American Journal of Chemistry 2023, 13(3): 49-67
DOI: 10.5923/j.chemistry.20231303.01

A Systematic Review of PFAS & Subcategory Chemicals: An Overview of the Testing Methods and a Comprehensive Summary of the Associated Legislations at National & Global Level

Sudhaunshu S. Purohit

ETS Laboratories, USA

Abstract The modern world though unfortunately but inevitably has succumbed to the repetitive incidences of environmental contamination through industrial pollution and chemical exposure. PFAS is a category of prevalently focused upon and alarmingly harmful substances along with other commonly known pollutants such as lead, arsenic, mercury, asbestos, dioxins, polychlorinated biphenyls (PCBs), pesticides, oil spills etc. PFAS are considered unique not only due to their toxicity but also because of their persistence and mobility in the environment. Considering the ineffective response of communities to environmental toxicities, in the light of corporate manipulation of regulatory frameworks, the role of litigations and new procedures of advocacy; promoting awareness in the sociopolitical dimensions about PFASs has become essential. This mission can be accomplished through scientific, media & public discourses alongside an inclusion of new forms of community organizing & citizen engagement in everyday life. This review systematically presents the acts, laws, rules & plans associated with PFAS and subcategory chemicals at national and global front; ultimately attempting to increase the understanding at personal & public levels of these dire environmental pollutants which are unimaginably menacing to the populous worldwide. The multi-faceted nature of this article introduces the novelty by including a myriad of facts on a special subject of scientific significance; thus, appealing to a multidisciplinary & diverse audience of scientists, policy makers and an overall broad environmental community.

Keywords PFAS, PFOA, PFOS, Hazardous Industrial Pollutants, Environmental Pollution, Climate Change, Drinking Water, Regulatory Frameworks, Litigations, Legislations, Analytical Testing Methods, LC-MS/MS, UPLC, HPLC, Environmental Protection Agency

1. Introduction

Perfluoroalkyl substances (PFAS) or polyfluorinated compounds (PFCs), such as perfluoro-1-octanesulfonic acid (PFOS) and perfluoro-n-octanoic acid (PFOA) are a large group of man-made chemicals composed of one or more carbon atoms on which all hydrogen substituents have been replaced with fluorine atoms. They were first commercially produced in 1940s. PFAS, the term first coined by Buck et al in 2011 are a class of thousands of synthetic chemicals with numerous industrial and commercial applications with an extensive number of compounds that can be included in this classification. These compounds are primarily carboxylic acid (PFOA) or sulfonic acid (PFOS) (sulfonates) with completely fluorinated alkyl groups of various lengths and can also form linear or branched chains. Buck et al described them as aliphatic substances containing the moiety $-C_nF_{2n+1}$ within their structure, where n is at least 1. PFCs and perfluorinated alkyl acids (PFAAs) are additional terms referring to this class of chemicals. PFAS chemicals have been used in a wide range of consumer products possessing properties such as electrical insulation and resistance to oil, water, heat, fire etc. PFAS are used in manufacturing of a variety of devices including but not limited to commercial aircrafts & transportation and in electronics industry. Their ability of effectively lowering the surface tension of water than comparable hydrocarbons makes them inseparable part of surfactant industry. They have several other industrial applications including carpeting, upholstery, apparel, floor wax, textiles, 'Aqueous Film-Forming Foams' (AFFFs) used in firefighting and sealants. Due to increasing concern for potential health effects associated with these compounds, PFOS is no longer produced in the United States and PFOA also known as C8, is currently being phased out of production [1-5].

* Corresponding author:
sudhaunshu.p@gmail.com (Sudhaunshu S. Purohit)
Received: May 23, 2023; Accepted: Jun. 8, 2023; Published: Jun. 12, 2023
Published online at http://journal.sapub.org/chemistry

The subcategories PFOA & PFOS are bio accumulative, anthropogenic, organic pollutants which do not easily degrade and can persist in the environment for a significant amount of time. The non-degradability of the longer chain chemicals is attributed to the strength of carbon-fluorine bond as they are also termed as '*Forever Chemicals*'. Large numbers of chemicals under the category of PFAS are used in a wide range of industries posing greater occupational exposure to the associated employees. PFAS such as PFOS & PFOA are prevalent throughout the environment, resulting in contamination of drinking water, surface water and soil. The highest concentrations are typically encountered in the areas in close proximity to facilities involving working of firefighting training, ski wax technicians, industrial production with manufacturing workers and discharge from wastewater treatment plants (both in effluents and bio solids). Human exposure to PFAS compounds occurs through use of commercial products, drinking water, air and dust. Studies have indicated that these compounds are present in virtually all individuals. Several years ago, manufacturers began to replace the previously produced long chain PFASs with short chain PFASs. 'Contaminants of Emerging Concern' (CECs), including PFAS are of interest to regulators, water treatment utilities, the general public & scientists worldwide and accordingly studies have been conducted from many 'Drinking Water Treatment Plants' (DWTPs) across the United States. Data on human health effects for the shorter chain PFASs is limited, but adverse effects from exposure have been indicated in some studies. PFAS are widely found in soil, air and groundwater at sites across the United States and have shown to accumulate in humans, trees and animals. The toxicity, mobility and bioaccumulation potential of PFAS pose potential adverse effects for the environment and human health. The exposure of PFAS and its adverse effects on human health were studied and the links between number of diseases such as Hypercholesterolemia, ulcerative colitis, cancer, thyroid disease, disruption of endocrine activity, reduced immune system function, impairment of various organs, pregnancy induced hypertension & preeclampsia and PFAS was established [6-17].

2. Analytical Techniques & Procedures of Testing and Method Performance for PFASs in Drinking Water

In general, the testing laboratories undertaking the task of PFAS analysis necessitates an industrialization of an adequate capacity that accommodates stations for sample extraction/preparation & pre-analysis sample treatment along with instrumental set-up and storage area for samples / standards. 'Gas Chromatography-Mass Spectroscopy' (GC-MS) in tandem either 'Electron Ionization' (EI) or 'Chemical Ionization' (CI) in 'Selected Ion Monitoring' (SIM) mode is a useful analytical technique for the neutral PFAS where most studies employed a WAX column such as DB-WAX (Agilent). A type of liquid chromatography that utilizes very small sized packing particles and a relatively high pressure is referred to as 'High-Performance Liquid Chromatography' (HPLC) and 'Ultra-Performance Liquid Chromatography' (UPLC) a specific term coined by company 'Waters'. The sample is forced by a liquid mobile phase at high pressure through a column that is packed with a solid stationary phase composed of irregularly or spherically shaped particles, a porous monolithic layer, or a porous membrane. HP/UP-LC-MS/MS with Electro-Spray Ionization (ESI) is a useful analytical technique for the ionic PFAS. Based on the difference in polarity of the mobile and stationary phases, the UPLC technique is sub-categorized as 'Normal Phase Liquid Chromatography' (NPLC) where stationary phase has higher polarity than mobile phase and 'Reversed Phase Liquid Chromatography' (RPLC) where mobile phase has higher polarity than stationary phase. The sample under study containing PFAS and its carboxylic & sulfonic acid derivatives can be effectively separated by implementing the principles of RPLC technique. Mixture of water or aqueous buffers and water soluble organic solvents such as isopropanol, methanol, acetonitrile etc. can be used as mobile phase along with silica based inert stationary phase such as C18 resins with identical retention properties. The pH of the mobile phase plays crucial role on the retention and the selectivity of certain compounds. Mass spectrometry is used in tandem with many chromatographic separation techniques where magnetically enhanced quadrupole mass analyzer being a mass selective filter is the prominent type. The 'Triple Quadrupole Mass Analyzer' (TQMA), a variation commonly known as 'Triple Quad' (TQ) has three consecutive quadrupole stages made to rapidly and repetitively cycle through a range of mass filter settings in order to effectively perform various scan types characteristic of tandem mass spectrometry. [18-24]

Industries have developed and validated methods utilizing LC-MS/MS systems in conjunction with the testing procedures capably meeting reference method guidelines to measure PFAS compounds in water & soil samples. UPLC coupled with TQ is widely used for the routine analysis of large number of PFASs in water matrices because of its high sensitivity and specificity. Laboratories are processing aqueous and solid samples through a pre-analysis treatment and various extraction processes such as Soxhlet, Ion Pair (IPE), Solid Phase (SPE) & Solid Phase Micro (SPME), Liquid-Liquid (LLE) & Dispersive Liquid-Liquid Micro-Extraction (DLLME) along with demonstrating method performance, determining limits of detection & quantification, assessing the accuracy & precision, performing recovery assessment of spiked matrices thus, developing standard operating procedures for the analysis of PFAS compounds. An essential part includes keenly executing strict implementation of Quality Control (QC) acceptance criteria set by US EPA to ensure the consistency and reproducibility of all the experimental results, particularly if the data were to be used for enforcing

regulation. [25-35] It is also important to study the 'Precursors' which are the known and unknown substances, possessing the potential to form PFAS compounds at degradation to elucidate present and future exposure for plants, animals & humans as well as levels in environmental matrices. Hence, the measurement of 'Total Oxidizable Precursors (TOP) Assay' a method involving oxidative conversion as a means of detecting PFAS compounds is a crucial process. The majority (~85%) of PFAS are PFAA precursors, which degrade or metabolize into PFAAs in the environment or in living organisms (transformed to dead end PFAAs) in such reactions [36-38]. Testing laboratories are observed to quickly adopting and efficiently handling the challenges incurred within the various requirements of the subsequent analysis.

EPA validated and published various analytical testing methods [39-41] such as 'Method 533' complimentary to 'Method 537.1' focusing on short chain (C_4 to C_{12}) thus adding total 29 PFAS compounds in the list. EPA Method 537, 537.1 and EPA Method 533 are the most prevalently practiced versions for the determination of PFAS compounds. EPA published Method 537 in 2008, an updated Version 1.1 in 2009, Method 8327 in 2021 and Method 1621 in 2022. These methods established analytical procedures for determining PFAA concentrations in drinking water. Method 537 lists many PFAA compounds and specifies the analytical protocol for the extraction and instrumental analysis EPA's important scientific advancement makes it possible for both government and private laboratories to effectively measure more PFAS chemicals in drinking water. In unison EPA and NIH researchers are working to develop new chemical testing approach methods to test 150 PFAS chemicals. These efforts are generating an informative data about toxicity, its kinetics and subsequently, the potential health effects of PFAS [42-50]. The published methods can be obtained at 'National Service Center for Environmental Publications' (NSCEP: https://www.epa.gov/nscep).

A General Description of the Analytical Testing Methods: An aliquot of a water sample is fortified with surrogates and passed through a solid phase cartridge of polystyrenedivinylbenzene, which captures the analytes of interest. The cartridge is eluted with a minimal volume of methanol and concentrated to dryness with nitrogen in a heated water bath. A solution of CH_3OH:H_2O is added to the extract and adjusted to the desired final volume (typically 1 mL) after addition of internal standards. An aliquot of the extract solution is introduced into a LC-MS/MS system equipped with a C18 column and data system. Comparison of the retention time and resulting mass spectra to reference standards used for instrument calibrations allows for identification of the compounds of interest. The concentration of analytes identified is determined by internal standard calibration techniques. The use of LC-MS/MS allows quantification of PFAS compounds in the parts per trillion (ppt) range due to its enhanced sensitivity. Coupled with the determinative capability of tandem mass spectrometry, these methods allows for the definitive assay of PFASs at trace levels in drinking water and other applicable matrices. These methods specifically establish 'Minimum Reporting Levels' (MRL) for each compound, a procedure to determine the lowest concentration of analyte that can be measured with a high degree of confidence. Tuning and calibration procedures ensure optimization of the instrument for the analysis of PFASs. Specifications for establishing and verifying the calibration curve are required to be met prior to sample analysis. System cleanliness is monitored through routine analysis of laboratory reagent blanks and supplied field blanks. Performance is assessed through monitoring the recovery of surrogates; laboratory fortified blanks & matrix samples as well as internal standards. System monitoring is assessed throughout the analytical event through various quality control evaluations.

