# Teflon's Toxic Legacy: Per- and Polyfluoroalkyl Substances (PFASs) Contamination and Why Further Regulation is Urgently Required

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## I. Introduction

Per and polyfluoroalkyl substances (PFASs) are a large group of synthetic chemicals that are widely used in numerous technologies, industrial processes and everyday applications.[1] A 2015 survey by the Swedish Chemicals Agency was able to identify 2060 PFASs on the global market, but estimated that more than 4000 types of PFASs have been synthesised.[2] This was confirmed by the Organisation for Economic Cooperation and Development (OECD) in 2018, when it identified a total of 4730 PFAS-related chemicals on the global market.[3]

Since the discovery of polytetrafluoroethylene (PTFE) in 1938, PFASs, both polymeric and non-polymeric, have been used extensively as ingredients or intermediates of surfactants and surface protectors for assorted industrial and consumer applications.[4] The distinguishing characteristic of PFAS compounds is a chain of carbon atoms bonded to fluorine atoms, resulting in toxic chemicals that have extremely poor environmental biodegradability (persistent), and accumulate in living organisms (bioaccumulating).[5] PFASs and other synthetic organic chemicals with these properties are generally referred to as persistent organic pollutants.[6] Many PFASs have

* LLB Honours, University of Waikato.

1 Organisation for Economic Co-operation and Development (OECD) *PFASs and Alternatives in Food Packaging (Paper and Paperboard) Report on the Commercial Availability and Current Uses* (OECD Environment, Health and Safety Division, Environment Directorate, OECD Series on Risk Management No 58, 2020) at 11.

2 KEMI Swedish Chemicals Agency *Occurrence and Use of Highly Fluorinated Substances and Alternatives* (KEMI, Report 7/15, 2015) at 27–32.

3 OECD *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)* (OECD Environment, Health and Safety Division, Environment Directorate, OECD Series on Risk Management No 39, 4 May 2018) at 6.

4 OECD *PFASs and Alternatives in Food Packaging*, above n 1, at 11.

5 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)* (OECD Environment, Health and Safety Division, Environment Directorate, 2013) at 4.

6 Frederick Pontius "Regulation of Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonic Acid (PFOS) in Drinking Water: A Comprehensive Review" (2019) 11 Water 1 at 1.

been detected globally in the environment,[7] biota,[8] humans,[9] and food items,[10] including in remote regions far from sources.[11] PFASs have therefore been recognised as global contaminants of high concern.[12]

Concerns about undesired adverse effects on humans and the environment have led to efforts toward the development of risk reduction approaches to reduce the global impact of these chemicals.[13] In many developed countries, the risk reduction approach for PFASs has been to restrict and/or eliminate their manufacture and use through regulatory measures.[14] This research paper will examine how PFASs are regulated internationally, in the European Union (EU) and in New Zealand. It will consider the efficacy of that regulation, and why further regulatory measures are urgently needed to prevent other PFASs from accumulating in the environment. As long as they continue to be released into the environment, humans and other species will be exposed to ever increasing concentrations of PFASs.[15] Due to the large number of PFAS chemicals, the current substance-by-substance risk assessment and management approach is not adequate to efficiently prevent risk to the environment and human health.[16] Precautionary risk management actions, such as regulating or prohibiting the entire class of PFASs, are therefore required.[17] Until such regulation or prohibition is achieved, experts advise that people should minimise their use of and exposure to products containing PFASs.[18] Consumer information on how to find PFAS-free alternatives will therefore play a significant role in helping to reduce exposure.[19]

7 See, for example, A Gawor and others "Neutral Polyfluoroalkyl Substances in the Global Atmosphere" (2014) 16 Environ Sci Process Impacts 404; H A Kaboré and others "Worldwide Drinking Water Occurrence and Levels of Newly-identified Perfluoroalkyl and Polyfluoroalkyl Substances" (2017) 10 Sci Total Enviro 1016; and K Rankin and others "A North American and Global Survey of Perfluoroalkyl Substances in Surface Soils: Distribution Patterns and Mode of Occurrence" (2016) 161 Chemosphere 333.

8 See, for example J P Giesy and K Kannan "Perfluorochemical Surfactants in the Environment" (2002) 36 Environ Sci Technol 146A; M Houde and others "Monitoring of Perfluorinated Compounds in Aquatic Biota: An Updated Review" (2011) 45 Environ Sci Technol 7962; and L Ahrens and M Bundschuh "Fate and Effects of Poly- and Perfluoroalkyl Substances in the Aquatic Environment: A Review" (2014) 33 Environ Toxicol Chem 1921.

9 See for example, R Vestergren and I T Cousins "Tracking the Pathways of Human Exposure to Perfluorocarboxylates" (2009) 43 Environ Sci Technol 5565.

10 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs), above n 5, at 4. See also KEMI Swedish Chemicals Agency*, above n 2, at 10.

11 C J Young and others "Perfluorinated Acids in Arctic Snow: New Evidence for Atmospheric Formation" (2007) 41 Environ Sci Technol 3455.

12 OECD *Toward a New Comprehensive Global Database*, above n 3, at 8.

13 At 8.

14 At 13–14.

15 Frederick A. McDonald "Omnipresent Chemicals: TSCA Preemption in the Wake of PFAS Contamination" (2019) 37 Pace Envtl L Rev 139 at 143–144.

16 European Environment Agency (EEA) *Emerging chemical risks in Europe – "PFAS"* (European Environment Agency, Briefing No 12/2019, 2019) at 1.

