Supplementary Information

Use and Release of Per- And Polyfluoroalkyl Substances (PFASs) in Consumer Food Packaging in U.S. and Canada

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S1. An Overview of the Origins of PFAS in Consumer Food Packaging (FP)

S1.1 United States (US) regulatory system for chemicals in consumer FP

As shown in Table S1, a number of PFASs have been authorised by the US Food and Drug Administration (FDA) for use in food contact applications through its Food Contact Notification process. Most of these compounds are side-chain fluorinated polymers. As explained by the California Environmental Protection Agency (EPA) and the Department of Toxic Substances Control (DTSC), it is possible for chemicals used in food packaging to enter the market if they are Generally Recognized as Safe (GRAS). The GRAS chemicals can be determined as such by the manufacturer and do not undergo the same review process as the Food Contact Notification process. However, no PFAS are among the GRAS chemicals.[1]

S1.2 Canadian regulatory system for chemicals in consumer FP

Canada, as a signatory to the Stockholm Convention, has prohibited the import, manufacture, use and sale of perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA) and long-chain perfluoroalkylcarboxylic acids (LC-PFCAs), and products containing these compounds. Specific exemptions exist for these PFASs, including incidental presence.

All food packaging materials that include domestic and imported materials, must comply with Division 23 of the Canadian Food and Drugs Regulations.[2] These provisions prohibit the sale of food in packaging that could transfer a chemical to the food that may be harmful to the health of the consumer. It is the responsibility of the vendor (food manufacturer, packager or distributor) to meet with this provision. Vendors of food packaging or food products can seek, voluntarily, an opinion from Canada's Food Directorate (part of Health Canada) on whether the food packaging materials are acceptable from a food safety perspective. If the food packaging is deemed to not pose a health risk when used as proposed, a "Letter of No Objection", or LONO, can be issued that indicates that the Food Directorate has no objection to the use of the food packaging as intended.

In more detail,[3] the assessment, conducted by the Food Directorate as part of the LONO process, considers residual concentrations of precursors (i.e., PFAS monomers), oligomers for polymeric materials, and by-products from the manufacturing process. The assessment involves estimating dietary exposures arising from the migration of (in this case) PFASs from the food packaging into the food. Here, migration/extraction data are required (e.g., extraction in 10% aqueous ethanol, 95% ethanol, others). Depending on the level of concern according to dietary exposure levels, toxicological data are requested according to the level of concern (from "very low" at a dietary exposure of 0.025-0.1 μg/kg bw to "high" at >25 μg/kg bw). A LONO is drafted if this analysis shows no significant health risk to the general public. We note that the guidance does not specify method(s) of analysis, detection limits, etc. From the migration data, an estimate is made of potential dietary exposure. The guidance does not specify if the dietary exposure estimate is done on a chemical-by-chemical basis of total PFASs.

Health Canada has compiled a list of chemicals from the LONOs that authorize a substance's safety in FP. This list exists for Heath Canada's internal use, and it is not available to industry or the public. The Bureau of Chemical Safety within Health Canada's Food Directorate has been considering revising this process.[4] It is worth mentioning that four fluorotelomer-based substances considered as precursors to LC-PFCAs have been prohibited.[5]

S1.3 Our analysis of the origins of PFAS in consumer food packaging in the U.S. and Canada

We have assumed that the U.S. and Canadian markets of food packaging are the same. This is a reasonable assumption given the provisions to facilitate trade as specified under the North American Free Trade Agreement (NAFTA) that was superseded by the new Canada-United States-Mexico Agreement (CUSMA) on July 1st, 2020, also known as the United States-Mexico-Canada Agreement (USMCA). As such, we thus rely on information provided by the U.S. FDA (Table S1) to establish a list of potential PFASs found in Canadian consumer FP.

PFASs can enter into consumer FP from complex pathways with many steps, including paper and plastic manufacturing, FP manufacturing, and food conversion (i.e., transfer of food into FP). Foremost, a number of PFASs may be directly added in consumer FP, including: (1) specific fluorotelomer-based side-chain fluorinated polymers and perfluoropolyethers to impart water- and grease-repellency to paper and paperboard, and (2) different fluoropolymers added as processing aids for improvement in the extrusion process of plastics or mold release of plant fiber-based FP.

These PFASs may contain a number of unreacted residuals, production by-products (e.g., oligomers), and transformation intermediates. In the case of fluoropolymers, they may also contain residual processing aids for the polymerization that are also PFASs, such as PFOA or perfluoroalkylether carboxylic acids (PFECAs).[6,7] As many of these PFASs are surface active, they may stick on the surface of the machinery, and thus, contaminate the subsequent manufacturing and processing of materials, thereby unintentionally adding PFASs to the food packaging.

In addition, PFASs have also been used in the processing machinery, as lubricants (e.g. CAS No. 1643944-25-5) or as parts (in the case of many fluoropolymers). They, or the other PFASs that they contain, may contaminate food packaging during manufacturing of FP and food processing.

Further, the PFASs mentioned above may remain in the secondary paper or plastic after recycling. However, this has not been sufficiently studied.

Table S1 Information on the PFASs authorized by the U.S. Food and Drug Administration (FDA) in consumer food packaging[8]

Substance	CAS number	Use information	Quantity authorized in consumer food packaging	Minimum quantity in consumer food packaging recommended in patent	Notes
SIDE-CHAIN FLUORINATED POLYMERS					
2-propenoic acid, 2-methyl-, 2-hydroxyethyl ester, polymer with 2-propenoic acid and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-methyl-2-propenoate, sodium salt	1878204-24-0	Oil, water and grease proofing agent in paper and paperboard	Maximum 1.2 % by weight of the finished paper.	NA	AGC
Copolymer of 2-(dimethylamino) ethyl methacrylate with 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl methacrylate, N-oxide, acetate	1440528-04-0	Grease resistant treatment employed either prior to or after the sheet forming operation for paper and paperboard intended to contact food	Maximum 0.26 mg/in^2 paper	NA	Archroma
2-Propenoic acid, 2-methyl-, 2-(dimethylamino)ethyl ester, polymer with 1-ethenyl-2-pyrrolidinone and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-propenoate, acetate .	1334473-84-5	Added at the size press or wet end to impart grease and oil resistance to paper and paperboard	Maximum 1% of the dry fiber	NA	Daikin
Butanedioic acid, 2-methylene-, polymer with 2-hydroxyethyl, 2-methyl-2-propenoate, 2-methyl-2-propenoic acid and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-methyl-2-propenoate, sodium salt	1345817-52-8	Oil, grease, and water-resistant treatment for paper and paperboard.	Maximum 1.2% by weight of the finished paper.	0.01 to 1.2% by mass (patent JP 2017078227)	Asahi
2-propenoic acid, 2-methyl-, 2-hydroxyethyl ester polymer with 1-ethyenyl-2-pyrrolidinone, 2-propenoic acid and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-propenoate sodium salt.	1206450-10-3	Added at the size press or prior to sheet formation to impart grease and oil resistance to paper and paperboard.	Maximum 1% of the dry fiber.	0.01 to 1.0 % by weight (patent WO 2011099650)	Daikin
2-propenoic acid, 2-methyl-, polymer with 2-hydroxyethyl 2-methyl-2-propenoate, α-(1-oxo-2-propen-1-yl)-ω-hydroxypoly(oxy-1,2-ethanediyl) and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-propenoate, sodium salt.	1158951-86-0	Oil and grease resistant treatment for paper and paperboard employed at the size press or prior to sheet formation.	Maximum 0.8% by weight of dry paper and paperboard.	NA	Daikin
2-propenoic acid, 2-hydroxyethyl ester, polymer with α-(1-oxo-2-propen-1-yl)-ω-hydroxypoly(oxy-1,2-ethanediyl), α-(1-oxo-2-propen-1-yl)-ω-[(1-oxo-2-propen-1-yl)oxy]poly(oxy-1,2-ethanediyl) and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-propenoate	1012783-70-8	Oil and grease resistant treatment for paper and paperboard employed at the size.	Maximum 0.4% by weight of dry paper and paperboard	NA	Daikin