3. Legislative Actions on PFAS at National Level

Over the period of time as advanced analytical techniques were invented improving the qualitative & quantitative detection, PFAS were discovered to be profoundly present in exceeding amounts in environment with proven potential to build up over time. They caught the attention of regulatory agencies because of their persistence, toxicity & widespread occurrence in the blood of general populations and wildlife. Non-governmental standardization bodies such as 'American Society for Testing & Materials' (ASTM International) and 'International Organization for Standardization' (ISO) have contributed in the development and validation of standardized analytical methods for LC-MS/MS. They have successfully established the protocols such as ISO-25101 & ASTM D7979-20 with isotopic dilution (developed by US EPA Region-5, Chicago Regional Laboratory: https://www.epa.gov/aboutepa/epa-region-5) for PFAS analysis in non-drinking environmental water, sludge effluent samples and 'SW-846: Test Method 8327' for soil/solid waste samples. All of these procedures specify the use of LC-MS/MS as the analytical technique and perform analysis of the complete list of the PFCs requested in the 'MDEQ IPP PFAS Program' [51-53]. The 'Michigan Department of Environmental Quality' (MDEQ) initiated in 1995 is a principal institution in the state of Michigan, which has been conducting environmental clean-up of regulated contaminants for decades. MDEQ discovered PFAS in the groundwater in 2010 while monitoring the wells at the former Wurtsmith air-force base. 'Remediation and Redevelopment Division' (RRD) is a leading investigation branch of MDEQ that establishes and implements the criteria to clean up the groundwater sites contaminated with PFAS since 2018. In January 2018, as a part of the 'Michigan PFAS Action Response Team' (MPART: https://www.michigan.gov/pfasresponse), 2 science advisory committees were created to coordinate & review medical & environmental

health, PFAS science and to develop evidence-based recommendations [54]. The 'Minnesota Department of Health' (MDH) in 2002 first developed health based values for PFOS, PFOA, PFBS, & PFBA, and uses the PFOS value as a surrogate for evaluating PFHxS. MDH partnered with 'Minnesota Pollution Control Agency' (MPCA) to investigate PFAS in drinking water east of Saint Paul near the 3M Cottage Grove plant and related legacy waste disposal sites in Washington County. In year 2000, 3M announced the termination of PFOA & PFOS production and also notified the MPCA in 2002, about finding a contaminated groundwater at its Cottage Grove plant [55].

The 'Interstate Technology Regulatory Council' (ITRC: https://itrcweb.org/home) a program of the 'Environmental Research Institute of the States' (ERIS), managed by the 'Environmental Council of the States' (ECoS) is a state-led, public-private coalition since 1995, dedicated to protect & improve the health of human & the environment across the U.S. ITRC represents over 700 individuals, across 50 states, by bringing together teams of state and federal regulators along with private, academic & stakeholder experts, all working to produce guidance and training on innovative environmental solutions. Their PFAS Team began working in January 2017 (https://pfas-1.itrcweb.org/) [56]. The 'National Toxicology Program' (NTP) by 'United States Department of Health and Human Services' (US-DoHHS) is an inter-agency program arose from congressional concerns about the health effects of chemical agents in the environment. It is headquartered at the 'National Institute of Environmental Health Sciences' (NIEHS: https://ntp.niehs.nih.gov/index.cfm) and established in 1978 to coordinate, evaluate and report on toxicology within public agencies. In order to help predict toxicity of new PFASs, NTP conducted sub-chronic toxicity & toxicokinetic studies of 7 PFAAs viz. 3 sulfonates (NTP TOX-96) & 4 carboxylates (NTP TOX-97) with varying chain lengths. The respective Toxicity Reports # 96 & 97 were published initially in August 2019 with later revised version in July 2022. These reports reflect studies usually involving a short-term (3 months to a year) exposure to small laboratory animals to evaluate the toxicity and the substances selected are primarily chosen on the basis of human exposure, level of production & chemical structure [57].

The creation of the 'United States Environmental Protection Agency' (US-EPA) in 1970 marked a period of landmark reforms. EPA and several states have developed human health guidelines for exposure to PFOS & PFOA (https://www.epa.gov/pfas). The 'Federal Water Pollution Control Act' (FWPCA) enacted in 1948 was significantly reorganized and expanded in 1972 to be known as the 'Clean Water Act' (CWA), under which the EPA has implemented pollution control programs such as setting wastewater standards for industry and developing national water quality criteria recommendations for pollutants in surface waters. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA is exploring data availability to support the development of CWA for human health and aquatic life along with the risk assessments of PFOA & PFOS in bio-solids to understand any potential health impacts [58-61]. EPA validated and published various testing methods under CWA (https://www.epa.gov/cwa-methods) such as Draft Method 1633 for PFAS analysis. The 'National Pollutant Discharge Elimination System' (NPDES) permit program is an important tool established through CWA in 1972 to help address water pollution by regulating point sources that discharge pollutants into the waters of the United States (https://www.epa.gov/npdes). EPA issues thousands of NPDES permits annually for 'Industrial Users' (IU), to establish important monitoring and pollution limits for publicly owned treatment works, industrial facilities and storm-water discharges nationwide. In order to understand the current and upcoming regulatory and analytical landscape, under the authority of CWA, EPA is in the process of developing additional analytical methods such as 608.3, 624.1 & 625.1 for NPDES permits [62-65]. In 1974, the 93rd US Congress passed a principal federal law, the 'Safe Drinking Water Act' (SDWA: https://www.epa.gov/sdwa) under which the EPA set the standards for drinking water quality and monitors states, local authorities & water suppliers who enforce those standards. The 94th US Congress enacted a principal federal law, the 'Resource Conservation and Recovery Act' (RCRA: https://www.epa.gov/rcra) program also nicknamed as 'Solid Waste Utilization Act' (SWUA), which is a joint federal and state endeavor, with the EPA in 1976 as an amendment of the 'Solid Waste Disposal Act' (SWDA) of 1965 to address the growing volume of municipal & industrial waste and to govern the disposal of solid & hazardous waste [66-70]. In the state of California, the 'Department of Toxic Substances Control' (DTSC: https://dtsc.ca.gov/) formed in 1991 is a division of 'California Department of Public Health' (CDPH: https://www.cdph.ca.gov/) and is also a part of 'California Environmental Protection Agency' (Cal-EPA: https://calepa.ca.gov/). DTSC is the primary authority enforcing the RCRA requirements, along with the 'California Hazardous Waste Control Law' (CHWCL) of 1972. As per explained in one of the DTSC's 23 constituent Candidate Chemicals authoritative lists, contains the entire class of PFAS namely, the 'Biomonitoring California Priority Chemicals List' (BCPCL) which in 2015, designated all PFAS, (as mentioned by Buck et al. [1]), as Priority Chemicals [71-73].

The 'Toxic Substances Control Act' (TSCA) a principal federal law of 1976, passed by 94th US Congress and administered by EPA was enacted to regulate commerce, protect human health & the environment by addressing the production, importation, use, disposal and by requiring testing along with using restrictions if necessary on certain chemicals such as PCBs, asbestos, radon, lead-based paint and PFAS [74-77]. The 'Comprehensive Environmental Response, Compensation and Liability Act' (CERCLA)

enacted by 96th US Congress in December 1980, provides a federal "Superfund" (https://www.epa.gov/superfund) empowering EPA to clean up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills and other emergency releases of pollutants & contaminants into the environment. The Superfund administered by the 'Office of Superfund Remediation and Technology Innovation' (OSRTI) which also implements CERCLA is in turn managed by the 'Office of Land and Emergency Management' (OLEM). EPA issued interim recommendations for addressing groundwater contaminated with PFOA & PFOS, which provides cleanup guidance for federal cleanup programs that will be helpful to states and tribes. EPA initiated the regulatory development process for listing 2 common types of PFAS chemicals (PFOA & PFOS) as hazardous substances under the CERCLA [78-83]. The 'National Oil and Hazardous Substances Contingency Plan' (NOHSCP) of 1968 or simply known as the 'National Contingency Plan' (NCP) is the Federal government's blueprint for responding to hazardous substance releases and oil spills that reach the environment. NCP also established the 'National Priorities List' (NPL), provided the guidelines & procedures required to respond to the potential releases of hazardous substances, pollutants or contaminants was enabled by CERCLA. The 'Agency for Toxic Substances and Disease Registry (ATSDR: https://www.atsdr.cdc.gov/)' (formed 1980-1985), originally authorized by CERCLA and additionally authorized by RCRA & SARA is a federal public health agency within the US-DoHHS which assists EPA in performing public health risk assessments associated with exposure to NPL hazardous substances waste sites along with establishing & maintaining toxicological databases, information dissemination and medical education. In June 2018, ATSDR released, "Toxicological Profile for PFAS", a 697-page draft report for public comment [84-90].

In 1986, the 99th US Congress passed the 'Emergency Planning and Community Right-to-Know Act' (EPCRA: https://www.epa.gov/epcra) to support & promote emergency planning and to provide the public with information about releases of toxic chemicals in their community [91,92]. Section 313 of EPCRA established the 'Toxics Release Inventory' (TRI: https://www.epa.gov/toxics-release-inventory-tri-program), a list of toxic chemicals. EPA proposed to establish drinking water regulations for these chemicals under the SDWA and add PFOA & PFOS to the TRI, listing them as hazardous air pollutants [93]. The Title-III of the 'Superfund Amendments and Reauthorization Act' (SARA) of 1986 reauthorized CERCLA to continue cleanup activities around the country. Several site-specific amendments, definitions clarifications and technical requirements were added to the legislation, including additional enforcement authorities. SARA also required EPA to revise the 'Hazard Ranking System' (HRS) to ensure that it accurately assessed the relative degree of risk to human health and the environment posed by uncontrolled hazardous waste sites that may be placed on the NPL [94,95].

In 1996 amendments to the SDWA by 104th US Congress outlined the requirement of the EPA to protect human health by establishing drinking water standards. EPA clearly enforced administrative penalty authority over federal agencies engaged in certain activities, such as owning or operating a public water system, to comply with all federal, state, interstate and local safe drinking water requirements under SDWA in section 1447, 42 U.S.C. §300j-6. The 'Federal Civil Penalties Inflation Adjustment Act' of 1990 required EPA to revise the penalty amounts available under federal environmental statutes every 4 years. In order to be able to understand the frequency & concentration of PFAS occurrence in drinking water, every 5 years, the SDWA charged EPA with developing the drinking water 'Contaminant Candidate List' (CCL: https://www.epa.gov/ccl) which identifies unregulated chemicals and microorganisms of health interest that are known or anticipated to occur in 'Public Water Systems' (PWS). In general, PWS (publicly or privately owned) provides water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year. EPA has classified PWS under 3 categories viz. Community Water System (CWS), Transient Non-Community Water System (TNCWS), Non-Transient Non-Community Water System (NTNCWS). The SDWA defines 'contaminants' as any physical, chemical, biological, or radiological substances other than water molecules and only a small number of contaminants are listed in the CCL which serves as the first level of evaluation for unregulated drinking water contaminants that may need further investigation of potential health effects and the levels at which they are found in drinking water. Once a final CCL is published, the EPA compiles any additional data to determine which contaminants have sufficient information to be evaluated against the 3 criteria listed in SDWA in order to decides if and which (at least) 5 contaminants from the CCL can be included in a separate process called 'Regulatory Determinations' (RD). CCL-1 being announced in March 1998, CCL-2 in February 2005 and CCL-5 in November 2022, SDWA further specified that the contaminants posing the greatest public health concern related to exposure from drinking water should be placed in the list by EPA on priority basis for regulatory decision making and information collection and accordingly RD-1 in July 2003 and RD-4 were issued in February 2021. Since, CCL-3 in 2009 to help identify and to consider for the CCL unregulated contaminants that may require a 'National Drinking Water Regulation' (NDWR) the 'National Drinking Water Advisory Council' (NDWAC: https://www.epa.gov/ndwac) and the 'National Academy of Sciences, Engineering, and Medicine' (NASEM: a combination of NAS, NAE & NAM) recommended EPA to include public participation early in the CCL development process. The Agency considered the best available data and information on health effects and occurrence to evaluate thousands of unregulated

contaminants. EPA used a multi-step process to select 116 candidates for the final CCL-3 thus, adding 104 chemicals or chemical groups & 12 microbiological contaminants. In June 2011, EPA hosted a public stakeholder meeting in Washington, DC, to discuss the Agency's RD-3. The CCL-4 was announced in November 2016 and was finalized in February 2021 in which PFOA & PFOS are 2 of the 97 chemicals [96-99].

