# Poly- and Perfluoroalkyl Substances (PFAS) – Emerging Pollutants in New England
# A White Paper

## 1. What are PFAS and how are they used?

Poly- and perfluoroalkyl substances (PFAS) are a group of manmade chemicals in production since the 1940s. They impart temperature resistance, friction reduction, and oil and water repellency to a wide variety of consumer products and industrial processes. These include uses in textiles, some firefighting foams, clothing, and food packaging (1).

Over 4,000 PFAS compounds have been manufactured. Chemically, PFAS contain a fully or partially fluorinated carbon chain. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are the most widely studied of these compounds, and, due to potential health risks, have been voluntarily phased out of production in the U.S., although they remain present in the environment. PFOA and PFOS are also commonly referred to as "C8" because they each contain a backbone chain of 8 carbon atoms (2).

The goal in identifying hazardous compounds is to replace them with safer alternatives. However, concerns regarding health effects also surround replacement PFAS, developed as a result of the phase-outs of PFOA and PFOS. "GenX," for example, is a trade name for a single compound developed as a replacement for PFOA. "GenX" is also a broader term commonly used to refer to the mixture of by-products associated with the production of the GenX chemical (3). As a result of their ubiquity in the environment and due to this history of chemical replacements following phase-outs, PFAS have been dubbed a "chemical whack-a-mole" (i.e. when one potentially toxic PFAS chemical is eliminated from the commercial stream, another PFAS with unknown toxicity is created to take its place)(4).

## 2. How are people exposed to PFAS?

Adding to the complexity, numerous avenues of exposure to PFAS have been identified. For most of the US population, exposure to PFAS can occur through the ingestion route, including contaminated municipal or private well drinking water; food packaging containing PFAS, including (but not limited to) grease-resistant paper, microwave popcorn bags, and pizza boxes; foods raised or grown in contaminated soil or water or stored in contaminated packaging, including (but not limited to) fish, fruits, vegetables, meat, microwave popcorn, and eggs (5). Routine showering, bathing, swimming, laundry, and washing dishes are not expected to be significant sources of exposure to PFAS. Inhalation of dust contaminated with PFAS is another possible route of exposure, especially in occupational settings. PFAS are not readily absorbed through the skin, so dermal exposure is of low concern (6).

Use of various consumer products, including non-stick cookware, stain-resistant carpets, dental floss, water repellant outdoor clothing, personal care products and cosmetics have also been identified as routes of exposure (6). For individuals, total exposure to PFAS can vary based on multiple factors. Studies have shown marked increases in the levels of certain PFAS with exposure to increasing levels in drinking water (7). However, some research has demonstrated that exposure to certain PFAS through consumer products, including specific stain-resistant carpeting, and a high frequency of use of these consumer products can contribute substantially to an individual's total exposure (8).

During pregnancy, PFAS can transfer through the mother's placenta into the umbilical cord blood, although different PFAS have different abilities to cross the barrier of the placenta (6). Specifically, for toddlers and infants, ingestion of PFAS can occur via formula prepared with contaminated water; breast milk from women exposed to PFAS; and the more frequent hand-to-mouth behaviors specific to young children when crawling and playing on the floor (1,6).

