold Country region. Overall, 30% (18 out of 60) of the collected tap water samples had a detection of at least one PFAS. Among the samples with detectable PFAS, 16 (89%) were from SELA; with 73% of the SELA samples having PFAS detections. The non-SELA PFAS detections were in one private well in Gold Country and one very small groundwater system in the Central Valley. A total of 14 water systems were sampled in SELA, and PFAS were detected in 12 (86%) of these systems.

Of the 32 PFAS measured (listed in Supplemental Table 1), seven were detected in at least one tap water sample (**Table 2**). Perfluorobutanoic acid (PFBA) was the most detected (n=12 samples), followed by PFOA (n=9), PFOS (n=9), perfluoroheptanoate (PFHpA , n=3), perfluorononanoate (PFNA, (n=2), perfluoro-1-hexanesulfonate (PFHxS, n=2), and perfluoro-n-pentanoate (PFPeA, n=2). PFOA and PFOS were detected in nine samples. Six of the samples with detections contained only one PFAS, one sample had two PFAS, five samples had three PFAS, three samples had four PFAS, and one sample had six PFAS detections.

The Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency recently adopted Public Health Goals (PHGs) for PFOS and PFOA in drinking water of 1.0 and 0.007 ng/L, respectively [37]; these concentrations were exceeded in every sample in which PFOS and PFOA were detected (**Table 2**). On April 10, 2024, US EPA released National Primary Drinking Water regulations for five PFAS including PFOA, PFOS, PFNA, PFHxS and GenX chemicals [38, 39]. EPA also established a Hazard Index Level (HI=1) for two or more of four PFAS (PFNA, PFBS, PFHxS and GenX) as a mixture. Enforceable maximum contaminant levels (MCLs) and non-enforceable maximum contaminant level goals (MCLGs) were set at 4 ng/L and zero for PFOA and PFOS, respectively while MCLs and MCLGs were set at 10 ng/L for PFNA, PFHxS and GenX chemicals [38, 39]. Crucially, all the detected concentrations of PFOA (9 samples; range 6.8-13.6 ng/L) and PFOS (9 samples; range 9.4-17.8 ng/L) exceeded their respective MCL. The Hazard Index was calculated for four tap water samples that had a detection of PFNA (N=2) or PFHxS (N=2). The Hazard Index values were all below the proposed limit of 1.0 (range 0.24 – 0.56 unitless). GenX chemicals and PFBS (perfluorobutane sulfonic acid) were not detected in our study. There are no EPA or State of California advisory levels established for PFHpA, and PFPeA.

The detected PFAS from the tap water samples are shown by water system in **Table 3**. The public water systems in the Los Angeles area vary in size from 5,500 people served to up to 3.9 million (Table 3). All but one of the SELA water systems sampled served less than 80,000 people. Seven of the 14 water systems in SELA that were included in our study also had publicly available well testing data from the California Division of Drinking Water (CDDW). PFBS was the most frequently reported PFAS by CDDW (in five out of seven water systems). In general, our results were concordant with the state water systems data. Our study found PFAS in all six of the systems with detected PFAS in the state database, although the specific PFAS that were detected sometimes differed (**Table 3**). One system with PFBA, PFHxS, PFOA, and PFOS detected in our study was reported as having no detections in the state database. Five systems with PFAS detected in our testing had no reported results in the state database. We did include one sample from the large public water system that serves 3.9 million people with a combination of groundwater and surface water. That system had PFAS detections both in our study and in the state database. The list of water systems included in this study, along with sampling dates and the PFAS testing results are shown in **Supplemental Table 3.**

According to the CalEnviroScreen, SELA is among the most disadvantaged communities in the Greater Los Angeles area and the State of California, with among the greatest cumulative impacts from environmental, health and socioeconomic stressors (**Figure 1**)[20, 40]. The number of PFAS detected in SELA systems suggested somewhat greater contamination in the Northeastern part of the study area, with the two systems with non-detects for PFAS clustered at the Western edge of SELA (Figure 1).

Based on mapping the industrial hazard sites within the water system service areas (and within 1 km of the service area boundaries), counts ranged from 8 industrial hazard sites in the smallest water system to over 490 in the largest system. All 14 of the small water systems in SELA had multiple groundwater threats (Table 3). Eight of the 14 water systems had chrome plating facilities in the area and nine had bulk fuel terminals and refineries (**Figure 2**)[36]. No statistical correlations (Spearman Rank correlation; p-values >0.05) were observed between number of PFAS detections and the number of potential hazards, including chrome plating facilities, ground water threats, refineries, and clean-up sites. Detections of individual PFAS (PFBA, PFHpA, PFHsS, PFNA, PFOA, PFOS and PFPeA) were also not statistically correlated with the types of industries surrounding the sampling sites.