2-Propenoic acid, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl ester, polymer with α-(1-oxo-2-propen-1-yl)-ω-hydroxypoly(oxy-1,2-ethanediyl)	68228-00-2	Oil or grease resistant treatment for paper and paperboard	Maximum 0.2% of the finished food-contact paper.	NA	Daikin
2-propen-1-ol, reaction products with 1,l,1,2,2,3,3,4,4,5,5,6,6-tridecafluoro-6-iodohexane, dehydroiodinated, reaction products with epichlorohydrin and triethylenetetramine	464178-94-7	Oil/grease resistant sizing agent employed either prior to the sheet forming operation and/or at the size press in the manufacture of paper and paperboard	Maximum 0.75% by weight of dry paper and paperboard	NA	Solenis
Copolymer of perfluorohexylethyl methacrylate, 2-N,N-diethylaminoethyl methacrylate, 2-hydroxyethyl methacrylate, and 2,2'-ethylenedioxydiethyl dimethacrylate, acetic acid salt or malic acid salt	863408-20-2 or malic acid salt 1225273-44-8	Oil, grease, and water resistant treatment for paper and paperboard employed either prior to the sheet forming operation or at the size press	Maximum 1.2% by weight of dry paper and paperboard	0.3 to 1.2% by mass (patent JP 2009102771)	AGC
2-propen-1-ol, reaction products with pentafluoroiodoethane-tetrafluoroethylene telomer, dehydroiodinated, reaction products with epichlorohydrin and triethylenetetramine	464178-90-3	Oil/grease resistant sizing agent employed either prior to the sheet forming operation or at the size press for paper and paperboard intended for use in microwave heat-susceptor packaging and may be used in contact with all food types	Maximum 0.5% by weight dry paper and paperboard	NA	Solenis
Hexane, 1,6-diisocyanato-, homopolymer, 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluoro-1-octanol-blocked.	357624-15-8	Oil and grease resistant treatment for paper and paperboard employed either prior to the sheet forming operation or at the size press	Maximum 0.18% by weight of finished dry paper or paperboard	NA	Chemours
2-propenoic acid, 2-methyl-, polymer with 2-(diethylamino)ethyl 2-methyl-2-propenoate, 2-propenoic acid and 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-methyl-2-propenoate, acetate	1071022-26-8	Oil and grease resistant treatment for paper and paperboard employed either prior to or after the sheet forming operation	Maximum 0.8% by weight of dry paper when applied prior to the sheet forming operation, or 0.42% by weight of dry paper and paperboard when applied after sheet formation	NA	Chemours
Copolymers of 2-perfluoroalkylethyl acrylate, 2-N,N-diethylaminoethyl methacrylate, glycidyl methacrylate, acrylic acid, and methacrylic acid	870465-08-0	Oil and grease resistant treatment for paper and paperboard employed either prior to the sheet forming operation or at the	Maximum 0.69% by weight (0.37% by weight fluorine) of dry paper	NA	DuPont

		size press			
Copolymers of 2-perfluoroalkylethyl acrylate, 2-N,N-diethylaminoethyl methacrylate, and glycidyl methacrylate.	247047-61-6	Oil or grease resistant treatment for paper and paperboard intended for food-contact use or for single service use in microwave heat-susceptor packaging	Maximum 0.33% by weight (0.18% by weight fluorine) of paper	NA	DuPont
Copolymer of 2-perfluoroalkylethyl acrylate, 2-(dimethylamino)ethyl methacrylate, and oxidized 2-(dimethylamino)ethyl methacrylate	479029-28-2	Oil and grease repellent in the manufacture of paper and paperboard	Added during the paper making process: (1) to the pulp slurry (wet-end) at a maximum level of 0.5% by weight of dry, finished paper, or (2) at the size press at a maximum level of 0.7% by weight of dry, finished paper	NA	Clariant
Siloxanes and silicones, methyl-phenyl, methyl-3,3,3-trifluoropropyl	1643944-25-5	Incidental lubricant to be used as, or a component of, bearing grease to lubricate facer roll bearings in paper and paperboard manufacturing	NA	NA	Dow
PERFLUOROPOLYETHERS					
Hexane, 1,6-diisocyanato-, homopolymer, α-[1-[[[3-[[3 (dimethylamino)propyl]amino]propyl]amino]carbonyl]-1,2,2,2-tetrafluoroethyl]-ω-(1,1,2,2,3,3,3-heptafluoropropoxy)poly[oxy[trifluoro(trifluoromethyl)-1,2-ethanediyl]]-blocked	1279108-20-1	Grease resistant treatment for paper and paperboard employed either prior to or after the sheet forming operation.	Maximum 0.6% by weight of dry paper and paperboard.	NA	Archroma
Diphosphoric acid, polymers with ethoxylated reduced methyl esters of reduced polymerized oxidized tetrafluoroethylene (also known as phosphate esters of ethoxylated perfluoroether, prepared by reaction of ethoxylated perfluoroether diol (CAS Reg. No. 162492-15-1) with phosphorous pentoxide (CAS Reg. No. 1314-56-3) or pyrophosphoric acid (CAS Reg. No. 2466-09-3))	200013-65-6	Water and oil repellant in the manufacture of food-contact paper and paperboard, or paper and paperboard	Maximum 1.5% by weight of finished dry paper or paperboard Maximum 1% by weight of finished dry paper or paperboard (in microwave susceptor applications).	NA	Solvay
Perfluoropolyether dicarboxylic acid ammonium salt	69991-62-4	Oil and water repellent employed in the manufacture of food-contact paper and paperboard either prior to the sheet-forming operation	Maximum 1% by weight of the finished dry paper and paperboard	NA	Solvay

		or at the size press.			
Diphosphoric acid, polymers with ethoxylated reduced methyl esters of reduced polymerized oxidized tetrafluoroethylene (also known as phosphate esters of ethoxylated perfluoroether, prepared by reaction of ethoxylated perfluoroether diol (CAS Reg. No. 162492-15-1) with phosphorous pentoxide (CAS Reg. No. 1314-56-3) or pyrophosphoric acid (CAS Reg. No. 2466-09-3))	200013-65-6	Oil and water repellent employed in the manufacture of food-contact paper and paperboard either prior to the sheet-forming operation or at the size press.	Maximum 1% by weight of the finished dry paper and paperboard	NA	Solvay
3-cyclohexane-1-carboxylic acid, 6-((di-2-propenylamino)carbonyl)-,(1R,6R), reaction products with pentafluoroiodoethane-tetrafluoroethylene telomer, ammonium salts.	NA	As an oil repellent sizing agent in the production of paper and paperboard	Maximum 0.55% by weight (equivalent to 0.33% fluoride) of finished paper and paperboard, where the paper or paperboard has a sheet basis weight of up to approximately 300 pounds per 3000 square feet.	NA	BASF
Fluorinated polyurethane anionic resin prepared by reacting perfluoropolyether diol (CAS Reg. No. 88645-29-8), isophorone diisocyanate (CAS Reg. No. 4098-71-9), 2,2-dimethylolpropionic acid (CAS Reg. No. 4767-03-7), and triethylamine (CAS Reg. No. 121-44-8).	328389-91-9	Water and oil repellent in the manufacture of paper and paperboard	Maximum 1.5% by weight of finished dry paper or paperboard	NA	Solvay
FLUOROPOLYMERS (INCLUDING FLUOROELASTOMERS)					
Fluorocarbon cured elastomer produced by copolymerizing tetrafluoroethylene (CAS Reg. No. 116-14-3) and propylene (CAS Reg. No. 115-07-1) and subsequent curing with triallylisocyanurate (CAS Reg. No. 1025-15-6) or triallylcyanurate (CAS Reg. No. 101-37-1) and 2,2-bis(tert-butylperoxy)diisopropylbenzene (CAS Reg. No. 25155-25-3)	NA	Used in the fabrication of molded parts for food processing equipment such as seals, gaskets, o-rings and other parts	NA	NA	AGC
Fluorocarbon cured elastomer produced by copolymerizing tetrafluoroethylene (CAS Reg. No. 116-14-3) and propylene (CAS Reg. No. 115-07-01) and subsequent curing of the copolymer with triallylisocyanurate (CAS Reg. No. 1025-15-6) and 2,2'-bis(tert-butylperoxy)diisopropylbenzene (CAS Reg. No 25155-25-3)	NA	Used in the fabrication of molded parts for food processing equipment such as seals, gaskets, o-rings and other parts	NA	NA	Process Technologies
Fluorocarbon cured elastomer produced by copolymerizing tetrafluoroethylene (CAS Reg. No. 116-14-3) and propylene (CAS Reg. No. 115-07-01) and subsequent curing of the copolymer (CAS Reg. No.	NA	Used in the fabrication of molded parts for food processing equipment such as seals, gaskets, o-rings	NA	NA	Greene, Tweed and Company