17 At 1–2.

18 At 5.

19 At 1–2.

## II. Properties and Uses of PFASs

PFASs are a large group of man-made chemicals containing more than 4700 individual substances.[20] PFASs consist of a fully (per) or partly (poly) fluorinated carbon chain connected to different functional groups.[21] These very stable carbon-fluorine bonds are what makes PFASs resistant to degradation and therefore highly persistent in the environment.[22] Based on the length of the fluorinated carbon chain, short and long chain PFASs can be distinguished:[23]

- perfluorocarboxylic acids (PFCAs) with carbon chain lengths C8 and higher, such as PFOA;
- perfluoroalkane sulfonic acids (PFSAs) with carbon chain lengths C6 and higher, such as PFOS; and
- precursors of these substances that may be produced or present in products.

PFASs were first created over 70 years ago. Polytetrafluoroethylene (PTFE) – a fluoropolymer or polymeric PFAS – was accidentally discovered in 1938 and was later introduced under DuPont's 'Teflon' brand in 1949.[24] Teflon has most commonly been used in pans and other cookware because of its non-stick coating capabilities, but is also used in household cleaning products and beauty items.[25]

For more than 50 years. PFASs have been used in a wide variety of consumer products and industrial applications because of their unique chemical and physical properties, including oil and water repellence, temperature and chemical resistance, and surfactant properties.[26] The two most well-known PFASs are perfluorooctanoic acid (PFOA), used to create Teflon and a by-product of many other processes, and perfluorooctane sulfonic acid (PFOS), used in Scotchguard, firefighting foam, and semiconductor devices.[27] Other major industry sectors using PFASs include:[28]

- aviation, aerospace and defence (e.g. additives in aviation hydraulic fluids, insulators, solder sleeves);
- biocides (e.g. active ingredient in ant baits);
- cable and wiring (e.g. coating for weathering);
- construction products (e.g. additives in paints and coatings);
- electronics (e.g. flame retardants, insulators);
- energy (film to cover solar collectors due to weatherability);
- fire-fighting (e.g. film formers in aqueous film-forming foams, raw materials for fire-fighting equipment, including protective clothing);

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20 Heads of EPAs Australia and New Zealand (HEPA) *PFAS National Environmental Management Plan Version 2.0* (HEPA, 2020) at 8.

21 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)*, above n 5, at 4.

22 OECD *Toward a New Comprehensive Global Database*, above n 3, at 8.

23 R C Buck and others "Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins" (2011) 7 Integr Environ Assess Manag 513 at 513–541.

24 McDonald, above n 15, at 142.

25 At 142.

26 EEA, above n 16, at 2; and HEPA, above n 20, at 8.

27 HEPA, above n 20, at 8; and McDonald, above n 15, at 142–143.

28 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)*, above n 5, at 12–13.

- household products (e.g. wetting agent or surfactant in products such as floor polishes and cleaning agents, non-stick coating);
- medical articles (e.g. surgical patches, cardiovascular grafts, stain- and water-repellents for surgical drapes and gowns)
- metal plating (e.g. wetting agent);
- oil and mining production (e.g. surfactants in oil well stimulation);
- paper and packaging (e.g. oil and grease repellent);
- polymerisation (e.g. polymerisation, or emulsion, processing aids);
- semiconductors (e.g. working fluids in mechanical vacuum pumps);
- textiles, leather and apparel (e.g. raw materials for highly porous fabrics, oil and water repellents and stain release.

## III. What Are the Concerns?

### *A. PFAS and the Environment*

PFASs have been detected in the natural environment since the early 2000s because of their widespread use and their extreme chemical stability.[29] These substances are ubiquitously present in the air, soil, and water, and while the chemical breakdown is quicker in the air, PFASs do not break down at all once they enter the water and soil.[30] The high water-solubility of PFASs mean that they readily leach from soil to surface water and groundwater, and ultimately enter creeks, rivers, lakes and oceans.[31] The distribution of PFAS in aqueous media is also of concern when the long-range transport potential of the substance is examined.[32] For example, findings of PFASs in remote areas like the Arctic or Antarctica give evidence for the long-range transport potential, because PFASs are not known to be used or produced in these regions.[33]

Another topic of concern is the bioaccumulation potential of PFASs, which has been linked to adverse impacts on some plants and animals.[34] Information that PFAS bioaccumulates can be drawn from biomagnification factors (BMFs) and trophic magnification factors (TMFs), which are both related to concentrations in predator/prey relationships.[35] The BMF expresses the extent to which a chemical's concentration increases (or biomagnifies) from one level of a trophic chain

29 Anja Duffek and others "Per- and polyfluoroalkyl substances in blood plasma – Results of the German Environmental Survey for children and adolescents 2014-2017 (GerES V)" (2020) 228 International Journal of Hygiene and Environmental Health 113549 at 113549.

30 McDonald, above n 15, at 144.

31 HEPA, above n 20, at 8.

32 Lena Vierke and others "Perfluorooctanoic acid (PFOA) – main concerns and regulatory developments in Europe from an environmental point of view" (2012) 24(16) Environmental Sciences Europe 1 at 4.

33 At 4.

34 Pattle Delamore Partners Ltd (PDP) *RNZAF Base Woodbourne PFAS Investigation: Comprehensive Site Investigation Report* (17 December 2019) at 2.