4. Discussion

Thirty percent of the tap water samples collected in our study had at least one PFAS detection, which is similar to the results from a recent nationwide survey of residential tap water from all 50 states [16]. The national assessment found at least one PFAS in 33% of tap water samples from 269 private wells and 447 public water supplies. The authors of that study modeled PFAS detections by urban and rural areas and estimated about 8% probability of PFAS detection in rural areas and greater than 70% probability of PFAS contamination in urban areas with known PFAS contamination sources [16]. This mirrors our study findings in which we found a 72% PFAS detection rate in SELA (16/22), the most urbanized area that we sampled. The PFAS detection rate was much lower in the less densely populated cities and suburban areas that we sampled in the Central Valley and Bay Area (9% detects out of 11 samples) and in the rural areas (4% detects out of 27 samples).

Our tap water samples were all collected from inside homes, after the water travelled through the distribution system and plumbing to the consumer's drinking water tap; it is unclear whether the site of the testing (e.g., point-of-use vs. testing at the well or water treatment plant) significantly affected PFAS detections. Currently, conventional water treatment typically used by community systems is not capable of removing PFAS [41]. Our study only detected 7 PFAS out of the 32 analyzed which could be due to regional differences in PFAS use, our small sample size, analytical detection limits higher than the newly finalized MCLs for some PFAS, or because individual PFAS degraded into common terminal products, either in the environment, during treatment or in the distribution system. For example, PFBA was the most common PFAS detected in our tap water samples, similar to other studies in industrialized areas [42, 43]. PFBA has been in industrial production as a substitute for longer chain, legacy PFAS (e.g., PFOS) but is also a breakdown product of several other PFAS used in stain-resistance fabrics, paper food packaging, and carpets [44-46]. PFBA is a shorter chain PFAS with a shorter half-life than the other PFAS that were also detected (PFOA, PFOS, PFNA, and PFHxS). The health advisory limits for PFBA and other shorter-chain PFAS are generally set at levels higher than the longer-chain PFAS [47]. PFOS, the second most frequently PFAS we detected in the SELA water samples, was commonly used in chromium plating, an industry found in this area [48].

Our study was limited by a relatively small sample size, especially in relation to the large number of water systems and private wells across California. Because our selection criteria were designed to attempt to identify water systems and regions with a higher likelihood of contamination, our findings may not be generalizable across other regions. Further, we only collected 1-2 samples in each water system, and only sampled at one time point, limiting our ability to assess spatiotemporal variability within systems. However, this study collected water at the point of consumption (at the home tap) rather than at a treatment plant, which is important for understanding the water people are consuming after the water passes through the distribution networks. The information generated at the treatment plant is important but is disconnected in time and space from the tap where drinking water consumption is taking place and does not capture chemical or biological transformations that may occur as drinking water moves through the distribution pipeline.

A recent study examined the associations between PFAS exposure and race, ethnicity, and poverty levels and identified environmental justice concerns about sources of PFAS water contamination disproportionally located in low-income and communities of color in the U.S. [49]. Another recent study conducted in California found that the supply wells for community water systems serving a large proportion of the Latinx population were located in areas with an increased likelihood of PFAS-contaminated pesticide applications [50]. Along with an extensive history of industrial development, SELA ranks in CalEnviroScreen's top 8% of California communities most impacted by multiple pollution threats and socioeconomic disadvantages [40]. As a predominantly Latino (95%) and first-generation immigrant community (43%), barriers such as citizenship and linguistic isolation could make this community more vulnerable to dealing with the burdens of pollution.

Potential sources of PFAS in SELA include the historic widespread use of PFAS as a fume suppressant in chromium plating operations, which are numerous in the study area; petroleum industry operations where PFAS may have been stored and used as a firefighting foam; and multiple clean-up sites and leaking underground storage tanks. Mapping these sites revealed a notable density of potential groundwater pollution sources across the entire area, but no specific associations were apparent with the affected water systems, which is attributed to the small sample size and limited variability in numbers of potential contaminant sources (i.e., no minimally impacted locations) and the dependence on surface water sources particularly in SELA. Other studies of PFAS and source of contamination have taken advantage of the large datasets and found associations between PFAS in drinking water and urban development, the presence of industrial sites, military fire training areas, and water treatment plants, as well as groundwater age [51-53].