An additional authority under the SDWA amendments of 1996 and the amendments by Section 2021 of 'America's Water Infrastructure Act' of 2018 (AWIA) [100] is the option allowing to gather nationwide occurrence data through the 'Unregulated Contaminant Monitoring Rule' (UCMR https://www.epa.gov/dwucmr). The UCMR was developed in coordination with CCL, a list of those contaminants which are not regulated by the 'National Primary Drinking Water Regulations' (NPDWR) which are legally enforceable primary standards and treatment techniques applied to PWS to protect public health by limiting the levels of contaminants in drinking water. Once every 6 years SDWA requires EPA to review and revise each NPDWR. Review-1 published in July 2003 (occurred 1993-97) included 69 contaminants from 16 states; Review-2 published in March 2010 (occurred 1998-2005) included 69 contaminants from 47 states; whereas; Review-3 published in December 2016 (occurred 2006-11) included 76 contaminants from 54 states [101,102]. In order to establish the list of contaminants for each UCMR cycle, the EPA evaluates candidate UCMR contaminants using a multi-step prioritization process which includes the CCL, other priority contaminants and multi-contaminant methods to collect occurrence data in an efficient, cost-effective manner. EPA uses the UCMR to collect data for contaminants that are suspected to be present in drinking water but lack health-based standards set under the SDWA. The UCMR was established to monitor priority unregulated contaminants in PWS for a maximum of 30 analytes in a 5 year cycle for all utilities that serve N10,000 people and a statistical sampling of those utilities serving b10,000 [103]. The data of occurrence and analytical results are stored in a 'National Contaminant Occurrence Database' (NCOD) [104]. Through assessment monitoring & screening survey UCMR-1 published in September 1999 (occurred 2001-03) included 26 & UCMR-2 published in January 2007 (occurred 2008-10) included 25 contaminants using analytical methods developed by EPA, consensus organizations or both which provided a basis for future regulatory actions to protect public health. The EPA's 'Office of Water' (OW) conducted UCMR-3 published in May 2012 (occurred 2013-15) which included 30 substances (28 chemicals & 2 viruses). It contains 6 PFAS compounds viz. perfluoro-butanesulfonic acid (PFBS), perfluoro-heptanoic acid (PFHpA), perfluoro-hexanesulfonic acid (PFHxS), perfluoro-nonanoic acid (PFNA), PFOS & PFOA. OW working along with EPA is responsible for implementing CWA, SDWA & RCRA as well as many other acts. UCMR-4 published in December 2016 (occurred 2018-20) included 10 cyanotoxins & 20 additional contaminants. EPA planned to propose nationwide drinking water monitoring for PFAS under the next monitoring cycle: UCMR-5 utilizing newer methods available to detect more PFAS chemicals and at lower MRLs than previously possible in earlier monitoring [105-109].

Even though, in 1960s and in the 1970s, the toxicology of PFOA was studied by DuPont and 3M collected data on exposure to workers respectively; it was late 1990s and early 2000s when PFOA became a focus of concern for regulatory agencies. In January 2006 the EPA negotiated an agreement, the 'PFOA Stewardship Program' (PSP) [75-77] in which 8 multinational corporations viz. Arkema, Asahi, BASF Corp., Clariant, Daikin, 3M/Dyneon, DuPont and Solvay Solexis committed to voluntarily phase out PFOA from production by 2015. EPA announced PFAS to be extremely persistent in the environment and resistant to typical environmental degradation processes in 2014 and hence listed them as emergent contaminants. In 2013–2015, EPA supervised nation-wide testing of municipal drinking water as a part of its monitoring process of unregulated contaminants and accordingly issued a health advisory for PFAS and subcategory chemicals in drinking water in which the limit of total PFOA & PFOS is set to 70 ppt (nano-gram/liter) [110]. As a nationwide PFAS problem grew, in June 2016 the 114th US Congress and Obama administration passed 'Frank R. Lautenberg Chemical Safety of the 21st Century Act' (LCSCA) also known as 'Chemical Safety Improvement Act of 2016'. LCSCA updated the TSCA to establish new chemical prioritization rules for EPA oversight and new notification and reporting were required, after which the House passed (H.R.2576), the 'TSCA Modernization Act of 2015' (TSCAMA) [111,112]. EPA issued an advanced notice of proposed rulemaking that would allow the public to provide input on adding PFAS to the TRI. The plan responds to the extensive public input the agency received during the 'PFAS National Leadership Summit' (PNLS) through multiple community engagements and the public docket. States, federal partners, territories, tribes and representatives from national organizations attended PNLS in May 2018, in Washington D.C. In the weeks following the summit, EPA travelled to a number of states with communities impacted by PFAS, heard directly from the public on how to best help states and communities facing this issue. Through the information from the PNLS, community engagements and public input provided by the docket, EPA planned to develop a 'PFAS Management Plan' (PMP) [113].

EPA designed and issued the 'PFAS Action Plan' (PAP) in February 2019, which outlines the tools being developed by EPA to assist states, tribes & communities, is the first multi-media, multi-program, national research, management and risk communication plan to address a challenge like PFAS chemicals. The notable actions EPA has taken under PAP to date highlighting the progress are worthy of

mentioning as they protect environment and human health [114-118]. The 117th US Congress passed legislation (H.R.2467), 'PFAS Action Act' (PAA) in July 2021, a sweeping package of measures that would establish federal regulations to address toxic, persistent PFAS chemical contamination and compelled clean-up of contaminated areas. The legislation reflects few years of growing anxiety in communities from Pennsylvania to Michigan to California, growing research about the potential health effects of the chemicals and growing agitation by lawmakers to add these chemicals to federal regulatory and cleanup programs [119]. EPA initiated a system to conduct research on innovative & cost-effective approaches to optimize the efficacy & efficiency of treatment and distribution of safe drinking water by tackling issues such as aging infrastructure, lead service lines, disinfection byproducts etc. The 'Drinking Water Treatability Database' (DWTD), which contains information on the properties of a wide range of different contaminants along with the possible treatment processes for their removal from drinking water is used by water utility managers, water treatment experts, states, tribes, local governments and EPA researchers to help treat PFAS in drinking water systems to protect the health of communities across the nation. EPA finalized an agreement with Swix Sport USA in May 2020 to resolve TSCA violations associated with the importation of noncompliant ski wax products containing PFAS where, Swix agreed to pay a fine of $375,625 as civil penalty and develop a $1M educational program referred to as a Responsible Waxing Project (RWP) to raise awareness to address the associated issue. EPA announced an update to its DWTD with new treatment options along with addition of 20 new scientific references and 4 new PFAS compounds in July 2020 thus, increasing the depth of scientific knowledge available in the existing database. Scientific references, journal articles, conference proceedings, reports and seminars support the information included in this database as EPA researchers continue to expand and improve information in the database. The information collected within the DWTD potentially be used for regulatory review, CCL determinations and in response to water security emergencies to water treatment design and in identifying research needs in designating best available technology. The release of this information continues to address the challenges laid out in the PAP [120-122].

July 2020, brought exciting news from the US House and the Senate as with outstanding votes both of them passed the bill, a NDAA for PFAS Provisions (H.R.6395 and S.4049) which was soon moved to a 'Conference Committee' for a final vote. The provisions grant enormous amounts of funding (~2 billion) assigned for research & development for environmental remediation activities and restoration projects including cleanup, safe disposal standards technologies along with replacement of firefighting agent & personal protective equipment. EPA issued a final regulation for FY 2020 to add a list of 172 PFAS chemicals not only to TRI as required by the 'National Defense Authorization Act' (NDAA) but also to stop products containing PFAS from entering or reentering the marketplace without EPA's explicit permission. This regulation observed amendment, No.121 for modification in FY 2021 to be applied for all PFASs with discharges over 100 pounds. The 'United States Chamber of Commerce' (US-CC) supported H.R.6395 and S.4049, the NDAA for FY 2021 and asked the conferees to consider recommendations to improve the overall legislation. USCC notably opposed the House by urging the conferees to drop language related to PFAS regulations on 2 provisions which circumvent the regulatory process under current statute. The provisions opposed are, i) arbitrarily banning procurement of PFAS products by DoD and ii) expanding the reporting under TRI program thus, effectively eliminating its long-standing exemptions viz. a minimum threshold that ensures the practicality of quantification along with a feasibility of a compliance of a chemical substance. EPA announced the availability of $4.8 million in funding for new research on managing PFAS in agriculture [123].

In the spring of 2020, in order to assist its officials with the cleanup of contaminated sites; the EPA expanded its research efforts and capabilities by launching its 'PFAS Innovative Treatment Team' (PITT) a 6-month dedicated, full-time team of multi-disciplined research staff. The PITT operated against a conventional administrative & procedural barriers in an effort to facilitate faster results concentrating their efforts and expertise on solving the disposal and/or destruction of PFAS-contaminated media & waste. The PITT developed a series of 'Research Briefs' which provided an overview of 4 promising technologies, the research underway by the EPA's 'Office of Research and Development' (ORD); for destroying PFASs actually added practical knowledge to EPA's PAP [124-128].

Since January 2021, under the 'Biden-Harris Administration', EPA has taken courageous actions (summarized in **Tables-1a, 1b, 1c**) needed to tackle the PFAS catastrophe and to restore scientific integrity by accelerating the pace of research, thus, protecting the American communities [75,129].

The EPA is researching & monitoring PFAS compounds and is pledged to take the next step in creating a drinking water regulation. EPA is developing some guidelines & exposure models as well as compiling & assessing human & ecological toxicity information to understand how PFAS moves through the environment to impact people & ecosystems. EPA uses enforcement tools whenever appropriate to address PFAS exposure in the environment and assists states in enforcement activities. EPA is also working collaboratively to improve a risk communication toolbox that includes multi-media materials and messaging for federal, state, tribal & local partners to use with the public [142]. In addition to updating the RSL & RRML, EPA is also updating the interim health advisories for PFOA & PFOS to reflect new science and inputs from the SAB. EPA has continued to develop a proposed NDWR for PFAS anticipating to finalizing the rule in the fall of 2023.

Table 1a. Bulletin of EPA's actions to address PFAS issue (February 2021-December 2021)

2021 February	EPA proposed and began developing the UCMR-5 (fifth & final) to provide new data on 29 PFASs that are critically needed to improve EPA's nationwide monitoring and understanding of PFAS impacts on community drinking water. They also published a final determination to regulate PFOA & PFOS by establishing 'National Primary Drinking Water Standard' (NPDWS) while also evaluating additional PFAS and considering regulatory actions. EPA also finalized CCL-4 to include 97 chemicals & 12 microbes [130].
2021 March	EPA initiated further data collection and analysis to support potential future rulemaking, under the CWA, relating to the effluent limitations guidelines, pretreatment standards and new source performance standards applicable to the Organic Chemicals, Plastics & Synthetic Fibers (OCPSF) point source category to address discharges from manufacturers of PFAS chemicals.
2021 April	EPA announced a policy of its expedited robust review process of new PFASs entering the market. An updated assessment of toxicity for PFBS authored by expert scientists was published which underwent rigorous external peer review. A new 'EPA Council on PFAS' was created, charged with building agency's ongoing work to better understand and ultimately reduce the potential risks caused by these chemicals.
2021 May	DWTD made information available for 35 treatment processes and 123 regulated & unregulated contaminants, including 37 PFAS compounds with 11 new additions.
2021 June	In order to expand data collection efforts, EPA engaged in developing a rule for designating PFOA & PFOS under the CERCLA hazardous substances to require all manufacturers and importers of PFAS to provide EPA with a wide range of data, since 2011 explaining the uses of certain PFASs.
2021 July	EPA released the first ever set of preliminary TRI data for more than 170 PFASs and continued working to further enhance the quality & quantity of reporting by removing certain exemptions & exclusions.
2021 August	EPA released a draft of toxicity assessment of the human health hazards of PFBA for public comment and external peer review.
2021 October	EPA announced the development of a 'National PFAS Testing Strategy' (NPTS) a key component of 'PFAS Strategic Roadmap' (PSR) through which TSCA authorities mandated manufacturers and importers of PFAS to inform about their consignment. EPA published GenX Chemical's final assessment of toxicity for human health authored by expert scientists which underwent rigorous external peer review and public comment. In order to improve the clean-up of PFAS contamination across the country through the RCRA corrective action process the EPA announced evaluation of the existing data for 4 PFAS compounds [131-133].
2021 November	EPA invited its 'Science Advisory Board' (SAB) to review 4 drafts of scientific documents including recent scientific data and new analyses that indicating occurrence of negative health effects even at much lower levels of exposure to PFOA & PFOS and that PFOA being carcinogenic.
2021 December	EPA published the fifth & final UCMR-5 requiring sample collection for 29 PFAS during 2023-25 to critically improve an understanding of occurrence and levels of 29 PFAS compounds in the nation's drinking water by acquiring new data through expanding the monitoring of PFAS.