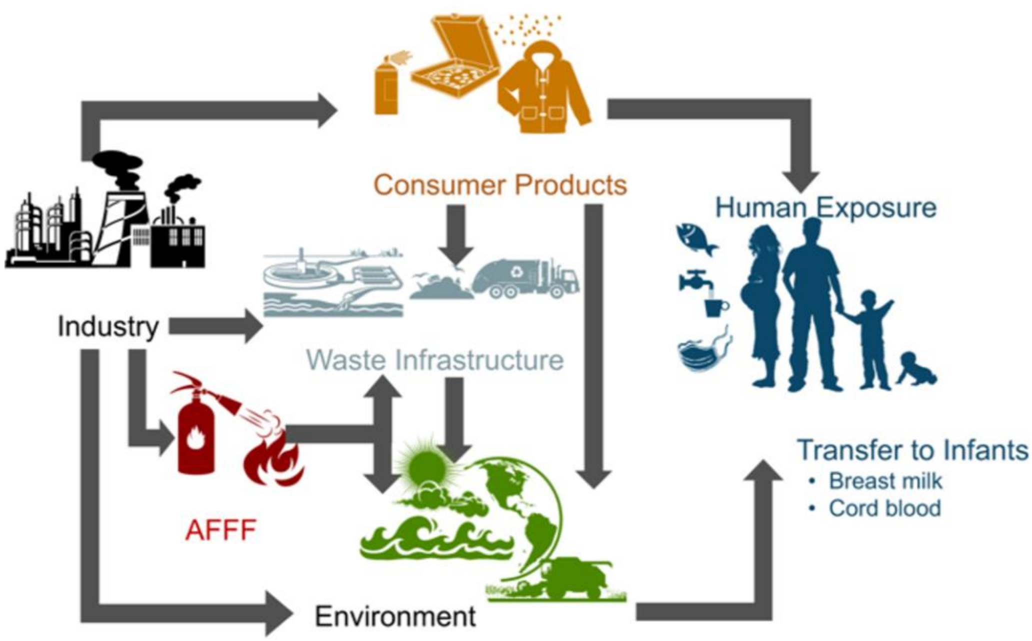



**Figure 1** from Sunderland et al. (2019) *Journal of Exposure Science & Environmental Epidemiology 29*(2). doi:10.1038/s41370-018-0094-1

## 3. How does exposure to PFAS impact human health?

*PFAS…affect multiple tissues in both males and females, of multiple species, at all developmental life stages. It's not just cancer. It's not just effects on the immune system, it's not just effects, for example, on the kidney or the liver, it's also effects on development and reproduction, and pretty much almost every system that you can think of.*

*Dr. Linda Birnbaum, director of the National Institute for Environmental Health Sciences and National Toxicology Program, in a Senate hearing on PFAS*

The ubiquity of PFAS in the environment and numerous sources of exposure greatly impact the prevalence of exposure. In a study with Americans aged 12 years or older, PFOS, PFOA, PFHxS, and were found in 90% of participants, suggesting a widespread exposure in the US (9).

PFAS chemicals can remain in the human body for many years after exposure as they have half-lives ranging from around 3 to over 5 years, depending on their specific chemical characteristics. For this reason, PFAS bioaccumulate—that is, become increasingly concentrated—in the human body with sustained exposure. The health effects of PFAS differ and depend on a variety of factors, including toxicity, other chemical properties, and bioaccumulation. The risks of adverse health effects due to exposure also depend on dose, frequency of exposures, route of exposure, genetic and genomic differences, and the timing of exposure during an individual's life stages, particularly in fetal and child development.

The C8 Health Study, a large epidemiologic study conducted in a community with high exposures to PFAS, found that exposure to PFOA is associated with high cholesterol; testicular, kidney, ovarian, prostate, and non-Hodgkin's lymphoma; high blood pressure during pregnancy; toxicity to the thyroid; toxicity to the immune system; and ulcerative colitis (10–13) Epidemiologic studies outside of the C8 Health Study, including those on PFOS, have found adverse effects on the immune system (14), and have corroborated adverse effects in the liver, kidney, endocrine, and reproductive systems.

Animal studies are a helpful tool for establishing a basis for evidence of potential health effects in humans. Animal studies on PFAS exposure have found toxicity to the liver, immune, and reproductive system; changes to the endocrine system's functioning; and harmful effects on development. Additionally, for rodents exposed to PFOS and PFOA before birth, increased risk of mortality just after birth, effects on weight after the weaning stage, delayed and abnormal development, adverse effects on the liver and thyroid, reduced ossification, reduced offspring bodyweight, increased mortality in offspring, and a number of other health effects have been observed (15,16). Animal studies have shown similar effects of shorter-chain PFAS on the liver and thyroid of rodents. These effects occur at higher doses due to the shorter half-lives of these chemicals in rodents, compared to longer-chain PFAS (17).

This information serves as a current summary of the health effects of PFAS, an active research area. The Agency for Toxic Substances and Disease Registry's 2019 Clinical Guidance on PFAS provides additional information regarding health effects of PFAS (6).

## *4. What are the limits to our knowledge on PFAS?*

Although our current knowledge of the health effects and extent of exposure to PFAS are limited, these are active areas of research with an evolving evidence base. Additionally, consistent findings for certain health outcomes have been shown in animals and humans.

PFAS are a very large group of chemicals, and epidemiological associations of the health effects of certain levels of exposure have focused primarily on PFOA and PFOS—not other PFAS. There are limited exposure assessments to PFAS, due to the limited amount of information regarding sources of exposure to all PFAS. Scientists do not yet know which PFAS manufacturers put into products due to the inability to quantify all PFAS individually, and thus exposure and toxicity can be difficult to characterize. Scientists also cannot yet quantify all PFAS concentrations in environmental media or human serum, especially those at low levels, because there are thousands of PFAS. However, new laboratory methods to quantify additional PFAS present in the human body and environment are in the early stages of use and under development (18,19).

