**PFOA, ITS SALTS AND PFOA-RELATED COMPOUNDS**

**DRAFT RISK MANAGEMENT EVALUATION**

**BACK GROUND DOCUMENT**

15 March 2017

Contents

[1 List of Acronyms 3](#_Toc477340223)

[2 Additional Annex E information 4](#_Toc477340224)

[2.1 Production data, including quantity and location 4](#_Toc477340225)

[2.2 Uses 5](#_Toc477340226)

[2.3 Releases, such as discharges, losses and emissions 8](#_Toc477340227)

[3 Summary of alternatives according to ECHA 12](#_Toc477340228)

[4 Information related to adverse effects of alternatives 14](#_Toc477340229)

[5 References considered for adverse effects of alternatives as summarized in table 6 20](#_Toc477340230)

# List of Acronyms

Table 1: List of acronyms used in the draft risk management evaluation

|  |  |
| --- | --- |
| AFFF | Aqueous film-forming foams |
| CEPA | Canadian Environmental Protection Act |
| CLP | Classification, Labelling and Packaging |
| CMP | Chemical Management Plan |
| EAA | Environment Agency Austria |
| EC50 | Half maximal effective concentration |
| ECF | Electrochemical fluorination |
| ECHA | European Chemicals Agency |
| EPA | Environmental Protection Agency |
| FFFC | Fire Fighting Film Coalition |
| ICT | Information and Communications Technology |
| LC | Long chain |
| LC/MS-MS | Liquid chromatography/tandem mass spectrometry |
| LC50 | Median lethal concentration |
| MCCP | Medium-chain chlorinated paraffin |
| NHANES | National Health and Nutrition Examination Survey |
| NOEC | Non-observed adverse effect level |
| NRL | United States Naval Research Laboratory |
| OECD | Organisation for Economic Co-operation and Development |
| OSPAR | Oslo/Paris Commission for the Protection of Marine Environment of the North East Atlantic |
| PBT | Persistence, Bioaccumulation, Toxicity |
| POPRC | Persistent Organic Pollutants Review Committee |
| PPA | Polymerization processing aids |
| RAC | Committee for Risk Assessment |
| REACH | REACH is a regulation of the European Union, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals |
| SAICM | Strategic Approach to International Chemicals Management |
| SCCP | Short-chain chlorinated paraffin |
| SEAC | Committee for Socio-economic Analysis |
| SVHC | Substances of Very High Concern |
| TSCA | Toxic Substances Control Act |
| UCMR | Unregulated Contaminant Monitoring Rule |
| US EPA | United States Environmental Protection Agency |
| ZDHC | Zero Discharge of Hazardous Chemicals |

# Additional Annex E information

1. Several parties and observers submitted additional Annex E information related to production, use or releases. . Information from Annex E related submissions are compiled in the present background document to the draft risk management evaluation.

## Production data, including quantity and location

1. The following table summarizes additional Annex E information on production data, including quantity and location submitted by reviewing parties and countries.

Table 2: Additional Annex E information on production data, including quantity and location