Prior to the 1930's, SELA was an alluvial flood plain that received the waters of the Los Angeles River and San Gabriel River watersheds (a total of 1,540 square miles). A flood in the 1930's as the area was newly undergoing development triggered major projects to pave and channelize the rivers [26]. The Central Groundwater Basin underlies this area of Los Angeles, with multiple known contaminant plumes [54] and multiple water systems dependent partially or entirely on groundwater wells. In addition to the industrial sites, the Central Basin has been a recipient of groundwater recharge efforts to combat depletion of the aquifers due to loss of infiltration from the channelization of the rivers and paving of the flood plain. The use of groundwater recharge in the Central groundwater basin raises the additional possibility that PFAS contamination may be introduced into the groundwater through recharge of treated wastewater.

This PFAS analysis was part of a larger investigation into chemical contaminants in California tap water that could be related to the development of breast cancer. While we did not collect breast cancer incidence data or any cancer risk factor information, the tap water was sampled in areas with elevated breast cancer incidence rates in an effort to characterize potential environmental exposures in these communities. PFAS may affect breast cancer risk through endocrine disruption pathways [5-9]. Epidemiologic studies of PFAS and breast cancer incidence risks have been inconsistent. The studies to date provide insufficient evidence to draw firm conclusions due to the large degree of heterogeneity across studies in terms of the populations included and the study designs [5, 9]. In particular, many studies have been limited in the timing of exposure assessment by measuring PFAS levels after the time of diagnosis. There has been some suggestion that the risk relationships between PFAS exposures and breast cancer may vary by important windows of susceptibility because of observed risk differences for pre-, peri- and post-menopausal women [9]. There is also some suggested evidence that the risks vary by hormone receptor status. Future studies of the relationship between breast cancer risk and PFAS will need to use research strategies that incorporate information on the heterogeneity of compounds, heterogeneity of breast cancer subtypes, and mechanisms of action, while also focusing on specific windows of susceptibility. Given that the present study found at least one PFAS in thirty percent of the tap water samples collected from homes located in areas with high breast cancer incidence rates in California, PFAS exposures may be important to consider as potential risk factors for cancer in these communities.

Years of drought, climate change, and an expanding population have stressed the drinking water supplies in many arid regions of the world, including California. The State is increasingly relying on groundwater which has the potential for PFAS contamination from industrial pollution, especially in urban areas. The California Water Boards have created a PFAS Team that is working to advance testing methods, collect and publicize data on PFAS in drinking water, and provide technical and financial assistance to drinking water systems managers and operators to address PFAS in their water supply [21].

5. Conclusion

In tap water samples collected from four different geographic regions of California, the most PFAS detections occurred in the heavily industrialized Southeast Los Angeles area. Seven different PFAS out of the 32 PFAS measured were detected in at least one water sample. These results indicate the importance of systematic testing of PFAS in water, continued development of regulatory guidelines for PFAS. Improved drinking-water treatments will be needed to mitigate potential health threats to communities, especially in socioeconomically disadvantaged urban and industrialized areas, such as Southeast Los Angeles.

Author contributions: GS and PR were responsible for the funding acquisition. Data curation and analysis were performed by CC, JVB, KMR, KLS, PMB, DWK, JLG, and GS. JVB and GS were primarily responsible for drafting the manuscript. CC provided mapping and geographic information support. All study authors were responsible for results interpretation, provided scientific feedback, contributed to editing the manuscript draft, and reviewed the final manuscript text.

Declarations

Ethical Approval: The study was approved by the Institutional Review Board of the Public Health Institute, IRB #I19-001, January 6, 2019. The study participants provided written informed consent.

Funding: This project was supported by the California Breast Cancer Research Program Grant 25UB-1202. Funding was also provided by the U.S. Geological Survey Ecosystems Mission Area, Environmental Health Program.

Conflicts of Interest: The authors declare no conflict of interest.

Data availability: Data is provided in Supplemental Table 3 and available in Romanok et al,2021 [34].

Acknowledgments: The authors would like to thank Ariadne Villegas, Roberto Bustillo, Taylor Schobel, Jesus Alonzo, and Annika Alexander-Ozinskas for assistance with tap water sample collection, and Michelle Wong for assistance with results return. This research was conducted under the USGS Ecosystems Mission Area Environmental Health Program. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

Abbreviations

GenX: hexafluoropropylene oxide dimer acid or 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy)propanoate

