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Man-Made Contaminants: PFAS (Per- and Polyfluoroalkyl Substances)

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Background

- **Parkersburg, West Virginia,** DuPont Washington Works Plant/Teflon/end of 1990's/ others potential sources date back to the 1940's / Minnesota Mining and Manufacturing - started using in approximately 1949 ; Wolverine World Wide back to the late 1950's
- **Some PF-285+** chemicals: PFAS, PFOS, PFOSA, PFHxS, PFNA, PFDeA, PFHpA, MeFOSAA, PFUA, PFOA, **PFBS** - Perfluorobutanesulfonic acid - and on and on = PF-285+. There are so many PFAS and related compounds, the last time counting them was attempted, the number of "285" was reached. However, many more were "in sight" ready to be counted, but for "counting fatigue". Accordingly, by preference they collectively carry the more accurate moniker of "PF 285+". Please see ATTACHMENT 1 for a far more detailed chemical explanation about "PF 285+."
- **Ubiquitous-PF-285+**, including commercial household products, food packaging, food grown in PF-285+ contaminated soils or waters, stain and water repellent fabrics, nonstick Teflon products, polishes, waxes, paints, cleaning products, chrome plating, electronics manufacturing, oil recovery, landfills, general manufacturing equipment, wastewater treatment plants, carpets, paper and packaging, coatings, rubber, plastics, textiles, Scotchguard (TM – Minnesota Mining and Manufacturing) just to name a few. They are everywhere.
- **Provisional (2009) and Revised Health Advisories (May 2016) for potable water** as established by **EPA**, singularly, at 70 ppt for PFAS, 70 ppt for PFOS, and also for a total of PFAS + PFOS = Total PF-EPA at 70 ppt. Concerned with the potential for PF285+ contamination in tap water, supply wells, and public water systems near the Chambers Works plant, in 2007 the NJDEP announced a Health Guideline for PFOA at 40 ppt for public water systems.
- **PF285+ inNew Jersey (potable water standards) PFNA – MCL -13 ppt; proposed rule issued on April 1, 2019 for standards of PFOA MCL 13 ppt, and PFOS –at MCL 14 ppt.for potable water supplies and formal groundwater quality standards for site remediation and discharges to the groundwater (60 public day comment period completed on May 31, 2019), but *interim groundwater remediation standards* put into place by the NJEP for PFOA and PFOS, each at 10 ppt. The proposed rules also require public water supply systems to quarterly monitor PFOA and PFOS starting within the first quarter of 2021, although a water supply system may choose to do so at any earlier time. The NJDEP will use the data to determine if monitoring frequency in the future should be reduced to one annual event for PFOA and PFOS. The Drinking Water Institute will also be looking at the collected data to determine if it needs to make any changes by rule making. THE PROPOSED RULE WILL ALSO REQUIRE PRIVATE WELL OWNERS TO TEST FOR PFNA, PFOA, AND PFOS AS PART OF REAL ESTATE TRANSACTIONS, AND PERIODICALLY FOR RENTAL PROPERTIES, WITH THESE REQUIREMENTS TO BE EFFECTIVE 18 MONTHS AFTER RULE ADOPTION. A synopsis of the Proposed Rule is appended as ATTACHMENT 2. NJDEP action on finalizing the Proposed Rule will likely take place in Q 1, 2020, as the agency carries a "Drop Dead Date" of April 1, 2020 to finalize rulemaking. Big issue is whether to what extent PFAS 285+ is a "pollutant" under CERCLA, and SARA (New Jersey Law) and New Jersey Spill Fund, and the Federal or State water pollution acts and if so, which ones.**
- **Potential Health Impacts:** low infant birth rates, adverse effects on immune system; cancer (PFOA only?), thyroid disruptions, liver damage, high cholesterol, decreased fertility. However, it needs to be noted that most of the disease causation analysis is based of animal and epidemiological studies.

- **Good Information:** Association of State Drinking Water Administrators
- **Laboratory Testing Methods and Costs.** For State Certifiable potable water results, Eurofins uses the EPA 537.1 test method (isotope) which measures a matrix of 18 PFAS compounds. For internal evaluations only of potable water, Eurofins uses a matrix of 36 target PFAS compounds. The cost for each is in the range of $350.00 to $450.00.
  - Eurfins has tested many products and media, including, cloth materials, resins, hydraulic fluids, fish, soil, groundwater, and milk to name a few. In order to do so, it uses a proprietary testing method based on EPA Method 537. 1. No tests have been conducted on air samples.
  - The EPA has developed a draft Method SW 846-8328 (no one outside of the EPA has yet to see this draft) and is now finalizing this method before a validation study will begin in selected laboratories. It is estimated that the validation study should start by late Fall.
  - DOD uses its own testing protocol with a matrix of 24 PSAF compounds which can expand to 28 by including GENX (no, not the moniker for a demographic population segment following the "baby boomers", but the name of a chemical process to develop advanced polymers, introduced by DuPont about a decade ago as a "safer" alternative to PFOA and PFOS – like MTBE being the GenX of lead in gasoline) and ADONA (ammonium 4,8-dioxa-3H-perfluorononoate), among others
- **Key inquiries:** nexus to potable water sources (only a few states, such as Minnesota and Vermont, currently have groundwater standards, although more states are likely in the future to extend PF-285+ concerns to groundwater standards)
- **Military bases and airports associated with firefighting and firefighting training** are the most "convenient" targets, but they are not alone. However, the locations of military bases and airports, and their usual surrounding "sensitive potable water receptors" throughout the country will increasingly become targets as the concerns over PF-285+ become more and more a matter of public health initiatives/concerns, local/regional blood testing programs, and private class-action or state Attorney General lawsuits.

Targets: current or prior airport grounds, military airplane based activities grounds, foam fire fighting training /foam storage grounds, industrial and commercial grounds upon which PF285+ has/had been used for at least 5 years, community and municipal drinking water systems, and any private water wells, including irrigation wells proximate to any of the afore described grounds.

Target asks: "What to do?"
Suggestion: the "R-Index" of risk management evaluations follows:

Local Passive Team ("LPT") – Limited likelihood of on-site PF-285+ impacts;
Regional Passive Team ("RPT") – High likelihood of on-site PF-285+ impacts potentially involving sensitive potable water receptors beyond the site in question;
Regional Proactive Team ("RPRO") - High likelihood of on-site PF-285+ impacts with high likelihood of impact to sensitive potable water receptors beyond the site in question;

These are general "T –Shirt sizes" based upon a "sensitive potable water receptor evaluation" quite different from current State and/or ASTM 1527-13 definitions (such as referenced in ASTM 1527-13, 3.2.4;3.2.67; 3.2.84; 8.2.2; 8.2.3; 8.2.4; 8.3.3; 9.4.1.3; 13.1.5.14). Remember, we are talking about "T-shirt sizes" with no particular weightings provided to the many following general considerations and variables. A "sensitive potable water receptor evaluation" is based upon readily obtainable information. As the result of past environmental spills/discharges and/or tank removals and replacements, at or near the site in question, one should know groundwater flow direction. The next considerations should be, but are not necessarily limited, to the following:

(1) proximities to community and public drinking water wells and systems, whether side-gradient, up-gradient (possible cones of influence), or down-gradient;

(2) proximities to lakes, rivers, and other water-ways
(3) extent of control or lack of control and directions of runoff from rainfall, snow melt, and regular water usage and discharges, and their proximities to community and public drinking water wells and to lakes, rivers and other waterways;
(4) man-made drainage systems, sewer system piping and pre-treatment equipment and retention/ storm-water detention ponds/ basins, and their proximities to community and public drinking water wells and to lakes, rivers and other waterways
(5) local irrigation wastewater flows and general wastewater outflows, and their proximity to the airport grounds
(6) stream channel, levee and dam constructions, and hydropower facilities, and their proximities to the site in question
(7) local and/or regional residential and commercial/ manufacturing developments (some commercial/ manufacturing activities may be taking place nearby) and their proximities to the site in question
(8) private drinking water wells servicing commercial and residential developments and their proximities to the site in question
(9) length of military history, if any, and regular AFFF foam fire-fighting, fire department, and foam fire-training using foam materials stored on-site, and used on or nearby the site in question.
(10) on-site and nearby manufacturing operations need to be specifically examined for any uses of PF285+, GENX, and ADONA; and
(11) proximities to upper groundwater levels.

So, what to do? Risk management assumes that, at some time in the future, as the result of being a target, your company need documents, information, and your **Team** at-the-ready.

<u>For R-LPT -</u> basic to LPT, RPT, and RPRO are the following recommendations:

(1) on-grounds fire department records, firefighting photographs, foam and related fire-fighting supply orders (as far back as possible) with notes, if possible, of foam manufacturers utilized, and any records pertaining to non-on-grounds, but nearly fire departments called upon in the past, as well as any other organizations participating in foam fire-fighting training on or near the property in question;
(2) general liability insurance policies as far back as possible;
(3) site plan, pre-construction, and any 'as built' plans showing locations of runways, chemical storage areas, detention basins, and all other items mentioned in the "sensitive potable water receptor evaluation" paragraph as they developed throughout the years, and as far back as possible;
(4) bank records, copies of checks, and internal accounts payable documents and ledgers pertaining to payments made for the previously mentioned items (1) - (3), as these records usually have some detailed information necessary to identify and search out documents relating to the purchased items;
(5) assemble documents and photographs concerning the length of military history, if any, and regular foam fire-fighting, fire department, and foam fire-training using foam materials stored on-site (and places of storage).

The photographs and historical on-grounds and off-grounds fire department documents may be particularly important in determining the approximate dates of discharges of PF-285+ materials which may have a substantial bearing on any insurance coverage claims.

All these documents should be placed in fire-proof safes.

Immediately obtain information pertaining to such documents, which may not all be found. The longer one waits, the more likely people with "corporate memory" will no longer be around to "fill in the blanks", such as, the information concerning the items referenced in the preceding paragraph as "(1)", the insurance companies that wrote general liability policies, or the identify of photographers used in the past and local newspaper articles (including photographs) reporting upon the fires and fire-fighting events in the past, the insurance brokers/ agents used in the past, the accountants and lawyers used in the past, the surveyors, land use planners, and construction/repair contractors used in the past. Record this information, and currently seek to obtain any documents that may be readily available from the stored records of these potential document vendor sources. Your insurance policies may also be identified on records provided to regulatory or client-based documents, and the plans prepared by the surveyors, land use planners, and construction/repair contractors used in the past will likely be available from local government or regulatory sources and agencies. Get them now through Right to Know laws.

The R-LPT Team should consist of specifically designated existing employees. However, before proceeding upon the activities suggested, it is recommended an attorney be consulted concerning the advantages that may be available in certain states to protect as "confidential" any analysis you may place in writing concerning "an audit" of your document readiness and/or any written analysis or "internal audit" of the threats that the property in question may or may not pose to potable waters from PF285+. Similar protections may be available as attorney-client privileged documents as the result of communications between you and your attorney concerning these issues. Please check out these possible protections with an attorney.

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For R-RPT – basic, however, to both **RPT** and **RPRO** are the following recommendations:

(1) determine other likely sources of PF-285+ in the region as possible sources for impacts to potable water quality and/or groundwater quality, and have them "mapped out";
(2) hire a public relations firm on a yearly "base-retainer basis" and lock them in by making sure that the public relations firm has agreed not to become in any way available to anyone else involved with similar CF-285+ issues, and meet with the firm to scope out the best possible and focused responses, particularly, given the ubiquitous nature of CF-285+ and other likely local sources;
(3) consult with an accountant and attorney to determine the best method to set aside an essential emergency risk management fund to which regular contributions should be made each year; and
(4) as needed, use paid advertising space in local and regional newspapers to make sure your message gets through to the public;
(5) it's "ok" to respond to local reporters' queries, but the response should only come from one designated person who needs to be prepared with a focused message and be sufficiently patient to sit down with any reporter to explain this highly complex set of issues. Many people "get into trouble" with reporters because they do not take the time (perhaps a few hours may be needed) to fully explain the complexities of scientific issues.
The importance of these approaches cannot be overstated, and are essential to getting a fair shake, at least in the article written by the reporter (the newspaper's editor will control the headlines); and
(6) if not already, become generally politically active with, and familiar to locally elected governmental municipal and county representatives and the municipal and county health department officials, generally stressing transparent communications with them, as well as the importance of the services, conveniences, and gratuities you provide to the region. A consistent reminder of these benefits to the region should also be part of regular public relations initiatives.

The R-RPT Team specifically designated existing employees, an attorney and accountant, a public relations firm retained on a yearly "base-retainer basis" locked-in by making sure that the public relations firm has agreed not to become in any way available to anyone else involved with similar CF-285+ issues, and as necessary, a person who is skilled in making rather detailed maps of other potential PF-285+ sources in the region (does not need to be a surveyor), and amongst these individuals, a specially designated person providing the rather delicate approaches needed to meet the goals noted in "(6)", above.

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For R-RPRO- basic to **RPRO** are the following recommendations:

(1) hire the very best environmental and "insurance claim" attorney(ies) you can locate on a yearly "base-retainer basis" and lock in the attorney by making sure that the attorney's firm has agreed not to become in any way available to anyone else involved with similar CF-285+ issues, (applied to even those without an apparent or potential conflict), and who are familiar with the defenses and third party actions available;
(2) hire the very best environmental laboratory specializing in testing for (even by refined "in-house proprietary" methods other than those recognized by governmental agencies) PF-285+ that you can locate on a yearly "base-retainer basis" and lock in the environmental testing laboratory, if possible, by making sure that the environmental testing laboratory

has agreed to only represent commercial, industrial, and manufacturing facilities involved with similar CF-285+ issues, and not the general public/citizenry or any governmental entity in any way;
(3) hire the very best environmental scientist specializing in PF-285+ that you can locate on a yearly "base-retainer basis" and lock in the scientist by making sure that the scientist has agreed to only represent commercial, industrial, and manufacturing facilities involved with similar CF-285+ issues, and not the general public/citizenry or any governmental entity in any way;
(4) as early as possible, determine an attorney the circumstances under which he/she can assert the earliest possible claim against general liability insurance carriers based upon claims that have been made or may come to be made;
(5) as early as possible, determine with an attorney the circumstances under which he/she can assert the earliest possible written notice of claims against any other potentially responsible parties, which would also require retention of all electronic communications, and non-spoliation of evidence;
(6) become part of an assemblage of locally potentially impacted PF 285+ properties to hire the very best political lobbyist in your state on a yearly "base-retainer basis" and lock in the political lobbyist by making sure that the political lobbyist has agreed to only represent commercial, industrial, and manufacturing facilities involved with similar CF-285+ issues, and is not nor will become associated in any way with the general public/citizenry, or any non-governmental agency or organization unless specifically approved.
(7) become part of an national assemblage of similarly situated property owners and retained the very best national political lobbyist on a yearly "base-retainer basis" and lock in the national political lobbyist by making sure that the national political lobbyist has agreed to only represent commercial, industrial, and manufacturing facilities involved with similar CF-285+ issues, and is not nor will become associated in any way with the general public/citizenry or any non-governmental agency or organization unless specifically approved.

The R-RPRO Team, in addition to the other persons mentioned previously, this TEAM consists of professionals as designated in the previous paragraphs, and to the maximum extent possible, one should seek out joint representation by these professionals, assuming various interim and informal groups fall into similar R-Index categories, and can define their common interests, and can agree upon conflict waivers.

Ultimately, it is anticipated that the only realistic efforts to deal with all or most of the issues of man-made contaminants (instead of ***ad hoc*** actions and reactions, featured by litigation and public relation initiatives) will come from a national health based approach which can only accomplish some "rough justice", most likely involving individual medical monitoring and water treatment system "upgrades" in certain instances (ion-exchange or carbon filter technologies) based upon community based blood levels and other yet to be determined variables and to be funded by the historically large CF-285+ manufacturers, the Federal government (as the result of military involvements and foam requirements for CF-285+), and perhaps some form of ad valorem tax on smaller manufacturers and even users of CF-285+ based upon the value of CF-285+ goods sold or used over specific time periods, all of which would be predicated upon outlawing the manufacture and importation of any goods containing a broad range of identified CF-285+ materials. While these PF285+ along with GenX and ADONA issues have been "hanging around" for a rather long time (it's not in any way, "emerging contaminants") with no apparent national leadership, until this series of issues rise to a level of a "clarion call", instead of the Federal and State related ad hoc whimpers (most of which, seek issue(s) and comprehensive solution avoidance), all the commercial, industrial, and manufacturing entities adversely touched by CF-285+ are on their own, and will be throughout (at least) this current Federal Administration and the 115th and 116th Congress.

Whatever more encompassing and far more practical commercial, industrial, and manufacturing entity efforts to holistically deal with these issues may be forthcoming, they will, for the moment, remain state and litigation centric. These issues currently provide many challenges, especially, for certain impacted states and their local political lobbyists to holistically propose comprehensive solutions. The "state level' is where some real action (call for a coordinated multi-state comprehensive legislative action seeking solutions) should be focused, and some real results achieved.

ENVIRONMENTAL PROTECTION

WATER RESOURCE MANAGEMENT

DIVISION OF WATER SUPPLY AND GEOSCIENCE

Discharges of Petroleum and Other Hazardous Substances Rules; Ground Water Quality Standards Rules; Private Well Testing Act Rules; Safe Drinking Water Act Rules; and New Jersey Pollutant Discharge Elimination System Rules

Ground Water Quality Standards and Maximum Contaminant Levels (MCLs) for Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS)

Proposed Amendments: N.J.A.C. 7:1E Appendix A, 7:9C Appendix Table 1, 7:9E-2.1, 7:10-5.2, and 12.30, 7:14A-4 Appendix A and 7.9

Authorized By: Catherine R. McCabe, Commissioner, Department of Environmental Protection.

Authority: N.J.S.A. 13:1B-3 et seq., 13:1D-1 et seq., 13:1D-125 through 133, 13:1E-1 et seq., 26:2C-1 et seq., 13:1K-1 et seq., 58:10-23.11, 58:10-46 through 50, 58:10A-1 et seq., 58:11A-1 et seq., 58:11-9.1 et seq., 58:11-23 et seq., 58:11-49 et seq., 58:11-64 et seq., 58:11A-1 et seq., 58:12A-1 et seq., and 58:12A-26 et seq.

Calendar Reference: See Summary below for explanation of exception to calendar requirement.

DEP Docket Number: 02-19-03.

Proposal Number: PRN 2019-042.

A public hearing concerning this notice of proposal will be held on May 15, 2019, at 2:00 P.M.

until the close of comments at:

New Jersey Department of Environmental Protection

Public Hearing Room

401 East State Street

Trenton, NJ 08625

Directions to the hearing room may be found at the Department's website, http://www.state.nj.us/dep/where.htm.

Written comments may also be submitted at the public hearing. It is requested (but not required) that anyone who testifies at the public hearing provide a copy of their comments to the stenographer at the hearing.

Submit comments by May 31, 2019, electronically at http://www.nj.gov/dep/rules/comments.

The Department of Environmental Protection (Department) encourages electronic submittal of comments. In the alternative, comments may be submitted on paper to:

Ryan H. Knapick, Esq.

Attn: DEP Docket Number: 02-19-03

Office of Legal Affairs

Department of Environmental Protection

401 East State Street, 7th Floor

Mail Code 401-04L

PO Box 402

Trenton, New Jersey 08625-0402

This rule proposal may be viewed or downloaded from the Department's website at http://www.nj.gov/dep/rules.

The agency proposal follows:

Summary

As the Department of Environmental Protection (Department) has provided a 60-day comment period on this notice of proposal, this notice is excepted from the rulemaking calendar requirement pursuant to N.J.A.C. 1:30-3.3(a)5.

The Department is proposing to amend the New Jersey Safe Drinking Water Act (SDWA) rules at N.J.A.C. 7:10 to establish, as recommended by the New Jersey Drinking Water Quality Institute (Institute), a maximum contaminant level (MCL) for perfluorooctanoic acid (PFOA) of 0.014 micrograms per liter (µg/l) and an MCL for perfluorooctanesulfonic acid (PFOS) of 0.013 µg/l. PFOA and PFOS are part of a larger class of substances referred to as per- and polyfluoroalkyl substances (PFAS, previously referred to by the Institute as perfluorinated compounds, or PFCs), which have been detected in drinking water supplies in New Jersey and which, as explained further below, pose serious health threats to consumers. The Department previously established an MCL for another PFAS, perfluorononanoic acid (PFNA), on September 4, 2018 (see 50 N.J.R. 1939(a)). Currently, there are no Federal drinking water standards for these contaminants.

MCLs apply to public community and public noncommunity water systems. Public community and public noncommunity water systems are required to routinely monitor for contaminants for which MCLs have been established and to treat water when there is an exceedance of an MCL. Public community water systems are water systems that have at least 15 service connections used by year-round residents, or regularly serve at least 25 year-round residents. Public noncommunity water systems include public nontransient noncommunity and public transient noncommunity water systems. Public nontransient noncommunity water systems do not serve year-round residents, but do serve at least 25 of the same individuals for more than six months of any calendar year. Examples include schools or office parks that have their own water source.

Monitoring requirements for PFOA and PFOS for public community and public nontransient noncommunity water systems are proposed and the existing rules at N.J.A.C. 7:10-5.2 will be recodified accordingly. In addition, proposed amendments delineate the information regarding PFOA and PFOS that public community water systems must include in the annual consumer confidence report (CCR) describing the quality of the water delivered to customers.

Further, the Department proposes to amend the Private Well Testing Act (PWTA) rules at N.J.A.C. 7:9E to require testing of private wells subject to sale or lease and to amend the SDWA rules to require testing of newly constructed wells for public noncommunity water systems and nonpublic water systems for PFNA, PFOA, and PFOS.