35 Vierke and others, above n 32, at 6.

to the next higher level.[36] In other words, it is the ratio of the concentration of the chemical in a predator (or consumer) organism to that in its prey (or diet).[37] TMFs represent an average BMF over several trophic levels, or even over a whole food chain.[38] Generally, factors higher than one indicate accumulation.[39] Studies have shown that PFASs bioaccumulate in food chains, and findings in top predators have been reported.[40] For example, studies on dolphins[41] and caribou[42] clearly show that PFASs are bioaccumulative. The occurrence of PFASs in endangered species and in vulnerable populations are also indicative of their bioaccumulative properties.[43] Detection of PFASs in biota of remote regions where no direct PFAS source is known, such as the detection of PFOA in polar bears, indicates uptake from the surrounding environment.[44]

## *B. Effects of PFAS on Human Health*

PFAS have become pervasive contaminants in both the environment and in humans. Numerous studies have documented the presence of PFASs in virtually all environmental media, wildlife, and in human blood samples worldwide.[45] Currently, PFAS are detectable in nearly all humans, with exposures beginning during foetal development; once taken up by the human body, PFASs will bind to blood proteins and bioaccumulate.[46] Toxicology and epidemiology studies have increasingly documented human health effects of exposure to PFASs, even at low does, including testicular, kidney and liver cancer, ulcerative colitis, neurotoxicity, endocrine disruption, developmental toxicity and impairment of the immune response shown as decreased antibody responses to

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36 James Franklin "How reliable are field-derived biomagnification factors and trophic magnification factors as indicators of bioaccumulation potential? Conclusions from a case study on per- and polyfluoroalkyl substances" (2016) 12(1) Integrated Environmental Assessment and Management 6 at 8.

37 At 8.

38 At 9.

39 Vierke and others, above n 32, at 4.

40 See, for example, M Houde and others "Biological monitoring of polyfluoroalkyl substances: A review" (2006) 40 Environ Sci Technol 3463.

41 B C Kelly and others "Perfluoroalkyl contaminants in an Arctic marine food web: trophic magnification and wildlife exposure" (2009) 43 Environ Sci Technol 4037; and M Houde and other "Biomagnification of perfluoroalkyl compounds in the bottlenose dolphin (Tursiops truncatus) food web" (2006) 40 Environ Sci Technol 4138.

42 C E Muller and others "Biomagnification of perfluoroalkyl compounds in a remote terrestrial food chain: Lichen-Caribou-Wolf" (2011) 45 Environ Sci Technol 8665.

43 Vierke and others, above n 32, at 6.

44 C M Butt "Levels and trends of poly- and perfluorinated compounds in the arctic environment" (2010) 408 Sci Total Environ) 2936; and Vierke and others, above n 32, at 6.

45 K J Hansen and others "Compound-specific, quantitative characterization of organic fluorochemicals in biological matrices" (2001) 35 Environ Sci Technol 766; Centers for Disease Control and Prevention (CDC) *Fourth national report on human exposure to environmental chemicals* (CDC, 2009); Houde and others, above n 40; K Harada and A Kolzumi "Environmental and biological monitoring of persistent fluorinated compounds in Japan and their toxicities" (2009) 14 Environ Health Prev Med 7 at 7–19; and C Lau and others "Perfluoroalkyl acids: A review of monitoring and toxicological findings" (2007) 99 Toxicol Sci 366 at 366–394.

46 Alexis M. Temkin and others "Application of the Key Characteristics of Carcinogens to Per and Polyfluoroalkyl Substances" (2020) 17 Int J Environ Res Public Health 1668 at 1668; W Cheng and C A Ng "Predicting relative protein affinity of novel per- and polyfluoroalkyl substances (PFASs) by an efficient molecular dynamics approach" (2018) 52 Environ Sci Technol 7972; and C A Ng and K Hungerbuhler "Bioaccumulation of perfluorinated alkyl acids: Observations and Models (2014) 48 Environ Sci Technol 4637 at 4639.

vaccines.[47] Links have also been identified between PFAS exposure and thyroid disorders, changes in the lipid metabolism like increases in serum lipid levels, particularly total cholesterol and LDL cholesterol, increased risk of decreased fertility determined as prolonged time to pregnancy, as well as pregnancy-induced hypertension and/or pre-eclampsia.[48]

## IV. Main Sources of Environmental PFAS Pollution

Production and use of PFASs, such as from the manufacture of fluoropolymers, installations and the use of PFAS-containing fire-fighting foams have been the main sources of PFAS contamination.[49] Other sources include PFASs produced and applied to textiles and paper and painting/printing facilities.[50] Potential releases of PFASs from other applications, such as oil extraction and mining,[51] and the manufacture of medical devices, pharmaceuticals and pesticides,[52] are less understood.

PFASs in consumer products, such as furniture, textiles, polishing and cleaning agents and creams, can contaminate dust and air, whereas food contact materials have been found to leach

47 Temkin, above n 46, at 1668-1669; Elicia Mayuri Cousins and others "Risky Business? Manufacturer and Retailer Action to Remove Per- and Polyfluorinated Chemicals From Consumer Products" (2019) 29(2) New Solutions: A Journal of Environment and Occupational Health Policy 242 at 244–245; Duffek and others, above n 29, at 2; S J Frisbee and others "The C8 health project: design, methods, and participants" (2009) 117 Environ Health Perspect 1873 at 1873–1882; M J Lopez-Espinosa and others "Association of Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS) with age of puberty among children living near a chemical plant" (2011) 45 Environ Sci Technol 8160 at 8160–8166; K Steenland, T Fletcher and D A Savitz "Epidemiologic evidence on the health effects of perfluorooctanoic acid (PFOA)" (2010) 118 Environ Health Perspect 1100 at 1100–1108; D J Watkins and others "Exposure to Perfluoroalkyl Acids and Markers of Kidney Function Among Children and Adolescents Living Near a Chemical Plant" (2013) 121 Environ Health Perspect 625 at 625–630; V Gallo and others "Serum perfluorooctanoate (PFOA) and perfluorooctane sulfonate (PFOS) concentrations and liver function biomarkers in a population with elevated PFOA exposure" (2012) 120 Environ Health Perspect 655 at 655–660; and M J Lopez-Espinosa and others "Comparison between free serum thyroxine levels, measured by analog and dialysis methods, in the presence of perfluorooctane sulfonate and perfluorooctanoate" (2012) 33 Reprod Toxicol 552 at 552–555.