27029-05-6) with triallylisocyanurate (CAS Reg. No. 1025-15-6) and 2,2'-bis(tert-butylperoxy)diisopropylbenzene (CAS Reg. No. 25155-25-3).		and other parts			
Copolymer of tetrafluoroethylene (CAS Reg. No. 116-14-3) and trifluoromethyl trifluorovinyl ether (CAS Reg. No. 1187-93-5), and optionally employing a halogenated alkene.	NA	For repeat-use in the fabrication of molded parts, such as o-rings, sanitary seals, butterfly valve seats, weir diaphragms, and heat exchanger gaskets.	NA	NA	DuPont
Copolymer of tetrafluoroethylene and perfluoromethylvinyl ether (CAS Reg. No. 26425-79-6) \ modified with 3,3,4,4,5,5,6,6,7,7,8,8-dodecafluoro-1,9-diene and 1,3,5-triallyl cyanurate or 1,3,5-triallyl isocyanurate.	NA	As a gasket or seal for food processing equipment	NA	NA	Precision Polymer Engineering
Copolymer of tetrafluoroethylene (TFE) and perfluoromethylvinyl ether (PFMVE) (CAS Reg. No. 26425-79-6) modified with 1,3,5-triallyl isocyanurate (TAIC) and 3,3,4,4,5,5,6,6,7,7,8,8-dodecafluoro-1,9-diene	NA	As a gasket or seal for food processing equipment.	NA	NA	Solvay
Perfluorocarbon cured elastomers produced by polymerizing perfluoro(methyl vinyl ether) (CAS Reg. No. 1187-93-5) with tetrafluoroethylene (CAS Reg. No. 116-14-3) and perfluoro(8-cyano -5-methyl -3,6-dioxa -1-octene) (CAS Reg. No. 69804-19-9), followed by curing with trimethylallyl isocyanurate (CAS Reg. No. 6291-95-8) and/or triallyl isocyanurate (CAS Reg. No. 1025-15-6), and with 2,5 -dimethyl -2,5-di (t-butylperoxy) hexane (CAS Reg. No. 78-63-7)	NA	Used in the fabrication of articles intended for repeated use in contact with food.	NA	NA	DuPont
Copolymer of propylene (CAS Reg. No. 115-07-1), tetrafluoroethylene (CAS Reg. No. 116-14-3), and 3,3,3-trifluoropropene (CAS Reg. No. 677-21-4) cured with a salt of a quarternary ammonium compound and phenol, 4,4'-(2,2,2-trifluoro-1-(trifluoromethyl)ethylidene)bis-	NA	For repeat use in the fabrication of molded parts such as o-rings and gaskets for food	NA	NA	Chemours
Copolymer of tetrafluoroethylene, perfluoromethylvinylether and 1-iodo-2-bromotetrafluoroethane intended to be cross-linked with triallylisocyanurate	NA	Used as an O-ring or gasket in food-processing machinery.	NA	NA	Unimatec
Copolymer of 4-bromo-3,3,4,4-tetrafluoro-1-butene, ethylene, tetrafluoroethylene and trifluoromethyl trifluorovinyl ether optionally cured with triallyl	105656-63-1	For repeat-use in the fabrication of molded parts such as o-rings and gaskets	NA	NA	Chemours

isocyanurate and 2,5-dimethyl-2,5-di(tert-butylperoxy)hexane.		for food processing equipment.			
Copolymer of 1,1-difluoroethylene, tetrafluoroethylene, trifluoromethyl trifluorovinyl ether and a halogenated alkene, optionally cured with triallyl isocyanurate and 2,5-dimethyl-2,5-di(tert-butylperoxy)hexane	NA	For repeat-use in the fabrication of molded parts such as o-rings and gaskets for food processing equipment.	NA	NA	Chemours
Copolymer of 1,1-difluoroethylene, hexafluoropropene, tetrafluoroethylene, and a halogenated alkene, optionally cured with triallyl isocyanurate and 2,5-dimethyl-2,5-di(tert-butylperoxy)hexane.	NA	For repeat-use in the fabrication of molded parts such as o-rings and gaskets for food processing equipment.	NA	NA	Chemours
Tetrafluoroethylene-ethylene-3,3,4,4,5,5,6,6,6-nonafluoro-1-hexene terpolymer.	68258-85-5	As a base resin or coating in repeat-use applications	NA	NA	AGC
Polymer produced from tetrafluoroethylene (CAS Reg. No. 116-14-3) and 1,1,2,2-tetrafluoro-2-((1,2,2-trifluoroethenyl)oxy)ethanesulfonyl fluoride (CAS Reg. No. 29514-94-1). The polymer is hydrolyzed and may optionally be further neutralized to its ammonium salt.	NA	As a component of coatings for repeat-use food filtration membranes	NA	NA	Solvay
1-hexene, 3,3,4,4,5,5,6,6,6-nonafluoro-, polymer with 1,1,2,2-tetrafluoroethene	82606-24-4	As a base resin or coating in repeat-use applications.	NA	NA	AGC
2,3,3,4,4,5,5-Heptafluoro-1-pentene polymer with ethene and tetrafluoroethene	94228-79-2	Used for the property improvement in extrusion process of all polymers for food packaging	NA	NA	Daikin
Vinylidene fluoride-hexafluoropropene copolymer	9011-17-0	As a processing aid for food contact polymers	NA	NA	Arkema
Copolymer of vinylidene fluoride and hexafluoropropene	9011-17-0	As a processing aid in all polymers (excluding polymers used in metal and paper coatings)	NA	NA	3M
Tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers	25190-89-0	As a processing additive for all polymers (excluding polymers used in metal and paper coatings)	NA	NA	3M
Tetrafluoroethylene-hexafluoropropylene-vinylidene fluoride copolymers	25190-89-0	As a processing additive for polyolefins for use in contact with food.	NA	NA	Dyneon
1-Propene,1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene (CAS Reg. No. 9011-17-0) modified with a halogenated ethylene as described in the food	NA	As a processing additive for all polymers for use in	NA	NA	Dyneon/3M