The Ground Water Quality Standards (GWQS) at N.J.A.C. 7:9C are implemented as limits on discharges to ground water pursuant to the New Jersey Pollutant Discharge Elimination System (NJPDES) rules at N.J.A.C. 7:14A and as ground water remediation standards. In addition, the Department is proposing to amend the GWQS to establish a specific ground water quality standard for PFOA of 0.014 µg/l and a specific ground water quality standard for PFOS of 0.013 µg/l. The Department previously established a specific ground water quality standard for PFNA on January 16, 2018 (see 50 N.J.R. 334(a)). Further, and in accordance with N.J.A.C. 7:14A-7.6, the Department is proposing to add PFNA, PFOA, and PFOS to the Permit Application Testing Requirements/Pollutant Listings and the Requirements for Discharges to Ground Water in NJPDES rules.

PFOA and PFOS exist as acids and anions. However, because established testing and reporting requirements use the acid form of both contaminants, the proposed amendments to the GWQS, and the PWTA, SDWA, and NJPDES rules reference the acid form.

Lastly, the Department is proposing to add PFOA and PFOS to the List of Hazardous Substances at N.J.A.C. 7:1E, Discharges of Petroleum and Other Hazardous Substances rules. The owners or operators of major facilities that store PFOA and PFOS may store these substances in multiple forms. Therefore, the listing will reference these forms, which include acids, anions, salts, and esters. In addition, the Department is proposing to add PFNA's anionic form, salts, and esters to the List of Hazardous Substances.

Proposed MCLs and Monitoring Requirements for PFOA and PFOS

Role of New Jersey Drinking Water Quality Institute

The Institute was established in 1983 pursuant to the SDWA at N.J.S.A. 58:12A-20 as a 15-member advisory body whose role is to provide the Department with recommendations regarding the drinking water program, including the development of New Jersey-specific drinking water standards. The SDWA at N.J.S.A. 58:12A-13.b requires MCLs to be established within the limits of medical, scientific, and technological feasibility, for carcinogens, based upon the goal of an excess cancer risk of no greater than one in one million over a lifetime exposure period. For chemicals causing effects other than cancer (noncarcinogens), the goal is the elimination of all adverse health effects resulting from ingestion, within the limits of practicability and feasibility.

Three subcommittees were established within the Institute to assist in the development of MCLs. The Health Effects Subcommittee recommends health-based levels for the contaminants listed in the SDWA and develops an additional list of drinking water contaminants based on occurrence in New Jersey drinking water. The Testing Subcommittee evaluates the limits of testing methodology in achieving the health-based levels established by the Health Effects Subcommittee. The Treatment Subcommittee evaluates best available treatment technologies for removal of the contaminants from drinking water to achieve the health-based level while considering the limits of available testing methodologies.

MCL for PFOA and PFOS

In 2014, the Department requested that the Institute recommend MCLs for several PFAS with long-chain molecular structures that tend to behave similarly in the environment, including PFOA and PFOS. PFOA and PFOS are man-made, and are used industrially and commercially. PFOA was used as a processing aid in the manufacture of fluoropolymers used in non-stick cookware and other products, as well as other commercial and industrial uses based on its resistance to harsh chemicals and high temperatures. PFOS is used in metal plating and finishing. Both PFOA and PFOS were previously used as ingredients in aqueous film forming foams for firefighting and training, and both compounds are found in consumer products, such as stain resistant coatings for upholstery and carpets, water resistant outdoor clothing, and grease-proof food packaging. Although the use of PFOA and PFOS has decreased substantially, the Department expects contamination to continue indefinitely, because they are extremely persistent in the environment and soluble and mobile in water.

The occurrence of PFOA and PFOS in drinking water in New Jersey has been documented through sampling conducted by the Department, public water systems, and third parties. As of December 2018, 39 systems had detections of PFOA exceeding the proposed MCL of 0.014 µg/l, while 19 public community water systems had detections of PFOS exceeding the proposed MCL of 0.013 µg/l. Of the 39 systems with detections of PFOA, the Department is aware of 11 that are in various stages of taking actions to reduce concentrations below 0.014 µg/l. Of the 19 systems with detections of PFOS, four are in various stages of taking actions to reduce concentrations below 0.013 µg/l. The Department is currently collecting additional sampling data that demonstrates public community and public noncommunity nontransient water systems located throughout the State have levels of PFOA and/or PFOS exceeding the proposed MCLs.

In 2006, the Department initiated a study to evaluate the occurrence of PFOA and other PFAS in the surface water and ground water sources and treated water of public water systems in New Jersey (see https://www.nj.gov/dep/dsr/dw/final_pfoa_report.pdf). The study focused on sample sites at 23 public water systems located near five facilities that had potentially used, handled, or manufactured PFOA, and included additional public water systems to expand the geographical extent of the study. Data was also collected for PFOS at these locations. In the study, the detection level of 0.004 µg/l for PFOA and PFOS was determined based on the analytical capability of the laboratory conducting the sample analysis. PFOA was detected at or above the detection level in 15 of the 23 public water systems sampled. PFOS was detected at or above this detection level in six of the 23 public water systems sampled.

A second occurrence study was conducted between July 2009 and February 2010, as a supplement to the 2006 study, to determine whether PFOA, PFOS, and eight other PFAS occur in drinking water sources throughout New Jersey, or only in the targeted study areas of the State near potential sources of contamination (see https://www.nj.gov/dep/watersupply/pdf/pfc-study.pdf). Sample sites in the 2009-2010 study were located throughout New Jersey and included 33 source water samples from 31 different public water systems supplied by both surface water and ground water sources. Similar to the

2006 study, the detection level for both PFOA and PFOS was set at 0.005 µg/l and was also based on the analytical capability of the laboratory conducting the sample analysis. PFOA was detected at or above 0.005 µg/l in 18 of the 33 samples. PFOS was found at or above 0.005 µg/l in nine of 33 samples. In response to these findings, the Department requested that all public water systems with detections of PFAS conduct voluntary follow-up monitoring to determine the extent that PFAS are present in the treated drinking water.

Pursuant to the Unregulated Contaminant Monitoring Rule (UCMR), the United States Environmental Protection Agency (USEPA) issues a new list every five years of up to 30 unregulated contaminants (meaning, no Federal MCL has been established for the contaminants) to be monitored by public water systems for purposes of collecting national drinking water occurrence data. In 2012, the USEPA issued the third list of unregulated contaminants, referred to as UCMR3 (see 77 FR 26,072), which was the first time that sampling for PFOA and PFOS was required nationwide. Monitoring was required at all public community water systems serving more than 10,000 people and certain public water systems serving 10,000 or fewer people (determined by the USEPA to be representative of small systems) during a 12-month period between January 2013 and December 2015.

Based on the UCMR3 data, PFOA was detected more than five times more frequently at or above the UCMR3 minimum reporting level of 0.02 µg/l in New Jersey public water systems than elsewhere in the U.S. Ten percent of New Jersey public water systems tested under UCMR3 had detections, compared to two percent of public water systems elsewhere in the U.S. Eighty-seven detections of PFOA at or above the minimum reporting level, ranging from 0.02

µg/l to 0.11 µg/l, were reported by 19 of the 175 public water systems in New Jersey that sampled for the contaminant (see https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#3). Twelve detections of PFOS at or above 0.04 µg/l, ranging from 0.043 µg/l to 0.098 µg/l, were reported by six of the 175 water systems. PFOS was found at or above 0.04 µg/l in 3.4 percent of water systems sampled, compared to 1.7 percent elsewhere in the U.S.

The Department has also sampled for PFAS as part of remedial investigations in specific locations around the State, including 992 private wells sampled as of June 2018. Through this targeted effort, PFOA was detected in 427 private wells, or 43 percent of the wells sampled, and 284 private wells were found to have levels of PFOA exceeding the proposed MCL of 0.014 µg/l. PFOS was found in 304, or 31 percent, of the private wells tested, with detections at 40 wells above the proposed MCL of 0.013 µg/l.

Institute Recommendation for PFOA MCL

In March 2017, after public comment and vote, the Institute recommended to the Department an MCL for PFOA of 14 nanograms per liter (ng/l), that is, 0.014 µg/l, which is the health-based level developed by the Health Effects Subcommittee. The Testing Subcommittee determined a practical quantitation level (PQL), the minimum concentration to which the contaminant can be reliably quantified within acceptable limits of uncertainty, for PFOA of six ng/l, that is, 0.006 µg/l, which is lower than the health-based level. The Treatment Subcommittee concluded that the availability of treatment to remove PFOA is not a limiting factor in achieving the health-based level. The Department has reviewed the Institute's recommendation and supporting data and reports and concurs with its recommendation. Consequently, based on the recommendation of the Institute, the Department is proposing an MCL for PFOA of 0.014 µg/l. The Institute recommendation and subcommittee reports, which are summarized below, are available at http://www.nj.gov/dep/watersupply/g_boards_dwqi.html.

Health Effects Subcommittee: The Health Effects Subcommittee conducted a literature search and solicited technical input from stakeholders and the public regarding the health effects of PFOA.

PFOA accumulates in the human body. Continued exposure to relatively low concentrations of PFOA in drinking water substantially increases the concentration of the contaminant in human blood serum over time, particularly when compared to the blood serum levels in the general population, believed to result primarily from exposures through food and consumer products. Elevated blood serum levels from drinking water exposures persist for many years after exposure ends. Human exposure to PFOA has been associated with health effects including increased cholesterol, increased liver enzymes (an indication of liver damage), decreased vaccine response, decreased birth weight, and testicular and kidney cancer. PFOA is transferred to breast milk, and infants drink more fluid (for example, breast milk or formula prepared with drinking water) on a body weight basis than older children and adults consuming contaminated drinking water from the same source. These higher exposures in infants are of concern because developmental effects from early life exposures to PFOA have been shown in animal toxicology studies to occur at lower exposures than other toxic effects of PFOA.

PFOA has also been demonstrated to cause liver, testicular, and pancreatic tumors in rats. Other toxicological effects in non-human primates and/or rodents include mortality, weight loss, and toxicity to the liver, immune system, kidney, and testes. Effects observed on the developing fetus and/or offspring include prenatal and neonatal mortality, decreased body weight, persistent liver toxicity, delays in reaching developmental milestones, such as eye opening, and persistent delays in the development of mammary glands.

The Health Effects Subcommittee developed its health-based level for PFOA based on both the non-carcinogenic and carcinogenic effects from exposure to the contaminant. For non-carcinogenic effects, the primary basis of the health-based level is increased liver weight in male mice exposed to PFOA for 14 days (Loveless et al., 2006). Increased liver weight is a well-established effect of PFOA in experimental animals and was observed at lower doses than most other effects, including toxicity to the immune system and most developmental effects.

Benchmark dose (BMD) modeling is an approach used in health risk assessment to estimate the dose below which a selected toxicological response is not expected to occur. The Health Effects Subcommittee used BMD modeling of PFOA levels in blood serum in Loveless et al. (2006) to determine the lower confidence limit on the BMD (BMDL) for the serum PFOA level resulting in a 10 percent increase in liver weight in mice. The Health Effects Subcommittee then determined a target human blood serum level of 14.5 ng/ml, the estimated blood serum level not likely to result in harmful effects during a person’s lifetime, by applying uncertainty factors to this BMDL serum PFOA level. The Health Effects Subcommittee also accounted for developmental effects in mice at doses far below those that caused increased liver weight, including delayed mammary gland development and persistent toxicity to the liver, through application of an uncertainty factor for potentially more sensitive effects.

Based on the findings in Lorber & Egeghy, 2011, the Health Effects Subcommittee utilized a clearance factor (which relates the level of PFOA in blood serum to an administered dose) of 1.4×10^{-4} L/kg/day to convert the target human serum level to a reference dose of two ng/kg/day. This reference dose is the estimated daily level of exposure to PFOA that is not likely to cause harmful effects through the course of a person's lifetime.

A default relative source contribution factor of 20 percent, which was used to account for sources of exposure to PFOA other than drinking water, and default adult exposure assumptions of 70 kg body weight and two l/day water consumption were used to develop a health-based level for non-carcinogenic effects of 0.014 µg/l.

The Health Effects Subcommittee determined a health-based level for carcinogenic effects was based on testicular tumor data from rats (Butenhoff, Kennedy, Chang, & Olsen, 2012). The BMDL for five percent tumor incidence is 2.36 mg/kg/day, and the corresponding cancer potency factor is 0.021 $(\text{mg/kg/day})^{-1}$. The dose in rats corresponding to a one in one million (1×10^{-6}) lifetime cancer risk, 48 ng/kg/day, was converted to the human equivalent dose of 0.4 ng/kg/day using a pharmacokinetic adjustment based on the ratio of half-lives in the two species. Using default drinking water assumptions of 70 kg body weight and two l/day water consumption, the health-based level based on the 1×10^{-6} lifetime cancer risk is 0.014 µg/l. This value is identical to the health-based level based on non-cancer endpoints discussed above. Based on its findings, the Health Effects Subcommittee recommended a health-based level of 0.014 µg/l.

Testing Subcommittee: The Testing Subcommittee identified acceptable methods for certified laboratories to analyze PFOA in drinking water samples and developed a PQL for PFOA. The PQL is the minimum concentration to which the contaminant can be reliably quantified within acceptable limits of uncertainty.

To accomplish this, the Testing Subcommittee reviewed the sampling data for PFOA to determine the availability of analytical methods with adequate sensitivity to reliably detect PFOA at the health-based level of 0.014 µg/l. The Testing Subcommittee reviewed data from Department studies conducted in 2006, July 2009, and February 2010, from follow-up monitoring described above, and from laboratories certified by the Department for the analysis of PFOA. In addition, the Testing Subcommittee reviewed data from laboratories that were approved by USEPA to analyze for PFOA as part of UCMR3 monitoring using EPA Method 537 (Determination of Selected Perflourinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS)) and were capable of detecting PFOA lower than the UCMR3 minimum reporting limit of 0.02 µg/l.

A laboratory must perform an initial demonstration of capability, which includes showing that a reporting limit can be consistently met. A reporting limit is the minimum concentration that can be reported as a quantified value for an analyte. A reporting limit must be greater than the lowest calibration standard, which is the lowest concentration that is used to calibrate the analyzing instrument. The reporting limit includes a measure of precision (how well the method gives the same result when a sample is tested repeatedly) and accuracy (a measure of confidence that describes how close a measurement is to its true value). In general, a laboratory must also statistically derive a method detection limit (MDL), that is, the minimum concentration that can be measured and reported with 99 percent confidence that the concentration is greater than zero. The MDL does not reliably quantify the exact concentration in a sample.

The Subcommittee evaluated five approaches for calculating the PQL, which are described in the Testing Subcommittee report (see https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixb.pdf). Two approaches considered the MDL that has historically been used by the Department to derive the PQLs for its MCLs. The other three approaches considered by the Testing Subcommittee considered the lower of the laboratory reporting limit or the lowest calibration standard. Because of the precision and accuracy criteria requirements for reporting limits, the Testing Subcommittee determined that deriving the PQL using reporting limit data was preferable to using the MDL data for PFOA.

The Testing Subcommittee considered an additional three factors to determine the PQL for PFOA using the reporting limit or lowest calibration standard, including (1) the mean of the reporting limits or lowest calibration standard, which was found to be 7.2 ng/L; (2) the median of the reporting limits or lowest calibration standard, which was found to be 5.0 ng/L; and (3) the bootstrap estimate of reporting limits or lowest calibration standard, which was found to be 6.0 ng/L. Bootstrap analysis is a technique that uses the samples at hand to generate additional statistically derived sample results that provide a normal distribution (also known as a bell curve) of the sample data, in this case reporting limits or lowest calibration standard. The Testing Subcommittee determined the median of these three factors to be six ng/L, or 0.006 µg/l. Therefore, the recommended PQL for PFOA is 0.006 µg/l.

Treatment Subcommittee: The Treatment Subcommittee researched treatment options for the long-chain PFAS, including PFOA, for which the Institute was investigating the development of MCLs, as the treatment options are expected to be the same because of the compounds' similar properties (for example, persistence in the environment, water solubility, similar structure, strong carbon-fluorine bonds, and high polarity). The Subcommittee reviewed the relevant literature, as well as pre- and post-treatment analytical results from drinking water plants with full scale treatment for long-chain PFAS, including some New Jersey plants. Long-chain PFAS can be removed from water with varying success using a number of treatment options, which are described in detail in the Subcommittee report. The most common treatment for removal of long-chain PFAS, such as PFOA and PFOS, both described in the literature and used at treatment plants, is granular activated carbon (GAC).

The Treatment Subcommittee recommended the use of GAC or an equally efficient technology, as identified in the Subcommittee report (see https://www.state.nj.us/dep/watersupply/pdf/pfna-pfc-treatment.pdf) and subsequent addendum (see https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixc.pdf), for treatment of PFOA. The Subcommittee concluded that the ability of treatment options to remove these contaminants was not a limiting factor in the development of the recommended

MCL of 0.014 µg/l for PFOA.

Institute Recommendation for PFOS MCL

In May 2018, after public comment and vote, the Institute recommended to the Department an MCL for PFOS of 13 ng/l, that is, 0.013 µg/l, which is the health-based level developed by the Health Effects Subcommittee. The Testing Subcommittee determined a PQL for PFOS of 4.2 ng/l, that is, 0.0042 µg/l, which is lower than the health-based level. The Treatment Subcommittee concluded that the availability of treatment to remove PFOS is not a limiting factor in achieving the health-based level. The Department has reviewed the Institute's recommendation and supporting data and reports and concurs with its recommendation. Consequently, based on the recommendation of the Institute, the Department is proposing an MCL for PFOS of 0.013 µg/l. The Institute recommendation and subcommittee reports, which are summarized below, are available at http://www.nj.gov/dep/watersupply/g_boards_dwqi.html.

The proposed amendments establish monitoring and reporting requirements that are based on an allowable amount of PFOS in drinking water. PFOS exists as an acid (perfluorooctanesulfonic acid) and an anion (perfluorooctane sulfonate). Although the Institute's recommendation references the anionic form, laboratories using the Department Sanctioned Analytical Methods for PFOS, including EPA Method 537, are required to report the acid form of the contaminant. Therefore, the proposed MCL for PFOS will reference the acid form of the contaminant.

Health Effects Subcommittee: The Health Effects Subcommittee conducted a literature search and solicited technical input from stakeholders and the public regarding the health effects of PFOS.

Similar to PFOA, PFOS accumulates in the human body. Continued exposure to relatively low concentrations of PFOS in drinking water substantially increases concentrations in human blood serum, particularly when compared to the blood serum levels in the general population believed to result primarily from exposures through food and consumer products. Elevated blood serum levels from drinking water exposures persist for many years after exposure ends. Human exposure to PFOS has been associated with health effects including decreased vaccine response and increased cholesterol. PFOS is transferred to breast milk, and infants drink more fluid (for example, breast milk or formula prepared with drinking water) on a body weight basis than older children and adults consuming contaminated drinking water from the same source. These higher exposures are of concern because infants may be particularly susceptible to PFOS toxicity.

PFOS has also been demonstrated to cause liver tumors in rats. Other toxicological effects in non-human primates and/or rodents include liver, immune system, endocrine, metabolic, and neurobehavioral toxicity. Effects observed on the developing fetus and/or offspring include decreased birth weight, neonatal mortality, structural malformations, liver and immune system toxicity, and changes in hormone levels.

Both non-carcinogenic and carcinogenic effects were evaluated in health-based level development. The primary basis of the health-based level is immune system suppression in mice exposed to PFOS, as measured by decreased plaque-forming cell response (Dong et al., 2009). Decreased plaque-forming cell response is a well-established effect of PFOS in mice that is analogous to decreased vaccine response in humans. It is more sensitive than other toxicological endpoints including liver and developmental effects.

The target human blood serum level of 23 ng/ml, which is the estimated blood serum level not likely to result in harmful effects during a lifetime, was determined by application of uncertainty factors to the level of PFOS in the blood serum of mice at which there was no statistically significant effect on plaque-forming cell response in Dong et al. (2009). Similar to PFOA and based on the findings in USEPA (2016), the Health Effects Subcommittee utilized a clearance factor of 8.1×10^{-5} L/kg/day to convert the target human serum level to a reference dose of 1.8 ng/kg/day.

A default relative source contribution factor of 20 percent, which was used to account for sources of exposure of PFOS other than drinking water, and default adult exposure assumptions of 70 kg body weight and two L/day water consumption were used to develop a health-based level for non-carcinogenic effects of 0.013 µg/l.

Cancer risk estimates were developed based on the incidence of liver tumor in females in a study of chronic toxicity in rats (Butenhoff et al., 2012). The human cancer potency factor based on intake dose was estimated as 9.0×10^{-6} $(\text{ng/kg/day})^{-1}$. This potency factor is too uncertain for use as the basis of a health-based level. Therefore, the human cancer potency factor was used to estimate the cancer risk at the health-based level of 0.013 µg/l. The risk was estimated as three in one million (3×10^{-6}), slightly above the cancer risk goal for New Jersey MCLs of one in one million (1×10^{-6}).

Based on its findings, the Health Effects Subcommittee recommended a health-based level of 0.013 µg/l.

Testing Subcommittee: The Testing Subcommittee identified acceptable methods for certified laboratories to analyze PFOS in drinking water samples and developed a PQL for PFOS.

As with PFOA, the Testing Subcommittee reviewed the PFOS data from Department studies conducted in 2006 and 2009-2010 and the follow-up monitoring described above to determine the availability of analytical methods with adequate sensitivity to reliably detect PFOS at the health-based level of 0.013 µg/l. In addition to these data, the Testing Subcommittee reviewed data from laboratories that were both approved by the USEPA to analyze for PFOS as part of UCMR3 monitoring using EPA Method 537 and capable of detecting PFOS lower than the UCMR3 minimum reporting limit of 0.04 µg/l. The Testing Subcommittee also reviewed data from laboratories certified by the Department for the analysis of PFOS.