48 Temkin, above n 46, at 1668–1670; Cousins and others, above n 47, at 245; Duffek and others, above n 29, at 2–3; S S Knox and others "Perfluorocarbon exposure, gender and thyroid function in the C8 Health Project" (2011) 36 J Toxicol Sci 403 at 403–410; Frisbee and others, above n 47, at 1873–1882; S J Frisbee and others "Perfluorooctanoic acid, perfluorooctane sulfonate, and serum lipids in children and adolescents: results from the C8 Health Project" (2010) 164 Arch Pediatr Adolesc Med 860 at 860–869; Javins B Hobbs and others "Circulating maternal perfluoroalkyl substances during pregnancy in the C8 Health Study" (2013) 47 Environ Sci Technol 1606 at 1606–1613; and D A Savitz and others "Relationship of perfluorooctanoic acid exposure to pregnancy outcome based on birth records in the mid-Ohio Valley" (2012) 120 Environ Health Perspect 1201 at 1201–1207.

49 Z Wang and others "Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, Part I: production and emissions from quantifiable sources" (2014) 70 Environment International 62 at 62–75; Z Wang and others "Global emission inventories for C4-C14 perfluoroalkyl carboxylic acid (PFCA) homologues from 1951 to 2030, Part II: The remaining pieces of the puzzle" (2014) 69 Environment International 166 at 166–176; and C X Hu and others "Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants" (2016) 3(10) Environmental Science & Technology Letters 344 at 345–350.

50 Danish EPA *Screeningsundersøgelse af udvalgte PFASforbindelser som jord- og grundvandsforurening i forbindelse med punktkilder* (Danish EPA, Miljøprojekt nr. 1600, 2014).

51 E Kissa *Fluorinated Surfactants and Repellents: Second Edition, Revised and Expanded Surfactant Science Series* (Marcel Dekker, New York, 2001) at 616.

52 M P Krafft and J G Riess "Per- and polyfluorinated substances (PFASs): Environmental challenges" (2015) 20(3) Current Opinion in Colloid & Interface Science 192 at 192–212.

into food.[53] Personal care products that contain PFASs have also been found to cause contamination after they enter into sewerage and wastewater treatment plants.[54]

Conventional wastewater treatment is not effective in removing PFASs from waste streams.[55] Industrial and urban wastewater treatment facilities are therefore major point sources for PFAS contamination of the aquatic environment.[56] Industrial production sites are also a major source of PFAS contamination of the air, soil and water bodies.[57] The reuse of contaminated sewage sludge as fertiliser has led to PFAS pollution of soil[58] and water in Austria, Germany, Switzerland and the United States of America (US).[59]

In Europe, PFASs are ubiquitous in the aquatic environment and organisms, and have been detected in air, soil, plants and biota.[60] Areas surrounding industrial production, manufacturing and application sites have been found to be highly polluted by PFASs.[61] This has resulted in contaminated surface, ground, and drinking water around factories in Belgium, Italy and the Netherlands, and around airports and military bases in Germany, Sweden and the United Kingdom.[62] PFAS water pollution has also been identified in countries outside the EU.[63]

In New Zealand, PFAS contamination resulting from the use of firefighting foams containing PFASs has been identified in a number of sites.[64] Over time, the chemicals have worked their way across and through the soil to contaminate surface and ground water, and have migrated into adjoining land areas.[65] PFASs have also been found to be present in sources of drinking water, waste streams, including at landfills and wastewater treatment facilities.[66]

Along with air, contaminated drinking water and consumer products containing PFASs, diet is considered another major exposure source in humans.[67] So too is occupational exposure, where

53 Nordic Council of Ministers *The Cost of Inaction: A socioeconomic analysis of environmental and health impacts linked to exposure to PFAS* (Nordic Council of Ministers Publication Unit, TemaNord No 516, 2019) at 73–81.

54 At 80.

55 A Adler and J Van der Voet "Occurrence and point source characterization of perfluoroalkyl acids in sewage sludge" (2015) 129 Chemosphere 62 at 64.

56 Nordic Council of Ministers, above n 53, at 80.

57 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 4.

58 R Ghisi and others "Accumulation of perfluorinated alkyl substances (PFAS) in agricultural plants: A review" (2019) 169 Environmental Research 326 at 326–341.

59 Nordic Council of Ministers, above n 53, at 80.

60 S Valsecchi and others "Determination of perfluorinated compounds in aquatic organisms: a review" (2013) 405(1) Analytical and Bioanalytical Chemistry 143; and Houde and others, above n 40.

61 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 4.

62 IPEN *Fluorine-free firefighting foams (3F) – Viable alternatives to fluorinated aqueous film forming foams (AFFF)* (IPEN, POPRC-14, White Paper, 2018); Hu and others, above n 49.

63 F Xiao "Emerging poly- and perfluoroalkyl substances in the aquatic environment: A review of current literature" (2017) 124 Water Research 482 at 483–495.

64 McDonald, above n 15; PDP *RNZAF Base Woodbourne*, above n 34; PDP *RNZAF Base Ohakea*; PDP *New Zealand Defence Force PFAS Investigation: Waitemata Harbour* (24 June 2019).

65 HEPA, above n 20, at 8.

66 McDonald, above n 15; PDP *RNZAF Base Woodbourne*, above n 34; PDP *RNZAF Base Ohakea*, above n 64; PDP *New Zealand Defence Force*, above n 64.