The health effects observed in animal studies may not be directly comparable to potential health effects in humans, due to the increased doses administered, shorter life spans, and numerous differences in biology, including metabolism, cellular actions, and kinetics of the chemicals within different organisms. There are also limits to knowledge on PFAS due to the nature of establishing causal links in epidemiology. Establishing a causal link of PFAS exposures to certain health effects requires assumptions regarding the strength, reproducibility, and validity of the association observed in the population under study. Even with reasonable certainty in these assumptions, translating these findings to external populations can be difficult.

That said, we see consistent findings on health effects of PFAS in human/epidemiological studies and animal studies. For example, researchers have concluded that exposure to PFOA and PFOS are presumed to be a hazard to multiple aspects of the human immune system based on the high level of evidence in animal studies and moderate evidence in epidemiological studies (20). This demonstrated agreement helps overcome some of the limitations inherent in both types of studies.

## 5. What information is there about PFAS in drinking water where I live?

***Federal level***

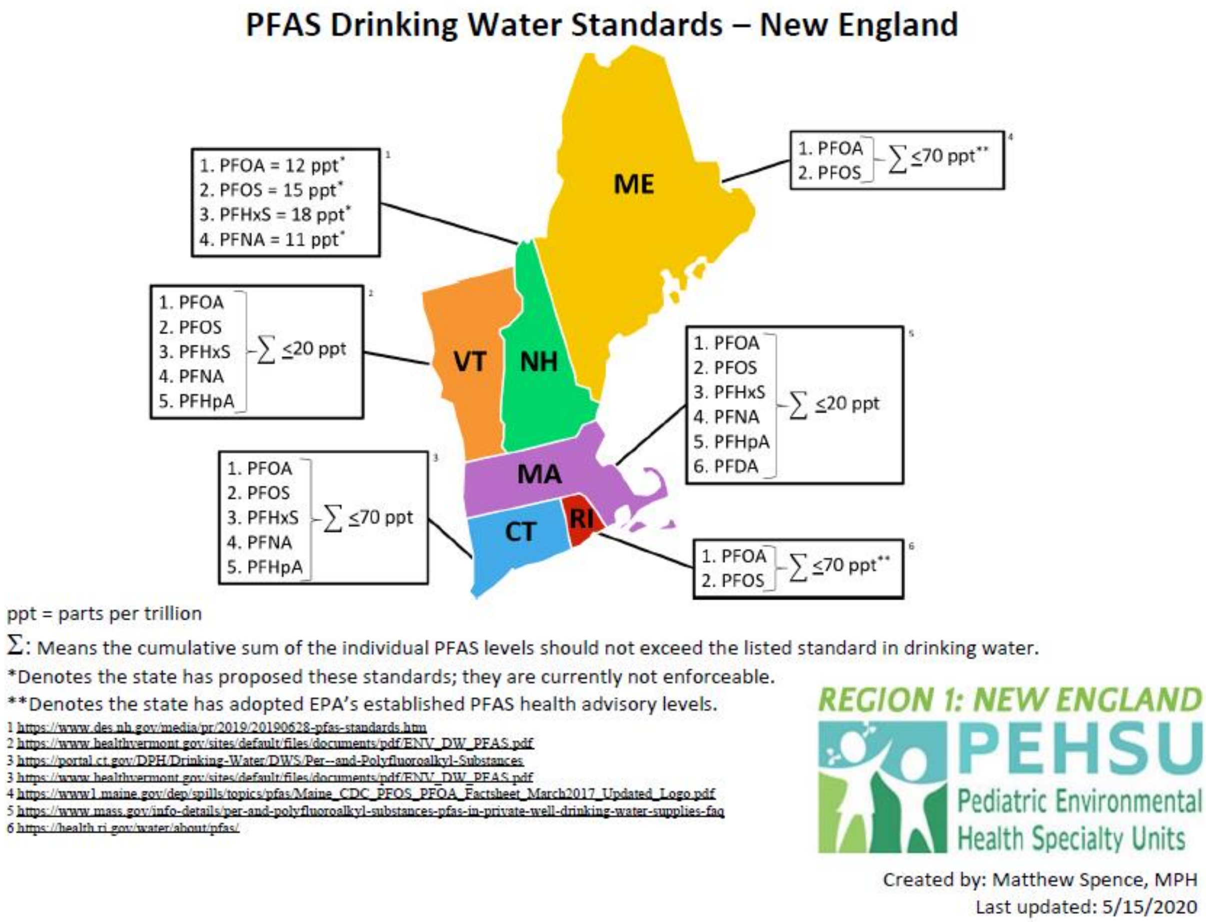
In 2016, the US EPA issued lifetime drinking water health advisories (LHA) for PFOA and PFOS concentrations of 70 parts per trillion (70 nanograms/liter; abbreviated ppt or ng/L) individually or combined. These health advisories are non-enforceable and non-regulatory but provide technical information to state agencies and other public health professionals on these compounds. They were developed to provide an acceptable margin of error against adverse health effects in the most vulnerable populations (21).