The Testing Subcommittee evaluated several approaches for calculating a PQL, as described in the Testing Subcommittee report (see https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-b.pdf). The Testing Subcommittee compiled the inter-laboratory MDL, reporting limit, and low calibration standard data for PFOS and, as with PFOA, determined that the reporting limit data were preferable to using the MDL data. Bootstrap estimates of the upper confidence interval of a mean for the both the reporting limits and the low calibration standards were calculated to normalize the data. Although the bootstrap upper confidence value for the low calibration standard was lower than the calculated bootstrap upper estimate of the reporting limits, the

Testing Subcommittee recommended the bootstrap estimate of the low calibration standard, 0.0042 µg/l, as the PQL for PFOSbecause laboratory performance data demonstrated that 15 of the 16 laboratories were able to meet this recommended PQL 95 percent of the time.

Treatment Subcommittee: The Treatment Subcommittee researched treatment options for the long-chain PFAS, including PFOS, for which the Institute was investigating the development of MCLs, as the treatment options are expected to be similar because of the compounds' comparable properties (for example, persistence in the environment, water solubility, similar structure, strong carbon-fluorine bonds, and high polarity). The Treatment Subcommittee reviewed the relevant literature, as well as pre- and post-treatment analytical results from drinking water systems with full scale treatment for long-chain PFAS, including systems located in the State. Long-chain PFAS can be removed from water with varying success using a number of treatment options, which are described in detail in the Subcommittee report. As stated above, the most common treatment for long-chain PFAS removal is GAC.

The Treatment Subcommittee recommended that the use of GAC or an equally efficient technology, as identified in the Subcommittee report (see https://www.state.nj.us/dep/watersupply/pdf/pfna-pfc-treatment.pdf), subsequent addendum (see https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixc.pdf), and second addendum (see https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-c.pdf), should be considered for treatment of PFOS. The Subcommittee concluded that the ability of treatment options to remove these contaminants was not a limiting factor in the development of a recommended MCL of 0.013 µg/l for PFOS.

Agency for Toxic Substances and Disease Registry Draft Toxicological Profile for Perfluoroalkyls

In June 2018, the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR) published notice in the Federal Register (see 83 FR 28,849 at https://www.federalregister.gov/documents/2018/06/21/2018-13385/availability-of-draft-toxicological-profile-perfluoroalkyls) of its Draft Toxicological Profile for Perfluoroalkyls. PFOA and PFOS are discussed in the Draft Toxicological Profile (see https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237), and the Department believes that ATSDR's evaluation of PFOA and PFOS lends further support to the MCLs recommended by the Institute for the contaminants.

In the Draft Toxicological Profile, ATSDR concluded that there is sufficient information for risk assessment of PFOA and PFOS and developed an Intermediate Oral Minimal Risk Level (MRL) for the contaminants. The ATSDR defines an MRL as "an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure." MRLs are derived for acute (one to 14 days), intermediate (15 to 364 days), and chronic (365 days and longer) exposure durations.

As did the Institute, ATSDR concluded that human epidemiology studies provide evidence that exposure to PFOA and PFOS may be associated with multiple human health effects, including increases in serum lipids, decreased antibody response to vaccines, and liver damage. Both the Institute and the ATSDR also concluded that the human data are useful for identification of health effects of PFOA and PFOS, but that uncertainties about these data preclude their use in the dose-response component of the risk assessment. Thus, both agencies based their quantitative risk assessments on animal toxicology data.

The Institute's reference dose for PFOA is two ng/kg/day, which is based on increased liver weight in rats and mice (Loveless et al., 2006) with an additional uncertainty factor to protect for sensitive developmental effects that may occur at much lower doses. The ATSDR Intermediate MRL is three ng/kg/day, which is based on behavioral effects in mice (Onishchenko et al., 2011) and permanent effects on the bone structure of mice (Koskela et al., 2016) from developmental exposures.

Because Intermediate MRLs are intended to protect for a shorter exposure duration (15 to 364 days) than chronic (lifetime) reference doses, it is logical and consistent that the Intermediate MRL for PFOA would be the same or higher than the reference dose. Therefore, the Department believes the Intermediate Oral MRL for PFOA developed by ATSDR provides additional support for the Institute's PFOA reference dose.

For PFOS, the Institute's reference dose is 1.8 ng/kg/day, essentially identical to the ATSDR Intermediate MRL of two ng/kg/day. Both the Institute and ATSDR concluded that decreased immune response in mice is the most sensitive toxicological endpoint appropriate for use in PFOS risk assessment. The Institute's reference dose is based on decreased immune response in mice from Dong et al. (2011), while the ATSDR Intermediate MRL is based on delayed development in mouse offspring (Luebker et al., 2005) with an additional uncertainty factor to protect for more sensitive immune suppression effects observed in several mouse studies.

Similar to PFOA, the ATSDR Intermediate MRL for PFOS is intended to protect for a shorter exposure duration, and it is logical and consistent that the Intermediate MRL for PFOS would be the same as or higher than the reference dose. Therefore, the Department believes the Intermediate Oral MRL for PFOS developed by ATSDR provides additional support for the Institute’s reference dose for PFOS.

European Food Safety Authority Tolerable Weekly Intakes for PFOA and PFOS

In December 2018, the European Food Safety Authority (EFSA) published tolerable weekly intakes for PFOA of six ng/kg body weight per week and of 13 ng/kg body weight per week for PFOS. A tolerable weekly intake is an estimate of the amount per unit body weight of a potentially harmful substance or contaminant in food or water that can be ingested over a lifetime without risk of adverse health effects. These tolerable weekly intakes are based on daily intake values (analogous to reference doses) of 0.8 ng/kg body weight per day for PFOA and 1.8 ng/kg body weight per day for PFOS. The EFSA values are based on human epidemiological studies, while the Institute’s reference doses are based on animal toxicology data. For PFOA, EFSA concluded that increased serum total cholesterol was the critical effect, supported by reduced birth weight and increased serum levels of the liver enzyme alanine aminotransferase (ALT). The EFSA daily intake value for PFOA (0.8 ng/kg/day) is lower than the Institute’s PFOA reference dose (two ng/kg/day). For PFOS, EFSA concluded that increased serum total cholesterol in adults and decreased antibody response to vaccination in children were the critical effects, supported by reduced birth weight. The EFSA daily intake value for PFOS (1.8 ng/kg/day) is identical to the Institute’s PFOS reference dose. Accordingly, the EFSA daily intake values that are based on human data can be considered consistent with the

Institute’s reference doses that are based on animal data. Therefore, the Department believes that the EFSA tolerable weekly intakes and associated daily intake values provide additional support for the Institute’s reference doses for PFOA and PFOS.

Monitoring Framework for PFOA and PFOS (N.J.A.C. 7:10-5.2(a)5)

The Department is proposing monitoring for PFOA and PFOS that follows the schedule set forth in the National Primary Drinking Water Regulations (National Regulations) at 40 CFR 141.24(f) for volatile organic compounds (VOCs). Consistent with Federal monitoring requirements for all other organic contaminants, the monitoring requirements for PFOA and PFOS will apply to both public community and public nontransient noncommunity water systems.

In accordance with the USEPA’s basis for its monitoring frameworks for organic contaminants (see 54 FR 22,062), the Department has determined that the Federal VOC monitoring framework is appropriate for PFOA and PFOS because their occurrence in New Jersey is widespread, and they are likely to be found in source water in areas of industrial activity.

Public community and public nontransient noncommunity water systems will be required to monitor initially on a quarterly basis. The Federal VOC monitoring framework establishes a threshold of 0.0005 mg/l (which is equivalent to 0.5 µg/l) for all VOCs, at or below which a water system may request that their monitoring requirement be reduced to a frequency less than quarterly. If a system is monitoring at a reduced frequency and a detection occurs above this threshold, the system is required to increase monitoring to a quarterly basis.

The National Regulations do not establish an MCL for PFOA or PFOS, and the quarterly monitoring threshold for VOCs in the National Regulations is much higher than the Department's proposed MCL of 0.014 µg/l for PFOA and 0.013 µg/l for PFOS. Therefore, the Department is proposing that the threshold for quarterly monitoring for PFOA and PFOS be established at 0.002 µg/l, corresponding with the threshold value recently set for monitoring PFNA (see 50 N.J.R. 1939(a)). The threshold value for PFNA represents the concentration of the contaminant that is the median of the lowest calibration standard for the nine laboratories whose performance data were analyzed by the Institute for the determination of the PQL for PFNA.

The Department is proposing to require all public community water systems and public nontransient noncommunity water systems begin monitoring within the first quarter of 2021. This will allow laboratories time to purchase equipment, train staff, and obtain certification in New Jersey, as necessary, and to coordinate with public water systems to ensure samples are collected and reported in accordance with proposed requirements, thus avoiding monitoring violations.

Under the proposed amendments, public community and public nontransient noncommunity water systems must begin compliance monitoring for PFOA and PFOS within the first quarter of 2021. However, the amendments include a "grandfathering" provision that will allow a public water system that begins compliance monitoring for PFNA prior to 2021 to submit monitoring data for PFOA and PFOS. The Department will use this data to determine whether monitoring frequency can be reduced to an annual basis. The monitoring data must be collected after January 1, 2019, and reported to the Department on or before the effective date of the proposed amendments. The analytical method most often used to test PFNA, EPA Method 537, also detects PFOA and PFOS. Additionally, the proposed monitoring framework for PFOA and PFOS is the same as that for PFNA. Thus, public water systems are not likely to incur additional costs because all three contaminants can be tested for at the same time and treatment can be designed accordingly, when necessary. For these reasons, the Department anticipates, upon publication of the notice of proposal, water systems will begin monitoring for PFOA and PFOS in order to be eligible for reduced monitoring beginning in January 2021.

Consumer Confidence Report Requirements (N.J.A.C. 7:10-5.2(b))

The National Regulations require public community water systems to deliver a Consumer Confidence Report (CCR) each year to their customers, providing information on the quality of the water delivered by the system. The CCR summarizes information regarding sources used for drinking water, any detected contaminants, and any violations of the SDWA rules, including MCLs, as well as health effects information. Because the National Regulations do not establish an MCL for PFOA or PFOS, the Federal CCR rule does not specify the health effects language that must be included in the CCR if there is a detection of either compound. Therefore, the Department is proposing amendments at N.J.A.C. 7:10-5.2(b)4 to update the number of State-regulated contaminants for which there is no Federal MCL and for which the Department provides the health effects information for systems to include in the CCR. The proposed amendments include specific health effects language for PFOA and PFOS.

Testing of Private Wells Subject to Sale or Lease and of Newly Constructed Wells for Public Noncommunity Water Systems and Nonpublic Water Systems

<u>Testing of Newly Constructed Wells for Public Noncommunity Water Systems and Nonpublic Water Systems, N.J.A.C. 7:10-12.30</u>

N.J.A.C. 7:10-12.30 sets forth construction standards for public noncommunity water systems and nonpublic water systems, and one-time testing requirements for newly constructed systems to ensure that the water systems are aware of the quality of the untreated drinking water in the new source prior to use.

The Department is proposing to amend N.J.A.C. 7:10-12.30(b), which requires the testing of public noncommunity water systems for inorganics, VOCs, the synthetic organic compounds 1,2,3-trichloropropane, ethylene dibromide, and 1,2-dibromo-3-chloropropane, and radionuclides upon completion of construction, to test for the same parameters under N.J.A.C. 7:10-5 and 7, as is already required of a public community water system when constructing a new ground water source (see N.J.A.C. 7:10-11.7(h)5). With these amendments, newly constructed public noncommunity water systems will be tested for PFOA, PFOS, and PFNA.

By definition, nonpublic water systems include systems providing potable water to individual dwellings, N.J.A.C. 7:10-1.3, which in most cases are private wells. Therefore, the water quality testing requirements at N.J.A.C. 7:10-12.30(c) for nonpublic water systems are the same as those applicable under the PWTA rules, N.J.A.C. 7:9E, for private wells subject to sale or lease. As described in more detail below with respect to the proposed amendments to the PWTA rules at N.J.A.C. 7:9E-2.1, the Department is proposing corresponding amendments at N.J.A.C. 7:10-12.30 to ensure the testing requirements in the two sets of rules are aligned.

Testing of Private Wells Subject to Sale or Lease, N.J.A.C. 7:9E-2.1

The Private Well Testing Act (PWTA), N.J.S.A. 58:12A-26 et seq., requires the testing of individual private wells as a condition of sale or lease of properties served by private potable wells to ensure that prospective purchasers and lessees are made aware of the quality of the drinking water source. The PWTA currently requires testing for a variety of parameters including, but not limited to, total coliform bacteria, Escherichia coli (*E. coli*), gross alpha particle activity, inorganic compounds, volatile organic compounds, and lead. The PWTA authorizes the Department to develop a list of additional parameters that the Department deems significant in each county or in any specific area within a county that must be tested as part of any water test to be conducted in accordance with the PWTA.

The Department is proposing amendments to the PWTA rules at N.J.A.C. 7:9E-2.1 to require owners of private wells subject to sale or lease to test for PFNA, PFOA, and PFOS starting 18 months after the amended rules are effective. This will allow enough time to address the technical complexity of sampling and analysis for these parameters and to ensure there is sufficient laboratory capacity available to meet testing needs.

All public community and public nontransient noncommunity water systems will be required to monitor and test for PFOA and PFOS to ensure water provided to consumers meets the MCLs. Given the recommendation of the Institute and the health effects associated with these two contaminants, as described above, the Department is proposing to require testing for

PFOA and PFOS under the PWTA rules.

Because the analytical method commonly used to test for PFOA and PFOS also detects PFNA, sampling for PFNA in addition to PFOA and PFOS is not likely to incur additional costs. Since exposure to PFNA is associated with negative health effects including toxicity to the liver, immune system, kidney, and testes and effects on the developing fetus or offspring, the Department is proposing to require testing for PFNA under the PWTA rules.

As mentioned above in the discussion of the proposed MCLs for PFOA and PFOS, the high occurrence of these contaminants in drinking water in New Jersey has been documented through the remediation of ground water at contaminated sites. If treatment for the contaminant is installed, the water must be sampled to ensure the treatment is effective in removing the contamination.

The Department anticipates approximately 8,000 samples from private wells will require new testing for PFOA, PFOS, and PFNA annually due to sale or lease in addition to those parameters currently sampled. Consequently, additional laboratories will need to obtain certification from the Department in order to maintain adequate laboratory capacity to meet the sampling requirements of both public water systems and private wells. Under the Regulations Governing the Certification of Laboratories and Environmental Measurements at N.J.A.C. 7:18, laboratories seeking certification for the testing of PFOA, PFOS, and PFNA will need to purchase and train in the operation of new testing instrumentation, and operate the new instrumentation for a minimum of six months prior to applying to the Department for certification. In addition, the Department requires certification for sampling conducted pursuant to the PWTA to train samplers in the appropriate collection and handling procedures. Thus, the Department estimates the timeframe for a laboratory to obtain the necessary certification(s) will be a minimum of 12 months.

Proposed Ground Water Quality Standards for PFOA and PFOS

The Department is proposing to amend the Ground Water Quality Standards (GWQS) at N.J.A.C. 7:9C to establish a specific ground water quality standard for PFOA of 0.014 µg/l and a specific ground water quality standard for PFOS of 0.013 µg/l.

The GWQS rules, N.J.A.C. 7:9C, establish the designated uses for all ground waters of the State, classify the ground waters based on the designated uses, and specify the ground water quality criteria that must be met to support the designated uses. N.J.A.C. 7:9C-1.7 sets forth the ground water quality criteria applicable to each class and subclass of ground water identified and described at N.J.A.C. 7:9C-1.5. The ground water quality criteria for Class II-A ground waters, which are ground waters for which the primary designated use is potable water supply, are established under N.J.A.C. 7:9C-1.7(c). The specific ground water quality criteria for constituent compounds and parameters (such as color and pH) in Class II-A ground water are listed in N.J.A.C. 7:9C Appendix Table 1.

N.J.A.C. 7:9C Appendix Table 1 contains all the constituents in Class II-A ground water for which the Department has derived specific ground water quality criteria and adopted through rulemaking. N.J.A.C. 7:9C Appendix Table 1 includes, for each constituent, the chemical name of the constituent, its Chemical Abstract Services Registry Number (CASRN), the numeric ground water quality criterion established in accordance with N.J.A.C. 7:9C-1.7(c)3, and the PQL selected or derived in accordance with N.J.A.C. 7:9C-1.9(c)3. For each constituent, the higher of the PQL and the criterion is the applicable ground water quality standard, in accordance with N.J.A.C. 7:9C-1.9(c).

The Department establishes specific ground water quality criteria for constituents in Class II-A ground waters in two ways: (1) where an MCL for a constituent is promulgated in the Department's SDWA rules, N.J.A.C. 7:10, the health-based level used to establish the MCL is the specific ground water quality criterion for that constituent (see N.J.A.C. 7:9C-1.7(c)3i); and (2) for all other constituents, the Department develops criteria based on the weight of evidence available regarding the particular constituent's carcinogenicity, toxicity, public welfare, or organoleptic effects, as appropriate for the protection of potable water (see N.J.A.C. 7:9C-1.7(c)3ii). Because both PFOA and PFOS fall into the first category, the health-based level used to establish the respective MCLs are the specific ground water quality criteria for these constituents.

The Department derives PQLs for constituents listed in N.J.A.C. 7:9C Appendix Table 1 using the most sensitive analytical method providing positive constituent identification from MDL data from the New Jersey Department of Health multiplied by five or, when such data is not available, from laboratory performance data that has been evaluated by the Department using the method of Sanders, Lippincott, and Eaton in accordance with N.J.A.C. 7:9C-1.9(c)3ii(2). In either case, the PQL is rounded to one significant figure (see N.J.A.C. 7:9C-1.9(c)3). Sufficient interlaboratory performance data was collected from 13 laboratories to support derivation of a PQL using a modified EPA Method 537 for ground water and Department Sanctioned Analytical

Methods (DSAMs). Both PFOA and PFOS appear as listed parameters in proprietary method standard operating procedures from three laboratories.

The Department is proposing to add specific ground water quality criteria, PQLs, and specific ground water quality standards for PFOA and PFOS to N.J.A.C. 7:9C Appendix Table 1. The proposed ground water quality criterion for PFOA is 0.014 µg/l, which is the health-based level used to establish the MCL for PFOA, in accordance with N.J.A.C. 7:9C-1.7(c)3i. The proposed PQL for the PFOA ground water quality criterion is 0.006 µg/l, which was derived in accordance with N.J.A.C. 7:9C-1.9(c)3i and ii using the bootstrap 95 percent upper confidence limit of the reported lowest calibration standard and is consistent with the recommendations of the Institute’s Testing Subcommittee for a PQL for PFOA in drinking water, as discussed above. Because the higher of the ground water quality criterion and the PQL is the constituent standard, the applicable ground water quality standard for PFOA will be 0.014 µg/l.

The proposed ground water quality criterion for PFOS is 0.013 µg/l, which is the health-based level used to establish the MCL for PFOS, in accordance with N.J.A.C. 7:9C-1.7(c)3i. The proposed PQL for PFOS is 0.004 µg/l, which was derived in accordance with N.J.A.C. 7:9C-1.9(c)3i and ii using the bootstrap upper confidence limit of the low point calibration curve rounded to one significant figure and is consistent with the recommendations of the Testing Subcommittee for a PQL for PFOS in drinking water. Because the higher of the ground water quality criterion and the PQL is the constituent standard, the applicable ground water quality standard for PFOS will be 0.013 µg/l. Similar to the proposed MCL for PFOS, the proposed ground water quality criterion will reference the acid form of the contaminant.

Once adopted, the new ground water quality standards for PFOA and PFOS will also serve as the minimum remediation standards for cleanup of contaminated ground water in accordance with N.J.A.C. 7:26D-2.2(a).

The GWQS, at N.J.A.C. 7:9C-1.7(c)2, allow the Department to establish interim specific ground water quality criteria prior to the adoption of specific criteria for Class II-A constituents that are not listed in N.J.A.C. 7:9C Appendix Table 1. On January 17, 2019, the Department posted on its website technical documents in support of draft interim specific ground water quality criteria and draft interim PQLs for PFOA and PFOS and requested comments on or before February 19, 2019. The Department considered the public comments received and in March 2019, posted to its website at https://www.state.nj.us/dep/wms/bears/gwqs.htm interim specific ground water quality standards for PFOA and PFOS, in accordance with N.J.A.C. 7:9C-1.7(c)2, 3, and 4 and 1.9(c)1 and 3.

Proposed Addition of PFOA and PFOS to Discharges of Petroleum and Other Hazardous Substances (DPHS) Rules (N.J.A.C. 7:1E), Appendix A: List of Hazardous Substances

N.J.A.C. 7:1E Appendix A to the Discharges of Petroleum and Other Hazardous Substances (DPHS) rules lists all the substances that, in addition to petroleum and petroleum products, are classified hazardous substances under the Spill Compensation and Control Act (Spill Act), N.J.S.A. 58:10-23.11 et seq. The Department is proposing to add the acidic and anionic forms of PFOA and PFOS and their respective Chemical Abstract Services (CAS) numbers to the DPHS Appendix A List of Hazardous Substances. The Department is also proposing to add a listing that includes the salts and esters of each contaminant. Similarly, the Department is proposing to add the anionic form of PFNA and a listing that includes the contaminant's salts and esters.

The Department has developed an extensive list of PFNA, PFOA, and PFOS salts and esters, as well as mixtures that contain these substances, that may be or have been used or stored commercially and industrially. The Department intends to make this list available electronically. This will assist owners or operators of major facilities who store PFNA, PFOA, and PFOS in identifying related salts and esters based on listed CAS numbers and that must be reported to the Department.