Table 1b. Bulletin of EPA's actions to address PFAS issue (April 2022-December 2022)

2022 April	EPA announced 3 CWAs under PSR- CWA-1: EPA proposed aquatic life criteria regarding the toxicological effects of PFOA & PFOS on freshwater aquatic organisms. CWA-2: EPA addressed PFAS discharges through 'Pretreatment Control Authority' in NPDES to proactively minimize PFAS pollution in surface water by setting 'Effluent Limitation Guidelines' (ELG), developing analytical methods and issuing water quality criteria. CWA-3: EPA published 'Method 1621' to measure 'Adsorbable Organic Fluorine' in water samples to broadly determine the chemicals containing carbon-fluorine bonds, including PFAS.
2022 May	EPA added 5 PFAS compounds to a list of risk-based values known as 'Regional Screening Levels' (RSL) and 'Regional Removal Management Levels' (RRML), an action that provides a critical tools needed for Superfund and other Agency programs to investigate contamination and site cleanups. RSL are used to identify contaminated media (air, water & soil) at a site that may need further investigation. If a contaminant concentration is below the RSL, no further action or investigation is needed. If the concentration is above the RSL, further investigation is generally needed to determine if some action is required. RRML are used to support EPA's decisions to undertake a removal action under CERCLA, such as providing alternative drinking water, or remediation of contaminated media, if necessary. [134].
2022 June	EPA invited states and territories to apply for $1 billion funding in 'Bipartisan Infrastructure Law' (BIL) grant to address PFAS issue. EPA issued its first test order with NPTS, a part of PSR under the TSCA to protect human health and the environment from the PFAS compounds.
2022 August	EPA posted in the 'Notice of Proposed Rule Making' (NPRM) to designate PFOA & PFOS as 'Hazardous Substances' under CERCLA and released 4 drinking water health advisories for PFAS [135,136]. EPA released the AWIA-Section 2003 Report to the US Congress in accordance with Section 1459C of the SDWA as amended by Section 2003 of the AWIA. EPA conducted a study with the 'United States Department of Agriculture' (US-DA) and the (US-DoHHS) on PWS during 2016-2018 to identify the characteristics of the 'Intractable Water Systems' (IWS) that meet the criteria [137].
2022 September	EPA released the AWIA-Section 2011 Report to the US Congress: the 'Drinking Water Compliance Monitoring Data Strategic Plan' (DWCMDSP), SDWA 1414; a plan to improve the accuracy, integrity & availability of the collected monitoring data submitted by PWSs to states or by states to the EPA in order to demonstrate compliance with NPDWRs [138].
2022 October	EPA issued regulations, known as 'Significant New Use Rules' (SNUR) to complement the PSP. It specifically requires that anyone intending to import, manufacture or process any chemical must notify EPA at least 90 days prior to the activity and inform about any new uses of these chemicals before they are commercialized [139-141].

2022 November	EPA published the CCL-5 after providing a period for public comment and consulting with EPA's SAB. This included 66 chemicals, 3 chemical groups viz. PFAS, cyanotoxins & disinfection byproducts (DBPs) and 12 microbes, selected from chemicals used in commerce, pesticides, biological toxins, disinfection byproducts, and waterborne pathogens.
2022 December	EPA issued an expanded April 2022's memo to the NPDES including Draft-3 of the Method-1633, additional permitting mechanisms and complementary recommendations by recommending states & municipalities to use the most current sampling, pretreatment & analysis methods in order to reduce PFAS discharges to waterways.

Table 1c. Bulletin of EPA's actions to address PFAS issue (January 2023-April 2023)

2023 January	In order to prevent anyone from starting or resuming (without a complete review and risk determination by EPA) the manufacture, processing or use of around 300 PFASs which have not been made or used for many years; EPA proposed a SNUR known as 'Inactive PFAS', a key action in EPA's PSR, applied to PFASs which are listed as "Inactive" in the inventory of TSCA.
2023 February	EPA announced an investment of USD 2 Billion allocated to states and territories from the US President Biden's BIL as grants through EPA's 'Emerging Contaminants in Small or Disadvantaged Communities' grant program in order to address emerging contaminants, including PFAS, in drinking water across the country.
2023 March	In order to fulfill a foundational commitment in the Agency's PSR, EPA proposed NPDWR to establish legally enforceable levels for 6 PFAS compounds in drinking water.
2023 April	EPA issued a request following September 2022's proposed rule, an 'Advance Notice of Proposed Rulemaking' (ANPRM) asking public for their input regarding potential future hazardous substance designations of 2 PFAS viz. PFOA &PFOS and their respective salts & structural isomers under the CERCLA.

4. Legislative Actions on PFAS at Global Level

The enormous amount of threat posed to human health by PFAS chemicals has been recognized around the globe and many countries have been engaged in inventing and implementing remedial measures. Several regulators highlighted that the range of possible research questions may go beyond what would be needed if the precautionary principle is applied and that there is a need to balance research efforts and the implementation of the precautionary principle. In order to strengthen the dialogue and foster cooperative actions between science & policy toward coordinated global efforts to further address PFAS problem multiple conferences have been held by the government agencies worldwide. Certain compounds of the PFAS class have been regulated by several authoritative bodies. In 2015, the 'Swedish Chemicals Agency' (KEMI) identified over 3,000 PFAS on the global market. In Zürich, Switzerland, in November 2017 a workshop engaged over 50 academic scientists and regulators (including government scientists) from across the globe. The Australian Government commissioned the 'Australian National University' in January 2018, to conduct a health study to examine patterns of PFAS contamination and potential implications for human health at defense sites in Australia and accordingly the 1st version of the 'PFAS National Environmental Management Plan' (PNEMP) was released. A more recent study presented during the 'Organization for Economic Cooperation and Development' (OECD) held in Paris, France in 2018 identified approximately 4,700 'Chemical Abstract Services' (CAS) Registry Numbers associated with individual PFAS or their mixture [143-150].

The United Nation's Stockholm Convention's 'Persistent Organic Pollutants Review Committee' (POPRC) is a team of 31 members, the government-designated experts established and tasked with reviewing proposals submitted by a party to list a new substance under the Stockholm Convention. The committee has 8 members from Africa, 8 from Asia-Pacific, 3 from Central & Eastern Europe, 5 from Latin America & the Caribbean and 7 from Western European and Other States. In October 2019, more than 100 scientists from many countries attended the 15th meeting, POPRC-15 whereas, the most recent POPRC-18 was convened in Rome, Italy at the headquarters of the 'Food and Agriculture Organization' (FAO) in September 2022. PFOS, its salts and perfluorooctanesulfonil fluoride (POSF) were listed as 'Persistent Organic Pollutants' (POPs) in Annex B, whereas, PFOA, its salts and related compounds are listed in Annex A of the Stockholm Convention. PFHxS, its salts and related compounds are being reviewed for listing. Several PFAS are included in the European Chemicals Agency's (ECHA) 'Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) Candidate List' of 'Substances of Very High Concern' (SVHC) and 'Danish Environmental Protection Agency'. In May 2020, the authorities of the 5 countries viz. Germany, Netherlands, Norway, Sweden and Denmark agreed to prepare a joint REACH restriction proposal (Annex XV dossier) over the next 2 years to limit the risks to the environment & human health from the manufacture and use of a wide range of PFAS. After submission the final proposal moved to ECHA's scientific committees. The respective decisions are made in the European Commission by the EU Member States and scrutinized by the European Parliament & Council with a possibility of expected date of an entry into force in 2025. The same 5 countries are also working together on a similar restriction dossier for all other uses of PFASs [151-156].

A large amount of information on substances from the product registries of 4 Nordic countries such as Denmark, Finland, Norway and Sweden is available on the 'Substances in Preparations in Nordic Countries' (SPIN) database which contains 4 large data sets describing information on uses. 2

of the data sets of SPIN viz. 'National Use Categories' & 'UC62' talk about the specific uses, whereas the remaining 2 viz. 'Industry National' & 'Industrial NACE' comment on the various sectors of uses. Even though, for the general public only a non-confidential data is accessible through SPIN webpage, there is also a substantial amount of confidential information present in the SPIN database [157].

In order to promote, facilitate and foster further international coordination various governments & agencies around the world are practicing strategies and taking cooperative actions to maintain a strong science-policy interface. The institutions such as 'Organization for Economic Cooperation and Development' (OECD), 'United Nations Environment Program' (UNEP), UN's 'Strategic Approach to International Chemicals Management' (SAICM), 'Network for Industrially Contaminated Land in Europe' (NICOLE) and the ITRC in the United States are contributing in actively transferring information about PFASs to many countries by developing a global web-knowledge base as a centralized depository of available scientific, technical and policy-related data on PFAS [158-161].

Table 2. Abbreviations

AFFF	Aqueous Film-Forming Foams
ANPRM	Advance Notice of Proposed Rulemaking
ASTM	American Society for Testing & Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AWIA	America's Water Infrastructure Act
BIL	Bipartisan Infrastructure Law
CAS	Chemical Abstract Services
CCL	Contaminant Candidate List
CDC	Center for Disease Control and Prevention
CDPH	California Department of Public Health
CDR	Chemical Data Reporting
CES	Contaminants of Emerging Concern
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CHWCL	California Hazardous Waste Control Law
CI	Chemical Ionization
CWA	Clean Water Act
CWS	Community Water System
DBP	Disinfection by-product
DEPA	Danish Environmental Protection Agency
DLLME	Dispersive Liquid-Liquid Micro-Extraction
DTSC	Department of Toxic Substances Control
DWCMDSP	Drinking Water Compliance Monitoring Data Strategic Plan
DWPD	Drinking Water Protection Division
DWTD	Drinking Water Treatability Database
DWTP	Drinking Water Treatment Plants
ECoS	Environmental Council of the States
EI	Electron Ionization
ELG	Effluent Limitation Guidelines
EPCRA	Emergency Planning and Community Right-to-Know Act
ERIS	Environmental Research Institute of the States
ERT	Environmental Response Team
ESI	Electron Spray Ionization
EWG	Environmental Working Group
FAO	Food and Agriculture Organization
FCPIAA	Federal Civil Penalties Inflation Adjustment Act
FWPCA	Federal Water Pollution Control Act
FY	Fiscal Year
GCMS	Gas Chromatography Mass Spectroscopy
HFPODA	hexafluoropropylene oxide dimer acid
HPLC	High Performance Liquid Chromatography
HRS	Hazard Ranking System
IPE	Ion Pair Extraction
ISO	International Organization for Standardization
ITRC	Interstate Technology Regulatory Council
IU	Industrial Users
IWS	Intractable Water Systems
LCMS	Liquid Chromatography Mass Spectroscopy
LCMRL	Lowest Concentration Minimum Reporting Level
LCSCA	Frank Raleigh Lautenberg Chemical Safety of the 21st Century Act
LLE	Liquid-Liquid Extraction
MDEQ	Michigan Department of Environmental Quality
MDH	Minnesota Department of Health
MPCA	Minnesota Pollution Control Agency
MRL	Minimum Reporting Levels
NASEM	National Academy of Sciences, Engineering, and Medicine
NCOD	National Contaminant Occurrence Database
NCP	National Contingency Plan
NDAA	National Defense Authorization Act
NDWAC	National Drinking Water Advisory Council
NDWR	National Drinking Water Regulation
NHANES	National Health and Nutrition Examination Survey
NICOLE	Network for Industrially Contaminated Land in Europe
NIEHS	National Institute of Environmental Health Sciences
NIST	National Institute of Standards and Technology
NOHSCP	National Oil and Hazardous Substances Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
NPDWS	National Primary Drinking Water Standard
NPL	National Priorities List
NPLC	Normal Phase Liquid Chromatography
NPRM	Notice of Proposed Rulemaking
NPTS	National PFAS Testing Strategy
NSCEP	National Service Center for Environmental Publications
NTNCWS	Non-Transient Non-Community Water System
NTP	National Toxicology Program