The lifetime health advisory is based on the lowest reference dose for development toxicity in animal studies, specifically reduced ossification in male and female mice pups and accelerated puberty in male pups. Due to the increased vulnerability throughout the pregnancy and lactation life stages, EPA has focused on lactating women as the target population and used parameters specific to this group (21).

Many scientists and regulators have raised concern that EPA's LHAs are not protective of human health, particularly for toxicity to the immune system, increases in cholesterol, and liver and testicular cancers. As a result, they have concluded that a lower LHA is needed (22–24). Environmental groups have also argued that, due to the sheer number of PFAS, a full assessment of each chemical is impractical, and therefore these chemicals must be regulated as a class (25). Additional arguments for this approach are based on the nature of their manufacture, potential for release of byproducts, and persistence in the environment, and ultimately recommend limiting PFAS to essential uses (26). This approach, however, does not assume that individual compounds may not have unique health effects that diverge from the overall assessment of the class.

See these links for additional resources on EPA's work on PFAS:

- EPA Fact Sheet and full advisory documents: https://www.epa.gov/ground-water-and-drinking-water/supporting-documents-drinking-water-health-advisories-pfoa-and-pfos
- PFAS infographic: https://www.epa.gov/pfas/pfas-what-you-need-know-infographic
- Timeline of EPA's actions: https://www.epa.gov/pfas/epa-actions-address-pfas
- Note: Multiple states in New England have enacted legislation to prohibit the sale of food packaging containing PFAS. Safer States maintains a running list of policies on PFAS in all states: https://www.saferstates.com/toxic-chemicals/pfas/




***Connecticut***

The Connecticut Department of Public Health (CT DPH) set a drinking water action level in 2016 for PFAS following EPA's lifetime health advisory numerically, but added PFNA, PFHxS, and PFHpA. This addition was made after CT DPH considered that PFHpA and PFHxS were detected with the same frequency as PFOA and PFOS in testing. The state also recognized a necessity for a precautionary approach for these three additional PFAS based on *in vitro* and *in vivo* studies. CT DPH also notes that measurements below 70 ppt should still be investigated and minimized to protect public health (27,28).

For those using a public water supply, CT DPH does not recommend testing by citizens themselves, as this water system may already have been tested. If you use a private well, you may have been contacted by your local health department if there is concern regarding PFAS in your area. You can find contact information for the Private Well Program within the state factsheet below (28).

See these links for additional resources on PFAS in Connecticut:

- State's fact sheet: https://portal.ct.gov/-/media/DEEP/site_clean_up/guidance/PFASFactSheetpdf.pdf?la=en
- CT DPH's main webpage on PFAS: https://portal.ct.gov/DEEP/Remediation--Site-Clean-Up/Contaminants-of-Emerging-Concern/Per--and-Polyfluoroalkyl-Substances#PFAS%20History
- For more information on state exposure and health studies, contaminated areas, and other resources, see PFAS Exchange's page for this state: https://pfas-exchange.org/connecting-communities/?state=Connecticut

***Maine***

Maine does not have a state-specific guidance or MCL for PFAS in drinking water; the federal health advisory is applicable to this state. A Governor's Task Force on PFAS has been established to identify the extent of PFAS exposure in Maine, risks to Maine residents and the environment, and recommended approaches for the state to manage risks. See here for more information: https://www.maine.gov/dep/spills/topics/pfas/. Also see the PFAS Exchange's page for more information on state exposure and health studies, contaminated areas, and other resources: https://pfas-exchange.org/connecting-communities/?state=Maine.