As discussed above, PFOA and PFOS are fully fluorinated alkane molecules historically used as a processing aid in the emulsion process used to make fluoropolymers, which are high-performance plastics that are resistant to harsh chemicals and high temperatures. They are also found in aqueous film forming foam, surfactants, and stain resistant coatings, and are used in metal plating and finishing. PFOA and PFOS are extremely persistent in the environment and soluble and mobile in water. PFOA and PFOS are developmental toxicants, liver toxicants, and immune system toxicants that are possibly carcinogenic and bioaccumulate in humans.

The Spill Act establishes a comprehensive scheme to regulate the transfer and storage of hazardous substances and imposes strict liability for cleanup and removal costs as a result of any discharge of a hazardous substance. A related statute, the Brownfield and Contaminated Site Remediation Act, N.J.S.A. 58:10B-1 et seq., additionally requires the discharge of a hazardous substance to be remediated by, among other persons, the discharger of a hazardous substance or a person in any way responsible for a hazardous substance under the Spill Act that has discharged a hazardous substance (see N.J.S.A. 58:10B-1.3(a)). The Spill Act also establishes the Spill Compensation Fund (Spill Fund) which may provide compensation to eligible applicants that have been damaged by a discharge.

The addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances will also require owners and operators of industrial establishments who are subject to the Industrial Site Recovery Act (ISRA), N.J.S.A. 13:1K-6 et seq., to remediate applicable sites prior to their sale or transfer or upon cessation of business operations. This will ensure that hazardous substances existing at industrial sites are remediated prior to their transfer to a new owner or operator. The inclusion of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances will impose upon all responsible parties, regardless of the environmental statute they are liable under, the obligation to identify and remediate PFOA and PFOS discharges.

To implement the Spill Act, the Department has promulgated four sets of rules: (i) rules establishing reporting, design, operational, and maintenance requirements applicable to major facilities (facilities and vessels having storage capacity for hazardous substances at or above certain defined thresholds) in the DPHS rules at N.J.A.C. 7:1E, and a notification requirement for any person responsible for a discharge to notify the Department if they know of or should reasonably know of a hazardous substance discharge; (ii) rules regarding the processing of claims under the Spill Act for damages from the discharge or threatened discharge of a hazardous substance in the Processing of Damage Claims Pursuant to the Spill Compensation and Control Act rules at N.J.A.C. 7:1J; (iii) rules for the remediation of discharges in the Administrative Requirements for the Remediation of Contaminated Sites at N.J.A.C. 7:26C; and

(iv) rules governing the technical requirements for the remediation of discharges in the Technical Requirements for Site Remediation at N.J.A.C. 7:26E.

The addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances will render the owners and operators of major facilities that handle PFOA or PFOS subject to all of the discharge prevention and control requirements of the Spill Act and DPHS rules, make available hazardous substance-based funding sources, such as the Spill Fund, for the cleanup and removal of discharges of PFOA and PFOS, enable payment of eligible damage claims regarding discharges of PFOA and PFOS pursuant to the Spill Compensation and Claims rules, and require persons with Spill Act liability to remediate discharges of PFOA and PFOS and reimburse the Department for any clean-up and removal costs incurred.

By 2002, the primary manufacturer of PFOS phased out its production voluntarily, and through the USEPA's 2010/2015 PFOA Stewardship Program, eight major leading companies have phased out the use of PFOA, their precursor chemicals, and related higher homologues (see http://www.epa.gov/oppt/pfoa/pubs/stewardship/). However, various mixtures of these substances are still used by secondary industries, including in aqueous film forming foam for firefighting. In addition, because environmental contamination caused by PFOA and PFOS is anticipated to continue for the foreseeable future due to their extreme persistence in the environment, formation from precursor substances, and continued manufacturing in other nations, the Department has determined that PFOA and PFOS should be included in the DPHS Appendix A List of Hazardous Substances.

Proposed Addition of PFNA, PFOA, and PFOS to the New Jersey Pollutant Discharge Elimination System (NJPDES) Rules (N.J.A.C. 7:14A), Chapter 4, Appendix A, Permit Application Testing Requirements/Pollutant Listings and Requirements for Discharges to Ground Water

N.J.A.C. 7:14A-4 establishes the application requirements for a New Jersey Pollutant Discharge Elimination System (NJPDES) permit or approval from the Department for the discharge of pollutants to waters of the State. N.J.A.C. 7:14A-4 Appendix A establishes the monitoring requirements for NJPDES permit applications. N.J.A.C. 7:14A-4 Appendix A is organized into tables indicating industrial category, pollutant type and testing method. N.J.A.C. 7:14A-7 establishes application requirements for a NJPDES permit that authorizes discharges of pollutants to ground water (NJPDES DGW permit).

Under N.J.A.C. 7:14A-7.6, all permits that authorize discharges to ground water must ensure that the discharge does not violate the Ground Water Quality Standards. Accordingly, the Department is proposing to add a new Table VI to N.J.A.C. 7:14A-4 Appendix A, Toxic Pollutants and Hazardous Substances Required to be Identified by Existing Dischargers if Expected to be Present, *Per- and Polyfluoroalkyl Substances (PFAS)*, which will include PFNA, PFOA, and PFOS. Facilities that discharge these contaminants to ground water will be required to sample and analyze for them; at a minimum frequency of one time per year. The Department is also adding the contaminants to the list of parameters required to be included with the information submitted to the Department in an application for a NJPDES DGW permit under N.J.A.C. 7:14A-7.9.

Social Impact

The Department anticipates that the proposed amendments will have an overall positive social impact. The proposed amendments to the SDWA rules at N.J.A.C. 7:10 establish an MCL for PFOA of 0.014 µg/l and an MCL of 0.013 µg/l for PFOS. The Department's policy of setting standards designed to protect public health will result in a positive social impact not only to the public, but also to the water supply industry, which strives to provide the best quality water possible to customers. The proposed amendments set forth monitoring requirements to ensure public community water systems and public nontransient noncommunity water systems consistently monitor the water to ensure compliance with the MCLs and treat to remove the contaminant as necessary. Public community water systems will also be required to sample any newly constructed wells for PFOA and PFOS. This requirement will reduce human exposure to this contaminant in drinking water and have a positive social impact by protecting consumers from the health effects associated with PFOA and PFOS. Further, the proposed amendments, which establish the information regarding these contaminants to be included in the CCR, will ensure that customers of public community water systems are informed on the quality of their water.

The proposed amendments also require all wells subject to the PWTA rules at N.J.A.C. 7:9E, which are sampled as part of a real estate transaction, and all wells sampled in order to comply with the lessor requirements of the PWTA, to be analyzed for PFOA, PFOS, and PFNA.

The proposed testing requirements described above will have a positive social impact by ensuring that all buyers and sellers of real property are provided with information regarding the quality of onsite potable well water in order to protect themselves from exposure to these contaminants, if detected. Similarly, landlords of property where the source of potable water is a well subject to the PWTA will also be required to test for these contaminants and to advise tenants accordingly.

The proposed amendments to the PWTA rules will also have a positive social impact resulting from the collection of more data on the quality of water Statewide. The Department will utilize the data to ascertain ground water quality throughout the State and to provide information to counties, municipalities, other government entities, and the public. This will assist the Department and local health authorities in identifying areas of health concerns and directing resources to reduce or eliminate human exposure to drinking water contaminants in those areas.

The proposed amendments also require all new public nontransient noncommunity and new nonpublic water systems subject to the SDWA rules at N.J.A.C. 7:10-12.30 to be analyzed for PFOA, PFOS, and PFNA. The additional sampling requirements will have a positive social impact because elevated levels could lead to the removal of these contaminants, thereby reducing exposure to consumers.

In New Jersey, approximately 40 percent of the potable water comes from ground water sources. Of the estimated total State population of 8.9 million, about 1.8 million people rely on ground water from about 3,375 public water supply wells, and about 1.2 million people rely on ground water from about 385,000 private domestic potable wells. The proposed amendments to the GWQS promulgating new specific ground water quality standards for PFOA and PFOS will ensure that current and scientifically based standards to protect, maintain, and restore ground water quality are in place.

There will be a positive social impact from the proposed addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances because, as discussed above, owners and operators of major facilities that handle PFOA or PFOS will be subject to all of the discharge prevention and control requirements of the Spill Act and DPHS rules, any person(s) responsible for a discharge of PFOA or PFOS who knows or reasonably should know of the discharge must immediately notify the Department, stop the discharge, and contain, mitigate, cleanup, and remove the discharge, and owners and operators of industrial establishments who are liable under ISRA will be required to, among other things, undertake an investigation of their industrial establishment and remediate any discharges of PFOA or PFOS that are discovered prior to sale or transfer of the industrial establishment or upon cessation of business operations. Further, the addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances will make available hazardous substance-based funding sources, such as the Spill Fund, for the cleanup and removal of PFOA and PFOS discharges under the Spill Act and enable payment of eligible damage claims regarding PFOA and PFOS discharges pursuant to the Spill Compensation and Claims rules.

The Department anticipates that the social impacts from the proposed amendments to the NJPDES rules will be positive and similar or the same as those from the amendments to the SDWA rules and the GWQS. A permittee that discharges PFOA and/or PFOS to ground water will be required to monitor annually for these pollutants. If the contaminants are detected above the applicable ground water quality standard, then the permittee will be required to remove the pollutant(s) from its waste stream. If the permittee is unable to remove the pollutant(s) from its waste stream, then treatment, which will likely include the addition of GAC, for the removal of PFOA and/or PFOS will be required. More frequent monitoring for these pollutants may also be required.

Economic Impact

Costs incurred to comply with the SDWA rules are standard business expenses for public water systems. The costs incurred as a result of the proposed amendments will be ultimately passed on to consumers and are necessitated by the statutory mandate at N.J.S.A. 58:12A-2 to ensure the provision of safe drinking water and to protect public health. The prevention of the known negative effects on human health will create eventual savings in avoided medical costs and avoided losses to productivity associated with illness.

Because currently there are no Federal or State drinking water quality standards or routine monitoring requirements for these contaminants, the proposed MCLs for PFOA and PFOS are expected to have an economic impact. The costs to public community and public nontransient noncommunity water systems as a result of the proposed amendments fall into two categories: monitoring expenses, which the water systems will incur in order to routinely test the quality of the drinking water for PFOA and PFOS; and expenses related to the installation and maintenance of adequate treatment to meet the new MCLs, if necessary.

As of 2018, the average cost of the analysis (EPA Method 537) for the group of PFAS that includes PFOA and PFOS was approximately $300.00 per sample. The Department expects the cost for sample analysis to diminish with time after an MCL is adopted, as more laboratories are certified by the Department for analysis of these contaminants and as market competition increases. In addition, as the analytical method commonly used to detect PFOA and PFOS is the same, sampling for both contaminants is routinely done together, which will decrease cost.

As a result of this rulemaking, up to 506 public community water systems and 715 public nontransient noncommunity water systems will be required to monitor for PFOA and PFOS. Public water systems without their own source that purchase all their water from another public water system will not be required to collect a sample. Under the SDWA rules, monitoring is required to be conducted at the point of entry to the distribution system. Monitoring includes initial monitoring, which is the minimum monitoring required for all public community and public nontransient noncommunity water systems, regardless of whether there is a detection, and monitoring associated with installed treatment. Water systems with sample results that comply with the proposed MCLs are permitted to reduce monitoring frequency to as low as once every three years, thereby reducing monitoring costs. The number of points of entry is dependent on the size and nature of the water system. A small water system may have one point of entry, while a large water system could have 25 or more points. As of January 2019, there are approximately 1,126 active entry points for public community water systems and 726 active entry points for public nontransient noncommunity water systems. Based on the costs associated with sampling discussed above, the Department estimates that a public water system will spend approximately $1,200 in the first year for quarterly sampling for the new

MCLs at each point of entry. The Department further estimates that a public water system that monitors at a reduced monitoring frequency will spend as little as $300.00 per point of entry every three years.

As discussed above, the analytical method commonly used to test for PFOA and PFOS, EPA Method 537, also detects PFNA. Thus, as systems are required to monitor for PFNA, the Department anticipates little to no additional cost to monitor for PFOA and PFOS.

The Department maintains a database that includes results of the analysis of drinking water for PFAS, including PFOA and PFOS. The results contained in this database include the results of Federally required sampling conducted between 2013 and 2015 under UCMR3, results of 2006 and 2009-2010 Department studies, and results of other sampling conducted by public water systems and third parties.

As of December 2018, the Department is aware of 39 systems of 224 water systems sampled that had detections above the recommended MCL for PFOA. If this rate of contamination is consistent throughout the State, the Department estimates that 207 systems (17 percent of 1,221 public community and nontransient noncommunity systems) may have detections of PFOA over the recommended MCL. Based on the results of Federally required sampling conducted between 2013 and 2015, PFOA was found much more frequently at levels above 0.02 µg/l in New Jersey (10.9 percent of all sampled water systems) than elsewhere in the U.S. (2.1 percent of all sampled water systems). Of the 39 systems with detections of PFOA, the Department is aware of 11 that have taken action to reduce concentrations below 0.014 µg/l.

The Department is also aware of 19 systems of 224 water systems (sampled as of December 2018) that had detections above the recommended MCL for PFOS. The Department estimates that 97 systems (eight percent of 1,221 public community and public nontransient noncommunity systems) may have detections of PFOS over the recommended MCL. Of the 19 systems with detections of PFOS, four have taken action to reduce concentrations below 0.013 µg/l. However, 16 systems with detections of PFOS also detected PFOA. Therefore, the Department believes that combined treatment of PFOA and PFOS may be possible for these systems.

If a public community or public nontransient noncommunity water system detects PFOA and/or PFOS above the proposed MCLs, the system will be required to take action to reduce levels below the MCLs, which may include the utilization of an alternate water source or the installation of treatment. The cost of treatment, including costs for construction, operation, and maintenance, varies based on the type of treatment selected, site conditions, initial concentration of the contaminant, the presence of other contaminants and organic materials in the raw water, the need for pre-treatment, and the size of the water system. A water system will be required to conduct quarterly compliance monitoring at the point of entry where treatment is installed and, as a condition of a treatment permit, to conduct sampling to ensure that the treatment is removing the target contaminants.

Granular activated carbon (GAC) was identified by the Institute as the best available technology for the removal of PFAS in its 2015 report (see https://www.state.nj.us/dep/watersupply/pdf/pfna-pfc-treatment.pdf). This finding was reiterated for PFOA in the Institute report addendum (see https://www.state.nj.us/dep/watersupply/pdf/pfoa-appendixc.pdf) and for PFOS in the Institute's second addendum (see https://www.state.nj.us/dep/watersupply/pdf/pfos-recommendation-appendix-c.pdf). According to Department records, the estimated cost of installing a GAC treatment system has ranged from $500,000 to $1 million for a one million-gallon-per-day (one MGD) treatment plant (serving about 10,000 people). Consistent with this estimate, a carbon system recently designed for a 16 MGD water supply plant is estimated to cost $16 million. Costs associated with the operation and maintenance of a GAC system, which include periodic regeneration or replacement of the carbon, vary depending on such factors as the background quality of the source water, the size of the installation, and the concentration of the target contaminant in the source water. Operating costs are estimated to be approximately $80,000 per year for a one MGD plant but can increase depending on the number of wells requiring treatment and the level of contamination, as carbon filters will need to be replaced more frequently in case of higher levels. However, as treatment technologies develop and become more readily available, the costs of treatment are likely to decrease over time. In addition, certain forms of GAC can treat for PFNA, PFOA, and PFOS collectively. Therefore, the Department anticipates that water systems that have already installed or are installing these forms of GAC for the treatment of PFNA will incur little to no additional cost for the treatment of PFOA and/or PFOS. The Department also offers a low interest loans to eligible water systems through the New Jersey Water Bank, as treatment of emerging contaminants such as PFNA, PFOA, and PFOS is now a high priority for State funding.

The Department is proposing to require owners of private wells and nonpublic water systems to test for PFOA, PFOS, and PFNA Statewide. For private well owners, testing occurs when a property changes hands, or every five years for landlords. New testing costs for nonpublic water systems Statewide will be incurred upon completion of well construction. The average cost of testing for PFOA, PFOS, and PFNA is approximately $300.00 per sample. Treatment is required for nonpublic water systems but is not required for private well owners under the PWTA. As of 2019, a small GAC point-of-entry treatment (POET) system that removes PFAS, costs between $1,500 and $2,000 to install. The National Sanitation Foundation's International Protocol P473 certification evaluates whether a Point Of Use (POU) treatment system can reduce levels of PFOA and PFOS. As of February 2019, there are approximately 75 POU treatment systems that have been certified under the protocol (see http://info.nsf.org/Certified/DWTU/). In addition, the listing of these contaminants in the DPHS Appendix A List of Hazardous Substances enables an eligible person who has incurred damages due to a discharge of PFOA, PFOS, and PFNA pursuant to the Processing of Damage Claims Pursuant to Spill Compensation and Claims rules, N.J.A.C. 7:1J, to seek reimbursement for, among other things, the cost of remediating the contamination, provided the person is not the responsible party.

Local health agencies are likely to incur costs associated with the increase of water systems and private wells that will be required to monitor and test as described above. These include costs associated with permitting, inspection, and enforcement for noncommunity water systems.

The proposed ground water quality standards for PFOA and PFOS are based on the health-based levels recommended by the Institute. Accordingly, public health will be protected and costs related to potential health impacts due to exposure to these substances in the environment will be limited. The proposed ground water quality standards for PFOA and PFOS will likely result in new or additional costs related to remediation or treatment of water to be discharged under a NJPDES DGW permit. However, the actual economic impact on persons remediating contaminated sites, or on facilities discharging to ground water pursuant to a NJPDES DGW permit, is site-specific and will depend on many factors, such as the portion of the plume that must be remediated, the volume and characteristics of wastewater being discharged, the specific contaminants in the wastewater or ground water, the number of monitoring wells required and the length of time needed for sampling, and the type of treatment currently being implemented for other contaminants, including PFNA, which is already regulated under the GWQS and DPHS rules.

The Department anticipates that the changes to the NJPDES rules will affect approximately 60 dischargers with NJPDES DGW permits. If monitoring indicates concentrations of PFOA, PFOS, or PFNA above the ground water quality standard in the effluent, then the discharger of this effluent will be required to locate the source(s) of the contaminant and remove it from the waste stream. If the elimination of the source is not possible, treatment will be required. Because the dischargers affected by this rulemaking must already meet the ground water quality standards, which are at least as stringent as the MCLs, the cost of additional treatment required by the rulemaking, is expected to be similar to the cost of treatment for drinking water.

As of December 2018, there were a total of 13,707 active site remediation cases in New Jersey. Ground water contamination has been found in approximately 40 percent of those cases. The proposed ground water quality standards for PFOA and PFOS will be applied to all new and existing cases in which either of these constituents may be present per the Technical Requirements for Site Remediation at N.J.A.C. 7:26E.

The Department is aware of 14 active site remediation cases in which PFOA was detected at concentrations above the proposed specific ground water quality standard. Of these 14 cases, PFOS was detected at concentrations above the proposed specific ground water quality standard at nine sites. While the proposed ground water quality standards might necessitate remediation of a more extensive area of ground water contamination, which could result in additional remediation costs, including, for example, costs for additional monitoring wells, sampling, and treatment of ground water, the proposed standards will be more protective of public health. In cases where PFNA is currently present, little additional cost is likely to be incurred as the sampling, laboratory analysis, and some treatment methods are the same for all the PFAS and will already have been implemented to comply with the ground water quality standard for PFNA promulgated in January 2018.

Cost for remediation will vary based on site specific circumstances. The Department estimates that the costs of installing a GAC pump and treatment system for ground water remediation will be similar to treatment costs for water systems. As stated above, costs associated with the operation and maintenance of a GAC system, which include periodic regeneration or replacement of the carbon, vary depending on such factors as contaminant loading, the background quality of the source water, the size of the installation, and the concentration of the target contaminant in the source water. Additionally, certain forms of GAC can treat PFNA, PFOA, and PFOS, collectively. Therefore, permitted dischargers or responsible parties who have already installed these forms of GAC for the treatment of PFNA will incur little to no additional cost for the treatment of PFOA and/or PFOS.

The addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances will, in accordance with the Spill Act, enable an eligible public water system or person who has incurred damages because of a PFOA or PFOS discharge to seek reimbursement for, among other things, the cost of remediating the PFOA or PFOS contamination, provided the person is not the responsible party. Listing PFOA and PFOS will also enable the Department to require the discharger of a hazardous substance or a person in any way responsible for a discharge of PFOA or PFOS to remediate the discharge and use hazardous substance-based funding sources, as available and necessary, to conduct remediation, and to undertake cost recovery actions against the responsible party or parties. It will also require owners and operators of industrial establishments who are liable under ISRA to, among other things, investigate their industrial establishment and remediate any discharges of PFOA or PFOS that are discovered prior to their sale or transfer or upon cessation of business operations.

Any existing facility that is deemed a major facility under the DPHS rules that uses or stores the acidic and anionic forms of PFOA or PFOS or their salts and esters will potentially incur the costs relating to preparing and submitting discharge prevention, containment and countermeasure plans, and discharge cleanup and removal plans; secondary containment for storage tanks, pipes, and process areas; and related requirements with respect to the use or storage of PFOA and PFOS. Under the DPHS rules, major facilities are facilities that have a total aggregate combined storage capacity of 20,000 gallons or more of a hazardous substance. PFOA and related substances has been phased out pursuant to USEPA's 2010/2015 PFOA Stewardship Program (see Summary above). However, secondary industries that use these substances, such as those producing aqueous film forming foam for firefighting, may have existing stocks of materials containing PFOA or PFOS that meet the criteria of a major facility.