NWIS	National Water Information System
OCPSF	Organic Chemicals, Plastics and Synthetic Fibers
OECD	Organization for Economic Co-operation and Development
OLEM	Office of Land and Emergency Management
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
OSRTI	Office of Superfund Remediation and Technology Innovation
OW	Office of Water
PAA	PFAS Action Act
PAP	PFAS Action Plan
PFAA	perfluorinated alkyl acid
PFAS	perfluoroalkyl Substances
PFBA	perfluoro-butanonic acid
PFBS	perfluoro-butanesulfonic acid
PFC	polyfluorinated Compound
PFHpA	perfluoro-heptanoic acid
PFHxS	perfluoro-hexanesulfonic acid
PFNA	perfluoro-nonanoic acid
PFOA	perfluoro-n-octanoic acid
PFOS	perfluoro-n-sulfonic acid
PITT	PFAS Innovative Treatment Team
PMP	PFAS Management Plan
PNEMP	PFAS National Environmental Management Plan
PNLS	PFAS National Leadership Summit
POP	Persistent Organic Pollutants
POPRC	Persistent Organic Pollutants Review Committee
POSF	perfluorooctanesulfonil fluoride
PSP	PFOA Stewardship Program
PSR	PFAS Strategic Roadmap
PWS	Public Water System
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RD	Regulatory Determinations
RPLC	Reverse Phase Liquid Chromatography
RRD	Remediation and Redevelopment Division
RRML	Regional Removal Management Levels
RSL	Regional Screening Levels
RWP	Responsible Waxing Project
SAB	Science Advisory Board
SAICM	Strategic Approach to International Chemicals Management
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SETG	Safety and Environmental Technology Group
SIM	Selected Ion Monitoring
SNUR	Significant New Use Rule
SPE	Solid Phase Extraction
SPIN	Substances in Preparations in Nordic Countries
SPME	Solid Phase Micro-Extraction
SVHC	Substances of Very High Concern
SWDA	Solid Waste Disposal Act
SWUA	Solid Waste Utilization Act
TNCWS	Transient Non-Community Water System
TOP	Total Oxidizable Precursors
TQ	Triple Quad
TQMA	Triple Quadrupole Mass Analyzer
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act
TSCAMA	TSCA Modernization Act of 2015
UCMR	Unregulated Contaminant Monitoring Rule
UNEP	United Nations Environment Program
UPLC	Ultra Performance Liquid Chromatography
US-CC	United States Chamber of Commerce
US-DA	United States Department of Agriculture
US-DoD	United States Department of Defense
US-DoHHS	United States Department of Health and Human Services
US-EPA	United States Environmental Protection Agency
US-GS	United States Geological Survey

5. Conclusions

It is quintessential to raise awareness among policy makers and general public emphasizing on the dire consequences associated to the health hazards caused by PFAS compounds and the large variety of substances that contain PFAS compounds. The multiple amendments sponsored by various representatives of House and Senate have required various government agencies in United States such as ‘Department of Defense’ (US-DoD), ‘Geological Survey’ (US-GS), ‘Department of Health and Human Services’ (US-DoHHS), ‘Environmental Protection Agency’ (US-EPA), ‘National Institute of Standards and Technology’ (NIST), ‘Center for Disease Control and Prevention’ (CDC), ‘National Health and Nutrition Examination Survey’ (NHANES), Occupational Safety and Health Administration (OSHA), to actively engage in research to support enhancement of public health and safety through quality testing and engineering. Through the ‘National Water Information System’ (NWIS), US-GS disseminates water data it has collected to the public.

It is needless to say that we as a society are required to attempt to avoid utilizing such substances and eventually achieve complete elimination. Even though, scientific community is encouraged to invent safe alternatives and replace/phase out current substances comprised of PFAS chemicals; until that discovery comes to fruition, the analysis of environmental samples on regular basis is a necessity. The concern for potential health-effects associated with PFAS compounds, such as PFOS & PFOA and their persistence in the environment requires to establish sampling and testing monitoring programs to assess the extent and degree of PFAS contamination in the environment. Drinking water monitoring is necessary to evaluate current levels and allow

determination of compliance with current advisory guidelines and future established standards. Monitoring of surface water is required to determine potential effects on aquatic life and human exposure. Areas that may be impacted by various manufacturing and application processes also require environmental assessments of soil and groundwater to evaluate possible impacts.

Many US based individual analytical testing laboratories have undertaken the critical task which holds a national importance of incorporating the analysis of potentially life-threatening environmental pollutants named PFAS and the other relevant chemicals that fall under the subcategory. Programs by US-DoD have been implemented to assess the extent of PFAS, especially PFOS & PFOA, contamination at military facilities that have extensively used these chemicals in firefighting training exercises. The drinking water from surface & ground water bodies as well as several recently discovered contaminated communities across nation linked to manufacturing, landfills, airports and military installations is essentially required to be tested on regular basis. The samples are received from US-GS and other local individual sources, generally obtained from the drinking water resource states of Great Lakes & Ohio River such as Minnesota, Wisconsin, Illinois, Indiana, Ohio, Michigan, Pennsylvania & New York and other regions. Laboratories located nationwide are the best potential service providers with proven abilities in analytical testing offering their services and expertise for the qualitative & quantitative determination of the levels of PFAS compounds.

Highlights

- Origin, Spread, Toxicity & Adverse Health Effects of PFAS
- Analytical Instrumentation & Testing Methods on PFAS
- Legislative Actions by Monitoring Agencies & Governmental Policies on PFAS

REFERENCES

[1] R.C. Buck, J. Franklin, U. Berger, J.M. Conder, I.T. Cousins, P. de Voogt, A.A. Jensen, K. Kannan, S.A. Mabury, S.P.J. van Leeuwen; "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins", *Integrated Environmental Assessment and Management*, 2011, *7*(*4*), 513-541. [DOI: 10.1002/ieam.258] (https://setac.onlinelibrary.wiley.com/doi/epdf/10.1002/ieam.258)

[2] R. Altman; "Time-Bombing the Future." *Aeon*, January 02, 2019. (https://aeon.co/essays/how-20thcentury-synthetics-altered-the-very-fabric-of-us-all)

[3] M. Liboiron, M. Tironi, N. Calvillo; "Toxic Politics: Acting in a Permanently Polluted World", *Social Studies of Science*, 2018, *48*(*3*), 331–349. [DOI: 10.1177/0306312718783087]

[4] A.M. Nading; "Living in a Toxic World", *Annual Review of Anthropology*, 2020, *49*, 209–224. [DOI: 10.1146/annurev-anthro-010220-074557]

[5] "Per- and Polyfluorinated Substances (PFAS) Factsheet", *National Biomonitoring Program*, (*CDC*) *Centers for Disease Control and Prevention*, last reviewed: May 02, 2022. (https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html)

[6] E. Sydney, D. Andrews, T. Stoiber, O. Naidenko; "PFAS Contamination of Drinking Water Far More Prevalent Than Previously Reported" (*EWG*) *Environmental Working Group*, January 23, 2020. (https://www.ewg.org/research/national-pfas-testing)

[7] "Mapping the PFAS contamination crisis: New Data Show 2,858 Sites in 50 States and 2 Territories", PFAS Contamination in the U.S., (*EWG*) *Environmental Working Group*, June 08, 2022.(https://www.ewg.org/interactive-maps/pfas_contamination)

[8] L. Richter, A. Cordner, P. Brown; "Non-Stick Science: Sixty Years of Research and (in) Action on Flourinated Compounds", *Social Studies of Science*, 2018, *48*(*5*), 691–714. [DOI: 10.1177/ 0306312718799960]

[9] "Risk to Human Health Related to the Presence of perfluorooctane sulfonic acid and perfluorooctanoic acid in Food", 2018, EFSA (European Food Safety Authority). [DOI: 10.2903/j.efsa.2018.5194]

[10] "C8 Science Panel", *Science Panel*, updated: January 2020. (http://www.c8sciencepanel.org/)

[11] "Toxicological Profile for Per-fluoroalkyls" Washington, DC", CS274127-A; (*ATSDR*) *Agency for Toxic Substances and Disease Registry*, *US Department of Health and Human Services*, May 2021, 1-17. (https://www.atsdr.cdc.gov/toxprofiles/tp200-p.pdf)

[12] W. Nicole; "Breaking It Down: Estimating Short-Chain PFAS Half-Lives in a Human Population", *Environmental Health Perspectives*, 2020, *128*(*11*), 114002_1-2. [DOI: 10.1289/EHP7853]

[13] S. Lerner; "New Teflon Toxin Found in North Carolina Drinking Water" *The Intercept*, June 17, 2017. (https://theintercept.com/2017/06/17/new-teflon-toxin-found-in-north-carolina-drinking-water/)

[14] I.T. Cousins, G. Goldenman, D. Herzke, R. Lohmann, M. Miller, C.A. Ng, S. Patton, M. Scheringer, X. Trier, L. Vierke, Z. Wang, J.C. DeWitt; "The Concept of Essential Use for Determining When Uses of PFAS Can Be Phased Out", *Environmental Science: Processes & Impacts*, 2019, *11*(*21*): 1803–1815. [DOI: 10.1039/ C9EM00163H]

[15] 2023, *Studying Social, Scientific and Political Factors of per & poly fluoroalkyl Substances*, (*SSEHRI*) *Social Science and Environmental Health Research Institute*, *Northeastern University*, *PFAS Project Lab*. (https://pfasproject.com/)

[16] PFAS, *Washington State Department of Health*, (https://doh.wa.gov/community-and-environment/contaminants/pfas)

[17] J.S. Boone, C. Vigo, T. Boone, C. Byrne, J. Ferrario, R. Benson, J. Donohue, J.E. Simmons, D.W. Kolpin, E.T. Furlong, S.T. Glassmeyer; "Per- and polyfluoroalkyl substances in source and treated drinking waters of the United States", *Science of the Total Environment*, 2019, *653*, 359-369. [DOI: 10.1016/j.scitotenv.2018.10.245]

[18] J.W. Martin, D.C.G. Muir, C.A. Moody, D.A. Ellis, C.K. Wai, K.R. Solomon, S.A. Mabury; 'Collection of Airborne Fluorinated Organics and Analysis by Gas Chromatography / Chemical Ionization Mass Spectrometry", *Analytical Chemistry*, 2002, *74*(*3*), 584-590. [DOI: 10.1021/ac015630d]

[19] Y. Yao, Y. Zhao, H. Sun, S. Chang, L. Zhu, A.C. Alder, K. Kannan; "Per- and polyfluoroalkyl Substances (PFASs) in Indoor Air and Dust from Homes and Various Microenvironments in China: Implications for Human Exposure", *Environmental Science & Technology*, 2018, *52*(*5*), 3156-3166. [DOI: 10.1021/ acs.est.7b04971]

[20] J.A. Padilla-Sanchez, E. Papadopoulou, S. Poothong, L.S. Haug; "Investigation of the Best Approach for Assessing Human Exposure to poly- and perfluoroalkyl Substances through Indoor Air", *Environmental Science & Technology*, 2017, *51*(*21*), 12836-12843. [DOI: 10.1021/acs.est.7b03516]

[21] M. Shoeib, T. Harner, C.L. Sum, D. Lane, J. Zhu; "Sorbent-Impregnated Polyurethane Foam Disk for Passive Air Sampling of Volatile Fluorinated Chemicals", *Analytical Chemistry*, 2008, *80*(*3*), 675-682. [DOI: 10.1021/ac701830s]

[22] C. Rauert, M. Shoieb, J.K. Schuster, A. Eng, T. Harner; "Atmospheric Concentrations and Trends of poly- and perfluoroalkyl Substances (PFAS) and Volatile Methyl Siloxanes (VMS) over 7 Years of Sampling in the Global Atmospheric Passive Sampling (GAPS) Network", *Environmental Pollution*, 2018, *238*, 94-102. [DOI: 10.1016/j.envpol.2018.03.017]

[23] M. Shoeib, T. Harner, P. Vlahos; "Perfluorinated Chemicals in the Arctic Atmosphere", *Environmental Science & Technology*, 2006, *40*(*24*), 7577-7583. [DOI: 10.1021/es0618999]

[24] Y. Tian, Y. Yao, S. Chang, Z. Zhao, Y. Zhao, X. Yuan, F. Wu, H. Sun; "Occurrence and Phase Distribution of Neutral and Ionizable per- and polyfluoroalkyl Substances (PFASs) in the Atmosphere and Plant Leaves around Landfills: A Case Study in Tianjin, China", *Environmental Science & Technology*, 2018, *52*(*3*), 1301-1310. [DOI: 10.1021/acs.est.7b05385]

[25] J. Li, S. Del Vento, J. Schuster, G. Zhang, P. Chakraborty, Y. Kobara, K.C. Jones; "Perfluorinated Compounds in the Asian Atmosphere", *Environmental Science & Technology*, 2011, *45*(*17*), 7241-7248. [DOI: 10.1021/es201739t]