| **Submission** | **Information** |
| --- | --- |
| Australia 2016 | Chemicals in this group are not currently imported into or manufactured in Australia.  In July 2006, NICNAS collected information on the manufacture, importation and uses of perfluorinated chemicals including PFOA-related substances and products/mixtures containing these substances for the calendar years 2004 and 2005. Information provided to NICNAS indicated that:   * No PFOA-related chemicals are manufactured in Australia. * PFOA containing products were imported into Australia. These were:  1. An antifoam product containing <10% of a PFOA-related chemical (CAS Nr not specified) was imported in 2005 for use in a dyeing process with sulfur dyes. The total quantity imported was approximately 10 kg. 2. A de-dusting product for industrial use and a consumer paint product, both containing less than 100 ppm of a PFOA salt, were imported. The total volumes of PFOA salt in both products were 10 kg and 71 kg in 2004 and 2005, respectively. The concentration of PFOA salts in these products was reduced to less than 10 ppm in 2006. |
| Austria 2016a | There is currently no production of PFOA in Austria |
| Canada 2016a | "[In 2000] No manufacturing or import of PFOA or long-chain PFCAs in Canada were reported above the 100 kg reporting threshold. However, the import of several long-chain PFCA precursors into Canada was reported in quantities greater than 100 kg.  In 2005, a second industry survey regarding PFA/FA substances was conducted by Environment Canada under the authority of section 71 of CEPA 1999 (Canada 2005). Long-chain PFCAs were not reported to be manufactured in Canada for the 2004 calendar year. However, some PFOA salts and long-chain PFCAs precursors were imported into Canada in quantities greater than the reporting threshold of 100 kg. " |
| Denmark 2016 | The report “PFOS, PFOA and other perfluoralkyl and polyfluoroalkyl substances”, Environmental Project 1475, 2013, which is part of the Danish review of the national list of unwanted substances (LOUS) may contain relevant information for Annex E, but also relevant information for Annex F. This publication covers relevant Danish information on regulation, use, waste issues, environmental and health issues and alternatives. The report is available at:  <http://www2.mst.dk/Udgiv/publications/2013/04/978-87-93026-03-2.pdf> |
| Monaco 2016 | This chemical is not produced nor used in Monaco |
| FluoroCouncil 2016a | FluoroCouncil companies have phased out the use, manufacture, and sale of PFOA and PFOA-related compounds in accordance with the U.S. EPA Product Stewardship Program. This phase out has been accomplished globally, including e.g. China, for all FluoroCouncil companies.  There are currently small amounts of PFOA related chemicals that are produced as a bi-product of short-chain fluorochemical production. They are captured and destroyed or converted to non-PFOA-related chemicals. |
| IP Europe 2016a | Member companies do not manufacture PFOA, its salts or related substances, and must purchase the necessary materials from suppliers (EU and non-EU).  From the purchased PFOA-related substances photographic product manufacturers then create mixtures, for internal use only. The photographic industry does not sell PFOA, its salts or PFOA-related substances nor preparations containing these materials, although some companies may transport mixtures between plant sites.  Imaging industry member companies use certain PFOA-related substances in critical manufacturing operations for a small number of traditional and digital imaging products manufactured predominantly in the USA, Europe, China, and Japan. |

## Uses

1. The following table summarizes additional Annex E information on the uses of PFOA, its salts and PFOA related compounds submitted by reviewing parties and countries.