Environmental Impact

The Department anticipates a positive impact on the environment as a result of the proposed rules, which set forth MCLs and ground water quality standards for PFOA and PFOS, and new monitoring requirements in NJPDES DGW permits for PFOA, PFOS, and PFNA. The proposed MCLs will have a positive environmental impact by requiring public water systems to address contamination from water sources that are used for water supply. The proposed ground water quality standards will have a positive environmental impact by establishing scientifically based standards to protect, maintain, and restore ground water quality. Permitted discharges to ground water and remediation of contaminated ground water will be required to achieve these health-based standards, which will reduce potential adverse impacts to public health and the environment from these contaminants in the ground water.

PFOA and PFOS are long-chain PFAS historically used in industrial applications due to their highly stable nature, ability to repel water and oils, and resistance to harsh chemicals and high temperatures. PFOA and PFOS are both extremely persistent in the environment and soluble and mobile in water. Due to this persistence, PFOA and PFOS are found worldwide in environmental media, plants, and wildlife, and PFOS is known to bioaccumulate in fish. This potential for contamination of multiple environmental media along with associated negative health effects has the potential to adversely affect ecosystems. Therefore, if PFOA or PFOS is detected as a result of monitoring by public community or public nontransient noncommunity water systems, the Department and/or the water supplier may investigate the origin of the contamination. This will have a positive impact on the environment as additional areas of PFOA and PFOS contamination are identified, more remedial activities are initiated, and responsible parties may be identified.

The proposed amendments will have a positive environmental impact based on the associated monitoring requirements in the SDWA rules, as well as the testing requirements for PFOA, PFOS, and PFNA under the PWTA rules. In addition, the resulting installation of treatment units at some public water systems and some private wells will have a positive environmental impact by removing these contaminants from the environment.

The proposed amendment that adds the acidic and anionic forms of PFOA and PFOS, and their salts and esters, to the DPHS Appendix A List of Hazardous Substances will have a positive environmental impact. As discussed above, the proposed amendment will require facilities to have discharge prevention plans in place to prevent discharges of PFOA and PFOS. The proposed amendments also require prompt notification and swift action if a discharge occurs and impose cleanup and removal obligations on responsible parties. The proposed amendments will also enable the Department to clean up and remove discharges of PFOA and PFOS and compel responsible parties to reimburse it for those costs. These are all beneficial to the environment, by making available additional resources to the Department to cleanup and remove PFOA and PFOS and reduce the potential for further environmental damage.

Federal Standards Statement

N.J.S.A. 52:14B-1 et seq. (P.L. 1995, c. 65) requires State agencies that adopt, readopt, or amend State rules that exceed any Federal standards or requirements to include in the rulemaking document a Federal Standards Analysis.

The Department's SDWA rules at N.J.A.C. 7:10 incorporate by reference the National Regulations at 40 CFR 141, as amended and supplemented, promulgated by the USEPA pursuant to the Federal Safe Drinking Water Act, 42 U.S.C. §§ 300f et seq., including all siting requirements, filtration and disinfection requirements, maximum contaminant levels, monitoring and analytical requirements, reporting requirements, public notification requirements, and recordkeeping requirements as the New Jersey primary drinking water rules, applicable to all public water systems. The Department's SDWA rules are, therefore, the Federal standards, except with respect to those areas for which the Department has determined, as authorized by the SDWA and allowed by the National Regulations, to establish New Jersey-specific requirements.

As described above, the Institute has recommended an MCL for PFOA of 0.014 µg/l and an MCL for PFOS of 0.013 µg/l. Pursuant to the SDWA, N.J.S.A. 58:12A-13, the Department is authorized to promulgate an MCL based on this recommendation. Under the existing rules, the Department has MCLs for 14 contaminants that are more stringent than the Federal standards and for seven contaminants for which no Federal standard has been established. With the addition of PFOA and PFOS, New Jersey will have nine State-established MCLs where no Federal standard exists.

The Institute's process for recommending MCLs is similar to the Federal process, with the differences noted below. The Institute considers three factors when recommending MCLs: health effects, technological ability to measure the contaminant level, and ability of existing treatment technologies to meet the MCL. For MCLs based on effects other than cancer (noncarcinogens), New Jersey's goal is the elimination of all adverse health effects resulting from ingestion, within the limits of practicability and feasibility. With respect to carcinogens, the recommended MCL is to be established, within limits of medical, scientific, and technological feasibility, at a level which permits cancer in no more than one in one million persons ingesting that chemical for a lifetime. The health-based goal, known as the maximum contaminant level goal, for Federal MCLs for carcinogens is zero, and cost-benefit may be considered. The Institute evaluated the most current information available regarding PFOA and PFOS in drinking water before recommending MCLs to the Department.

The development of New Jersey-specific MCLs for PFOA and PFOS is necessary to protect public health. As stated in the Institute's Health Effects Subcommittee reports, PFOA and PFOS are persistent in humans with a half-life for elimination of several years, exposure to relatively low drinking water concentrations is expected to substantially increase human body burden and the toxicological effects in laboratory animal studies are relevant to humans.

PFOA was detected over the proposed MCL in 18 percent of public water systems sampled during UCMR3 and Department-initiated sampling as part of the 2006 and 2009-2010 Statewide occurrence study. PFOS was detected over the proposed MCL in nine percent of public water systems sampled. PFOA and PFOS were found more frequently in New Jersey than in other parts of the country based on results of sampling conducted pursuant to the UCMR3. While the Department has encouraged public water systems with elevated levels of PFOA and PFOS to continue to monitor and, where necessary, install treatment to remove these contaminants, those systems are under no obligation to comply with this request because an MCL has not yet been established. Therefore, without an adopted State-MCL, the Department cannot reduce exposure and protect public health. Through the Department's stakeholder process some water systems expressed support for the adoption of MCLs for unregulated contaminants because adopted rules provide predictability. Design of treatment systems in the absence of a removal target, such as an MCL, can be both challenging and risky as the target is susceptible to change. Thus, systems are hesitant to invest in treatment without an MCL.

The PWTA rules, N.J.A.C. 7:9E, are not promulgated under the authority of, or in order to implement, comply with, or participate in any program established under Federal law or under a State statute that incorporates or refers to Federal law, Federal standards, or Federal requirements. Therefore, the Department has determined that a Federal standards analysis is not required.

The GWQS, N.J.A.C. 7:9C, are not promulgated under the authority of, or in order to implement, comply with, or participate in any program established under Federal law or under a State statute that incorporates or refers to Federal law, standards, or requirements. The proposed ground water quality standards for PFOA and PFOS do not exceed any Federal standards or requirements. The authority for the ground water quality standards comes solely from New Jersey law and has no Federal counterpart. Because the NJPDES rules require all discharges to ground water to comply with the GWQS, the NJPDES rules are proposed for amendment to be consistent with the GWQS rule changes. The proposed amendments to the NJPDES rules are governed by State statutes, including the New Jersey Water Pollution Control Act, which has no Federal counterpart, except regarding underground injection wells. USEPA regulates injection wells under its rules for the Federal Underground Injection Control Program created pursuant to the Federal Safe Drinking Water Act. The proposed amendments to the NJPDES rules do not exceed Federal underground injection control mandates. Therefore, the Department has determined that a Federal standards analysis is not required.

The DPHS rules, N.J.A.C. 7:1E, are not promulgated under the authority of, or in order to implement, comply with, or participate in, any program established under Federal law, or under a State statute that incorporates or refers to Federal law, Federal standards, or Federal requirements. While there are Federal regulations promulgated pursuant to the Federal Water Pollution Control Act and the Comprehensive Environmental Response, Compensation and

Liability Act that govern discharge prevention and reporting that are generally analogous to the DPHS rules, PFOA and PFOS are not among the substances to which those Federal programs apply. The Department has determined that because PFOA and PFOS in the environment pose an unacceptable risk to public health, it is appropriate to include PFOA and PFOS on the DPHS Appendix A List of Hazardous Substances. Doing so will require responsible parties to notify the Department of a discharge and initiate remediation with a Licensed Site Remediation Professional and require owners and operators of industrial establishments who are liable under ISRA to, among other things, undertake an investigation of their industrial establishment and remediate any discharges of PFOA or PFOS that are discovered prior to their sale or transfer or upon cessation of business operations. In addition, including PFOA and PFOS on the DPHS Appendix A List of Hazardous Substances will enable the Department to, in accordance with the Spill Act, direct persons with Spill Act liability to remediate discharges of PFOA and PFOS, use available hazardous substance-based funding sources, as necessary, to conduct remediation of PFOA and PFOS, and undertake cost recovery actions against the party responsible for the discharge.

Jobs Impact

The Department anticipates that the proposed amendments will have a positive impact on jobs for certified laboratories based on the additional testing requirements outlined in the Summary above. Public community water systems and public nontransient noncommunity water systems will be required to sample for the new MCLs beginning in 2021. New testing requirements for private wells and new nonpublic or public noncommunity wells is also expected to create additional work for certified laboratories in sampling and analyzing the water source for the required parameters.

There may also be a small growth of jobs in industries related to designing and installing treatment for the regulated contaminants, such as engineering consulting firms and manufacturers of water treatment equipment such as granular activated carbon, which can be used to treat both PFOA and PFOS.

There will be some indirect, but positive, impact on entrepreneurial activity, interstate commerce, or international trade by ensuring the public of a safe and dependable water supply.

The Department does not anticipate that the proposed amendments to the GWQS or NJPDES rules will impact employment. As discussed in the Economic Impact above, the implementation of the proposed ground water quality standards for PFOA and PFOS might result in new or additional costs for remediation; however, those costs will be site-specific and the resultant effect, if any, on employment would depend on the business operation decisions of the persons responsible for conducting the remediation.

Finally, the effect on employment for major facilities that handle or store PFOA or PFOS or are subject to ISRA because of the addition of PFOA and PFOS to the DPHS Appendix A List of Hazardous Substances, will depend on the business operation decisions of the owners and operators of those facilities.

Agricultural Industry Impact

Pursuant to N.J.S.A. 52:14B-4, the Department has evaluated this rulemaking to determine the nature and extent of the impact of the proposed amendments on the agricultural industry. The proposed amendments are anticipated to have minimal impact on agriculture in New Jersey. Water for agricultural purposes is typically sourced from irrigation wells, which, because they are nonpotable water supply wells, are not subject to the SDWA rules. A water system that meets the definition of a public water system under the SDWA rules must comply with the applicable monitoring and other requirements of the proposed rules, even as they must do so under the existing rules, as the potential health risk of contamination must be addressed irrespective of whether the water from the public water system is used for irrigation or other agricultural purposes.

The Department is not aware of any products containing PFOA or PFOS used for agricultural purposes. However, if the Department determines that an irrigation well has been impacted by PFOA or PFOS and poses a health risk, treatment would likely be required to meet the proposed ground water quality standards for PFOA and PFOS. The proposed addition of the acidic and anionic forms of these two chemicals, and their salts and esters to the DPHS Appendix A List of Hazardous Substances are not expected to have any impact on the agriculture industry. Similarly, the Department does not anticipate that the changes to the NJPDES rules will have an adverse effect on agriculture.

Regulatory Flexibility Analysis

In accordance with the New Jersey Regulatory Flexibility Act, N.J.S.A. 52:14B-16 et seq., the Department has evaluated the reporting, recordkeeping, and other compliance requirements that the proposed amendments would impose on small businesses. As defined by the Regulatory Flexibility Act, a “small business” is one that is independently owned and operated and employs fewer than 100 full-time employees. The Department estimates that of the 3,723 public water systems in New Jersey, approximately 2,500 are small businesses. The proposed amendments require suppliers of water from public water systems to monitor and, when applicable, treat to remove PFOA and PFOS, as discussed in the Summary above. These requirements apply to water systems that may be considered a small business, but that also serve many customers potable water on a regular basis. A relaxation of these standards would not be protective of public health and would be inconsistent with the existing application of the requirements of the New Jersey Safe Drinking Water Program, which have been effective for decades.

A small business responsible for compliance with its NJPDES DGW permit or conducting remediation of PFOA and/or PFOS to meet the proposed ground water quality standard(s) would have to conduct new or additional monitoring or remediation to comply with the new standard, including the associated recordkeeping and reporting requirements. However, the risk to public health posed by the contamination is the same whether or not the person responsible for conducting the permit monitoring or remediation is a small business. Consequently, the Department’s rules governing site remediation do not provide any reduction in cleanup requirements based on small business status, except that those small businesses that meet the definition in the New Jersey Regulatory Flexibility Act, as well as the definition of small business set forth in the Administrative Requirements for the Remediation of Contaminated Sites at N.J.A.C. 7:26C-1.3, are not required to post financial assurance when engineering controls are installed as part of a remedial action.

The proposed amendment adding the acidic and anionic forms of PFOA and PFOS, and their salts and esters, to the DPHS Appendix A List of Hazardous Substances will affect any small business that meets the threshold hazardous substance storage capacity requirements in the Spill Act and DPHS rules because it uses or stores PFOA or PFOS or is subject to ISRA. Due to the public health and environmental risks of a discharge of a hazardous substance, the discharge notification requirements of the DPHS rules that are applicable to any person responsible for a discharge will also apply to any small businesses responsible for a discharge of PFOA or PFOS.

Housing Affordability Impact Analysis

In accordance with N.J.S.A. 52:14B-4, the Department has evaluated the proposed amendments to determine their impact, if any, on the affordability of housing. Where contaminants are detected in a public water system, the costs of monitoring and treatment are passed on to the residential customer. However, these costs are associated with a public water system bill and are not expected to impact the cost of housing. The amendments to the PWTA will increase testing for either the seller or buyer, whoever assumes the cost of testing. The cost of testing incurred by landlords may be passed along to lessees but is expected to be minimal as testing is only required every five years. Testing costs are expected to increase by an average of $300.00 due to additional testing for PFOA, PFOS, and PFNA. However, the Department expects the cost of the analysis to decrease following the promulgation of MCLs for PFOA and PFOS as more laboratories become certified to perform analysis of the contaminant. In addition, the overall health effects associated with PFOA, PFOS, and PFNA are significant and the protection of public health outweighs the increase in cost.

The Department anticipates the proposed amendments will have minimal impact on the affordability of housing because it is unlikely that the amendments will evoke a major change in the average costs associated with housing. The proposed amendments to the GWQS and NJPDES rules, which will ensure that scientifically based standards for PFOA and PFOS are in place for purposes of discharge to ground water permitting and ground water remediation, are extremely unlikely to evoke a change in the average costs associated with housing.

To the extent the proposed amendment adding the acidic and anionic forms of PFOA and PFOS and their salts and esters to the DPHS Appendix A List of Hazardous Substances would trigger additional discharge prevention and planning requirements for facilities subject to the DPHS rules, there would be no impact on the average costs of housing. To the extent the proposed amendments adding the acidic and anionic forms of PFOA and PFOS and their salts and esters to the DPHS Appendix A List of Hazardous Substances makes it possible to use available hazardous substance-based funding sources to cover the costs of remediating PFOA and PFOS contamination, the Department does not expect there would be a change in the average costs associated with housing.

Smart Growth Development Impact Analysis

In accordance with N.J.S.A. 52:14B-4, the Department has evaluated the proposed amendments to determine their impact, if any, on housing production within Planning Areas 1 or 2, or within designated centers, under the State Development and Redevelopment Plan. The proposed amendments establish new MCLs, including monitoring and treatment for public community and public nontransient noncommunity water systems, as well as testing for private and nonpublic wells. The Department anticipates the proposed amendments will have no smart growth development impact because it is extremely unlikely that the rules will evoke a change in housing production in Planning Areas 1 or 2, or within designated centers.

The proposed amendments to the GWQS and NJPDES rules, which will ensure that scientifically based standards for PFOA and PFOS are in place for purposes of discharge to ground water permitting and ground water remediation, are extremely unlikely to evoke a change in housing production in Planning Areas 1 or 2, or within designated centers.

To the extent the proposed amendments adding the acidic and anionic forms of PFOA and PFOS and their salts and esters to the DPHS Appendix A List of Hazardous Substances would trigger additional discharge prevention and planning requirements for facilities subject to the DPHS rules, there would be no change in housing production in Planning Areas 1 or 2, or within designated centers. To the extent the proposed amendment adding the acidic and anionic forms of PFOA and PFOS and their salts and esters to the DPHS Appendix A List of Hazardous Substances require the owners and operators of industrial establishments who are liable under the ISRA to, among other things, undertake an investigation of their industrial establishment and remediate any discharges of PFOA or PFOS that are discovered prior to their sale or transfer or upon cessation of business operations, there would be no change in housing production in Planning Areas 1 or 2, or within designated centers. To the extent the proposed amendment adding the acidic and anionic forms of PFOA and PFOS and their salts and esters to the DPHS Appendix A List of Hazardous Substances makes it possible to use available hazardous substance-based funding sources to cover the costs of remediating PFOA and PFOS contamination, the Department does not expect there would be a change in housing production in Planning Areas 1 or 2, or within designated centers.

Racial and Ethnic Community Criminal Justice and Public Safety Impact

The Department has evaluated this rulemaking and determined that it will not have an impact on pretrial detention, sentencing, probation, or parole policies concerning adults and juveniles in the State. Accordingly, no further analysis is required.

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11. USEPA. 2016. United States Environmental Protection Agency. Health Effects Support Document for Perfluorooctane Sulfonate (PFOS). Office of Water. EPA 822-R-16-002. May 2016.

Full text of the proposal follows (additions indicated in boldface **thus**; deletions indicated in brackets [thus]):

CHAPTER 1E

DISCHARGES OF PETROLEUM AND OTHER HAZARDOUS SUBSTANCES

APPENDIX A

LIST OF HAZARDOUS SUBSTANCES

(Alphabetical Order)

Name	CAS Number
…	
Perfluorononanoate (PFNA)	**72007-68-2**
Perfluorononanoic acid (PFNA), salts and esters	*********
Perfluorooctane sulfonate (PFOS)	**45298-90-6**
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**
Perfluorooctanesulfonic acid (PFOS), salts and esters	*********
Perfluorooctanoate (PFOA)	**45285-51-6**
Perfluorooctanoic acid (PFOA)	**335-67-1**
Perfluorooctanoic acid (PFOA), salts and esters	*********
…	

*In accordance with N.J.A.C. 7:1E-1.7(b)2, this substance is not considered a hazardous substance for purposes of this chapter.

LIST OF HAZARDOUS SUBSTANCES

(Listed by CAS Number)

CAS Number	Name

…	
*****	Organorhodium Complex (PMN-82-147)
*********	**Perfluorononanoic acid (PFNA), salts and esters**
*********	**Perfluorooctanesulfonic acid (PFOS), salts and esters**
*********	**Perfluorooctanoic acid (PFOA), salts and esters**
*****	Petroleum oil/motor oil
…	
335-67-1	**Perfluorooctanoic acid (PFOA)**
…	
1763-23-1	**Perfluorooctanesulfonic acid (PFOS)**
…	
45285-51-6	**Perfluorooctanoate (PFOA)**
45298-90-6	**Perfluorooctane sulfonate (PFOS)**
…	
72007-68-2	**Perfluorononanoate (PFNA)**
…	

CHAPTER 9C

GROUND WATER QUALITY STANDARDS

APPENDIX

Table 1

Specific Ground Water Quality Criteria—Class II-A and Practical Quantitation Levels

(**Agency Note:** The table headings below are existing permanent boldface text in the New Jersey Administrative Code, only the substantive information in the table that is in bold is proposed as new.)

Constituent	**CASRN**	**Ground Water Quality Criterion***	**Practical Quantitation Level (PQL)***	**Higher of the PQL and Ground Water Quality Criterion***
…				
Perfluorooctanoic acid (PFOA)	**335-67-1**	**0.014**	**0.006**	**0.014**
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**0.013**	**0.004**	**0.013**
…				

CHAPTER 9E

PRIVATE WELL TESTING ACT RULES

SUBCHAPTER 2. SAMPLING AND TESTING REQUIREMENTS

7:9E-2.1 Parameters for which testing is required

(a) Each water sample shall be analyzed for the following parameters:

1.-9. (No change.)

10. Gross alpha particle activity, determined using the 48 Hour Rapid Gross Alpha Test, in accordance with N.J.A.C. 7:18; [and]

11. As of March 3, 2019, the synthetic organic compounds, 1,2,3-trichloropropane, ethylene dibromide, and 1,2-dibromo-3-chloropropane[.]**; and**

12. As of (18 months after the effective date of this amendment), the per- and polyfluoroalkyl substances perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), and perfluorooctanesulfonic acid (PFOS).

(b)-(c) (No change.)

CHAPTER 10

SAFE DRINKING WATER ACT

SUBCHAPTER 5. STATE PRIMARY DRINKING WATER REGULATIONS

7:10-5.2 Discretionary changes to National Regulations

(a) In accordance with the discretionary authority permitted by the National Regulations, for compliance with the State primary drinking water regulations, the following shall apply:

1.- 4. (No change.)

5. [The] MCL**s** for the State-regulated [perfluorinated compound] **per- and polyfluoroalkyl substances** perfluorononanoic acid (PFNA)**, perfluorooctanoic acid (PFOA), and perfluorooctanesulfonic acid (PFOS)** shall be [0.013 µg/l] **those established at (a)5i, ii, and iii below**. Monitoring requirements for PFNA**, PFOA, and PFOS** shall be those established under

the National Regulations at 40 CFR 141.24(f) and at (a)7 below[, beginning as set forth at (a)5i below and subject to the condition at (a)5ii below]. **For PFNA, the conditions at (a)5i apply. For PFOA, the conditions at (a)5ii apply. For PFOS, the conditions at (a)5iii apply.**

i. For PFNA, the MCL shall be 0.013 µg/l. Monitoring requirements shall begin as set forth at (a)5i(1) below and are subject to the condition at (a)5i(2) below.