[26] S.P.J. van Leeuwen, J. De Boer; "Extraction and Clean-Up Strategies for the Analysis of poly- and perfluoroalkyl Substances in Environmental and Human Matrices", *Journal of Chromatography A*, 2007, *1153*(*1-2*), 172-185. [DOI: 10.1016/ j.chroma.2007.02.069]

[27] A. Jahnke, U. Berger; "Trace Analysis of per- and polyfluorinated alkyl Substances in Various Matrices-How Do Current Methods Perform?" *Journal of Chromatography A*, 2009, *1216*(*3*), 410-421. [DOI: 10.1016/j.chroma.2008.08 .098]

[28] M. Lorenzo, J. Campo, Y. Pico; "Analytical Challenges to Determine Emerging Persistent Organic Pollutants in Aquatic Ecosystems", *Trends in Analytical Chemistry*, 2018, *103*, 137-155. [DOI: 10.1016/j.trac.2018.04.003]

[29] C. Gremmel, T. Fromel, T.P. Knepper, "HPLC-MS/MS Methods for the Determination of 52 perfluoroalkyl and polyfluoroalkyl Substances in Aqueous Samples", *Analytical and Bioanalytical Chemistry*, 2017, *409*(6), 1643-1655. [DOI: 10.1007/s00216-016-0110-z]

[30] M. Monteleone, A. Naccarato, G. Sindona, A. Tagarelli, "A Rapid and Sensitive Assay of perfluorocarboxylic acids in Aqueous Matrices by Headspace Solid Phase Micro-extraction Gas Chromatography-Triple Quadrupole Mass Spectrometry", *Journal of Chromatography A*, 2012, *1251*, 160-168. [DOI: 10.1016/ j.chroma.2012.06.033]

[31] J. Wang, Y. Shi, Y. Cai, "A Highly Selective Dispersive Liquid-Liquid Micro-extraction Approach Based on the Unique fluorous Affinity for the Extraction and Detection of per- and polyfluoroalkyl Substances Coupled with High Performance Liquid Chromatography Tandem Mass Spectrometry", *Journal of Chromatography A*, 2018, *1544*, 1-7. [DOI: 10.1016/ j.chroma.2018.02.047]

[32] L.W.Y. Yeung, C. Stadey, S.A. Mabury, "Simultaneous Analysis of perfluoroalkyl and polyfluoroalkyl Substances Including Ultra-Short Chain C2 and C3 Compounds in Rain and River Water Samples by Ultra-Performance Convergence Chromatography", *Journal of Chromatography A*, 2017, *1522*, 78-85. [DOI: 10.1016/j.chroma.2017.09.049]

[33] C. Patterson, J. Burkhardt, D. Schupp, E.R. Krishna, S. Dyment, S. Merritt, L. Zintek, D. Kleinmaier; "Effectiveness of Point-of-Use/Point-of-Entry Systems to Remove per- and polyfluoroalkyl Substances from Drinking Water", *American Water Works Association, Water Science*, 2019, *1*(*2*), 1-12. [DOI: 10.1002/aws2.1131]

[34] D.Q. Andrews, J. Hayes, T. Stoiber, B. Brewer, C. Campbell, O.V. Naidenko; "Identification of Point Source Dischargers of-Use/Point-of per- and polyfluoroalkyl Substances from in the United States", *American Water Works Association, Water Science*, 2021, *3*(*5*), 1-16. [DOI: 10.1002/aws2.1252]

[35] S.F. Nakayama, M. Yoshikane, Y. Onoda, Y. Nishihama, M. Iwai-Shimada, M. Takagi, Y. Kobayashi, T. Isobe; "Worldwide Trends in Tracing poly- and perfluoroalkyl Substances (PFAS) in the Environment", *Trends in Analytical Chemistry*, 2019, *121*, 115410: 1-20. [DOI: 10.1016/j.trac.2019.02.011]

[36] D. Chiang; "What Total Oxidizable Precursor Assay Can and Cannot Tell Us about Precursors of Perfluoroalkyl Acids", *CDM Smith*, White Pages published: January 2019, 1-5. (file:///C:/Users/ASUS/Downloads/PFAS-precursor-TOPA-%20Article.pdf)

[37] P. Larsson; "Total oxidizable Precursor Assay: Applications and Limitations. A study on the Occurrence of perfluoroalkyl and polyfluoroalkyl Substances (PFASs) in Chinese Wastewater Treatment Plants", *Ö rebro Universitet*, 2020-06-01. (https://www.diva-portal.org/smash/get/diva2:1560003/FULLTEXT01.pdf)

[38] M. Ateia, D. Chiang, M. Cashman, C. Acheson; "Total Oxidizable Precursor (TOP) Assay: Best Practices, Capabilities and Limitations for PFAS Site Investigation and Remediation", *Environmental Science & Technology Letters*, 2023, *10*(*4*), 292-301. [DOI: 10.1021/acs.estlett.3c00061]

[39] "Methods Approved to Analyze Drinking Water Samples to Ensure Compliance with Regulations", *U.S. Environmental Protection Agency*. (https://www.epa.gov/dwanalyticalmethods)

[40] "PFAS Analytical Methods Development and Sampling Research", *U.S. Environmental Protection Agency*.

(https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research)

[41] "Status of EPA Research and Development on PFAS", *U.S. Environmental Protection Agency*. (https://www.epa.gov/chemical-research/status-epa-research-and-development-pfas)

[42] L. Rosenblum, S.C. Wendelken; "Method 533: Determination of per- and polyfluoroalkyl Substances in Drinking Water by Isotope Dilution Anion Exchange Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry", *U.S. Environmental Protection Agency Cincinnati OH*, EPA Document No. 815-B-19-020, EPA Contract EP-C-17-014, *Office of Water* (MS-140), December 2019, 1-48.(https://www.epa.gov/sites/default/files/2019-12/documents/method-533-815b19020.pdf)

[43] J.A. Shoe maker, P.E. Grimmett, B.K. Boutin; "Method 537: Determination of Selected Perfluorinated Alkyl Acids in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) Version 1.1", *National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency Cincinnati OH*, Document # EPA/600/R-08/092, September 2009 (Last Revised: July 2015). (file:///C:/Users/ASUS/Downloads/METHOD%20537_FINAL_REV1.1.PDF)

[44] J.A. Shoe maker, D.R. Tettenhorst, P.E. Grimmett, B.K. Boutin; "Method 537.1: Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS), Version 1.0", *National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency Cincinnati OH*, Document # EPA/600/R-18/352, November 2018. (https://www.epa.gov/water-research/water-research-webinars)

[45] "Method 8327: Per- and Polyfluoroalkyl Substances (PFAS) Using External Standard Calibration and Multiple Reaction Monitoring (MRM) Liquid Chromatography/tandem Mass Spectrometry (LC/MS/MS) Revision 0", SW-846, *U.S. Environmental Protection Agency*, June 2019, 1-58. (https://19january2021snapshot.epa.gov/sites/static/files/2019-06/documents/proposed_method_8327_procedure.pdf)

[46] "Method 8327: Per- and Polyfluoroalkyl Substances (PFAS) Liquid Chromatography/tandem Mass Spectrometry (LC/MS/MS) Revision 0", SW-846 Update VII, *U.S. Environmental Protection Agency*, July 2021, 1-40. (https://www.epa.gov/system/files/documents/2021-07/8327.pdf)

[47] "EPA Analytical Methods for PFAS in Drinking Water", *U.S. Environmental Protection Agency*, EPA Document # 815-B-19-021, *Office of Water* (MS-140), December 2019. (https://www.epa.gov/sites/default/files/2019-12/documents/table_of_pfas_methods_533_and_537.1.pdf)

[48] "EPA PFAS Drinking Water Laboratory Methods", *U.S. Environmental Protection Agency*. (https://www.epa.gov/pfas/epa-pfas-drinking-water-laboratory-methods)

[49] "PFAS Analytical Methods Development and Sampling Research", *U.S. Environmental Protection Agency*. (https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research)

[50] "PFAS Chemical List and Tiered Testing Methods Description", *U.S. Environmental Protection Agency*. (https://www.epa.gov/chemical-research/pfas-chemical-lists-and-tiered-testing-methods-descriptions)

[51] ASTM Standard D7979-20, "Standard Test Method for Determination of Perfluorinated Compounds in Water, Sludge, Influent, Effluent and Wastewater by Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS)", *ASTM International, West Conshohocken, PA*, September 2020, *11*(*02*), D19.06, 1-31. [ICS Code: 13.060.50; 71.080.20] [DOI: 10.1520/D7979-20] (https://www.astm.org/d7979-20.html)

[52] "Water Quality-Determination of perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA)-Method for Unfiltered Samples using Solid Phase Extraction and Liquid Chromatography/Mass Spectrometry", *Technical Committee* ISO/TC 147, *Water Quality* Subcommittee SC 2, *Physical, chemical and biochemical methods*, *International Organization for Standardization*, Reference # ISO 25101:2009(E), 2009, 1-7.

[53] "Standard Operating Procedure for the Analysis of Polyfluorinated Compounds of Interest to OSRTI in Water, Sludge, Influent, Effluent and Wastewater by Multiple Reaction Monitoring Liquid Chromatography/Mass Spectrometry (LC/MS/MS)", *U.S. Environmental Protection Agency, Region 5 Laboratory*, 2016, 1-75.

[54] 'Michigan Department of Environment, Great Lakes and Energy' (https://www.michigan.gov/egle).

[55] "History of MDH Activities - Per- and Polyfluoroalkyl Substances (PFAS)", Minnesota Department of Health. (https://www.health.state.mn.us/communities/environment/hazardous/topics/history.html)

[56] PFAS Fact Sheets, *Interstate Technology Regulatory Council*, (https://pfas-1.itrcweb.org/fact-sheets/), (https://itrcweb.org/teams/active/pfas).

[57] "Toxicity Report: 'NTP TOX 96' Toxicity Studies of Perfluoroalkyl Sulfonates (Perfluorobutane Sulfonic Acid, Perfluorohexane Sulfonate Potassium Salt, and Perfluorooctane Sulfonic Acid)" and "Toxicity Report 97: 'NTP TOX 97' Toxicity Studies of Perfluoroalkyl Carboxylates (Perfluorohexanoic Acid, Perfluorooctanoic Acid, Perfluorononanoic Acid, and Perfluorodecanoic Acid)", Administered by Gavage to Sprague Dawley (Hsd: Sprague Dawley SD) Rats, National Toxicology Program, Public Health Service, U.S. Department of Health and Human Services, August 2019, (Revised) July 2022. (ISSN: 2378-8992).(https://ntp.niehs.nih.gov/publications/reports/index.html?type=Short-Term+Toxicity)

[58] "Federal Water Pollution Control Act", (33 U.S.C. § 1251 et seq.), Amended Through Public Law 107–303, *U.S. Environmental Protection Agency*, November 2002. (https://www.epa.gov/sites/default/files/2017-08/documents/federal-water-pollution-control-act-508full.pdf)

[59] "Navigation and Navigable Waters", Title-33, Chapter-26, US Code-2018, 326-558. (https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf)

[60] "Summary of the Clean Water Act", (33 U.S.C. § 1251 et seq.), 1972, *U.S. Environmental Protection Agency*. (https://www.epa.gov/laws-regulations/summary-clean-water-act)

[61] "Clean Water Act Effluent Limitations Guidelines and Standards for the Organic Chemicals, Plastics and Synthetic

Fibers Point Source Category", (40 CFR 414), *U.S. Environmental Protection Agency*, March 2021, Federal Register *56*(*50*), 14560-14567. [Docket # EPA-HQ-OW-2020-0582; FRL-10019-06-OW], [RIN 2040–AG10] (https://www.govinfo.gov/content/pkg/FR-2021-03-17/pdf/2021-05402.pdf)

[62] "National Pollutant Discharge Elimination System", *U.S. Environmental Protection Agency*, (https://www.epa.gov/npdes-permits), (https://www.epa.gov/npdes/about-npdes)

[63] "Public Participation in the NPDES Permit Issuance Process", *U.S. Environmental Protection Agency*, 832-F-12-033, September 2013, 1-4. (https://www.epa.gov/system/files/documents/2022-06/public%20participation%20brochure%20v2.pdf)

[64] R. Fox; "Addressing PFAS Discharges in EPA-Issued NPDES Permits and Expectations Where EPA is the Pretreatment Control Authority", *U.S. Environmental Protection Agency*, *Office of Water*, April 2022, 1-4. (https://www.epa.gov/system/files/documents/2022-04/npdes_pfas-memo.pdf)