Table 3: Additional Annex E information on uses of PFOA, its salts and related

| **Submission** | **Information** |
| --- | --- |
| Australia 2016 | The following Australian industrial uses were reported under previous mandatory and/or voluntary calls for information:   * As a primer for non-stick metal cookware * As fluoropolymer dispersion polymers in paints * In fire-fighting foams * In textile and carpet protection |
| Austria 2016a | Currently several uses are possible. |
| Canada 2016a | Please refer to section 2.2 of the Regulatory Impact Analysis Statement (RIAS), Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012. Available at: http://www.gazette.gc.ca/rp-pr/p2/2016/2016-10-05/html/sor-dors252-eng.php  "PFOA and LC-PFCAs are primarily used as water, oil and grease repellants; as surfactants; and as spreading and wetting agents. PFOA and LC-PFCAs were historically imported and may continue to be imported for use in the following manufacturing sectors: textile mills, paper and packaging, paints and coatings, inks and photo media, chemical manufacturing, electrical and electronics, cleaning products, plastic and rubber products. A study conducted for the Department estimated that approximately 308 t of PFOA and LC-PFCAs were imported into Canada in 2010."  Please refer to section 4 of the Proposed Risk Management Approach for Perfluorooctanoic Acid (PFOA), its Salts, and its Precursors and Long-Chain (C9-C20) Perfluorocarboxylic Acids (PFCAs), their Salts, and their Precursors. 2012. Available at:  <http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=451C95ED-1>  "Manufacturing was the main industrial sector using these substances according to the reported North American Industry Classification System (NAICS) codes. The manufacturing sub-sectors identified include:  • Textile Mills  • Paper Manufacturing  • Chemical Manufacturing  • Plastic and Rubber Products Manufacturing  Historical uses of PFOA include applications in industrial processes and in commercial and consumer products. PFOA and its salts are used as polymerization aids in the production of fluoropolymers and fluoroelastomers. APFO (PFOA ammonium salt), the most common commercially used salt form of PFOA, is the ammonium salt, is used primarily as a commercial polymerization aid in the manufacture of fluoropolymers such as polytetrafluoroethylene and polyvinylidene fluoride (US Government 2003; OECD 2006; Prevedouros et al. 2006), which are used in various sectors, including the automotive, electronics, construction and aerospace industries. Fluoropolymers are used in the manufacture of stain- and water-resistant coatings on textiles and carpet; hoses, cable and gaskets; non-stick coatings on cookware; and personal care products (US Government 2003). APFO is also used as a constituent in aqueous fluoropolymer dispersions, which are formulated into paints, photographic film additives and in the textile finishing industry (OECD 2006). Aqueous fire-fighting foams may also contain APFO as a component (OECD 2006; Prevedouros et al. 2006). Fluorochemicals that are potential PFOA precursors are used in the treatment of food packaging materials to enhance their properties as a barrier to moisture and grease (Begley et al. 2005). Thus, although APFO is typically not intended to remain in manufactured articles, trace amounts may be present as a contaminant or degradation product."  Please refer to section 2.1 of the Consultation document - Proposed Risk Management Measure for Perfluorooctanoic Acid (PFOA) Its Salts, and Its Precursors and Long-Chain (C9-C20) Perfluorocarboxylic Acids (PFCAs), their Salts, and their Precursors. 2014. Available at: http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=2A11BA77-1#s2\_1  "PFOA, itself, is not manufactured in Canada. However, quantities of the ammonium salt are imported. LC-PFCAs are not manufactured in Canada; however, several precursors to the long-chain (C9-C20) perfluorocarboxylic acids were reported to be imported into Canada.  PFOA, its salts and its precursors and LC-PFCAs, their salts and their precursors were historically used, and may continue to be used, in the following industry sectors and are potentially contained in the associated products (OECD 2013).  • Films, paints and coatings: paint, photographic film, water-based inks  • Fire-Fighting: aqueous fire-fighting foams  • Electrical and Electronics: cables, wiring, semiconductors  • Product components and finished products: hoses, gaskets, non-stick cookware, personal care products  • Paper and packaging: oil and grease repellent  • Polymerization: polymerization processing aids (surfactants)  • Textiles: protective clothing, oil and water repellent and stain release fabrics, carpet  Other industry sectors would be implicated if they use product components or finished products identified in the list above. "  A recent report Occurrence and use of highly fluorinated substances and alternatives by KEMI, Swedish Chemicals Agency (2015), is available at: http://www.kemi.se/en/global/rapporter/2015/report-7-15-occurrence-and-use-of-highly-fluorinated-substances-and-alternatives.pdf. The objectives of this report are ‘to give a clearer picture of where highly fluorinated substances (including PFOA) are currently used and what alternative substances, materials and technologies are available.’ |
| India 2017 | The uses of PFOA in India are; textile and leather treatment, paper treatment, firefighting agents, paints and inks, photo industry, semiconductor industry, production of fluoropolymer, surface coatings etc. |