Recodify existing i. and ii. as **(1) and (2)** (No change in text.)

ii. For PFOA, the MCL shall be 0.014 µg/l. Monitoring requirements shall begin as set forth at (a)5ii(1) below and are subject to the conditions at (a)5ii(2) and (3) below.

(1) All public community and public nontransient noncommunity water systems shall begin monitoring within the first quarter of 2021.

(2) Nothwithstanding the threshold set forth at 40 CFR 141.24(f)(11), the requirement for quarterly monitoring at 40 CFR 141.24(f)(11)(i) shall apply if PFOA is detected at a level exceeding 0.002 µg/l.

(3) A public community water system or a public nontransient noncommunity water system may submit monitoring data for PFOA to the Department for a determination of whether the system may reduce monitoring frequency to an annual basis provided:

(A) The monitoring data are collected in accordance with (a)7 below after January 1, 2019; and

(B) The monitoring data are reported to the Department in accordance with N.J.A.C. 7:10-5.4 on or before (the effective date of this amendment).

iii. For PFOS, the MCL shall be 0.013 µg/l. Monitoring requirements shall begin as set forth at (a)5iii(1) below and are subject to the conditions at (a)5iii(2) and (3) below.

(1) All public community and public nontransient noncommunity water systems shall begin monitoring within the first quarter of 2021.

(2) Nothwithstanding the threshold set forth at 40 CFR 141.24(f)(11), the requirement for quarterly monitoring at 40 CFR 141.24(f)(11)(i) shall apply if PFOS is detected at a level exceeding 0.002 µg/l.

(3) A public community water system or a public nontransient noncommunity water system may submit monitoring data for PFOS to the Department for a determination whether the system may reduce monitoring frequency to an annual basis provided:

(A) The monitoring data are collected in accordance with (a)7 below after January 1, 2019; and

(B) The monitoring data are reported to the Department in accordance with N.J.A.C. 7:10-5.4 on or before (the effective date of this amendment).

6. (No change.)

7. Water systems that, as provided at 40 CFR 141.23 and 141.24, are monitoring for inorganics (except asbestos, nitrate, and nitrite), volatile organic compounds, and

synthetic organic compounds or for PFNA**, PFOA, and PFOS** at a frequency less than annually shall monitor once in each Federal three-year compliance period in accordance with the schedule in the table below.

Monitoring Schedule	Water System Type
Year one of the applicable three-year Federal compliance period (for example, 2017, 2020, 2023, 2026)	Any public community water system using a surface water source(s) and any public community water system serving a population greater than 10,000.
Year two of the applicable three-year Federal compliance period (for example, 2018, 2021, 2024, 2027)	Any public community water system using a groundwater source(s) serving a population equal to or less than 10,000.
Year three of the applicable three-year Federal compliance period (for example, 2019, 2022, 2025, 2028)	Any public nontransient noncommunity water system.

8.-13. (No change.)

(b) The National Regulations, at 40 CFR 141.151, require each community water system to annually develop and deliver to its customers a Consumer Confidence Report (CCR)**,** which provides information on the quality of the water delivered by the system and characterizes the risks (if any) from exposure to contaminants detected in the drinking water in an accurate and understandable manner. In addition to the standards and requirements in the National Regulations for the development and distribution of the CCR, the following requirements shall apply:

1.-3. (No change.)

4. For the [seven] **nine** State-regulated contaminants for which there is no Federal MCL, the Consumer Confidence Report shall include the information set forth below:

Contaminant	New Jersey MCL (µg/l)	MCL in units for CCR	Major Sources in Drinking Water	Health Effects Language

...

Perfluorooctanoic Acid (PFOA)	**0.014**	**14 ppt**	**Discharge from industrial, chemical, and manufacturing factories, release of aqueous film forming foam.**	**Some people who drink water containing PFOA in excess of the MCL over many years could experience problems with their blood serum cholesterol levels, liver, kidney, immune system, or, in males, reproductive system. Drinking water containing PFOA in excess of the MCL over many years may also increase the risk of testicular and kidney cancer. For females, drinking water containing PFOA in excess of the MCL over**

				many years may cause developmental delays in a fetus and/or an infant.
Perfluorooctanesulfonic Acid (PFOS)	**0.013**	**13 ppt**	**Discharge from industrial, chemical factories, release of aqueous film forming foam.**	**Some people who drink water containing PFOS in excess of the MCL over many years could experience problems with their immune system, kidney, liver, or endocrine system. For females, drinking water containing PFOS in excess of the MCL over many years may cause developmental effects and problems with the immune system, liver,**

or endocrine system in a fetus and/or an infant. Some of these developmental effects can persist through childhood.

SUBCHAPTER 12. STANDARDS FOR THE CONSTRUCTION OF PUBLIC NONCOMMUNITY WATER SYSTEMS AND NONPUBLIC WATER SYSTEMS

7:10-12.30 Water quality analysis and treatment

(a) (No change.)

(b) Upon completion of construction of a water system, the owner of a public noncommunity water system shall sample and analyze the raw water from the system for inorganics, volatile organic compounds (VOCs), the SOCs 1,2,3-trichloropropane, ethylene dibromide, [and] 1,2-dibromo-3-chloropropane, **the per- and polyfluoroalkyl substances perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS),** and radionuclides in accordance with N.J.A.C. 7:10-5 and for secondary contaminants in accordance with N.J.A.C. 7:10-7. If the system uses a surface water source, the administrative authority shall require the system owner to sample and analyze the water for disinfection by-products and pesticides regulated pursuant to N.J.A.C. 7:10-5.

(c) Upon completion of construction of a water system, the owner of a nonpublic water system shall sample and analyze the raw water from the system for the parameters listed at (c)1 through [11] **12** below. The administrative authority may require sampling and analysis for inorganic chemicals, volatile organic compounds**,** and/or radionuclides**,** as appropriate**,** based on the region and the aquifer in which the water source is located.

1.-9. (No change.)

10. As of (18 months after the effective date of this amendment), the per- and polyfluoroalkyl substances PFNA, PFOA, and PFOS;

[10.] **11.** In addition to the parameters listed at (c)1 through [9] **10** above, if the water system is located in Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Monmouth, Ocean, or Salem County, mercury; and

[11.] **12.** In addition to the parameters listed at (c)1 through [9] **10** above, if the water system is located in Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Morris, Passaic, Somerset, Sussex, Union, or Warren County, uranium.

(d) – (i) (No change.)

CHAPTER 14A

NEW JERSEY POLLUTANT DISCHARGE ELIMINATION SYSTEM

SUBCHAPTER 4. PERMIT APPLICATION REQUIREMENTS

APPENDIX A

PERMIT APPLICATION TESTING REQUIREMENTS/POLLUTANT LISTINGS

...

PERMIT APPLICATION TESTING REQUIREMENTS/POLLUTANT LISTINGS

Table I – V (No change.)

Table VI

Toxic Pollutants and Hazardous Substances Required to be Identifed by Existing Dischargers if Expected to be Present

Per- and Polyfluoroalkyl Substances (PFAS)

Perfluorononanoic acid (PFNA)

Perfluorooctanoic acid (PFOA)

Perfluorooctanesulfonic acid (PFOS)

SUBCHAPTER 7. REQUIREMENTS FOR DISCHARGES TO [GROUNDWATER] **GROUND WATER** (DGW)

7:14A-7.9 General requirements for applications for discharge to [groundwater] **ground water** permit

(a) In addition to the information required pursuant to N.J.A.C. 7:14A-4.3, an applicant for a NJPDES Discharge to [Groundwater] **Ground Water** permit shall submit information to the Department as follows:

1. (No change.)

(b)-(c) (No change.)

(d) The following information shall be submitted in the application for the Discharge to Ground Water permit pursuant to (a) above:

1. (No change.)

2. Pollutant characteristics as follows:

i.-ii. (No change.)

iii. Characteristics of the quality of the discharge.

(1) Unless otherwise approved by the Department, all analyses or estimates shall include the following parameters at a minimum:

(A)-(Q) (No change.)

(R) Volatile organics; [and]

(S) Pesticides[.]**; and**

(T) Per- and Polyfluoroalkyl substances (PFAS).

(i) Perfluorononanoic acid (PFNA);

(ii) Perfluorooctanoic acid (PFOA); and

(iii) Perfluorooctanesulfonic acid (PFOS).

(2) Dependent on the nature of the facility as described in accordance with (d)1 above, base/neutral compounds, acid extractable compounds, volatile organics**, per- and polyfluoroalkyl substances (PFAS),** and pesticides shall be analyzed for as required pursuant to N.J.A.C. 7:14A-4 Appendix A; and

iv. (No change.)

3.-6. (No change.)

Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS)

1 Introduction

The following topics are covered in this fact sheet:

- Polymer vs. Non-Polymer PFAS
- Perfluoroalkyl substances
- Polyfluoroalkyl substances
- PFAA Naming Conventions
- Long-Chain vs. Short-Chain
- Linear vs. Branched
- Acid vs. Anion
- Replacement Chemistry
- Physical and Chemical Properties

ITRC has developed a series of six fact sheets to summarize the latest science and emerging technologies regarding PFAS. The purpose of this fact sheet is to:

- Provide an overview of terminology, names, and acronyms for PFAS, focusing on those most commonly reported in the environment. The fact sheet focuses on those PFAS most commonly tested for by current analytical methods, but also describes other important classes of PFAS.
- Summarize the common physical and chemical properties associated with PFAS, along with a discussion of those properties for which no data are currently available.

This fact sheet uses three conventions worth highlighting:

- **Anionic form of chemical names:** Many PFAS can exist in various ionic states (for example, acids, anions, cations), which has important implications for their chemical and physical properties. In most cases, this fact sheet uses the anionic form of a given PFAS name, as this is the state in which most PFAS exist in the environment.
- **"PFC" is not used:** The acronym "PFC" is poorly defined in the scientific literature, but typically refers to "**per**fluorinated compounds." It does not include polyfluorinated substances which are increasingly recognized as important contaminants at many PFAS sites, while it does include unrelated chemicals that are not of concern at those sites.
- **"PFAS", not "PFASs":** The acronym "PFAS" stands for "poly- **and** perfluoroalkyl substances." No single chemical within the PFAS class can be both polyfluorinated and perfluorinated, so by definition "PFAS" is plural and a small "s" is not needed. Some authors elect to add a small "s" to this acronym (PFASs) to emphasize the fact that it is plural, but it is not needed. When referring to a single chemical within the PFAS class, it is usually more accurate to simply name that specific chemical.

USEPA has compiled an online resource for PFAS information. The information includes topics such as Policy and Guidance, Chemistry and Behavior, Occurrence, Toxicology, Site Characterization and Remediation Technologies (USEPA 2017h).

1.1 Why do we need to understand PFAS Naming Conventions?

The number and complexity of environmentally-relevant PFAS and the exponential increase in related scientific publications have led to confusion in the environmental community and the public (Buck et al. 2011; Wang et al. 2017). The use of non-specific acronyms, such as perfluorinated compound (PFC), has hampered clarity of investigative results. Use of consistent naming conventions by researchers, practitioners, regulators, and stakeholders will reduce confusion and support clearer communication.

Proper naming also helps to distinguish PFAS from other organic compounds that contain fluorine. PFAS, which are fluorinated aliphatic (carbon chain) substances, do not include aromatic (carbon ring) substances that contain carbon-fluorine (C-F) bonds (for example, active pharmaceutical ingredients, crop protection) or chlorofluorocarbons (refrigerants). This is another reason to avoid the use of the more generic acronym, PFC, which can include these non-PFAS.

Chemical Abstract Service (CAS) numbers are another helpful tool for clearly identifying the chemical that is being referenced. However, even these have led to confusion when it comes to PFAS. Some PFAS may occur in various ionic states, such as acids, anions (negatively charged), cations (positively charged salts), and zwitterions (both positively and negatively charged dipolar molecules), each of which has its own CAS number (and some have no CAS number). The ionic state determines its electrical charge and its physical and chemical properties, which in turn controls its fate and transport in the environment and potential human health and ecological effects. Chemical and physical properties of the various states of a given per- or polyfluoroalkyl substance can be so different that they completely alter critical aspects of the substance, such as solubility, volatility, and bioaccumulative potential. As a result, care must be taken in selecting the correct CAS number to avoid confusion regarding the chemistry and behavior of the chemical being described.

2 PFAS Families

PFAS encompass a wide universe of substances with very different physical and chemical properties, including gases (for example, perfluorobutane), liquids (for example, fluorotelomer alcohols), surfactants (for example, perfluorooctane sulfonate), and solid material high-molecular weight polymers (for example, polytetrafluoroethylene [PTFE]). For this reason, it is helpful to arrange PFAS that share similar chemical and physical properties into families.

The PFAS families may be divided into two primary categories: polymer and non-polymer as shown in Figure 2-1. This fact sheet focuses primarily on non-polymer PFAS most commonly detected in the environment. The polymer family of PFAS is not addressed in detail in this fact sheet. Buck et al. (2011) is an open-access paper that provides a more detailed explanation of PFAS terminology, classification, and origins, and recommends specific and descriptive terminology, names, and acronyms for PFAS.

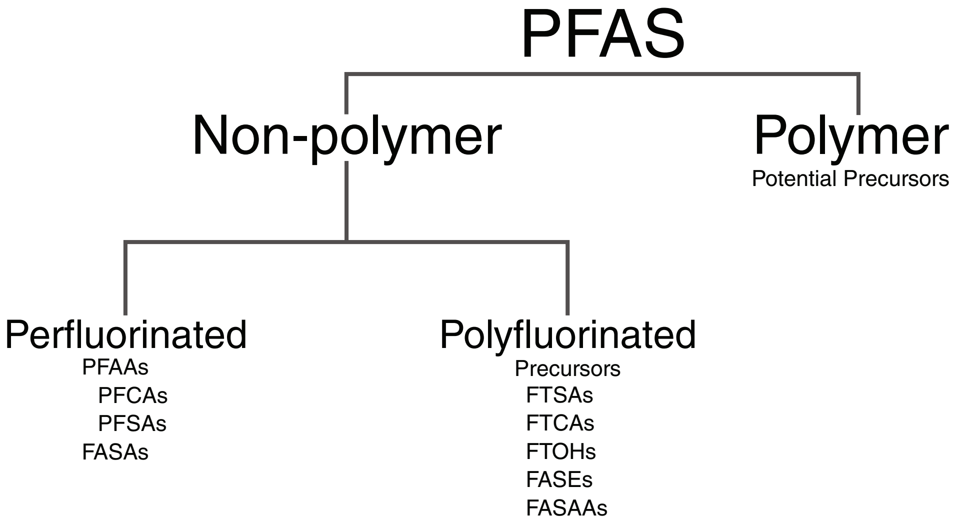


Figure 2-1. Summary of PFAS families

2.1 Non-Polymer PFAS

The family of non-polymeric PFAS encompasses two major classes: perfluoroalkyl substances and polyfluoroalkyl substances, which include many subgroups of chemicals, examples of which are shown in Figure 2-1. Table 2-1 provides general classification and chemical structures, examples of each class, and primary uses of the non-polymer PFAS highlighted in Figure 2-1. These compounds were selected as the focus of this fact sheet because they (1) are most commonly detected in humans, biota, and other environmental media; (2) appear to be relatively more abundant at PFAS investigation sites; (3) may have state or federal guidance values (see the *Regulations, Guidance, and Advisories Fact Sheet*); and/or (4) are included in most laboratory PFAS analyte lists.

2.1.1 Perfluoroalkyl Substances

Perfluoroalkyl substances are fully fluorinated (perfluoro-) alkane (carbon-chain) molecules. Their basic chemical structure is a chain (*or tail*) of two or more carbon atoms with a charged functional group *head* attached at one end. The functional groups commonly are carboxylic or sulfonic acids, but other forms are also detected in the environment. Fluorine atoms are attached to all possible bonding sites along the carbon chain of the tail, except for one bonding site on the last carbon where the functional group head is attached. This structure, which is illustrated in Figure 2-2 for perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA), can be written as:

$$C_nF_{2n+1}\text{-}R$$

where "C_nF_{2n+1}" defines the length of the perfluoroalkyl chain tail, "n" is >2, and "R" represents the attached functional group head. Note that the functional group may contain 1 or more carbon atoms, which are included in the total number of carbons when naming the compound.

Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS) *continued*

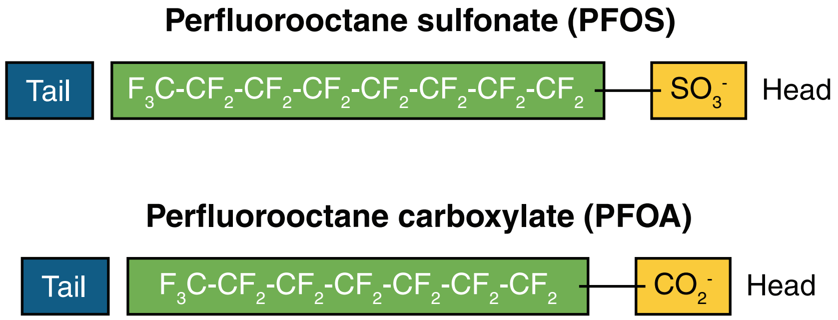


Figure 2-2. The tail and head structure of PFOS and PFOA molecules

Table 2-1. Major PFAS classes discussed in this fact sheet

Source: Adapted with permission from Buck, R.C., J. Franklin, U. Berger, J. M. Conder, I. T. Cousins, P. de Voogt, A. A. Jensen, K. Kannan, S. A. Mabury, and S. P. van Leeuwenet. 2011. "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins." Integrated Environmental Assessment and Management, 7:513-541. Open access. Copyright 2011 SETAC. http://dx.doi.org/10.1002/ieam.258

Family	Class	Group	General Chemical Structure: $C_nF_{2n+1}R$, where R =	Examples	Uses
PERFLUORINATED	Perfluoroalkyl acids (PFAAs)	Perfluoroalkyl carboxylic acids (PFCAs)	-COOH	Perfluorooctanoic acid (PFOA), $C_7F_{15}COOH$	Surfactant
		Perfluoroalkyl carboxylates (PFCAs)	$-COO^-$	Perfluorooctanoate (PFOA), $C_7F_{15}COO^-$	
		Perfluoroalkane sulfonic acids (PFSAs)	$-SO_3H$	Perfluorooctane sulfonic acid (PFOS), $C_8F_{17}SO_3H$	Surfactant
		Perfluoroalkane sulfonates (PFSAs)	$-SO_3^-$	Perfluorooctane sulfonate, (PFOS), $C_8F_{17}SO_3^-$	
	Perfluoroalkane sulfonamides (FASAs)		$-SO_2NH_2$	Perfluorooctane sulfonamide, $C_8F_{17}SO_2NH_2$	Major raw material for surfactant and surface protection products
		N-Alkyl perfluoroalkane sulfonamides (MeFASAs, EtFASAs, BuFASAs	$-SO_2N(R')H$ where $R' = C_mH_{2m+1}$ (m = 0, 1, 2,4)	N-Ethyl perfluorooctane sulfonamide (EtFOSA), $C_8F_{17}SO_2N(C_2H_5)H$	Intermediate environmental transformation products
				N-Methyl perfluorooctane sulfonamide (MeFOSA), $C_8F_{17}SO_2N(CH_3)H$	

Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS) *continued*

Family	Class	Group	General Chemical Structure: CnF2n+1R, where R =	Examples	Uses
POLYFLUORINATED	Fluorotelomer substances	n:2 Fluorotelomer alcohols (n:2 FTOHs)	$-CH_2CH_2OH$	10:2 Fluorotelomer alcohol (10:2 FTOH), $C_{10}F_{21}CH_2CH_2OH$	Major raw material for surfactant and surface protection products
		n:2 Fluorotelomer sulfonic acids (n:2 FTSAs)	$-CH_2CH_2SO_3H$	8:2 Fluorotelomer sulfonic acid (8:2 FTSA), $C_8F_{17}CH_2CH_2SO_3H$	Surfactant and environmental transformation products
		Fluorotelomer carboxylic acids (FTCAs)	$-CH_2COOH$	6:2 Fluorotelomer carboxylic acid (6:2 FTCA), $C_6F_{13}CH_2COOH$	Intermediate environmental transformation product
			$-CH_2CH_2COOH$	5:3 Fluorotelomer carboxylic acid (5:3 Acid), C5F11(CH2)$_2$COOH	
	Perfluoroalkane sulfonamido substances	Perfluoroalkane sulfonamido ethanols (FASEs) and N-alkyl perfluoroalkane sulfonamido ethanols (MeFASEs, EtFASEs, BuFASEs)	$-SO_2N(R')CH_2CH_2OH$ where $R' = C_mH_{2m+1}$ $(m = 0, 1, 2, 4)$	N-Ethyl perfluorooctane sulfonamidoethanol (EtFOSE), $C_8F_{17}SO_2N(C_2H_5)CH_2CH_2OH$	Major Raw Material for surfactant and surface protection products
				N-Methyl perfluorooctane sulfonamido ethanol (MeFOSE), $C_8F_{17}SO_2N(CH_3)CH_2CH_2OH$	
		Perfluoroalkane sulfonamido acetic acids (FASAAs) and N-alkyl perfluoroalkane sulfonamido acetic acids (MeFASAAs, EtFASAAs, BuFASAAs)	$-SO_2$N(R')CH2COOH where $R' = C_mH_{2m+1}$ $(m = 0, 1, 2,4)$	N-Ethyl perfluorooctane sulfonamido acetic acid (EtFOSAA), $C_8F_{17}SO_2N(C_2H_5)CH_2CO_2H$	Intermediate environmental transformation product
				N-Methyl perfluorooctane sulfonamido acetic acid (MeFOSAA), $C_8F_{17}SO_2N(CH_3)CH_2CO_2H$	

2.1.1.1 Perfluoroalkyl acids (PFAAs)

Perfluoroalkyl acids (PFAAs) are some of the most basic PFAS molecules. They are essentially non-degradable and currently are the class of PFAS most commonly tested for in the environment. Biotic and abiotic degradation of many polyfluoroalkyl substances may result in the formation of PFAAs. As a result, PFAAs are sometimes referred to as "terminal PFAS" or "terminal degradation products," meaning no further degradation products will form from them under environmental conditions. Polyfluoroalkyl substances that degrade to create terminal PFAAs are referred to as "precursors." The PFAA class is divided into two major groups (also shown in Table 2-1):

- *Perfluoroalkyl carboxylic acids* (PFCAs), or perfluoroalkyl carboxylates, are terminal degradation products of select precursor polyfluoroalkyl substances, such as fluorotelomer alcohols (FTOHs). The most frequently detected PFCA is PFOA.
- *Perfluoroalkane sulfonic acids* (PFSAs), or perfluoroalkyl sulfonates, are also terminal degradation products of select precursor polyfluoroalkyl substances, such as perfluoroalkylsulfonamidoethanols (PFOSEs). The most frequently detected PFSA is PFOS.