contact notification.		contact with food			
1-Propene,1,1,2,3,3,3-hexafluoro-, polymer with 1,1-difluoroethene and tetrafluoroethene (CAS Reg. No. 25190-89-0) modified with triallyl isocyanurate and 3,3,4,4,5,5,6,6,7,7,8,8-dodecafluoro-1,9-diene	NA	As a gasket or seal for food processing equipment.	NA	NA	Solvay
A perfluorocarbon cured elastomer (PCE) produced by terpolymerizing tetrafluoroethylene, (CAS Reg. No. 116-14-3), perfluoro-2,5-dimethyl-3,6-dioxanonane vinyl ether (CAS Reg. No. 2599-84-0), and perfluoro-6,6-dihydro-6-iodo-3-oxa-1-hexene (CAS Reg. No. 106108-22-9), and subsequent curing of the terpolymer (CAS Reg. No. 106108-23-0) with triallylisocyanurate (CAS Reg. No. 1025-15-6) and 2,5-dimethyl-2,5-di(t-butylperoxy)hexane (CAS Reg. No. 78-63-7)	NA	In the fabrication of molded parts for food processing equipment, such as o-rings, gaskets, diaphragms and other materials, that function being primarily in sealing applications.	NA	NA	Greene, Tweed and Company
A perfluorocarbon cured elastomer (PCE) produced by terpolymerizing tetrafluoroethylene, (CAS Reg. No. 116-14-3), perfluoromethyl vinyl ether (CAS Reg. No. 1187-93-5), and perfluoro-6,6-dihydro-6-iodo-3-oxa-1-hexane (CAS Reg. No. 106108-22-9), and subsequent curing of the terpolymer (CAS Reg. No. 193018-53-0) with triallylisocyanurate (CAS Reg. No. 1025-15-6) and 2,5-dimethyl-2,5-di(t-butylperoxy)hexane (CAS Reg. No. 78-63-7).	NA	In the fabrication of molded parts for food processing equipment, such as o-rings, gaskets, diaphragms and other materials, that function primarily in sealing applications.	NA	NA	Greene, Tweed and Company
A perfluorocarbon-cured elastomer (PCE) produced by terpolymerizing tetrafluoroethylene (CAS Reg. No. 116-14-3), perfluoro(2,5-dimethyl-3,6-dioxanone vinyl ether) (CAS Reg. No. 2599-84-0) and perfluoro (6,6-dihydro-6-iodo-3-oxa-1-hexene) (CAS Reg. No. 106108-22-9) and subsequent curing of the terpolymer (CAS Reg. No. 106108-23-0) by crosslinking with triallylcyanurate (CAS Reg. No. 101-37-1) and vulcanizing with 2,5-dimethyl-2,5-di(t-butylperoxy) hexane (CAS Reg. No. 78-63-7), as a 68% dispersion on finely divided silica	NA	In the fabrication of vulcanized molded parts for food processing equipment, such as o-rings, gaskets, diaphrams and other materials, that function primarily in sealing applications	NA	NA	Greene, Tweed and Company
Ethene, 1,1,2,2-tetrafluoro-, polymer with 1,1,2-trifluoro-2-(1,1,2,2,2-pentafluoroethoxy)ethene	31784-04-0	As a component of repeat-use, food-contact articles	NA	NA	Chemours
Ethene, tetrafluoro-, polymer with 1,1-difluoroethene and trifluoro(trifluoromethoxy)ethene (CAS Reg. No. 56357-87-0) modified with 1,3,5-triallyl isocyanurate (TAIC) and 3,3,4,4,5,5,6,6,7,7,8,8-dodecafluoro-1,9-diene,	NA	As a gasket or seal for food processing equipment.	NA	NA	Solvay

1,9-Decadiene,3,3,4,4,5,5,6,6,7,7,8,8-dodecafluoro-, polymer with tetrafluoroethene and trifluoro(trifluoromethoxy)ethene (CAS Reg. No. 190062-24-9)	NA	As a gasket or seal for food processing equipment.	NA	NA	Solvay
Glycine, N,N-bis[2-hydroxy-3-(2-propenyloxy)propyl]-, monosodium salt, reaction products with ammonium hydroxide and pentafluoroiodoethane-tetrafluoroethylene telomer (CAS Reg. No. 220459-70-1).	NA	As a component of paper and paperboard in contact with nonalcoholic food.	Maximum 15 pounds of actives (7.8 pounds of fluorine) per ton of treated paper of a sheet basis weight of up to 300 lbs per 3,000 square feet	NA	BASF
OTHERS					
3-pyridinecarbonitrile, 4-methyl-2,6-bis[(4-methylphenyl)amino]-5-[[2-(trifluoromethyl)-phenyl]azo]-	669005-94-1	A colorant for use in authorized poly(ethylene phthalate) polymers, including those modified with 1,4-cyclohexanedimethanol	NA	NA	Ciba

S2 Substance Flow Analysis (SFA) Framework

S2.1 Framework and Application

Figure S1 describes the framework of the SFA. The capital letter *F* is used to designate PFAS flows (in metric tonnes per year) contained in consumer FP.

The flows numbers (e.g., F_1 to F_6), are described in the following paragraphs.

The following flows are included for completeness, but they could not be quantified due to a lack of information. These include:

<u>General flows:</u>

- F_{FP}: flow of PFASs produced for FP
- $F_{storage}$: flow of PFASs in FP that is stored
- F_{intake}: flow of PFASs from FP ingested or inhaled by humans resulting from food heating or consumption
- $F_{human\ WWTP}$: flow of PFASs rejected by humans and sent to WWTP
- $F_{leachate}$: flow of PFASs from landfill leachate sent to WWTP
- $F_{biosolids\ WWTP}$: flow of PFASs from WWTP that enters biosolids
- $F_{destruction}$: flow of PFASs destroyed during incineration of FP

<u>Flows of PFAS released to the environment:</u>

- $F_{PFAS\ prod.}$: flow of PFASs released during the production of PFAS
- $F_{production}$: flow of PFASs released during the production of FP
- F_{litter}: flow of PFASs contained in littered FP
- $F_{incineration}$: flow of PFASs in incinerated FP
- F_{WWTP}: flow of PFASs in WWTP effluent
- $F_{bio.\ to\ env.}$: flow of PFASs from WWTP biosolids
- $F_{recycling}$: flow of PFASs from recycled FP
- $F_{compost}$: flow of PFASs from municipal compost

The consumer FP considered in the current analysis included plastic- and paper-based packaging containing food and found in grocery stores and fast-food restaurants. Examples of FP considered included exterior paper board boxes, flexible plastic food pouches, food wrappers and plant fiber-based compostable bowls (e.g., bagasse containers). Some FP considered would be in direct contact with food (e.g., food wrappers, fiber-based bowls), whereas others are outside layers (exterior paper board boxes).