67 Duffek and others, above n 29, at 113549.

individuals are exposed to high quantities of PFASs through their occupation (for example, workers in factories producing PFASs or PFAS-treated products).[68]

## V. PFAS Regulation – International Law

The Stockholm Convention on Persistent Organic Pollutants (hereafter the Stockholm Convention, or the Convention) is an international treaty to protect human health and the environment from persistent organic pollutants (POPs) by restricting and ultimately eliminating their production, use, trade, release and storage.[69] It was adopted in 2001 and entered into force in 2004.[70] POPs are organic compounds that are resistant to environmental degradation through chemical, biological and photolytic processes.[71] POPs persist in the environment for long periods, become distributed geographically, bioaccumulate in human and animal tissue, and have harmful impacts on human health or on the environment.[72]

Two of the most extensively used PFASs are already globally regulated: PFOS and PFOA were listed as POPs under the Stockholm Convention in 2009 and 2019, respectively.[73] The listing of PFOS and PFOA includes their respective salts and related compounds.[74] PFOS is listed under Annex B (Restriction), whereby Parties to the Convention must take measures to restrict the production and use of the chemical "in light of any applicable acceptable purposes and/or specific exemptions listed in the Annex."[75] PFOA is listed under Annex A (Elimination), whereby Parties must take measures to eliminate the production and use of the chemical.[76] Specific exemptions for use or production are listed in the Annex and apply only to Parties that register for them for a specific period of time.[77] This is to enable Parties to the Convention to take measures to reduce or eliminate releases of POPs from intentional production and use, for which alternatives do not exist yet or are not readily available.[78] Examples of exempted uses for PFOS include metal plating and fire-fighting foam.[79] Exempted uses for PFOA include semiconductors, photographic coating, textile for protection and medical devices.[80]

68 Nordic Council of Ministers, above n 53, at 95.

69 Stockholm Convention Secretariat *The 16 New POPs: An introduction to the chemicals added to the Stockholm Convention as Persistent Organic Pollutants by the Conference of the Parties* (UN Environment, June 2017) at 4.

70 At 4.

71 At 4.

72 At 4.

73 HEPA, above n 20, at 10.

74 At 10.

75 Stockholm Convention Secretariat, above n 69, at 7.

76 At 7.

77 At 6–7.

78 At 6.

79 Stockholm Convention on Persistent Organic Pollutants 2256 UNTS 119 (opened for signature 23 May 2001, entered into force 17 May 2004) at Annex B.

80 Stockholm Convention on Persistent Organic Pollutants, Conference of the Parties *Decision SC-92-12: Listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds* (2019).

## VI. PFAS Regulation – European Union (EU)

The EU has taken a regulatory approach to reduce risks to certain PFASs.[81] Within the European Economic Area (EEA), member countries are subject to the provisions of the EU Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation, as well as to the regulation implementing the Stockholm Convention on POPs.[82]

PFOS has been prohibited/restricted in its use, production, import, and export under EU Commission Regulation No 757/2010 of 24 August 2010, "a regulation that complements provisions of international agreements on POPs."[83] In 2014, Norway and Germany joined in submitting a proposal for the EU to restrict PFOA, which led to the adoption of Commission Regulation (EU) 2017/1000 of 13 June 2017 amending Annex XVII to REACH.[84]

In March 2017, Sweden and Germany proposed to consider another PFAS, perfluorohexane sulfonic acid (PFHxS), a substance of very high concern.[85] This was adopted by the European Chemicals Agency (ECHA) later the same year, and the substance is now on the Candidate List.[86] Norway has registered an intention to submit a restriction proposal for PFHxS under REACH.[87]

Sweden and Germany also jointly proposed in 2017 to restrict the manufacturing and placing on the market of six other PFASs.[88] The aim in restricting these PFASs is to prevent industry from switching to them once the restriction of PFOA goes into effect in 2020.[89] Both the Risk Assessment Committee (RAC) and the Committee for Socio-economic Analysis (SEAC) have agreed to the restriction proposal.[90]

Across Europe, a number of countries have been involved in the monitoring of PFAS in environmental media as well as in humans and consumer goods.[91] Some countries have set national limit values for water and soil (Denmark, Germany , the Netherlands and Sweden), textiles (Norway) and food contact materials (Denmark).[92] Several EU Member States have defined drinking water limits for various PFAS and PFAS categories, and Denmark declared a ban on food contact materials treated with PFAS in June 2019, to enter into force in 2020.[93]

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81 OECD *Risk Reduction Approaches for PFASs – A Cross-Country Analysis* (OECD Environment, Health and Safety Division, Environment Directorate, OECD Series on Risk Management No 29, 2015) at 30.

82 Nordic Council of Ministers, above n 53, at 31.

83 OECD *Risk Reduction*, above n 81, at 30.

84 Nordic Council of Ministers, above n 53, at 31.

85 At 31.

86 At 31.

87 At 31.

88 At 31.

89 At 31.

90 At 31.

91 At 45.

92 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 10.