***Massachusetts***

The Massachusetts Department of Environmental Protection (MassDEP) has proposed a Maximum Contaminant Level (MCL) and a groundwater standard for the sum of six PFAS (PFOA, PFOS, PFNA, PFHxS, PFDA, and PFHpA) of 20 ppt in drinking water. These standards are based on the same literature as EPA's lifetime health advisory but incorporate an additional uncertainty factor, which lowers the final calculated level. This uncertainty factor was added based on the weight of evidence suggesting potential health effects at lower exposure levels. The four additional PFAS were included due to MassDEP's conclusion that these compounds are similar in toxicology (29). Note that MassDEP's MCL is enforced by the state's Drinking Water Program for public water systems (30).

Additionally, MassDEP regulates the application of sludge and septage for beneficial purposes, and PFAS testing is required for these waste products (31).

The Agency for Toxic Substances and Disease Registry (ATSDR) is conducting a health study on human health effects of PFAS exposure through drinking water in Hyannis and Ayer, MA. More information is available here: https://silentspring.org/project/cdcatsdr-pfas-health-study.

See these links for additional resources on PFAS in Massachusetts:

- Primary page containing public drinking water testing results in the state, fact sheet, how to interpret lab results, and many other resources: https://www.mass.gov/info-details/per-and-polyfluoroalkyl-substances-pfas

- For more information on state exposure and health studies, contaminated areas, and other resources, see PFAS Exchange's page for this state: https://pfas-exchange.org/connecting-communities/?state=Massachusetts

***New Hampshire***

The New Hampshire Department of Environmental Services (NHDES) has five MCLs and Ambient Groundwater Quality Standards for PFAS: 12 ppt for PFOA; 15 ppt for PFOS; 18 ppt for PFHxS; and 11 ppt for PFNA. These MCLs are not enforceable at the time of publication of this guidance, but the previous regulations (70 ppt for PFOS, PFOA, or combination of the two) remain in effect (32,33). These values are informed by separate animal studies with differing critical health effects, as well as the inclusion of EPA's LHA for the sum of PFOS and PFOA (34).

The state has also adopted five Ambient Groundwater Quality Standards (which are equal to each of these MCLs), which dictate the remedial action and provision of alternative drinking water sources at a contaminated location, as well as the conditions under which treated and untreated wastewater may be discharged to a groundwater source (23).

The ATSDR conducted a two-phase blood testing program in 2015 for residents on the Pease Tradeport impacted by elevated levels of PFOS, PFOA, and PFHxS in drinking water wells. The Pease Study continues to enroll participants (who meet specific eligibility requirements) to further the understanding of PFAS and various health outcomes (35).

See these links for additional resources on PFAS in New Hampshire:

- NH PFAS Investigation website: https://www4.des.state.nh.us/nh-pfas-investigation/
- The Pease Study Community Fact Sheet: https://www.atsdr.cdc.gov/pfas/Pease-Health-Study-Community-Fact-Sheet.html

For more information on state exposure and health studies, contaminated areas, and other resources, see PFAS Exchange's page for this state: https://pfas-exchange.org/connecting-communities/?state=New%20Hampshire

***Rhode Island***

Rhode Island does not have a state-specific guidance or MCL for PFAS in drinking water; the federal LHA is applicable to this state. The state has taken steps to sample PFAS in select water systems in the state (36). The Rhode Island Department of Health has a FAQ on PFAS: https://health.ri.gov/water/about/pfas/. For more information on state exposure and health studies, contaminated areas, and other resources, see PFAS Exchange's page for this state: https://pfas-exchange.org/connecting-communities/?state=Rhode%20Island.

***Vermont***

The Vermont Department of Environmental Health (VT DEH) has set a health advisory level of 20 ppt for the sum of five PFAS: PFOA, PFOS, PFHxS, PFHpA, and PFNA. For tested waters that

Please note: Pages 6, 7, 8 and the first half of page 9 have been removed from the original document. They contain PFAS standards for the New England states. Because those standards and values have not been vetted by the states, we have chosen to exclude the state data from this version of the report.

## *6. What can I do in my community?*

Various community groups in New England and beyond are involved in campaigns to educate the public, advocate for action by retailers, and support legislation on PFAS. The PFAS Exchange, referenced throughout this guidance document, is an online resource center on PFAS in drinking water for communities throughout the US. For each state above in the links provided, the website maintains a list of state-level community groups focused on public awareness, community education, research advocacy, and changes to public policies.


The PFAS Project is a New-England-based coalition of community leaders concerned about PFAS drinking water contamination, and their site contains webinars, health information, and conference presentations: https://pfasproject.net/.