[65] "Frequent Questions about PFAS Methods for NPDES Permits", Clean Water Act Analytical Methods, *U.S. Environmental Protection Agency*, Last Updated: February 2023. (https://www.epa.gov/cwa-methods),(https://www.epa.gov/cwa-methods/frequent-questions-about-pfas-methods-npdes-permits)

[66] "Safe Drinking Water Act", (42 U.S.C. § 300f), Public Law 93-523, 1974, *U.S. Environmental Protection Agency*, (https://www.epa.gov/sdwa)

[67] "Solid Waste Disposal Act", (42 U.S.C. § 6901 et seq.), Public Law 89-272, (amended through Public Law 117-58, enacted 2021), 1965, 1-192. (https://www.govinfo.gov/content/pkg/COMPS-893/pdf/COMPS-893.pdf)

[68] "Summary of the Resource Conservation and Recovery Act", (42 U.S.C. § 6901-6992), Public Law 94-580, Chapter-82, 1976, *U.S. Environmental Protection Agency*, (https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act)

[69] "Resource Conservation and Recovery Act", *Federal Register-The Daily Journal of the United States Government*, (https://www.federalregister.gov/resource-conservation-and-recovery-act-rcra-)

[70] M. Horinko, C. Courtin, J. Berlow, S. Bromm, A. Farmer; "Waste Management-A Half Century of Progress", *EPA Alumni Association*, 2020, 1-25. (https://www.epaalumni.org/hcp/rcra.pdf)

[71] L. Konkel; "The P-Sufficient Approach: A Strategy for Regulating PFAS as a Class", *Environmental Health Perspectives*, 2021, *129*(*5*), 054002_1-2. [DOI: 10.1289/EHP9302]

[72] "Potential Designated Chemicals: Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)", Scientific Guidance Panel Meeting, Biomonitoring California, *Sacramento, CA: California Environmental Contaminant Biomonitoring Program*, March 2015, 1-22. (https://biomonitoring.ca.gov/sites/default/files/downloads/PotenDesigPFASs_031315.pdf)

[73] "Priority Chemicals", Scientific Guidance Panel Meeting, Biomonitoring California, *Sacramento, CA: California Environmental Contaminant Biomonitoring Program*, February 2019, 1-7. (https://dtsc.ca.gov/wp-content/uploads/sites/31/2019/07/2-F-CA-Biomonitoring.pdf)

[74] "Summary of the Toxic Substances Control Act", (15 U.S.C. § 2601 et seq.), Public Law 94-469, Chapter-53, 1976, *U.S. Environmental Protection Agency*. (https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act)

[75] "Risk Management for Per- and Polyfluoroalkyl Substances (PFAS) under TSCA", *U.S. Environmental Protection Agency*. (https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-management-and-polyfluoroalkyl-substances-pfas)

[76] S.L. Johnson; "2010/15 PFOA Stewardship Program", *U.S. Environmental Protection Agency*, January 2006. (https://www.epa.gov/sites/default/files/2015-10/documents/dupont.pdf)

[77] "Fact Sheet: 2010/15 PFOA Stewardship Program", *U.S. Environmental Protection Agency*. (https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program)

[78] "Comprehensive Environmental Response, Compensation and Liability Act", (42 U.S.C. § 9601 et seq.), Public Law 96-510, Title-42, Chapter-103, 1980, (https://www.govinfo.gov/content/pkg/USCODE-2011-title42/html/USCODE-2011-title42-chap103.htm)

[79] "Summary of the Comprehensive Environmental Response, Compensation and Liability Act (Superfund)", *U.S. Environmental Protection Agency*. (https://www.epa.gov/laws-regulations/summary-comprehensive-environmental-response-compensation-and-liability-act)

[80] "Superfund CERCLA Overview", *U.S. Environmental Protection Agency*. (https://www.epa.gov/superfund/superfund-cercla-overview)

[81] "EPA History: Superfund", *U.S. Environmental Protection Agency*. (https://www.epa.gov/history/epa-history-superfund)

[82] "SUPERFUND Trends in Federal Funding and Cleanup of EPA's Nonfederal National Priorities List Sites", GAO-15-812, GAO-03-850, GAO-04-475R, *US Government Accountability Office*, September 2015, 1-58. (https://www.gao.gov/assets/680/673051.pdf), (http://www.gao.gov)

[83] T.C. Voltaggio, J. Adams, J. Bachmann, B. Wayland; "Superfund: A Half Century Progress", *EPA Alumni Association*, April 2020, 1-20. (https://www.epaalumni.org/hcp/superfund.pdf)

[84] "About the Office of Land and Emergency Management", *U.S. Environmental Protection Agency*. (https://www.epa.gov/aboutepa/about-office-land-and-emergency-management)

[85] "National Contingency Plan", (42 U.S.C. § 9605), (https://uscode.house.gov/view.xhtml?req=(title:42%20section:9605%20edition:prelim))

[86] A. Cardno; "What is the National Contingency Plan ?", 2018, (https://www.lion.com/lion-news/june-2018/what-is-the-national-contingency-plan)

[87] "National Oil and Hazardous Substances Contingency Plan Overview", *U.S. Environmental Protection Agency*. (https://www.epa.gov/emergency-response/national-oil-and-hazardous-substances-pollution-contingency-plan-ncp-overview)

[88] "Superfund: National Priorities List", *U.S. Environmental Protection Agency*. (https://www.epa.gov/superfund/superfund-national-priorities-list-npl)

[89] "Basic NPL Information", *U.S. Environmental Protection Agency*. (https://www.epa.gov/superfund/basic-npl-information

[90] "Safeguarding Communities from Chemical Exposure", *Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services*. (https://www.atsdr.cdc.gov/docs/APHA-ATSDR_book.pdf)

[91] "Summary of the Emergency Planning and Community Right-to-Know Act", (42 U.S.C. § 11001 et seq.), Public Law 99-499, 1986 *U.S. Environmental Protection Agency*. (https://www.epa.gov/laws-regulations/summary-emergency-planning-community-right-know-act)

[92] "EPCRA Overview", *U.S. Environmental Protection Agency*. (https://www.epa.gov/epcra/what-epcra)

[93] "What is the Toxics Release Inventory", *U.S. Environmental Protection Agency*. (https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory), (https://www.epa.gov/trinationalanalysis)

[94] "Superfund Amendments and Reauthorization Act", Public Law 99-499, amended through Public Law 116-92, 1986 (https://www.govinfo.gov/content/pkg/COMPS-894/pdf/COMPS-894.pdf)

[95] "Superfund Amendments and Reauthorization Act", *U.S. Environmental Protection Agency*. (https://www.epa.gov/superfund/superfund-amendments-and-reauthorization-act-sara)

[96] "S.1316, Safe Drinking Water Act Amendments of 1996", Public Law 104–182, 1996, *U.S. Environmental Protection Agency*. (https://www.congress.gov/bill/104th-congress/senate-bill/1316)

[97] "Application of SDWA to Federal Agencies", *U.S. Environmental Protection Agency*. (https://www.epa.gov/enforcement/safe-drinking-water-act-sdwa-and-federal-facilities)

[98] "Basic Information on the CCL and Regulatory Determination", *U.S. Environmental Protection Agency*. (https://www.epa.gov/ccl/basic-information-ccl-and-regulatory-determination#what-crieria-reg-det)

[99] "Information about Public Water Systems", *U.S. Environmental Protection Agency*. (https://www.epa.gov/dwreginfo/information-about-public-water-systems)

[100] "America's Water Infrastructure Act of 2018", *U.S. Environmental Protection Agency*. (https://www.epa.gov/ground-water-and-drinking-water/americas-water-infrastructure-act-2018-awia)

[101] "National Primary Drinking Water Regulations", *U.S. Environmental Protection Agency*. (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations)

[102] "Proposed PFAS National Primary Drinking Water Regulation", *U.S. Environmental Protection Agency*. (https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas)

[103] "Learn About the Unregulated Contaminant Monitoring Rule", *U.S. Environmental Protection Agency*. (https://www.epa.gov/dwucmr/learn-about-unregulated-contaminant-monitoring-rule)

[104] "National Contaminant Occurrence Database", *U.S. Environmental Protection Agency*. (https://www.epa.gov/sdwa/national-contaminant-occurrence-database-ncod)

[105] "Provisional Health Advisories for perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS)", *US Environmental Protection Agency, Office of Water*, January 2009, 1-5. (https://www.epa.gov/sites/default/files/2015-09/documents/pfoa-pfos-provisional.pdf)

[106] "About the Office of Water", *U.S. Environmental Protection Agency*. (https://www.epa.gov/aboutepa/about-office-water)

[107] "Technical Basis for the Lowest Concentration Minimum Reporting Level (LCMRL) Calculator", *US Environmental Protection Agency, Office of Water*, December 2010, 1-30. [Docket # EPA 815-R-11-001] (https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100J7CA.txt)

[108] "Revisions to the Unregulated Contaminant Monitoring Regulation (UCMR 3) for Public Water Systems", (40 CFR Parts 141 & 142), *U.S. Environmental Protection Agency*, May 2012, Federal Register *77*(*85*), 26071-26101. [Docket # EPA-HQ-OW-2009–0090; FRL-9660-4], [RIN 2040-AF10] (https://www.govinfo.gov/content/pkg/FR-2012-05-02/pdf/2012-9978.pdf)

[109] "Drinking Water Health Advisory for perfluorooctane sulfonate (PFOS)", *US Environmental Protection Agency, Office of Water, Health and Ecological Criteria Division, Office of Science and Technology*, May 2016, 1-88. [Docket # EPA 822-R-16-002, 003, 004, 005] (https://www.epa.gov/sites/default/files/2016-05/documents/pfos_health_advisory_final-plain.pdf)

[110] D. Renfrew, T.W. Pearso; "The Social Life of the "Forever Chemical", PFAS Pollution Legacies and Toxic Event", *Environment and Society: Advances in Research*, 2021, *12*, 146-163. [DOI:10.3167/ares.2021.120109]

[111] "Frank R. Lautenberg Chemical Safety for the 21st Century Act", (15 U.S.C. 2602), Public Law 114–182, December 2016, 1-67. (https://www.govinfo.gov/content/pkg/PLAW-114publ182/pdf/PLAW-114publ182.pdf)

[112] "TSCA MODERNIZATION ACT OF 2015", report 114-176, June 2015, 1-88. (https://www.congress.gov/114/crpt/hrpt176/CRPT-114hrpt176.pdf)

[113] "2018 PFAS National Leadership Summit", *U.S. Environmental Protection Agency*. (https://www.epa.gov/pfas/2018-pfas-national-leadership-summit)

[114] "EPA's PFAS Action Plan: A Summary of Key Actions", *U.S. Environmental Protection Agency*. (https://nepis.epa.gov/Exe/ZyPDF.cgi/P100WD84.PDF?Dockey=P100WD84.PDF)

[115] "EPA Continues Progress under the PFAS Action Plan", *U.S. Environmental Protection Agency.* November 2019. (https://www.epa.gov/newsreleases/epa-continues-progress-under-pfas-action-plan)

[116] "EPA Acting Administrator Announces First-Ever Comprehensive Nationwide PFAS Action Plan", *U.S. Environmental Protection Agency*. (https://www.youtube.com/watch?v=xaRgWcwwmXc)

[117] "EPA's Per- and Polyfluoroalkyl Substances (PFAS) Action Plan", *U.S. Environmental Protection Agency*, February 2019, 1-17. [EPA Publication # 823R18004] (https://www.epa.gov/sites/default/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf)

[118] "PFAS Action Plan Program Update", *U.S. Environmental Protection Agency*, February 2020, 1-17. [EPA Publication # 100K20002] (https://www.epa.gov/sites/default/files/2020-01/documents/pfas_action_plan_feb2020.pdf)

[119] "H.R. 2467 PFAS Action Act of 2021", 117th US Congress, July 2021.(https://www.congress.gov/bill/117th-congress/house-bill/2467/text)

[120] "Drinking Water Treatment and Distribution Systems Research", *U.S. Environmental Protection Agency*. (https://www.epa.gov/water-research/drinking-water-treatment-and-distribution-systems-research)

[121] "Drinking Water Treatability Database: Information on treatment processes for controlling contaminants", *U.S. Environmental Protection Agency*. (https://www.epa.gov/water-research/drinking-water-treatability-database-tdb)