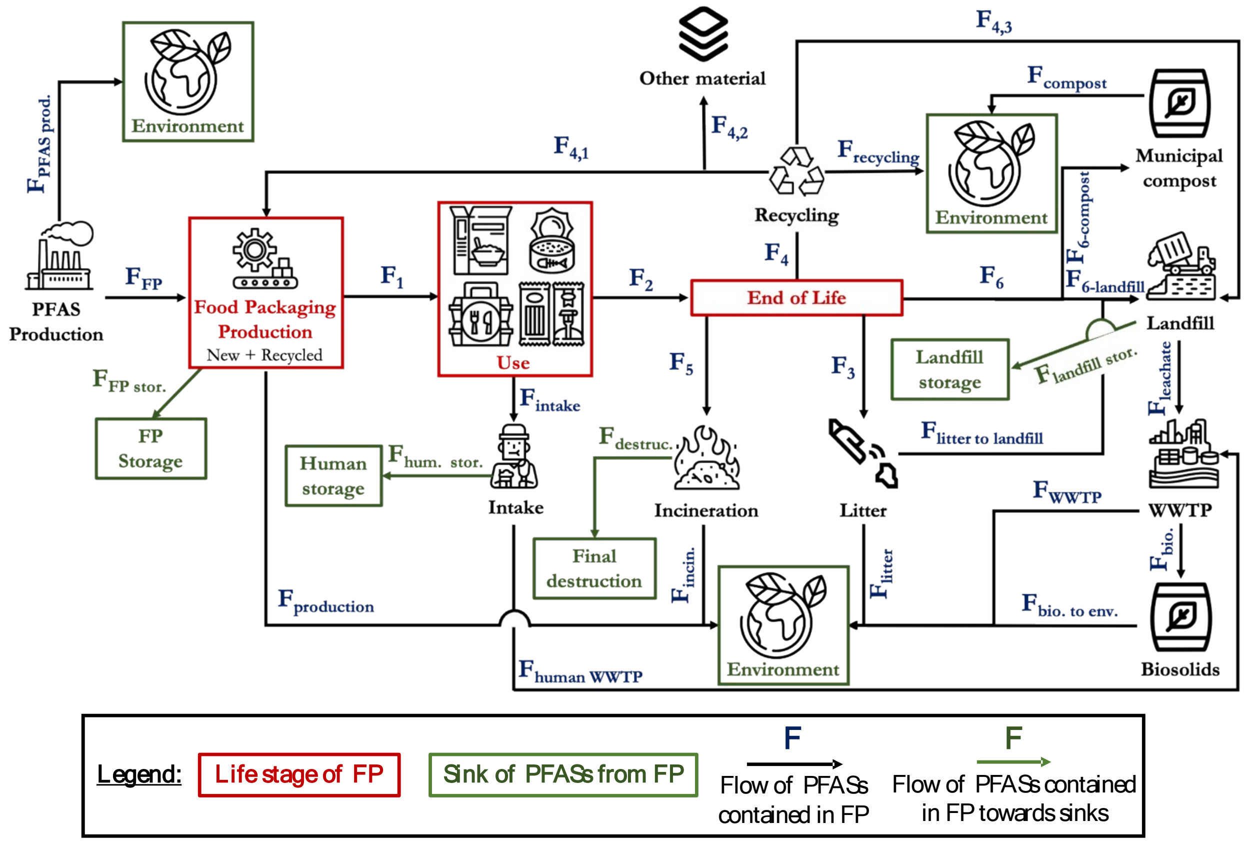

Figure S1. A schemeatic overview of the general substance flow analysis (SFA) framework for PFASs in consumer food packaging (FP). The numbered flows are quantified in the case study. "Environment" is used to designate air and surface water.

S2.2 $F_{\text{FP storage}}$ and $F_{\text{production}}$: Flows of PFASs from Consumer Food Packaging Production

F_{FP} is the flow of PFASs produced for use in FP. Due to a lack of information, we could not quantify this flow.

When incorporated into FP, there are releases of PFASs to the environment ($F_{\text{production}}$). For example, documents submitted to the U.S. FDA have shown that paper mills are important sources of environmental contamination by PFASs.[9] However, the information is insufficient on the releases of PFASs during FP manufacturing. More research is needed to quantify this emission pathway.

Additionally, some FP are stored along with the PFASs they contain ($F_{\text{FP storage}}$). We have assumed that $F_{\text{FP storage}}$ is negligible given the short shelf- or storage-life of FP.

S2.3 F_1: Flow of PFASs in the Sales of Consumer Food Packaging - F_2: Flow of PFASs in Discarded Consumer Food Packaging

Since we could not get information on the sales of food in grocery stores and fast-food restaurants in Canada and in the U.S., we assumed that the sale and waste flows of PFASs are equal, and we quantified the flow of PFASs in the sales of FP (F_1) as the flow of PFASs in discarded FP (F_2). This assumption is also based on the other assumptions of limited storage of

FP (we assumed a short lifetime of FP, i.e., all FP from food bought in a given year is discarded in the same year) and of negligible loss of PFASs during the lifetime of FP (e.g., volatilization losses, human intake – see next paragraph).

The mass of FP discarded every year M_{FP} is defined in equation (1), where M_{waste} is the mass of municipal solid waste, and $\%_{\mathrm{FP}}$ (paper and plastic) is the proportion of FP in municipal solid waste.

$$M_{FP} = M_{waste} * \%_{FP} \qquad (1)$$

The Government of Canada[10] estimates that FP represents about one-third of the municipal solid waste. In 2015 and 2017, U.S. EPA estimated that about 23%[11] and 29.9 %[12] of municipal solid waste were containers and packaging, i.e., products considered discarded the same year they were bought, which are not all specific to food. We thus assumed that 29% of household waste is FP in both countries, with bounding (i.e., low and high) values of 23% and 33% (Table S2).

Table S2 Proportion of FP constituting municipal solid waste[10–12]

	Low	Middle	High
$\%_{\mathbf{FP}}$	23%	29%	33%

To determine the amount of municipal solid waste in a given year between 2018 and 2020 in Canada, we used data from Statistics Canada[13] on the amount of municipal solid waste from 2010 to 2018. We used a third order polynomial approximation to project the data to 2020 (Figure S2). We obtained an estimate of 26.1 (25.7 to 26.7) million tonnes of municipal solid waste in 2020 in Canada. As a result, we assumed that 7.6 (5.9–8.8) million tonnes of FP were discarded every year in Canada.

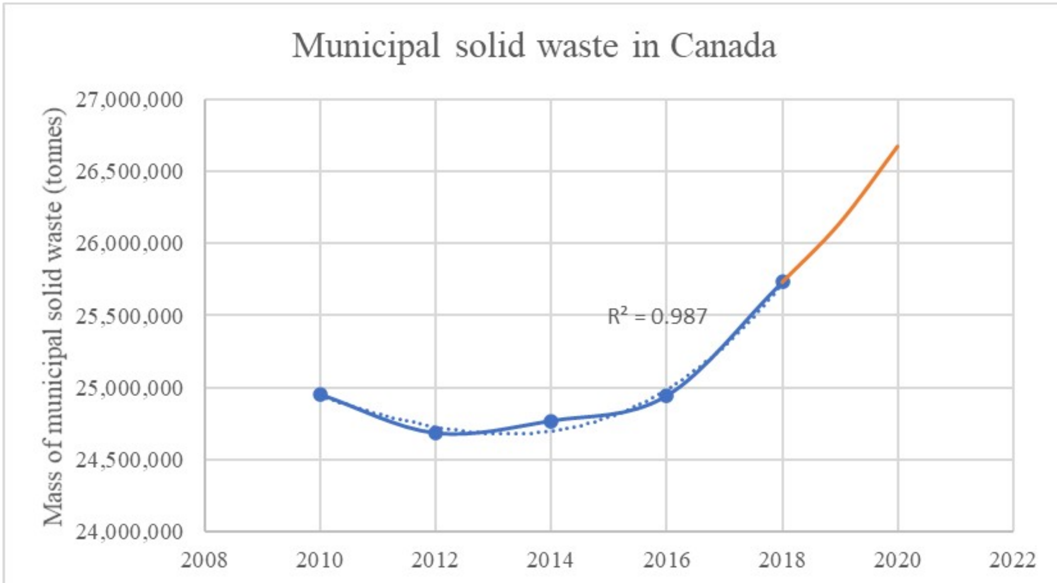

Figure S2 Mass of Canadian municipal solid waste from 2010 to 2018, and projection for 2019 and 2020[13]

Using a similar method for the U.S. (Figure S3),[14] we estimated that 249 (246–252) million tonnes of municipal solid waste is discarded every year, which gives about 72 (57–83) million tonnes of FP.

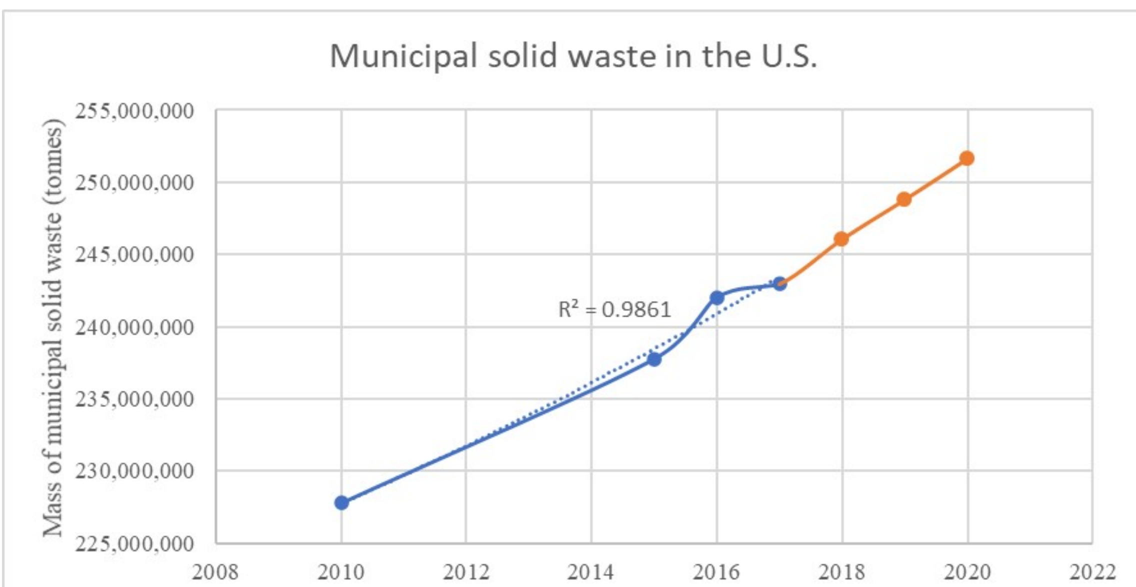

Figure S3 Mass of U.S. municipal solid waste from 2010 to 2017, and projection for 2018, 2019 and 2020[14]