The Toxics Action Center is a New-England-based organization with a mission to organize community plans and strategies to combat pollution locally. The Center also maintains a webpage on PFAS with action steps, facts sheets, health studies, and conference presentations: https://toxicsaction.org/issues/pfas-water-contamination/.

Safer Chemicals, a national organization, has a mission to push for strong federal and state policies on chemicals, advocate for retailer action to institute safer alternatives, and educate consumers. For more information on current opportunities, see https://saferchemicals.org/get-involved/.

## 7. What can I do for myself?

Most Americans have been exposed to PFAS (particularly PFOS and PFOA) and have measurable levels in their blood (39). The following steps are aimed towards those at risk for elevated exposure, as well as the general population, to reduce exposure to PFAS:

***Water and PFAS*** (31,40)

- In New England, it is possible that if you drink water from a public water supply, your water has already been tested for PFAS or will be tested. Therefore, if you use a public water supply, you do not need to test your own water for PFAS. Check your public water supply's Consumer Confidence Report and/or contact your public water supply for more information. The EWG also hosts a map on PFAS levels in tap water throughout the country, and a tap water database: https://www.ewg.org/interactive-maps/pfas_contamination/ and https://www.ewg.org/tapwater/
- If you use a private well, contact your local board of health, town, or nearest public water supply for testing information. State-certified testing laboratories are recommended to complete PFAS drinking water testing.
- If drinking water is above the EPA or state-specific health advisories or MCLs, sensitive subgroups (pregnant women, nursing mothers, and infants) should consider bottled water that has been tested for PFAS for drinking, cooking, brushing teeth, and preparation of baby formula until water can be properly filtered or a new water source is made available. Parents may also consider using formula that does not require water. Breast-feeding is recommended regardless of the mother's status with respect to her own present or past exposure to PFAS in drinking water.
- Some home treatment systems have been certified to remove PFAS in contaminated drinking water, including granulated activated carbon, ion exchange resins, and reverse osmosis systems. See your state health department for more information. The PFAS Exchange project also has a fact-sheet aimed at treatment options ("PFAS in Drinking Water: What You Should Know"): https://pfas-exchange.org/resources/
- The STEEP Superfund Research Program Center has a webpage on tips for private well owners on PFAS: https://web.uri.edu/steep/tips-for-well-owners/
- Routine showering and bathing are not expected to be significant sources of exposure for water contaminated with PFAS. However, shorter showers/baths, particularly for children or those with skin conditions, would limit exposure.
- Although it is difficult to predict the potential health effects of PFAS in pets, these health effects may be like those seen in humans. As a precaution, if you have elevated levels of PFAS in your water, you may consider using alternative water for pets or contacting your veterinarian for concerns.
- In areas with elevated levels of PFAS in tap water, families consuming a large portion of their produce from homegrown foods may consider using rainwater or an alternative water source for gardening; washing their produce after harvesting; increasing the use

of compost rich in organic matter, which may reduce PFAS uptake; or using raised beds with fresh soil.
- Boiling water does not reduce PFAS levels. Rather, boiling water concentrates PFAS.

***Other Sources of Exposure*** (41,42)

- If you are concerned about exposure from non-stick cookware, consider disposing old and damaged or flaking non-stick pans. Do not clean non-stick cookware in the dishwasher.
- Discard old, frayed, stain-resistant carpeting and upholstery and old cans of waterproofing treatments.
- PFAS Central maintains a list of apparel, shoes, outdoor gear, personal care, and other products with PFAS-free policies: https://pfascentral.org/pfas-basics/pfas-free-products/
- Silent Spring Institute's free mobile app, Detox Me, includes a buying guide: https://silentspring.org/detox-me-app-tips-healthier-living

*Date: September 30, 2020*

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ACKNOWLEDGMENTS

This publication was supported by the American Academy of Pediatrics (AAP) and funded (in part) by the cooperative agreement award number 1 NU61TS000296-01-00 from the Agency for Toxic Substances and Disease Registry (ATSDR). The U.S. Environmental Protection Agency (EPA) supports the PEHSU by providing partial funding to ATSDR under Inter-Agency Agreement number DW-75-95877701. Neither EPA nor ATSDR endorse the purchase of any commercial products or services mentioned in PEHSU Publications.

This publication was a collaboration between the Region I PEHSU at Boston Children's Hospital and personnel from the Community Engagement Core of the Harvard Chan-NIEHS Center for Environmental Health.  The Harvard Chan Center is funded by federal grant P30 ES000002 from the National Institute of Environmental Health Sciences.