93 At 10.

## VII. PFAS Regulation – New Zealand

Following the introduction of the Hazardous Substances and New Organisms (HSNO) Act in 1996, regulation of hazardous substances was the responsibility of the Environmental Risk Management Authority (ERMA) until it became the Environmental Protection Agency (EPA) in 2011.[94] The first New Zealand specific controls on PFAS use actually predate the addition of PFOS to the Stockholm Convention.[95] In 2006, ERMA revised the Fire Fighting Chemicals Group Standard to exclude any substance that is or contains PFOS or PFOA, which reflected voluntary restrictions imposed in Europe and the US at the same time.[96]

New Zealand is a signatory to the Stockholm Convention and ratified it in 2004.[97] The Ministry for the Environment (MfE) leads New Zealand's participation in the Convention and coordinates the Convention's implementation across government.[98] Article 7 of the Convention requires each party to develop an National Implementation Plan (NIP), which outlines how a country will address its obligations under the convention.[99] New Zealand submitted its first NIP in 2006 (NIP1), followed by an Addendum in 2014.[100] New Zealand submitted its second NIP in 2018 (NIP2), which outlines its implementation measures in relation to the chemicals listed since NIP1, including PFOS.[101]

The HSNO Act 1996 is the primary legislation that implements New Zealand's principal obligations under the Convention.[102] The Act's purpose is to protect the environment and health and safety of people and communities by preventing or managing the adverse effects of hazardous substances and new organisms.[103] Schedule 2A (POPs) prohibits any POP, or product containing a POP, from being imported into, manufactured or used in New Zealand (subject to limited exceptions,[104] such as the use of listed POPs in research and development within a contained laboratory).[105] Schedule 2A lists all POPs added to the Convention between 2001 and 2017, including PFOS.[106] All uses of PFOS are prohibited, and no exemptions are provided.[107]

In 2017, three PFASs (PFOS, PFOS and PFHxS) emerged as contaminants of concern in New Zealand.[108] That same year, Food Standards Australia and New Zealand proposed health

94 Tonkin & Taylor Ltd *Scoping Study: Non fire-fighting foam sources of PFAS contamination in New Zealand* (July 2018) at 6.

95 At 6.

96 At 6–7.

97 Secretariat of the Stockholm Convention "Status of Ratification" <http://chm.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx>.

98 Ministry for the Environment *New Zealand's updated National Implementation Plan under the Stockholm Convention on Persistent Organic Pollutants* (ME 1392, 2018) at 11.

99 At 11.

100 At 11.

101 At 12.

102 At 19.

103 Hazardous Substances and New Organisms (HSNO) Act 1996, s 4.

104 Hazardous Substances and New Organisms Act, s 30.

105 Ministry for the Environment *New Zealand's updated National Implementation Plan*, above n 98, at 19.

106 At 19; and Hazardous Substances and New Organisms Act, sch 2A.

107 Hazardous Substances and New Organisms Act, sch 2A.

108 Tonkin & Taylor Ltd *Scoping Study*, above n 94, at 72.

based guidance values for those PFASs.[109] The Australian drinking water quality guidelines for these chemicals was subsequently accepted by the New Zealand Ministry of Health, however these guidelines do not directly regulate use.[110] PFOS remains the only comprehensively regulated PFAS in New Zealand, and so New Zealanders may still be exposed to PFASs through imported consumer products as well as existing contamination.[111]

## VIII. The Efficacy of PFAS Regulation

Although effective regulation has been achieved for PFOS and PFOA, many PFASs remain largely understudied and weakly regulated.[112] In response to the regulation of long-chain PFASs, such as PFOS and PFOA, there has been a shift from the use of long chain to short chain PFASs, which are not currently regulated.[113]

European authorities are increasingly concerned about the risks for health and the environment exhibited by short chain PFASs.[114] These concerns are due to their persistence, high mobility in water and soil and potential toxic properties.[115] Short-chain PFASs have already been identified as ubiquitously present in the environment, even in remote areas.[116] The higher water solubility of some short chain PFASs compared to long chain PFASs means that they enter drinking water reservoirs faster and tend to accumulate in water-rich edible plant tissues like leaves and fruits.[117] Removal from water cannot be performed effectively due to the low adsorption potential of short chain PFASs, even with modern expensive technologies, such as nano-filtration or using granular activated carbon.[118]

Short chain PFASs have also been found to have similar adverse effects on human health to those associated with long chain PFAS exposure. For example, GenX, a short-chain alternative to PFOA, has been associated with elevated risk of cancer in human populations.[119]

It is clear that PFASs have unique properties which make them useful, such as dielectric properties, resistance to heat and chemical degradation, and low friction properties.[120] This had led to their continued use in a vast range of consumer products and industrial applications.[121] PFASs

109 At 7.

110 At 7.

111 At 8.

112 Cousins and others, above n 47, at 242.

113 Cousins and others, above n 47, at 246.

114 United Nations Environment Programme (UNEP) *Report of the Persistent Organic Pollutants Review Committee on the work of its thirteenth meeting: Addendum – Risk management evaluation on pentadecafluorooctanoic acid (CAS No: 335-67-1, PFOA, perfluorooctanoic acid), its salts and PFOA-related compounds* (UNEP/POPS/POPRC.13/7/Add.2, 16 November 2017) at 36.

115 At 36.

116 Z Zhao and others "Distribution and long-range transport of polyfluoroalkyl substances in the Arctic, Atlantic Ocean, and Antarctic coast" (2012) 170 Environmental Pollution 71 at 71–77.