S2.4 F_{intake}: Flow of PFASs in Consumer Food Packaging Digested or Inhaled by Humans

Several studies have documented the ability of PFASs to transfer from FP to food,[15,16] which leads to ingestion of PFASs by humans through food consumption. Susmann et al.[17] found a strong association between serum PFASs concentrations and intake of food from restaurants (as opposed to food from home). They also showed that the consumption of microwaved popcorn led to increased serum concentrations of PFASs in the following 12 to 24 hours.

The process of heating FP such as popcorn microwave bags can also lead to gas releases of PFASs that can later result in the inhalation of PFASs.[18] A study conducted in 2007 estimated that food intake represents about 60% of the total daily intake of PFCAs and perfluorooctanesulfonic acid (PFOS).[19] Some PFASs are bioaccumulative, meaning that they partly accumulate in the human body ($F_{\text{human storage}}$). Another fraction of the ingested and/or inhaled PFAS is eliminated whereby it enters in the influent of WWTPs ($F_{\text{human WWTP}}$).

Due to a lack of data, we assumed the flow F_{intake} is negligible.

S2.5 F_3: Flow of PFASs in Littered Consumer Food Packaging

Littering of FP is common. Based on an audit conducted in 2016,[20] the City of Toronto reported several FP as one of their top 20 large litter items. These include cup lids, pieces of lids and straws, snack food packaging, paper cups, paper board (cereal type), and plastic wrap. We expect similar observations for other locations in Canada and in the US. However, there were no data available on the percentage of FP that is littered. We thus assumed the following values (Table S3).

We assumed that all PFASs contained in littered FP are ultimately released to the environment (F_{litter}), although no study has yet investigated this flow. In the absence of data, we assumed that F_3 and F_{litter} are equal.

Table S3 Proportion of FP littered

	Low	Middle	High
$\%_{\text{litter}}$	5%	15%	30%

S2.6 F_4: Flow of PFASs in Recycled Consumer Food Packaging

The Government of Canada[10] estimated that 20% of food packaging waste is reused and recycled. In Ontario, 27.9% of paper-based packaging is recycled, and 12% of plastic is recycled (residential waste).[21] U.S. EPA estimated in 2017 that 50.1% of containers and packaging products were recycled[12]. Table S4 lists the values considered in the calculation of F_4.

Table S4 Proportion of FP recycled[10,12,21]

	Low	Middle	High
$\%_{\text{recycling}}$	10%	20%	30%

S2.6.1 $F_{4,1}$: Flow of PFASs from Recycled FP that is Recycled Back to FP

In Canada[22] and in the U.S.,[23] recycled plastic can be used in food packaging under specific conditions, notably if the recycled plastic complies with the same regulatory requirements as for non-recycled plastic for FP. The same applies for paper food packaging in Europe.[24]

According to U.S. EPA,[25] about one-third of the recycled paper is used in the production of new paper in the US. Additionally, in 2011, 42% of the recovered paper was exported to overseas markets. About 53% stayed in the U.S. to be recycled into paper and paperboard products. The remaining 5% was used to make other non-paper products.

We assumed that the same values were valid for both paper and plastic food packaging; thus, the percentage of recycled material used in packaging is equal to 53% × 1/3, i.e., 18%. We used the same number for Canada (Table S5).

Table S5 Proportion of FP recycled to FP[25]

	Low	Middle	High
$\%_{\text{FP recycled to FP}}$	5%	18%	33%

S2.6.2 $F_{4,3}$: Flow of PFASs from FP Initially Intended for Recycling but that is Ultimately Landfilled or Exported

In 2018, China (and, since then, other countries such as Malaysia) have banned most imports from the U.S. and Canada of material designated for recycling, leaving many communities with no other choice than to discard their recyclable waste into landfills or seek other overseas destinations, since their recycling facilities could not accommodate such a drastic increase in input.[26,27]

Prior to this, it was estimated that about one-third of the recyclable waste from the U.S. was sent abroad,[26] and 20% of the plastic waste from Canada was sent to China.[28] Considering that one-third of the FP intended for recycling ends up in landfills is most certainly an overestimation, we considered 30% as our upper limit. We took 15% as the middle value, and 5% as the lower boundary (Table S6). As with other parameter values, we note the uncertainty in these values and that more research is needed to determine the fate of FP that is intended for recycling, but in fact is not recycled and enters the waste stream.

Table S6 Proportion of FP intended for recycling sent to landfills or exported[26–28]

	Low	Middle	High
$\%_{\text{recycling to landfill}}$	5%	15%	30%

S2.6.3 $F_{recycling}$: Flow of PFASs from the Recycling Process of FP Emitted in the Environment

Documents submitted to U.S. FDA have showed that paper mills are important sources of environmental contamination by PFASs,[9] suggesting that this flow cannot be neglected. However, there is still a lack of information in the literature on the releases of PFASs during FP recycling. We thus considered $F_{\text{recycling}}$ negligible.

S2.6.4 $F_{4,2}$: Flow of PFASs from FP Recycled into Other Materials

We calculated $F_{4,2}$ as the difference between F_4 and $F_{4,1}$ and $F_{4,3}$.

$$F_{4,2} \cong F_4 - F_{4,1} - F_{4,3} \qquad (2)$$

We assumed that F_{recycle}, the flow of PFASs from the recycling stream to the environment, was negligible due to a lack of data.

S2.7 F_5: Flow of PFASs in Incinerated Consumer Food Packaging

About 5% of the municipal waste was incinerated in 2000 in Canada.[29] In 1998, it was estimated at ~8%.[30] We assumed that the same percentage of FP is sent to incineration.

According to U.S. EPA,[14] in 2018, 6.7% of paper and paperboard went to incineration, and 15.8% of plastics. We took the average between 67% and 15.8% to determine the percentage of food packaging that is incinerated, i.e., 11 % (Table S7).

Table S7 Percentage of FP incinerated[14,29,30]

		Low	Middle	High
$\%_{\text{recycling to landfill}}$	Canada	3%	5%	8%
	U.S.	7%	11%	16%

We assumed complete incineration efficiency although some emissions of PFASs may occur. The fate of PFASs in incinerated FP has not been studied. We assumed that some PFASs are definitively destroyed ($F_{\text{destruction}}$). However, releases of PFASs are likely to occur during incineration of FP based on studies on polytetrafluoroethylene.[31,32] We did not quantify $F_{\text{destruction}}$ and F_{release} due to a lack of quantitative information.