2.1.1.2 Perfluoroalkane sulfonamides (FASAs)

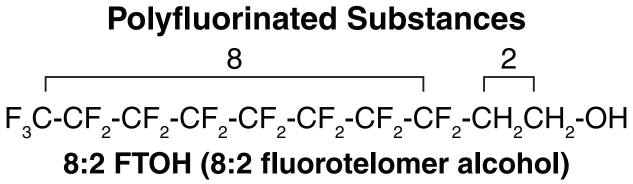
Perfluoroalkane sulfonamides (FASAs), such as perfluorooctane sulfonamide (FOSA), are used as raw material to make perfluoroalkyl sulfonamide substances that are used for surfactants and surface treatments. FASAs can degrade to form PFAAs such as PFOS. Examples include N-Methyl perfluorooctane sulfonamide (MeFOSA) and *N*-Ethyl perfluorooctane sulfonamide (EtFOSA).

2.1.2 Polyfluoroalkyl Substances

Polyfluoroalkyl substances and some side-chain fluorinated polymers are increasingly being identified as important to understanding the fate and transport of PFAS at release sites and in the environment (OECD 2013; Butt, Muir, and Mabury 2014; Liu and Mejia-Avendaño 2013; Wang et al. 2011; Mejia-Avendaño et al. 2016). Figure 2-1 highlights the polyfluoroalkyl substances that, to date, have most commonly been detected at PFAS sites (see Barzen-Hanson et al. 2017).

Polyfluoroalkyl substances are distinguished from perfluoroalkyl substances by not being fully fluorinated. Instead, they have a non-fluorine atom (typically hydrogen or oxygen) attached to at least one, but not all, carbon atoms, while at least two or more of the remaining carbon atoms in the carbon chain tail are fully fluorinated (Figure 2-3).

Fluorotelomer-based polyfluoroalkyl substances are named using an "n:x" prefix where "n" indicates the number of fully fluorinated carbon atoms (n >2) and "x" indicates the number of carbon atoms that are not fully fluorinated (x > 1). An example of a polyfluoroalkyl substance is shown in Figure 2-3, which also illustrates the "n:x" naming convention.



Polyfluorinated Substances

$$\overbrace{F_3C\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2}^{8}\text{-}\overbrace{CH_2CH_2}^{2}\text{-}OH$$

8:2 FTOH (8:2 fluorotelomer alcohol)

Figure 2-3. Example of a polyfluoroalkyl substance where two of the carbons in the tail (shaded blue) are not fully fluorinated, while the remaining carbons are. This also illustrates the "n:x" naming convention where "n" is the number of fully fluorinated carbons (in this case, 8) and "x" is the number of carbons that are not fully fluorinated (in this case, 2).

The carbon-hydrogen (or other non-fluorinated) bond in polyfluoroalkyl molecules creates a "weak" point in the carbon chain that is susceptible to biotic or abiotic degradation. As a result, many polyfluoroalkyl substances that contain a perfluoroalkyl C_nF_{2n+1} group are potential precursor compounds that have the potential to be transformed into PFAAs.

Figures 2-4 and 2-5 provide some examples of degradation pathways for environmentally relevant polyfluoroalkyl precursors derived from two PFAS production methods, telomerization and electrochemical fluorination (ECF), respectively. Note that these figures include some PFAS not discussed in this fact sheet, but described in Buck et al. (2011).

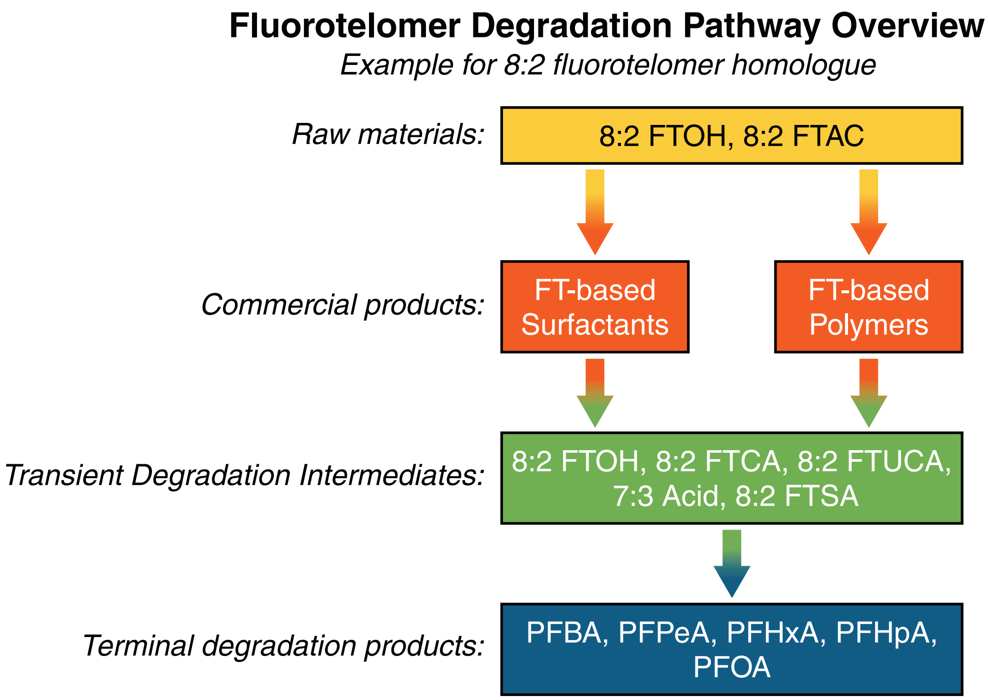


Figure 2-4. Fluorotelomer degradation pathway overview (*Example for 8:2 fluorotelomer homologue*)

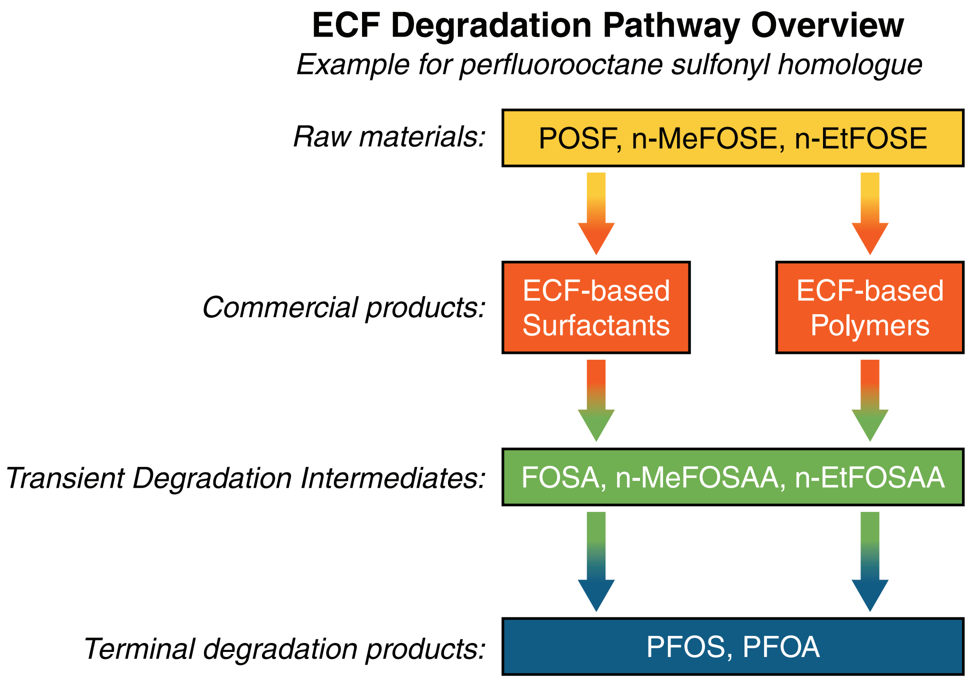


Figure 2-5. ECF degradation pathway overview (*Example for perfluorooctane sulfonyl homologue*).

2.1.2.1 Fluorotelomer Substances

Fluorotelomer substances are polyfluoroalkyl substances produced by the telomerization process. As shown in Figure 2-4, the degradation of fluorotelomer-based substances is a potential source of PFCAs in the environment (Buck et al. 2011). For many of these compounds, the naming convention identifies the number of perfluorinated and non-fluorinated carbons.

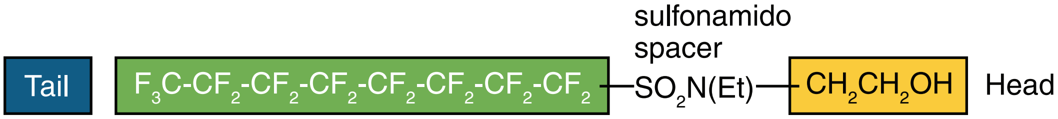
The following fluorotelomer substances (also shown in Table 2-1) are those most commonly detected in the environment to date:

- *Fluorotelomer alcohols* (FTOH): The n:2 fluorotelomer alcohols (n:2 FTOHs) are key raw materials in the production of n:2 fluorotelomer acrylates and n:2 fluorotelomer methacrylates (Buck et al. 2011).
- *Fluorotelomer sulfonic acids* (FTSA): The n:2 fluorotelomer sulfonic acids (n:2 FTSAs) have been detected in environmental matrices at sites where aqueous film forming foam (AFFF) have been used, and also in wastewater treatment plant effluents and landfill leachate. FTSAs are precursor compounds and can undergo aerobic biotransformation to form PFCAs (Buck et al. 2011).
- *Fluorotelomer carboxylic acids* (FTCA): These compounds form through the biodegradation of FTOHs (Figure 2-3; Buck et al. 2011; Liu and Avendaño 2013) and have been detected in landfill leachate. Note that the –COOH functional group on these fluorotelomer compounds mean they may have either an even or odd number of carbons, so they may have n:2 or n:3 prefixes.

2.1.2.2 Perfluoroalkane Sulfonamido Substances

All of the families of perfluoroalkane sulfonamido substances shown in Table 2-1 and discussed below have been detected in the environment and humans. *Perfluoroalkane* refers to the fully fluorinated carbon chain tail, but these compounds also contain one or more CH2 groups in the head of the molecule attached to the sulfonamido spacer (see Figure 2-6). They are either used as raw materials for surfactant and surface treatment products, or they are present as intermediate transformation products of these raw materials. As shown in Figure 2-5, some perfluoroalkane sulfonamido substances have been found to degrade to PFOS (Mejia and Liu 2015). Environmentally relevant perfluoroalkane sulfonamido substances include:

- *Perfluoroalkane sulfonamido ethanols* (FASEs) and *N-alkyl perfluoroalkane sulfonamido ethanols* (MeFASEs, EtFASEs, BuFASEs) are raw materials for surfactant and surface treatment products (Buck et al. 2011). Figure 2-6 illustrates the structure of N-EtFOSE.
- *Perfluoroalkane sulfonamido acetic acids* (FASAAs) and *N-alkyl perfluoroalkane sulfonamido acetic acids* (MeFASAAs, EtFASAAs, BuFASAAs) are intermediate transformation products of FASEs, MeFASEs, EtFASEs, and BuFASEs (see Figure 2-5) (Buck et al. 2011).



N-EtFOSE (n-ethyl perfluorooctane sulfonamido alcohol)

Figure 2-6. Example perfluoroalkane sulfonamido alcohol (FASE)

2.2 Polymeric PFAS

Polymers are large molecules formed by combining many identical smaller molecules (or monomers) in a repeating pattern. Polymeric substances in the PFAS family include fluoropolymers, polymeric perfluoropolyethers, and side-chain fluorinated polymers.

Side-chain fluorinated polymers contain a nonfluorinated polymer backbone from which fluorinated side chains branch off. Some may become precursors for PFAAs when the point of connection of a fluorinated side-chain on a polymer is broken to release a PFAA.

In general, polymeric PFAS are currently believed to pose less immediate human health and ecological risk relative to some non-polymer PFAS. As stated previously, most compounds of interest at environmental release sites are non-polymers.

3 PFAA Naming Conventions

PFAAs are the class of PFAS that make up the majority of PFAS typically included in commercial laboratory target analyte lists and are the primary PFAS for which federal or state health-based guidance values have been established. As a result, they tend to drive site investigation and remediation decisions, and so it is helpful to understand the naming conventions for this class. Many of the commonly detected PFAAs are denoted using the structural shorthand:

PFXY

where:
PF = perfluoroalkyl
X = the carbon chain length (using the same naming conventions as hydrocarbons based on the number of carbons ([for example, B for butane or 4 carbons, Pe for pentane or 5 carbons])
Y = the functional group

Table 3-1 illustrates how this naming structure works for the PFCAs and PFSAs, which collectively are referred to as PFAAs.

Table 3-1. Basic naming structure and shorthand for perfluoroalkyl acids (PFAAs)

X	Y	Acronym	Name	Formula	CAS No.
B = buta (4 carbon)	A = Carboxylate or carboxylic acid	PFBA	Perfluorobutanoate	$C_3F_7CO_2^-$	45048-62-2
			Perfluorobutanoic acid	C_3F_7COOH	375-22-4
	S = Sulfonate or sulfonic acid	PFBS	Perfluorobutane sulfonate	$C_4F_9SO_3^-$	45187-15-3
			Perfluorobutane sulfonic acid	$C_4F_9SO_3H$	375-73-5
Pe = penta (5 carbon)	A = Carboxylate or carboxylic acid	PFPeA	Perfluoropentanoate	$C_4F_9CO_2^-$	45167-47-3
			Perfluoropentanoic acid	C_4F_9COOH	2706-90-3
	S = Sulfonate or sulfonic acid	PFPeS	Perfluoropentane sulfonate	$C_5F_{11}SO_3^-$	NA
			Perfluoropentane sulfonic acid	$C_5F_{11}SO_3H$	2706-91-4
Hx = hexa (6 carbon)	A = Carboxylate or carboxylic acid	PFHxA	Perfluorohexanoate	$C_5F_{11}CO_2^-$	92612-52-7
			Perfluorohexanoic acid	$C_5F_{11}COOH$	307-24-4
	S = Sulfonate or sulfonic acid	PFHxS	Perfluorohexane sulfonate	$C_6F_{13}SO_3^-$	108427-53-8
			Perfluorohexane sulfonic acid	$C_6F_{13}SO_3H$	355-46-4
Hp = hepta (7 carbon)	A = Carboxylate or carboxylic acid	PFHpA	Perfluoroheptanoate	$C_6F_{13}CO_2^-$	120885-29-2
			Perfluoroheptanoic acid	$C_6F_{13}COOH$	375-85-9
	S = Sulfonate or sulfonic acid	PFHpS	Perfluoroheptane sulfonate	$C_7F_{15}SO_3^-$	NA
			Perfluoroheptane sulfonic acid	$C_7F_{15}SO_3H$	375-92-8
O = octa (8 carbon)	A = Carboxylate or carboxylic acid	PFOA	Perfluorooctanoate	$C_7F_{15}CO_2^-$	45285-51-6
			Perfluorooctanoic acid	$C_7F_{15}COOH$	335-67-1
	S = Sulfonate or sulfonic acid	PFOS	Perfluorooctane sulfonate	$C_8F_{17}SO_3^-$	45298-90-6
			Perfluorooctane sulfonic acid	$C_8F_{17}SO_3H$	1763-23-1
N = nona (9 carbon)	A = Carboxylate or carboxylic acid	PFNA	Perfluorononanoate	$C_8F_{17}CO_2^-$	72007-68-2
			Perfluorononanoic acid	$C_8F_{17}COOH$	375-95-1
	S = Sulfonate or sulfonic acid	PFNS	Perfluorononane sulfonate	$C_9F_{19}SO_3^-$	NA
			Perfluorononane sulfonic acid	$C_9F_{19}SO_3H$	474511-07-4
D = deca (10 carbon)	A = Carboxylate or carboxylic acid	PFDA	Perfluorodecanoate	$C_9F_{19}CO_2^-$	73829-36-4
			Perfluorodecanoic acid	$C_9F_{19}COOH$	335-76-2
	S = Sulfonate or sulfonic acid	PFDS	Perfluorodecane sulfonate	$C_{10}F_{21}SO_3^-$	126105-34-8
			Perfluorodecane sulfonic acid	$C_{10}F_21SO_3H$	335-77-3

Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances (PFAS) *continued*

X	Y	Acronym	Name	Formula	CAS No.
Un = undeca (11 carbon)	A = Carboxylate or carboxylic acid	PFUnA or PFUnDA	Perfluoroundecanoate	$C_{10}F_{21}CO_2^-$	196859-54-8
			Perfluoroundecanoic acid	$C_{10}F_{21}COOH$	2058-94-8
	S = Sulfonate or sulfonic acid	PFUnS or PFUnDS	Perfluoroundecane sulfonate	$C_{11}F_{23}SO_3^-$	NA
			Perfluoroundecane sulfonic acid	$C_{11}F_{23}SO_3H$	749786-16-1
DoD = dodeca (12 carbon)	A = Carboxylate or carboxylic acid	PFDoDA	Perfluorododecanoate	$C_{11}F_{23}CO_2^-$	171978-95-3
			Perfluorododecanoic acid	$C_{11}F_{23}COOH$	307-55-1
	S = Sulfonate or sulfonic acid	PFDoDS	Perfluorododecane sulfonate	$C_{12}F_{25}SO_3^-$	NA
			Perfluorododecane sulfonic acid	$C_{12}F_{25}SO_3H$	79780-39-5
TrD = trideca (13 carbon)	A = Carboxylate or carboxylic acid	PFTrDA	Perfluorotridecanoate	$C_{12}F_{25}CO_2^-$	862374-87-6
			Perfluorotridecanoic acid	$C_{12}F_{25}COOH$	72629-94-8
	S = Sulfonate or sulfonic acid	PFTrDS	Perfluorotridecane sulfonate	$C_{13}F_{27}SO_3^-$	NA
			Perfluorotridecane sulfonic acid	$C_{13}F_{27}SO_3H$	NA
TeD = tetradeca (14 carbon)	A = Carboxylate or carboxylic acid	PFTeDA	Perfluorotetradecanoate	$C_{13}F_{27}CO_2^-$	365971-87-5
			Perfluorotetradecanoic acid	$C_{13}F_{27}COOH$	376-06-7
	S = Sulfonate or sulfonic acid	PFTeDS	Perfluorotetradecane sulfonate	$C_{14}F_{29}SO_3^-$	NA
			Perfluorotetradecane sulfonic acid	$C_{14}F_{29}SO_3H$	NA

NA = not available

Note that for carboxylates, the total number of carbons used for naming the compound includes the carbon in the carboxylic acid functional group (COOH), and so although PFOA has seven carbons in its fluoroalkyl tail, all eight of the carbons in the molecule are used to name it, hence *perfluorooctanoate*. However, in terms of chemical behavior, PFOA would be more analogous to seven-carbon perfluoroheptane sulfonate, PFHpS, than to eight-carbon perfluorooctane sulfonate, PFOS.

Note that in Table 3-1, PFAA names and formulas are shown in both the anionic (also referred to as “deprotonated”) and acid (or neutral; also referred to as protonated) forms. The anionic form is the state that PFAAs are found in the environment, except in very rare situations (for example, extremely low pH). The anionic and acid forms of PFAA names are often incorrectly used interchangeably (for example, perfluorooctane sulfonate and perfluorooctane sulfonic acid), and the same acronym (in this case, PFOS) applies to both forms. However, as discussed in Sections 3.2 and 6.2.2, their physical and chemical properties are different and it is important to know which form is being described.

Until recently, carboxylates and sulfonates have been the classes most commonly tested for in the environment. However, a wide range of PFAS with other functional groups exist for which the same “PFXY” shorthand shown above may or may not apply. For naming conventions for these compounds, please refer to Buck et al. (2011).

A Note About PFAS Naming in Laboratory Reports

Even though PFAAs occur as anions in the environment, some laboratories report all of their results in the acidic form, while others may report PFCAs as acids (for example, perfluorooctanoic acid) and PFSAs as anions (for example, perfluorooctane sulfonate). Different naming conventions in laboratory reports has led to confusion regarding exactly which form of the PFAA they are measuring. Although the lab is measuring the concentration of PFAA anions present in the sample, where the results are reported as an acid, the lab has adjusted for the H^+ cation (which has so little mass, this does not affect the resulting concentration).