117 UNEP, above n 114, at 36.

118 At 36.

119 Temkin and others, above n 46, at 1668.

120 Tonkin & Taylor Ltd *Scoping Study*, above n 94, at 5.

121 At 5.

continue to be manufactured globally. For example, as recently as 2016, PFOS was still being manufactured in Germany, Italy and China.[122] There is also reason to believe that overall production of PFASs has continued to increase,[123] particularly in China and Southeast Asia.[124]

## IX. Looking Ahead

PFASs are persistent, bioaccumulative and toxic to animals and humans.[125] Their widespread occurrence leading to significant adverse human health and/or environmental effects warrants global action.[126] However, with over 4700 known PFASs, undertaking substance-by-substance risk assessments and comprehensive environmental monitoring to understand exposure would be an extremely lengthy and resource-intensive process.[127] As a result, complementary and precautionary approaches to managing PFASs are being explored in the EU. This includes the regulation of PFASs as a class, or as subgroups, based on toxicity or chemical similarities, and restricting PFAS use to only essential uses.[128]

### *A. Elimination of Entire Class of PFASs*

The proposal to eliminate the entire class of PFASs is consistent with sustainable development plans that seek to reduce emissions of toxic chemicals and several of the 2015 globally adopted Sustainable Development Goals (SDGs).[129] The 2030 Agenda for Sustainable Development and its 17 SDGs were adopted by the General Assembly of the United Nations in September 2015.[130] The objective of the SDGs is to meet the dual challenge of overcoming poverty and protecting the planet. They illustrate a comprehensive vision that embraces economic, social and environmental dimensions for sustainable growth.[131]

Sound management of chemicals and waste is a specific target under SDG 12 on Sustainable Consumption and Production.[132] Chemicals, waste and air quality are also referred to under SDG 3 on Good Health and Well-being, SDG 6 on Clean Water and Sanitation, SDG 7 on Affordable and Clean Energy, SDG 11 on Sustainable Cities and Communities and SDG 14 on Life Below Water.[133]

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122 At 6.

123 Z Wang and others "A never-ending story of per- and polyfluoroalkyl substances (PFASs)?" (2017) 51 Environ Sci Technol 2508 at 2508–2518.

124 J S Bowman "Fluorotechnology is critical to modern life: the fluorocouncil counterpoint to the Madrid statement" (2015) 123 Environ Health Perspect A112.

125 UNEP, above n 114, at 43.

126 At 43.

127 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 10.

128 At 10.

129 UNEP, above n 114, at 41.

130 UNEP "The Strategic Approach to International Chemicals Management and the 2030 Agenda for Sustainable Development" <www.saicm.org>.

131 UNEP, above n 130.

132 UNEP, above n 130.

133 UNEP, above n 130.

The Strategic Approach to International Chemicals Management (SAICM) is a policy framework to promote chemical safety around the world and provides the essential link between chemical safety and the SDGs.[134] SAICM aims to achieve, by 2020, the sound management of chemicals throughout their life cycle so that chemicals that pose an unreasonable and otherwise unmanageable risk to human health and the environment are no longer produced or used.[135] SAICM's Global Plan of Action contains guidance on measures to support risk reduction that includes prioritising safe and effective alternatives for persistent, bioaccumulative, and toxic substances.[136]

### *B. Elimination of All Non-essential Uses of PFASs*

In June 2019, the European Council of Ministers highlighted the widespread occurrence of PFASs in the environment, products and people, and called for an action plan to eliminate all non-essential uses of PFASs, such as use in food containers and cosmetics.[137] The first step to adopting such an approach would be to distinguish between essential and non-essential uses. Essential uses are likely those applications that are critical for health and proper functioning of society, such as medical devices and safety equipment, and for which there are neither fluorine-free alternatives nor alternative methods.[138] This is possibly due to the unique properties of PFASs, and are thus known to be irreplaceable in many applications.[139] One question that can be raised is whether these properties are really essential for all applications.[140] For example, PFAS use in textiles could be restricted to clothing for occupational and protective purposes, given that there are a number water-repelling substances that can be applied instead of PFASs.[141] Paper and food packaging is another sector where non-fluorine containing alternatives can be used. At least one manufacturer in Norway has developed a fluorine-free alternative using a high-density paper, which prevents the passage of grease.[142] The Norwegian paper producer Nordic Paper is using mechanical processes to produce, without using any persistent chemical, extra-dense paper that inhibits leakage of grease through the paper.[143]

### *C. Consumer Information*

Until regulation or prohibition of the entire class of PFASs is achieved, experts advise that people should minimise their use of and exposure to products containing PFASs.[144] Exposure can be reduced by avoiding direct contact with PFAS-containing products, and using PFAS-free personal

134 UNEP, above n 114, at 41.

135 UNEP, above n 114, at 41; and UNEP, above n 129.

136 UNEP, above n 114, at 41.

137 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 10.

138 KEMI Swedish Chemicals Agency, above n 2, at 69.

139 At 69.

140 At 69.

141 UNEP, above n 114, at 31.

142 KEMI Swedish Chemicals Agency, above n 2, at 63.

143 KEMI Swedish Chemicals Agency, above n 2, at 63; and UNEP, above n 114, at 34.

144 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 5.

care products and cooking materials.[145] This will require consumers "to change their mindset and understand which products contain PFASs and what their risks are."[146] Consumer information on how to find PFAS-free alternatives will therefore play a significant role in helping to reduce exposure.[147]

Information about PFAS-free products in the US is available on the PFAS Central website.[148] PFAS Central provides current and curated information about PFAS, including press releases, peer-reviewed scientific articles, and consumer information.[149] Content is provided by a partnership between the Green Science Policy Institute and the Social Science Environmental Health Research Institute (SSEHRI) at Northeastern University.[150] The Green Science Policy Institute aims to facilitate responsible use of chemicals to protect human and ecological health.[151] To achieve this, the Institute provides unbiased scientific data for informed decision-making, motivates and participates in scientific research that serves the public interest, and promotes policy and purchasing decisions that reduce the use of classes of harmful chemicals.[152] The SSEHRI PFAS Project works on a variety of environmental health, social science, and public policy aspects of PFASs.[153]

For residents of the EU and the United Kingdom (UK), information on PFAS-free products can be obtained from the PFAS Free website.[154] The PFAS Free project is run by Fidra, "an environmental charity working to reduce chemical and plastic pollution in our seas, on our beaches and in the wider environment."[155] Fidra uses the best available science to identify and understand environmental issues, and works with the public, industry, and governments to deliver solutions which support sustainable societies and healthy ecosystems.[156] General and specific guidance to consumers and business on how to find PFAS-free alternatives is also provided by some national institutions, such as the Danish Environmental Protection Agency, the German Environmental Protection Agency and Swedish Chemicals Agency.[157]

Unfortunately, there is no equivalent source of information on PFAS free products for consumers based in New Zealand.