S2.8 F_6: Flow of PFAS from Landfilled and Composted Consumer Food Packaging

FP that is not littered, incinerated or recycled is sent to landfill and/or composting facilities in the U.S. and Canada, or abroad.

$$F_6 = F_2 - F_3 - F_4 - F_5 \qquad (3)$$

Some waste from Canada is sent to Michigan (U.S.) through mutual agreement. Among the Canadian waste sent to landfills, 3,178,054 tonnes of waste in 2019 were sent to Michigan,[33] which corresponds to 11% of the then Canadian municipal solid waste according to equation (4) where:

- $\%_{\text{Can. Waste to Mich..}}$ is the proportion of landfilled Canadian waste sent to Michigan
- M_{Mich} the mass of landfilled Canadian waste sent to Michigan
- M_{Can} the mass of landfilled Canadian waste

$$\%_{Can.\ waste\ to\ Mich.} = \frac{M_{Mich}}{M_{Can}} \qquad (4)$$

Table S8 Proportion of Canadian FP waste sent to Michigan[33]

	Low	Middle	High
$\%_{\text{Can. Waste to Mich}}$	5%	11%	20%

FP accumulated in landfills contribute to the accumulation of PFASs in landfill leachates that is then often transferred to wastewater treatment plants (WWTPs), which are not adapted to treat them. Indeed, many PFASs have been detected in WWTP effluents[34–37] and biosolids[38–40] in several countries. As a result, we expect releases of PFASs from water and biosolids from WWTP to the environment (F_{WWTP} and $F_{\text{bio. to the env.}}$).

Additionally, PFASs have been detected in municipal compost, notably in Washington, Oregon, California, Massachusetts, and North Carolina in the U.S. [41], leading to releases of PFASs into the environment (F_{compost}).

S2.9 $F_{leachate}$: Flow of PFASs from Landfill Leachate to Wastewater Treatment Plants

According to Chen et al.[42], the flow of PFASs from the landfill to the wastewater treatment plant (WWTP) F_{leachate} can be estimated as follows:

$$F_{leachate} = x_T * \frac{M_{FP}}{SA} * LG$$

where:

- x_T: average PFAS concentrations in landfill leachate from discarded food packaging
- $M_{FP/FCM}$: total mass of end-of-life food packaging accumulated in landfills (assumed to be F_6)
- SA: average mass of waste per surface area for landfills
- LG: leachate generation rate

For x_T, we used the same assumption as in Chen et al.[42], and assumed that the PFASs composition and leaching rate were the same for FP and other wastes. We used data from Lang et al.[43] for the low and high values of non-polymeric PFASs, and took the average as the middle value. Due to a lack of data for polymeric PFASs, we were unable to quantify this flow.

Table S9 PFAS concentrations in landfill leachate (µg/L)tm

	Low	Middle	High
x_T (non-polymeric PFASs)	0.6	10.6	20.6

For SA for both Canada and the U.S., we used the range of values from Lang et al.[43], who estimated that in the U.S. the average mass of waste per surface area in landfills is 140 ± 98 tonnes/ha (Table 12).

Table S10 Average mass of waste per surface area for landfills (tonnes/ha)

	Low	Middle	High
SA	42	140	238

In Lang et al.[43], the leachate generation rate was dependent on the annual precipitation. The climates were categorized between arid (<38 cm), temperate (38−75), and wet (>75). Depending on the location in the U.S. and in Canada, the climate can fall within each of the three categories; as a result, the possible leachate generation rates cover a large range of values (Table 13).

Table S11 Leachate generation rate (m^3/ha-day)

	Low	Middle	High
LG	0.01	2	10

We obtained values of 0.26 ($1.8 * 10^{-4}$ – 1.84) and 2.27 ($1.7 * 10^{-3}$ – 15.0) tonnes of non-polymeric PFASs contained in landfill leachate and sent to WWTP for Canada and the U.S. respectively.

Furthermore, Lenka et al.[44] explained that the majority of studies on PFASs in WWTP report higher PFAS concentrations in effluents than influents. The values provided above are thus low estimates of the releases of non-polymeric PFASs contained in food packaging into the environment.

S3. Case Study

S3.1 PFAS Concentrations Assumed in Consumer Food Packaging

We conducted a literature review to estimate the non-polymeric PFAS concentrations in FP with functional addition of PFASs. We indicate below the papers presenting analyses of PFASs in FP identified.

Trier et al. [45] provides qualitative information on FP collected in Denmark: they indicate which components were detected in FP, but do not indicate concentrations.

Begley et al.[16] indicates concentrations of total PFOA comprised between 6 and 290 ng/g in the U.S. FP.

Yuan et al.[46] provides median concentrations as well as ranges of concentrations for total n:2 FTOHs measured in different types of FP collected in China. The highest values are a median of 18,200 with a range of 2,620–24,100 ng/g.

Tokranov et al.[47] reports total PFAS concentrations measured in different U.S. FP, as well as the proportion of PFCAs, PFSAs and their precursors in nmol/m^2. Since we work with mass data, converting m^2 into a weight would generate additional uncertainties.

Schaider et al.[48] only specifies how many times each PFAS compound was detected in the U.S. FP sampled. Note that the main finding of the Schaider et al.[48] is that 33% of fast food packaging has a total F concentration higher than the LOD (lowest detection limit). In our paper, we are using the values of 2% of FP with functional PFAS addition and another ~50% with non-functional PFAS addition. The middle value we use for non-functional concentration of polymeric PFASs is right at the LOD for Schaider et al.[48], suggesting that the values of 2% and ~50% are reasonable.

In Robel et al.,[49] results on the U.S. FP samples are only presented as nmol F/cm^2.

Poothong et al.[50] presents results for FP samples in Bangkok, Thailand in ng/dm^2.

Shoeib et al.[51] reports concentrations of PFCAs and PFSAs determined in the Egyptian FP materials collected from Cairo, Egypt. The highest concentration detected was 93.62 ng/g of PFOA.

Zafeiraki et al.[52] analysed several PFCs, and the highest concentration detected in Greek FP was 341.21 ng/g of perfluorohexanoic acid (PFHxA).

Zabeleta et al.[53] detected a maximum concentration of perfluorobutanoic acid (PFBA) of 291.0 ng/g in Spanish FP samples.

Dolman et al.[54] measured a maximum concentration of 9.1 μg/kg of PFOA in the Australian FP they analyzed.

The highest median of n:2 FTOH detected by Kotthoff et al.[55] in German FP was 15.2 μg/kg of 8:2 FTOH. They also measured peaks at 182.8, 658.1 and 489.4 μg/kg for PFHxA, PFOA, and perfluorodecanoic acid (PFDA).

Rewerts et al.[56] measured the concentrations of different n:2 FTOHs in the U.S. FP samples and obtained a maximum total n:2 FTOH concentration of 4,840 ng/g, with a minimum of 3,000 ng/g (without accounting for FP with concentrations lower than the limit of detection), and an average of 3,835 ng/g.

Brenes et al.[57] reports a maximum total perfluoroalkyl acid (PFAA) concentration measured in the U.S. FP samples of 29.2 ng/g.

The maximum total FTOH concentration measured by Liu et al.[58] in the U.S. FP samples was 25,200 ng/g. The average was 2,820 ng/g and the minimum (above the quantification limit) was 374 ng/g.

Zabaleta et al.[59] did not measure PFAS concentrations above the method detection limit in the U.S. microwave bag samples.

Benotti et al.[60] measured an average of 19,980 μg/g of targeted PFASs in FP from the U.S., with concentrations ranging between 373 and 93,529 μg/g, but this value includes both polymeric and non-polymeric PFAS.

Sinclair et al.[18] provides mean concentrations of PFCAs and FTOHs in popcorn packaging paper in ng/cm^2.

To span a large range of non-polymeric concentrations detected in North American FP, we used values from the study of Liu et al.[58] We took 370, 2,820 and 25,200 ng/g for the lower, middle and high values of non-polymeric PFASs in FP with functional addition of PFASs. For FP with non-functional addition of PFASs, we used 370 ng/g as our upper boundary, 0 ng/g as the minimum, and 200 ng/g as the middle value.

As for polymeric PFASs intentionally added in FP ("functional" category), we combined information from the U.S. FDA database on PFASs authorized for use in food contact material (Table S1)[8] with instructions from the corresponding patents (when available). Table S1 summarizes this information. The PFAS with the CAS number 1345817-52-8 has the highest quantity authorized: 1.2% by weight of finished paper. We thus took this percentage as our highest bound for the calculation of polymeric PFAS concentration in "functional" FP. The same substance also had the lowest recommended concentration in its patent, i.e., 0.1% by mass, which we took for our lower bound. We chose 0.5% as our middle value. We chose 0.01% by mass as the upper boundary of the polymeric PFAS concentration in FP with non-functional addition of PFASs, 0% as the lower boundary and 0.005% as the middle value.