MCL: Maximum Contaminant Level

PFAS: per- and polyfluoroalkyl substances

PFBA: perfluorobutanoic acid or perfluorobutyrate

PFBS: perfluoro-1-butanesulfonate

PFHpA: perfluoroheptanoate

PFHxS: perfluoro-1-hexanesulfonate

PFNA: perfluorononanoate

PFOA: perfluorooctanoic acid or perfluorooctanoate

PFOS: perfluorooctanesulfonic acid or perfluorooctanesulfonate

PFPeA: perfluoro-n-pentanoate

SELA: Southeast Los Angeles

US EPA: United States Environmental Protection Agency

Table 1. Number of tap water samples with per- and polyfluoroalkyl substances (PFAS) detected by sampling region of California, 2020-2021. All data is available in Romanok et al. [34]

Sampling region of California	Number of tap water samples	# samples with any detection of (PFAS)
Central Valley (Fresno, Madera, Merced and Kern Counties)	20	1 (5%)
Gold Country (Nevada County)	12	1 (8%)
San Francisco Bay Area (Alameda, Santa Clara and San Mateo Counties)	6	0
Southeast Los Angeles (city)	22	16 (73%)
Total	**60**	**18 (30%)**

Table 2. Summary of individual PFAS detected and concentration ranges from tap water in Los Angeles, California compared to California Health goals and newly established National Primary Drinking Water Regulations, 2020-2021. All data is available in Romanok et al. [34]

PFAS compounds	# Samples with detections	Range (ng/L)	Number of samples exceeding CA Notification Level	CA Public Health Goal[b]	US EPA Maximum Contaminant Level MCL*	US EPA Maximum Contaminant Level Goal MCLG*
PFOA	9	6.8-13.6	9	0.007 ng/L	4.0 ng/L	zero
PFOS	9	9.4-17.8	9	1.0 ng/L	4.0 ng/L	zero
PFNA	2	2.2-2.4	NA	NA	10 ng/L	10 ng/L
PFHxS	2	5.0-5.2	2	NA	10 ng/L	10 ng/L
PFBA	12	3.4-24.0	NA	NA	NA	NA
PFHpA	3	3.1-4.5	NA	NA	NA	NA
PFPeA	2	3.7-10.0	NA	NA	NA	NA

[a] Division of Drinking Water, California State Water Resources Control Board

[b] Office of Environmental Health Hazard Assessment, California Environmental Protection Agency

*U.S. Environmental Protection Agency (EPA) unitless Hazard Index based on the Health Based Water Concentrations (HBWCs) of four PFAS: GenX chemicals, PFBS, PFNA, and PFHxS [38, 39].

Table 3. PFAS Detections and industrial hazards by water system in Los Angeles, California.

Population served	Number of tap water samples	Detected PFAS in tap water samples	Detected PFAS by State Water Board in well samples	Industrial hazards within the water system service areas *			
				chrome plating facilities	groundwater threats**	clean up sites	bulk fuel terminals and refineries
5,500	2	PFBA	no testing	1	8	7	1
6,349	1	PFBA, PFOS	PFOS	2	14	25	1
7,500	2	PFBA, PFHxS, PFOA, PFOS	none	0	12	12	0
9,500	1	PFOS	no testing	2	14	25	1
11,292	2	PFBA, PFHpA, PFNA, PFOA, PFOS, PFPeA	PFBS, PFHA, PFHpA, PFHxSA, PFNA, PFNDCA, PFOA, PFOS	0	11	9	0
14,000	2	PFBA, PFOA, PFOS	no testing	0	11	13	1
15,414	2	PFBA	no testing	7	20	33	1
16,180	2	none	no testing	0	12	10	0
24,171	1	PFBA, PFHpA, PFHxS, PFOA, PFOS	PFBS, PFHA, PFHpA, PFHxSA, PFOA, PFOS	0	15	0	1
54,548	2	PFBA, PFOA, PFOS	PFBS, PFHA, PFHpA, PFHxSA, PFOA, PFOS	2	21	16	3
62,941	1	none	no testing	6	25	38	0
66,967	1	PFBA	no testing	8	27	20	1
76,443	2	PFBA,PFHpA, PFNA,PFOA,PFOS	PFBS, PFHA, PFHpA, PFHxSA, PFNA, PFOA, PFOS	4	30	36	2
3,953,941	1	PFBA	PFBS, PFHxSA	70	>490	>160	22

*Includes industrial hazard sites located within 1 km of the water system boundaries.
**Groundwater threats used the categories in CalEnviroScreen 3.0, which included any cleanup sites, land disposal sites, leaking underground storage tanks, and produced water ponds from oil and gas production.

Figure 1. Map of the tap water sampling area with CalEnviroScreen (CES) Pollution Burden Score and number of PFAS detections in small water systems in Southeast Los Angeles, California [40].

Figure 2. Map of the tap water sampling area with possible sources of PFAS contamination in small water systems in Southeast Los Angeles, California [36].

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