[122] "EPA Settlement with Swix Sport USA Resolves TSCA Violations Involving PFAS", *U.S. Environmental Protection Agency*, May 2020. (https://www.epa.gov/newsreleases/epa-settlement-swix-sport-usa-resolves-tsca-violations-involving-pfas)

[123] N.L. Bradley; "U.S. Chamber Letter on H.R.6395/S.4049, "National Defense Authorization Act for Fiscal Year 2021", Chamber of Commerce of the United States of America, October 2020. (https://www.uschamber.com/assets/documents/201002_fy21ndaa_conferees.pdf)

[124] "PFAS Innovative Treatment Team", *U.S. Environmental Protection Agency*. (https://www.epa.gov/chemical-research/pfas-innovative-treatment-team-pitt)

[125] M. Krause, M. Magnuson, B. Crone; "Potential PFAS Destruction Technology: Electrochemical Oxidation", Research Brief: Innovative Research for a Sustainable Future, *U.S. Environmental Protection Agency*, January 2021, 1-3.(https://www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_electrochemical_oxidation_final_jan_25_2021_508.pdf)

[126] E. Shields, A. Whitehill; "Potential PFAS Destruction Technology: Mechanochemical Degradation", Research Brief: Innovative Research for a Sustainable Future, *U.S. Environmental Protection Agency*, January 2021, 1-2. (https://www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_mechanochemical_final_jan_25_2020_508.pdf)

[127] C. Acheson, M. Mills, M. Krause, E. Thoma; "Potential PFAS Destruction Technology: Pyrolysis and Gasification", Research Brief: Innovative Research for a Sustainable Future, *U.S. Environmental Protection Agency*, January 2021, 1-3.(https://www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_pyrolysis_final_jan_27_2021_508.pdf)

[128] E. Sahle-Damesessie, M. Krause; "Potential PFAS Destruction Technology: Supercritical Water Oxidation", Research Brief: Innovative Research for a Sustainable Future, *U.S. Environmental Protection Agency*, January 2021, 1-2. (https://www.epa.gov/sites/default/files/2021-01/documents/pitt_research_brief_scwo_final_jan_25_2021_508.pdf)

[129] "Key EPA Actions to Address PFAS", *U.S. Environmental Protection Agency*. (https://www.epa.gov/pfas/key-epa-actions-address-pfas)

[130] "EPA Takes Actions to Address PFAS in Drinking Water", *U.S. Environmental Protection Agency*. February 2021. (https://www.epa.gov/newsreleases/epa-takes-action-address-pfas-drinking-water)

[131] "National PFAS Testing Strategy: Identification of Candidate Per- and Polyfluoroalkyl Substances (PFAS) for Testing", *U.S. Environmental Protection Agency*, October 2021, 1-16.(https://www.epa.gov/system/files/documents/2021-10/pfas-natl-test-strategy.pdf)

[132] "PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024", *U.S. Environmental Protection Agency*, October 2021, 1-23. [EPA Publication # 100K21002] (https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf) (https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024)

[133] "EPA's PFAS Strategic Roadmap: A Year of Progress", *U.S. Environmental Protection Agency*, November 2022, 1-11. [EPA Publication # 800K22001] (https://www.epa.gov/system/files/documents/2022-11/PFAS%20Roadmap%20Progress%20Report_final_Nov%2017.pdf)

[134] "Regional Removal Management Levels (RMLs) User's Guide", *U.S. Environmental Protection Agency*, November 2022. (https://www.epa.gov/risk/regional-removal-management-levels-rmls-users-guide)

[135] "Designation of Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS) as CERCLA Hazardous Substances", (40 CFR 302), *U.S. Environmental Protection Agency*, September 2022, Federal Register *87*(*171*), 54415-54442. [Docket # EPA–HQ–OLEM–2019–0341; FRL–7204– 02–OLEM], [RIN 2050-AH09], [Document # 2022-19202] (https://www.govinfo.gov/content/pkg/FR-2022-09-06/pdf/2022-18657.pdf)

[136] "Notice of Proposed Rulemaking: Designating PFOA and PFOS as CERCLA Hazardous Substances", *U.S. Environmental Protection Agency*, August 2022. (https://www.epa.gov/system/files/documents/2022-09/Overview%20Presentation_NPRM.pdf)

[137] "Study on Intractable Public Water Systems Serving Fewer Than 1,000 People: Compliance with National Primary Drinking Water Regulations, Barriers, and Case Studies", *Office of Water*, EPA 815-R-19-005, July 2022, 1-55. (https://www.epa.gov/system/files/documents/2023-02/8296_AWIA%20Study%20on%20Intractable%20PWS_RTC_Transmitted%2008-30-22.pdf)

[138] "Drinking Water Compliance Monitoring Data Strategic Plan, SDWA 1414, as amended by Section 2011 of America's Water Infrastructure Act", *U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Drinking Water Protection Division*, EPA 810-R-19-002, July 2022, 1-28. (https://www.epa.gov/system/files/documents/2022-09/7967_AWIA%20Compliance%20Monitoring%20Strategic%20Plan%20RtC_20220812_ADMIN.pdf)

[139] "Long-Chain Perfluoroalkyl Carboxylate and Perfluoroalkyl

Sulfonate Chemical Substances; Significant New Use Rules", (40 CFR 721), *U.S. Environmental Protection Agency*, June 2022, Federal Register *80*(*13*), 2885-2898. [Docket # EPA–HQ–OPPT–2013–0225; FRL–9915–63], [RIN 2070-ABJ99], [Document # 2014-30388] (https://www.govinfo.gov/content/pkg/FR-2015-01-21/pdf/2015-00636.pdf)

[140] "Significant New Use Rules", (40 CFR 721), *U.S. Environmental Protection Agency*, June 2022, Federal Register *87*(*121*), 37783-37807. [Docket # EPA-HQ-OPPT-2021-0568; FRL-9779-01-OCSPP], [RIN 2070-AB27], [Document # 2022-13360] (https://www.govinfo.gov/content/pkg/FR-2022-06-24/pdf/2022-13360.pdf)

[141] "Significant New Use Rules on Certain Chemical Substances", (40 CFR Parts 9 & 721), *U.S. Environmental Protection Agency*, September 2022, Federal Register *87*(*188*), 58999-59012. [Docket # EPA-HQ-OPPT-2021-0030; FRL-8805-02-OCSPP], [RIN 2070-AB27], [Document # 2022-21042] (https://www.govinfo.gov/content/pkg/FR-2022-09-29/pdf/2022-21042.pdf)

[142] "Previous Actions to Address PFAS", *U.S. Environmental Protection Agency*.(https://www.epa.gov/pfas/previous-actions-address-pfas)

[143] "Report of the United Nations Conference on Environment and Development", *United Nations Conference on Environment and Development*, Rio de Janiro, Brazil, June 1992. (https://www.un.org/en/conferences/environment/rio1992)

[144] "The Rio Declaration on Environment and Development", *United Nations Conference on Environment and Development*, Rio de Janiro, Brazil, June 1992. (https://www.iau-hesd.net/sites/default/files/documents/rio_e.pdf)

[145] "Occurrence and Use of Highly Fluorinated Substances and Alternatives. Report from a Government Assignment". Report 7/15, *Swedish Chemicals Agency* (KEMI), 2015. [ISSN 0284-1185], [Article # 361 164]. (https://www.enviro.wiki/images/d/df/KEMI2015.pdf)

[146] "International Workshop Supporting the Dialogue between Science and Policy on PFASs 9–10 November 2017 in Zurich, Switzerland Thought Starter", *Safety and Environmental Technology Group*, 2017.(https://www.ipcp.ch/news/international-workshop-supporting-the-dialogue-between-science-and-policy-on-pfass-at-eth-zurich)

[147] "PFAS National Environmental Management Plan", *Heads of EPAs Australia and New Zealand (HEPA)*, January 2018, 1-47.(https://www.dcceew.gov.au/sites/default/files/documents/pfas-nemp-1.pdf)

[148] "Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)", OECD Environment, Health and Safety Publications, *Organization for Economic Co-operation and Development*, Paris, France, 2013. (https://wedocs.unep.org/bitstream/handle/20.500.11822/32445/SPPPC.pdf?sequence=1&isAllowed=y)

[149] "Toward a New Comprehensive Global Database of Per- and Polyfluoroalkyl Substances (PFASs): Summary Report on Updating the OECD 2007 List of Per- and Polyfluoroalkyl Substances (PFASs)", *Organization for Economic Co-operation and Development*, 2018, 1-24. [Series on Risk Management # 39], [HERO # 5099062]. (https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/5099062)

[150] "Working towards a Global Emission Inventory of PFAS: Focus on PFAS-Status Quo and the Way Forward", *Organization for Economic Co-operation and Development*, 2015, 1-84. [Series on Risk Management # 30]. (https://www.oecd.org/chemicalsafety/Working%20Towards%20a%20Global%20Emission%20Inventory%20of%20PFASS.pdf

[151] "Summary of the Eighteenth Meeting of the Persistent Organic Pollutants Review Committee: 26-30 September 2022", *Earth Negotiations Bulletin*, October 2022, *15*(*292*), 1-12. (https://enb.iisd.org/sites/default/files/2022-10/enb15292e.pdf)

[152] "POPRC Recommendations for Listing Chemicals", *Persistent Organic Pollutants Review Committee*, 2023. (https://echa.europa.eu/list-of-substances-proposed-as-pops)

[153] "All POPs listed in the Stockholm Convention", *United Nations Environment Program*, 2023. (http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx)

[154] "UN Expert Recommend Elimination of Additional Chemicals to Protect Human Health and the Environment", *Stockholm Convention, United Nations Environment Program*, 2020.(http://chm.pops.int/Implementation/PublicAwareness/PressReleases/POPRC15expertsrecommendeliminationofPFHxS/tabid/8153/Default.aspx)

[155] "Candidate List of Substances of Very High Concern for Authorization", *European Chemicals Agency*, 2020. (https://echa.europa.eu/candidate-list-table), (https://www.intertek.com/assuris/chemicals/regulatory/reach-svhc-candidate-list/)

[156] "Short-Chain Polyfluoroalkyl Substances (PFAS). A Literature Review of Information on Human Health Effects and Environmental Fate and Effect Aspects of Short-Chain PFAS", *Danish Environmental Protection Agency*, Copenhagen, Denmark, 2015, 1-106. [Environmental Project No. 1707]. (https://www2.mst.dk/Udgiv/publications/2015/05/978-87-93352-15-5.pdf)

[157] Norden, *SPIN – Substances in preparations in Nordic countries*. (http://www.spin2000.net/spinmyphp/)

[158] A. Blum, S.A. Balan, M. Scheringer, X. Trier, G. Goldenman, I.T. Cousins, M. Diamond, T. Fletcher, C. Higgins, A.E. Linderman, G. Peaslee, P. de Voogt, Z. Wang, R. Weber; "The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)", *Environmental Health Perspectives*, 2015, *123*(*5*), A107–A111. [DOI: 10.1289/ehp.1509934]

[159] A. Ritscher, Z. Wang, M. Scheringer, J.M. Boucher,L. Ahrens, U. Berger, S. Bintein, S.K. Bopp, D. Borg, A.M. Buser, I. Cousins, J. DeWitt, T. Fletcher, C. Green, D. Herzke, C. Higgins, J. Huang, H. Hung, T. Knepper, C.S. Lau, E. Leinala, A.B. Lindstrom, J. Liu, M. Miller, K. Ohno, N. Perkola, Y. Shi, L.S. Haug, X. Trier, S. Valsecchi, K. van der Jagt, L. Vierke; "Zürich Statement on Future Actions on Per- and Polyfluoroalkyl Substances", *Environmental Health Perspectives*, 2018, *126*(*8*), 084502: 1-5. [DOI: 10.1289/EHP4158]

[160] S.A. Bălan, V.C. Mathrani, D.F. Guo, A.M. Algazi; "Regulating PFAS as a Chemical Class under the California

Safer Consumer Products Program", *Environmental Health Perspectives*, 2021, *129*(*2*), 025001: 1-9. [DOI: 10.1289/EHP7431]

[161] J. Glüge, M. Scheringer, I.T. Cousins, J.C. DeWitt, G. Goldenman, D. Herzke, R. Lohmann, C.A. Ng, X. Trier, Z. Wang, "An overview of the uses of per- and polyfluoroalkyl substances (PFAS)", *Environmental Science: Processes & Impacts*, 2020, 22, 2345-2373. [DOI: 10.1039/D0EM00291 G]