The category of FP with "no PFAS" was added for completeness.

S3.2 Flows of PFASs Originating from the Different Categories of Consumer Food Packaging

Tables S11 and S12 describe the flows of PFASs contained in FP with functional and non-functional concentrations of PFASs.

As a check of our choice of parameters, and especially the assumed percentage distribution of each category of FP (i.e., with functional PFAS addition, with non-functional PFAS addition, without PFASs), we compared our estimate of polymeric PFAS content in FP with values extracted from the literature.

The global consumption of all fluoropolymers in 2015 was 297,000 tonnes, of which 22% was in the US, i.e., about 65,000 tonnes (note that the fluoropolymers production volumes are likely considerably higher than the production volumes of other PFASs such as side-chain fluorinated polymers).[61] Additionally, it was estimated that 33% of the production of fluorinated substances (mostly non-polymeric PFASs, side-chain fluorinated polymers and perfluoropolyethers) in Europe was used in paper and board food packaging.[45] Assuming this value is the same for North America, we estimated that about 21,600 tonnes of fluorinated substances could be used in the U.S. for FP every year. This value could be too high due to the likely lower usage of fluoropolymers as extrusion aids in FP plastic processing than 33%, and thus we took this value of 21,600 tonnes for our upper boundary for the use of PFASs in FP in the U.S. (flow F_1). Our middle scenario was about 10,000 tonnes (50% of the high scenario) and 1,080 tonnes (5% of the high scenario) for the low scenario. Since data for Canada was not available, we assumed the same distribution of types of FP as for the US.

Table S11 Quantification of the Main Flows of PFASs from Consumer Food Packaging in the U.S. (in tonnes/year)

		FP with functional addition of PFASs			FP with non-functional addition of PFASs		
		Low	Middle	High	Low	Middle	High
		Polymeric PFASs					
F_1	flow in the sales of FP	1.1E+03	7.2E+03	2.0E+04	0	1.8E+03	5.0E+03
F_2	flow from discarded FP	1.1E+03	7.2E+03	2.0E+04	0	1.8E+03	5.0E+03
F_3	flow from littered FP	3.4E+02	3.6E+02	3.0E+03	0	9.0E+01	7.5E+02
F_4	flow from recycled FP	7.9E+01	1.4E+03	5.1E+03	0	3.4E+02	1.3E+03
$F_{4,1}$	flow from recycled FP that is recycled back to FP	4.0E+00	2.5E+02	1.7E+03	0	6.2E+01	4.2E+02
$F_{4,2}$	flow from recycled FP that is recycled into other materials	7.1E+01	9.2E+02	1.9E+03	0	2.3E+02	4.7E+02
$F_{4,3}$	flow from FP initially intended for recycling but that is ultimately landfilled or exported	4.0E+00	2.1E+02	1.5E+03	0	5.1E+01	3.8E+02
F_5	flow in incinerated FP	3.2E+01	7.5E+02	2.9E+03	0	1.9E+02	7.2E+02
F_6	flow from landfilled and composted FP	6.8E+02	4.7E+03	9.0E+03	0	1.2E+03	2.2E+03
		Non-polymeric PFASs					
F_1	flow in the sales of FP	4.2E-01	4.0E+00	4.2E+01	0	7.2E+00	1.8E+01
F_2	flow from discarded FP	4.2E-01	4.0E+00	4.2E+01	0	7.2E+00	1.8E+01
F_3	flow from littered FP	1.3E-01	2.0E-01	6.3E+00	0	3.6E-01	2.8E+00
F_4	flow from recycled FP	2.9E-02	7.7E-01	1.1E+01	0	1.4E+00	4.7E+00
$F_{4,1}$	flow from recycled FP that is recycled back to FP	1.5E-03	1.4E-01	3.5E+00	0	2.5E-01	1.6E+00
$F_{4,2}$	flow from recycled FP that is recycled into other materials	2.6E-02	5.1E-01	4.0E+00	0	9.2E-01	1.7E+00
$F_{4,3}$	flow from FP initially intended for recycling but that is ultimately landfilled or exported	1.5E-03	1.2E-01	3.2E+00	0	2.1E-01	1.4E+00
F_5	flow in incinerated FP	1.2E-02	4.2E-01	6.1E+00	0	7.5E-01	2.7E+00
F_6	flow from landfilled and composted FP	2.5E-01	2.7E+00	1.9E+01	0	4.7E+00	8.3E+00

Table S12 Quantification of the Main Flows of PFASs from Consumer Food Packaging in Canada (in tonnes/year)

		FP with functional addition of PFASs			FP with non-functional addition of PFASs		
		Low	Middle	High	Low	Middle	High
		Polymeric PFASs					
F_1	flow in the sales of FP	1.2E+02	7.5E+02	2.1E+03	0	1.9E+02	5.3E+02
F_2	flow from discarded FP	1.2E+02	7.5E+02	2.1E+03	0	1.9E+02	5.3E+02
F_3	flow from littered FP	3.5E+01	3.8E+01	3.2E+02	0	9.4E+00	7.9E+01
F_4	flow from recycled FP	8.3E+00	1.4E+02	5.4E+02	0	3.6E+01	1.3E+02
$F_{4,1}$	flow from recycled FP that is recycled back to FP	4.1E-01	2.6E+01	1.8E+02	0	6.4E+00	4.4E+01
$F_{4,2}$	flow from recycled FP that is recycled into other materials	7.4E+00	9.6E+01	2.0E+02	0	2.4E+01	5.0E+01
$F_{4,3}$	flow from FP initially intended for recycling but that is ultimately landfilled or exported	4.1E-01	2.1E+01	1.6E+02	0	5.4E+00	4.0E+01
F_5	flow in incinerated FP	2.5E+00	3.6E+01	1.4E+02	0	9.0E+00	3.6E+01
F_6	flow from landfilled and composted FP	7.2E+01	5.4E+02	1.1E+03	0	1.3E+02	2.8E+02
$F_{6,Michigan}$	flow in landfilled FP sent to Michigan	3.6E+00	5.9E+01	2.2E+02	0	1.5E+01	5.6E+01
$F_{6,Canada}$	flow in FP landfilled or composted in Canada	6.8E+01	4.8E+02	8.9E+02	0	1.2E+02	2.2E+02
		Non-polymeric PFASs					
F_1	flow in the sales of FP	4.4E-02	4.2E-01	4.4E+00	0	7.5E-01	2.0E+00
F_2	flow from discarded FP	4.4E-02	4.2E-01	4.4E+00	0	7.5E-01	2.0E+00
F_3	flow from littered FP	1.3E-02	2.1E-02	6.7E-01	0	3.8E-02	2.9E-01
F_4	flow from recycled FP	3.1E-03	8.0E-02	1.1E+00	0	1.4E-01	5.0E-01
$F_{4,1}$	flow from recycled FP that is recycled back to FP	1.5E-04	1.4E-02	3.7E-01	0	2.6E-02	1.6E-01
$F_{4,2}$	flow from recycled FP that is recycled into other materials	2.8E-03	5.4E-02	4.2E-01	0	9.6E-02	1.8E-01
$F_{4,3}$	flow from FP initially intended for recycling but that is ultimately landfilled or exported	1.5E-04	1.2E-02	3.4E-01	0	2.1E-02	1.5E-01
F_5	flow in incinerated FP	9.2E-04	2.0E-02	3.0E-01	0	3.6E-02	1.3E-01
F_6	flow from landfilled and composted FP	2.7E-02	3.0E-01	2.3E+00	0	5.4E-01	1.0E+00
$F_{6,Michigan}$	flow in landfilled FP sent to Michigan	1.3E-03	3.3E-02	4.7E-01	0	5.9E-02	2.1E-01

$F_{6,Canada}$	flow in FP landfilled or composted in Canada	2.5E-02	2.7E-01	1.9E+00	0	4.8E-01	8.2E-01

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