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145 At 8.

146 European Chemicals Agency (ECHA) "PFAS – convenience but at what cost?" *ECHA Newsletter* (online edition, European Union, 28 May 2020).

147 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 1–2.

148 PFAS Central: A Project of Green Science Policy "PFAS-Free Products" <www.pfascentral.org>.

149 PFAS Central: A Project of Green Science Policy "About Us – What We Do" <www.pfascentral.org>.

150 PFAS Central, above n 149.

151 Green Science Policy Institute "Who We Are" <www.greensciencepolicy.org>.

152 Green Science Policy Institute, above n 151.

153 Social Science Environmental Health Research Institute (SSEHRI), Northeastern University "About SSEHRI" <www.northeastern.edu>.

154 PFAS Free "PFAS free products" <www.pfasfree.org.uk>.

155 PFAS Free "About us" <www.pfasfree.org.uk>.

156 PFAS Free, above n 155.

157 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 8.

## X. Conclusion

Like many inventions, the discovery of Teflon happened by accident.[158] In 1938, chemists from DuPont (now Chemours) unintentionally created a chemical compound, PTFE, that was extremely stable, noncorrosive and highly resistant to heat.[159] This compound was marketed under DuPont's "Teflon" brand, and in 1954, the revolutionary non-stick frying-pan was introduced.[160] Since then, an entire class of man-made chemicals has evolved: per- and polyfluoroalkyl substances (PFASs). Despite major environmental and human health concerns, there are more than 4700 of these chemicals on the market today.[161]

PFASs are in everything from pizza boxes to polar bears.[162] They are persistent, bioaccumulative, and toxic to animals and humans.[163] PFASs have been detected globally in the environment, biota, and humans.[164] They have been found in clothing, plastic, food packaging, electronics, personal care products, firefighting foams, medical devices and numerous other products.[165]

Numerous studies have documented adverse human health effects of exposure to PFASs, including cancer, liver damage, decreased fertility and thyroid disease.[166] Researchers have also documented that PFAS exposure reduces the effectiveness of vaccines,[167] which is particularly concerning amid the COVID-19 pandemic.

PFASs have become so ubiquitous in the environment that health experts say it is virtually impossible to completely avoid exposure.[168] For example, new laboratory tests commissioned by the Environmental Working Group indicate that PFASs are likely detectable in all major water supplies in the US, and more than 110 million Americans could be drinking PFAS-contaminated water.[169] Even with the most sophisticated treatment processes, it is extremely difficult and costly to remove these chemicals from drinking water.[170] And it is impossible to remove PFASs entirely from lakes, rivers and oceans.[171] The costs involved in the remediation of land contaminated with PFASs is also high, and in many cases, the total remediation cost is not yet known.[172]

The reality is that, as a global community, we are facing a tipping point from which we may struggle to recover. PFASs are persistent organic pollutants, otherwise known as forever

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158 McDonald, above n 15, at 142.

159 At 142.

160 At 142.

161 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)*, above n 5, at 4.

162 Nordic Council of Ministers, above n 53, at 73-81; Butt, above n 44; and Vierke and others, above n 32 at 6.

163 UNEP, above n 114, at 31.

164 Gawor and others, above n 7; Giesy and Kannan, above n 8; and Vestergren and Cousins, above n 9.

165 OECD *Synthesis Paper on Per- and Polyfluorinated Chemicals (PFCs)*, above n 5.

166 Temkin, above n 46, at 1668–1669; Duffek and others, above n 29, at 2; Steenland, Fletcher and Savitz, above n 47, at 1100–1108.

167 Temkin, above n 46, at 1668–1669.

168 EEA *Emerging chemical risks in Europe – "PFAS"*, above n 16, at 1–2.

169 Sydney Evans and others "PFAS Contamination of Drinking Water Far More Prevalent Than Previously Reported" (22 January 2020) Environmental Working Group <www.ewg.org>.

170 UNEP, above n 114, at 36.

171 At 36.

172 At 39.

chemicals.[173] The magnitude and extent of the risks of many types of PFAS cannot be quantified.[174] What we do know, however, is that most of the widespread contamination resulting from their manufacture and use will never be remediated. Continuing to produce and use PFASs at our current rate is simply a risk too great to accept.[175]

Further regulation eliminating all non-essential uses and restricting or prohibiting the entire class of PFASs is therefore urgently required. Doing so would positively impact human health and the environment including biota "by decreasing emissions and subsequently reducing human and environmental exposure."[176] This would also provide benefits for agriculture by decreasing the adverse effects of PFASs on agricultural crops.[177] Until such regulation is achieved, consumer information on where and how to source PFAS-free products will help people to reduce their risk of exposure and associated harm.[178] This will require a significant change in the mindset of consumers.[179] PFASs and PFAS-containing products have continued to be used because they offer comfort and convenience; without them, the non-stick frying pan would not be possible. Consumers must therefore ask themselves: convenience – but at what cost?

173 At 46.

174 At 46.

175 PFAS Free "What are PFAS?" <www.pfasfree.org.uk>.

176 UNEP, above n 114, at 46.

177 At 46.

178 EEA *Emerging chemical risks in Europe – 'PFAS'*, above n 16, at 8.

179 At 1–2.