It should be noted that the standards used by laboratories to perform analyses may be prepared from PFAA salts, as is often the case for sulfonate standards. If so, the lab must adjust the reported concentration to account for the mass of the counterion (typically Na+ or K+). The calculation to do this is described in Section 7.2.3 of EPA Method 537 (Shoemaker, Grimmett, and Boutin 2009).

3.1 Long Chain versus Short Chain Distinction

PFAAs are sometimes described as *long-chain* and *short-chain* as a shorthand way to group PFCAs and PFSAs that may behave similarly in the environment. However, it is important not to make generalizations about PFAA behavior based only on chain length. As recent research suggests, other factors besides chain length may affect bioaccumulation potential of PFAS (Ng and Hungerbühler 2014).

According to the Organisation for Economic Co-operation and Development (OECD 2013):

- *Long-chain* refers to:
    - o perfluoroalkyl carboxylic acids, PFCAs, with eight or more carbons (seven or more carbons are perfluorinated)
    - o perfluoroalkane sulfonates, PFSAs, with six or more carbons (six or more carbons are perfluorinated)

- *Short-chain* refers to:
    - o perfluoroalkyl carboxylic acids with seven or fewer carbons (six or fewer carbons are perfluorinated)
    - o perfluoroalkane sulfonates with five or fewer carbons (five or fewer carbons are perfluorinated)

Table 3-2 illustrates the differences in the short-chain and long-chain PFCAs and PFSAs.

Table 3-2. Short-chain and long-chain PFCAs and PFSAs

Short-chain PFCAs				Long-chain PFCAs				
PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS
Short-chain PFSAs		Long-chain PFSAs						

3.2 Anion versus Acid Form

As noted above, the names for the anionic and acid forms of PFAAs are often used interchangeably. However, it is critical to know which form is being discussed because of differences in their physical and chemical properties and behavior in the environment (see Section 6). Some important things to keep in mind regarding the anionic vs. acid forms are:

- Most PFAAs are present in environmental and human matrices in their anionic form. For example, PFOS is present in the environment in the anionic form, perfluorooctane sulfonate.
- Although laboratories may be reporting PFOA or PFOS using the acid form of their name, they are actually measuring the anionic form (for example, octanoate or sulfonate), as this is the form that exists in the environment.
- The acid form and their associated cationic salts have CAS numbers, while the anionic forms may not (see Table 3-1). For example, PFOS can exist as different salts (cationic), including sodium, lithium, potassium, or ammonium. Each of these salts will have a different CAS number:
    - o PFOS, acid form CAS No.: 1763-23-1
    - o PFOS, potassium salt CAS No.: 2795-39-3
    - o PFOS, ammonium salt CAS No.: 29081-56-9
- When the salt or acid exists in water or other liquids, it will dissociate and the salt or acid will break off and form the anion (COO^-). Figure 3-1 illustrates the dissociation of perfluorobutanoic acid.
- It is most important to distinguish between the acid form and anionic form when reporting the physical and chemical properties. The discussion of PFAS properties in this fact sheet generally refers to the anionic form; it will be specifically called out if the acid form is being discussed.

$$F_3C\text{-}CF_2\text{-}CF_2\text{-}COOH \rightleftharpoons F_3C\text{-}CF_2\text{-}CF_2\text{-}CO_2^- + H^+$$

Perfluorobutanoic acid **Perfluorobutanoate (+ dissociated proton)**

Figure 3-1. Dissociation of perfluorobutanoic acid

4 Linear and Branched Isomers of PFAS

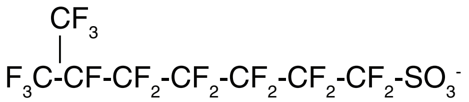
Many PFAS may be present as mixtures of linear and branched isomers (chemicals with the same chemical formula, but different molecular structures) depending on the manufacturing process that was used. These structural differences are important because they may affect how the compounds behave in the environment and may provide an indicator of their source. Structural differences are described below:

- A *linear isomer* is composed of carbon atoms bonded to only one or two carbons, which form a straight carbon backbone. There can be only one linear isomer in a C_n homologue (compounds with the same number of carbons in their tail) group.
- In a *branched isomer*, at least one carbon atom is bonded to more than two carbon atoms, which forms a branching of the carbon backbone. There can be many isomers per C_n homologue group.

Figure 4-1 illustrates the structures of linear and branched PFOS.

$F_3C\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}SO_3^-$

Linear Perfluorooctane sulfonate (PFOS)



$$F_3C\text{-}\overset{\overset{\displaystyle CF_3}{|}}{C}F\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}SO_3^-$$

Branched Perfluorooctane sulfonate (PFOS)

Figure 4-1. Linear and one branched isomer of PFOS

The formula "C_nF_{2n+1}-" (where n is greater than or equal to 3) includes linear and branched structures. For example, PFOS and PFHxS are routinely present in environmental samples as a mixture of linear and branched isomers.

Accurate quantification of PFAS that are mixtures of linear isomers and branched isomers in environmental matrices can be difficult (Riddell et al. 2009). However, they may be useful in understanding sources of PFAS and the age of the source, since the production of isomers varies by manufacturing processes. For example, the telomerization process produces only linear PFAAs, whereas the ECF process produces a mixture of linear and branched PFAA isomers (see Table 4-1 and the *History and Use Fact Sheet*). The presence of linear and branched isomers may also have implications for partitioning and transport.

Table 4-1. Manufacturing processes and potential PFAAs produced

Manufacturing Process	Commonly Found Polyfluorinated Substance (Precursors)	Potential PFAAs Produced
Telomerization	FTSA[1]	Linear PFCAs
	FTCA[2]	Linear PFCAs
	FTOH	Linear PFCAs
Electrochemical Fluorination	FOSE	Branched and Linear PFCAs Branched and Linear PFSAs
	FOSAA	Branched and Linear PFCAs Branched and Linear PFSAs

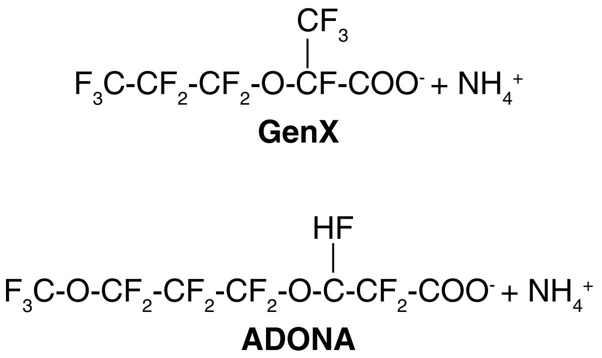
[1] Fluorotelomer sulfonate: found at AFFF sites
[2] Fluorotelomer carboxylic acids (for example, 5:3 Acid) found in landfill leachate

5 Replacement Chemistry

Concern regarding the persistence, bioaccumulation, and possible ecological and human health effects of long-chain PFAAs has led manufacturers to develop replacement short-chain PFAS chemistries that should not degrade to long-chain PFAAs (USEPA 2006a; OECD 2017). The short-chain alternatives include fluorotelomer-based products with a six-carbon perfluorohexyl chain and ECF-based products with a four-carbon perfluorobutyl chain. These products may degrade to form short-chain PFAAs, such as PFHxA and PFBS, respectively (Wang et al. 2013; Buck 2015). While a full discussion of such replacement chemistries is not possible here, it is important to be aware of this trend toward shorter-chain chemistries, as some of these PFAS increasingly may be detected in the environment.

Examples of this trend are replacement PFAS that have been developed for use as processing aids in the manufacturing of fluoropolymers. The replacements are generally fluorinated ether carboxylates. Two of these that have been detected in the environment and generated public concern and regulatory actions are given here (their molecular structures are illustrated in Figure 5-1):

- GenX–trade name for ammonium, 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate ($CF_3CF_2CF_2OCF(CF_3)COO^- NH_4^+$, CAS No. 62037-80-3), a perfluoropolyether carboxylate surfactant (Wang et al. 2013; Buck 2015)
- ADONA–trade name for ammonium 4,8-dioxa-3H-perfluorononanoate ($CF_3OCF_2CF_2CF_2\text{-}OCHFCF_2COO^- NH_4^+$ (CAS No. 958445-44-8), a polyfluoropolyether carboxylate surfactant (Gordon 2011)



$$F_3C\text{-}CF_2\text{-}CF_2\text{-}O\text{-}\overset{\overset{CF_3}{|}}{C}F\text{-}COO^- + NH_4^+$$

GenX

$$F_3C\text{-}O\text{-}CF_2\text{-}CF_2\text{-}CF_2\text{-}O\text{-}\overset{\overset{HF}{|}}{C}\text{-}CF_2\text{-}COO^- + NH_4^+$$

ADONA

Figure 5-1. Example replacement chemistry structures

6 Physical and Chemical Properties

The physical and chemical properties of PFAS, in concert with the characteristics of the environmental system, determine the environmental behavior of organic contaminants, including the compound's state and partitioning behavior (Banks, Smart, and Tatlow 1994). Partitioning can occur between neutral and ionic molecular forms, solid and liquid states, and between different media and biota (aqueous, pure phase, soil/sediment, biota, and atmospheric). The environmental behavior of many PFAS is further complicated by their surfactant properties.

Figure 6-1 illustrates key chemical and physical properties and distribution coefficients. Comparing the chemical and physical properties of different PFAS provides insight into similarities and differences in their environmental behavior and can inform investigation design.

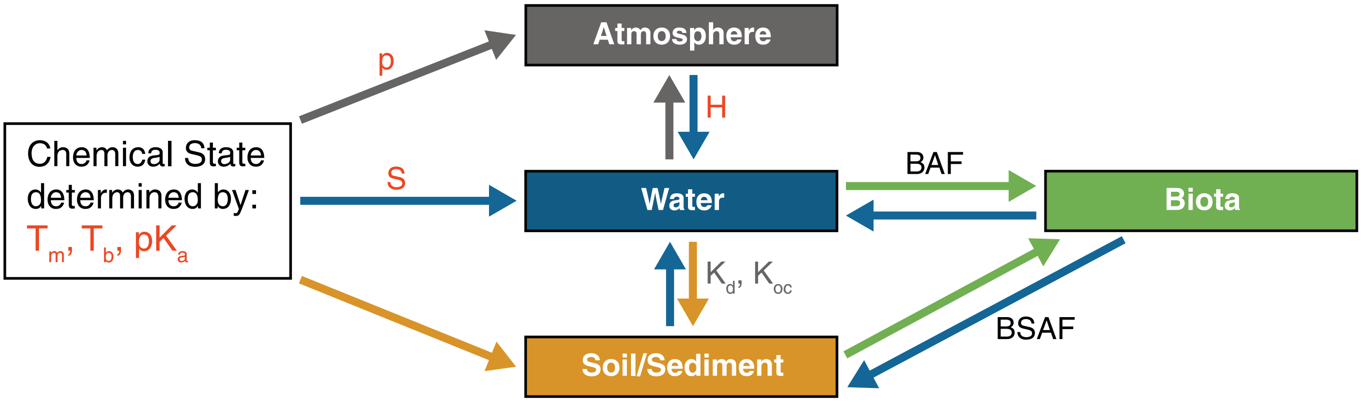


Figure 6-1. The role of key physical and chemical properties (shown in red) in influencing environmental compound behavior. Other key distribution coefficients (for example, Kd, Koc shown in grey) are addressed in the *Environmental Fate and Transport Fact Sheet*. Tm = melting point; Tb = boiling point; pKa = acid dissociation constant; p = vapor pressure; S = solubility; H = dimensionless Henry's law constant; Kd = soil and sediment partitioning coefficient; Koc = organic carbon partitioning coefficient; BAF = bioaccumulation factor; and BSAF = biota-sediment accumulation factor.

There is a large variation in published data on chemical and physical properties of PFAS. Reliable physical and chemical properties of PFAS are scarce (for example, vapor pressure and Henry's law constants), and some of the available values are modeled, as opposed to directly measured. Many of the available properties are based on the acid form of the PFAA, which are not present in the environment, unless at pH <3, which is not typical. Table 6-1 provides a general summary of the available chemical and physical property information for PFCAs and the sensitivity of this information in relation to the acid vs. anionic form. For example, the anionic forms of PFOA and PFOS have documented bioconcentration factor and bioaccumulation factor properties (Martin et al. 2003a; 2003b) while other properties are not readily available.

Table 6-1. Available physical and chemical properties for PFCAs

Properties								Environmentally Relevant?
PFAA State	CAS No.	S_w	P^o	K_h	K_{ow}	K_{oc}	BCF and/or BAF	
Acid	Y	Y	Y	E	E	E	N	No
Cation:								No
NH_4^+	Y	Y	N	N	N	N	N	
Li^+	Y	Y	N	N	N	N	N	
Na^+	Y	Y	N	N	N	N	N	
Anion	M	N	N	N	N	N	Y	Yes

S_w = solubility in water
P^o = vapor pressure
K_h = Henry's Law Constant
K_{ow} = octanol/water partition coefficient
K_{oc} = organic carbon partition coefficient
BAF = bioaccumulation factor
BCF = bioconcentration factor

Y = data available
N = no data available
M = data may be available for some
E = data estimated, not directly measured

6.1 Physical Properties

Many PFAS are in solid form at room temperature, often as a white powder or waxy substance, though some may be liquids. As mentioned before, data regarding physical properties of PFAS are scarce, and for PFAAs may relate to the acid form of the compound, which is not the most environmentally relevant form. Some melting point data are available for standards of PFCAs in the acid form. Measured vapor pressures for the acid form of PFOA, PFNA, PFDA, PFUnA, and PFDoA (Barton, Botelho, and Kaiser 2008; Kaiser et al. 2005) and fluorotelomer alcohols (Krusic et al. 2005) are also available. Similarly, Henry's Law constants are available for fluorotelomer alcohols (Goss et al. 2006). For PFAAs, the acid form is known to partition into air from aqueous solutions at very low pH (Kaiser et al. 2010). Care should be taken when reviewing available physical property information for PFAS to ensure that it applies to the form (for example, acid or anionic) of concern to the project or site in question.

6.2 Chemical Properties

6.2.1 Fluorine and the Carbon-fluorine (C-F) Bond

As previously mentioned, understanding PFAS chemical properties is key to understanding the diversity of uses and applications associated with this class of compounds, as well as their unique environmental behavior. Some key fluorine chemical properties and the characteristics they impart to PFAS are provided in Table 6-2.

Properties such as the high electronegativity and small size of fluorine lead to a strong C-F bond, the strongest covalent bond in organic chemistry (Kissa 2001; Banks, Smart, and Tatlow 1994). The low polarizability of fluorine further leads to weak intermolecular interactions, such as van der Waals interactions and hydrogen bonding (Kissa 2001; Banks, Smart, and Tatlow 1994). It is mainly the unique properties of fluorine that give many PFAS their mutually hydro- and lipophobic (stain-resistant) and surfactant properties and make them thermally and chemically stable. Not all of these characteristics (for example, surface activity) are universal to all PFAS.

Table 6-2. Fluorine characteristics, resulting characteristics and properties of PFAS

Fluorine Characteristic	Description	Result	Resulting Property of PFAS
High electronegativity	Tendency to attract shared electrons in a bond	Strong C-F bond	Thermal stability
			Chemical stability (low reactivity)
		Polar bond with partial negative charge towards F	Strong acidity (low pKa)[1]
Low polarizability	Electron cloud density not easily impacted by the electric fields of other molecules	Weak intermolecular interactions (for example, van der Waals, hydrogen bonds)	Hydrophobic and lipophobic surfactant properties2
		Low surface energy	
Small size	Atomic radius of covalently bonded fluorine is 0.72 Å	Shields carbon	Chemical stability (low reactivity)

[1] When paired with an acid functional group such as a carboxylic or sulfonic acid
[2] When paired with a functional group that is hydrophilic (for example, a carboxylate)
Å = Angstrom

6.2.2 Acid Dissociation Constants

Knowing whether a chemical will dissociate in other liquids is important to understanding its fate and transport in the environment. The acid dissociation constant (K_a) is a quantitative measurement of the strength of an acid in solution, although it is usually presented in the form of the logarithmic constant (pK_a). The larger the value for pKa, the smaller the extent to which the chemical will dissociate at a given pH. Chemicals with small pKa values are called *strong acids* and those with large pKa values are called *weak acids*.

Many PFAAs, such as PFCAs and PFSAs, are strong acids due to the electron withdrawing effects of fluorine extending to their acid functional groups (Kissa 2001, Banks, Smart, and Tatlow 1994). As a result, most PFAAs readily dissociate in water and other environmental matrices. Therefore, at most environmentally relevant pHs, PFCAs and PFSAs are present in the dissociated anionic form rather than the acid form.

The acid and anionic forms have very different physical and chemical properties. For example, perfluorooctanoate anion is highly water soluble and has negligible vapor pressure, whereas perfluorooctanoic acid has very low water solubility and sufficient vapor pressure to partition out of water into air. It is essential to distinguish between the acid form and the anionic form when looking at physical and chemical properties or fate and transport evaluations.

Specific pKa values for PFAAs are generally not available. Limited model-predicted and experimental values are available for PFOA, and range from -0.5 to 3.8 (Burns et al. 2008; Kissa 2001; Barton, Kaiser, and Russell 2007; Goss 2008), suggesting that at nearly neutral pH (near pH = 7.0), PFOA will exist in the aqueous phase in anionic form and the amount of acid PFOA in most environmentally relevant systems will be negligible. A recent study estimates that the pKa values of PFBA, PFHxA, PFHpA, PFOA, PFNA, PFDA, and PFUnA are all less than 1.6 and pKa values of PFSAs are expected to be even lower (Vierke, Berger, and Cousins 2013).

6.2.3 Thermal and Chemical Stability

Terminal PFAAs, such as PFOA and PFOS, are extremely stable, thermally and chemically, and resist degradation and oxidation. Thermal stability of PFAAs is primarily attributable to the strength of the C-F bond in the fluoroalkyl tail (Kissa 2001). The stability is determined by the specific functional group that is attached to the fluoroalkyl tail. PFCAs and PFSAs are the most stable fluorinated surfactants. The acid forms of these PFAAs decompose at temperatures greater than 400°C, but complete mineralization occurs at temperatures greater than 1000°C. In a practical situation like a municipal incinerator, the mineralization temperature may be lower due to the presence of other substances that contain hydrogen. The thermal stability is lower for the salts of PFAA compounds and depends on which cation is the counter ion. For example, the 20% decomposition temperature of sodium perfluorooctanoate is 298°C, but is 341°C for lithium perfluorooctanoate (Kissa 2001). Additionally, salts of PFSAs are more thermally stable than the corresponding salts of PFCAs (Kissa 2001).

The strength of the C-F bond, shielding of carbon by fluorine, and inductive effects (caused by fluorine electronegativity) also lead to PFAS chemical stability. For example, electron-rich chemical species called nucleophiles normally would be attracted to the partial positive charge of carbon. If they can get close enough to the carbon to bond with it, this would eliminate a fluorine from the molecule, making it vulnerable to degradation. However, the size of the fluorine atoms surrounding the carbon prevents this from happening (Banks, Smart, and Tatlow 1994; Schwarzenbach, Gschwend, and Imboden 2003). This is why processes such as hydrolysis, which involve eliminating one or more fluorines, are ineffective at degrading PFAS. Similarly, many PFAS are resistant to degradation by oxidative processes that rely on a loss of electrons (Kissa 2001). PFAS are also resistant to reductive processes, which involve gaining electrons. Despite having a high affinity for electrons, fluorine does not have vacant orbitals favorable for accepting additional electrons (Park et al. 2009).

6.2.4 Octanol/Water Partition Coefficient, K_{ow}

The octanol/water partition (K_{ow}) coefficient is sometimes used as a proxy for uptake in biological systems. The K_{ow} value is defined as "the ratio of a chemical's concentration in the octanol phase to its concentration in the aqueous phase of a two-phase [octanol/water system]" (USEPA 2015d). The vapor pressure, melting point, and boiling point of neutral, volatile, non-polymeric PFAS (for example, FTOH) can be measured, and K_{ow} can be either estimated or measured. The K_{ow} values that are typically tabulated for the PFCAs and PFSAs are for the acid form and are therefore not relevant because PFCAs and PFSAs are anionic at environmental pHs. Additionally, because many PFAS bind to proteins (proteinphiles), some PFAS may bioaccumulate by mechanisms other than those that drive more traditional hydrophobic contaminants (Ng and Hungerbühler 2013; 2014). Other PFAS may simply be detected in organisms due to ongoing exposures and their extended human half-lives (for example, concentrations in drinking water) (Wiesmueller 2012; Gyllenhammar et al. 2015). It should be noted that although the K_{ow} for some organic contaminants can be used for estimating K_{oc}, this cannot be performed for estimating values for PFAS.

7 Summary

This fact sheet addresses naming conventions and physical and chemical properties of some of the most commonly reported PFAS considering historical use, current state of science research related to environmental occurrence, and available commercial analyses. For naming conventions related to additional PFAS, refer to Buck et al. (2011). In general, values for physical and chemical properties of many non-polymeric PFAS are not available. With the 2015 major global manufacturer phase-out of long-chain PFAAs and their potential precursors, such as those based on C8 chemistry (see *History and Use Fact Sheet*), replacement PFAS (for example, short-chain alternatives and non-polymer perfluoropolyethers) have been commercially introduced (many following review by USEPA) and may continue to be developed. In the future, it may be necessary to expand the current naming conventions and acronym approaches to ensure that standardized naming is available for additional members of the PFAS class of compounds. Further, additional information on physical and chemical properties of these compounds may become available as increased numbers of PFAS are included in environmental and human health-related studies. Refer to the other PFAS fact sheets for further information on these properties and how they are practically applied.

8 References and Acronyms

The references cited in this fact sheet, and the other ITRC PFAS fact sheets, are included in one combined list that is available on the ITRC web site. The combined acronyms list is also available on the ITRC web site.

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