| Japan 2016 | There are identified uses in Japan as follows:  PFOA and its salts  ･Photo-resist and anti-reflective coatings for semi-conductors  ･Bleed inhibitors in bonding agents for semi-conductors  ･Surfactant for enzyme electrodes of clinical analyzer  ･Water-repellent agents for textiles  ･Electric insulator and moisture-proof coating agent for printed circuit board  PFOA-related compounds  ･Photo-resist and anti-reflective coatings for semi-conductors  ･Dispersant to adjust the electrical characteristics of polymers  ･Water-repellent agents for glass products  ･Coatings and levelling agents  Perfluorooctyl iodide (CAS:507-63-1)  Intermediate in production of perfluorooctyl bromide which is used as solvent in pharmaceuticals manufacturing process. |
| Monaco 2016 | This chemical is not produced nor used in Monaco |
| VTB SWT 2016 | Professional, technical protective textiles which must meet durable repellency performance standards. |
| FluoroCouncil 2016a | Some PFOA Related Chemicals are produced as bi-products of other fluorochemical production which may be used as raw materials for, e.g. artificial blood |
| TM 2016 | Professional, technical and protective textiles which must meet durable repellency performance standards. |
| IP Europe 2016a | PFOA-related substances are essential for the application of coating layers during the manufacture of some remaining conventional photographic products, i.e. products in which the image formation is based on silver halide technology: they have multiple functions, serving   * as surfactants, * as static control agents, * as dirt repellents during coating operations, * as friction control agents, * and to provide adhesion control of coated layers.   PFOA-related substances are unique in that they provide the combination of all these properties in one molecule, without any adverse effects on photographic performance.  As static control agents, PFOA-related substances are needed to prevent damage to the sensitized photographic layers and thus prevent product damage or even waste.  These substances not only provide performance features necessary for the manufacture and use of conventional photographic products, they also provide important safety features by controlling the build-up and discharge of static electricity.  The ability of PFOA-related substances to control surface tension is a critical aspect of the use of these materials as coating aids. In order to function, imaging materials must be coated with multiple thin layers at high speed – some having as many as 18 thin layers containing up to 200 chemicals and with an overall total thickness of about 0.11 mm. During the coating process the chemicals in these layers should not mix. The PFOA related materials play a key role in minimizing manufacturing waste by contributing to the technology for creating coatings of high complexity in a highly consistent manner. The coating aid must allow the rapid uniform spreading of the layers so that irregularities in the coatings are avoided. Any irregularity in coating thickness makes conventional imaging materials unusable and increases manufacturing waste significantly. Coating aids must also not be photoactive and thus not interfere with the imaging process, otherwise unacceptable fogging or speed effects may occur in the end material. |
| IPEN 2016 | PFOA-related compounds have been widely used in consumer products and in industrial applications, including as surfactants and/or fluorinated polymers for treatments for leather, textiles particularly for all weather outdoor clothing, carpets, paper packaging and ski waxes. PFOA and its salts have been used in the manufacture of fluoropolymers to produce hoses, cable and gaskets; non-stick coatings on cookware; and personal care products. PFOA is also used as a surfactant and processing aid in the manufacture of semi-conductors used in the photolithographic process. PFOA-related compounds are used as a surface treatment for stone and tiles, in medical devices, in paints and inks, floor waxes and stone/wood sealants and as an antifoam products for use in the dyeing process using sulfur dyes. PFOA-related compounds are also used as non-polymeric substances for firefighting foams, wetting agents or cleaners. |
| SIA 2016 | The semiconductor industry uses PFOA and related chemical substances during photolithography and related processes. These chemicals provide critical acidity, surfactancy and anti-reflectivity properties for photoresists, anti-reflective coatings, immersion topcoats, and overcoats used in the photolithographic process.  In 2015, SIA conducted a survey of the ten major semiconductor lithography chemical suppliers. All ten suppliers responded and provided data on 2014 sales of PFOA and related substances. The total amount of PFOA and related chemical substances in semiconductor photolithography formulations sold in North America in 2014 was 532 kg. A second survey was conducted in 2016 and the total amount of PFOA and related substances in semiconductor photolithography formulations sold in North America in 2015 was 720 kg.  PFOA may also be contained in semiconductor manufacturing equipment, parts, fab infrastructure and ancillary equipment. SIA conducted a survey of its members in 2016 and found that legacy PTFE is installed in facilities that were made with PFOA. The association of the industry’s suppliers, SEMI, estimates that the mass / weight of PFOA introduced into the EU annually by all semiconductor manufacturing equipment is no more than 8.40 kg per year. This represent a marginal source (0.1%) of PFOA, even in the category Articles, as the total PFOA present in articles is estimated to be <10 ton/year by the Dossier Submitter as indicated in the background document. We do not have available estimates for uses in other geographies. |

## Releases, such as discharges, losses and emissions

1. The following table summarizes additional Annex E information on releases, such as discharges, losses and emissions submitted by reviewing parties and countries.

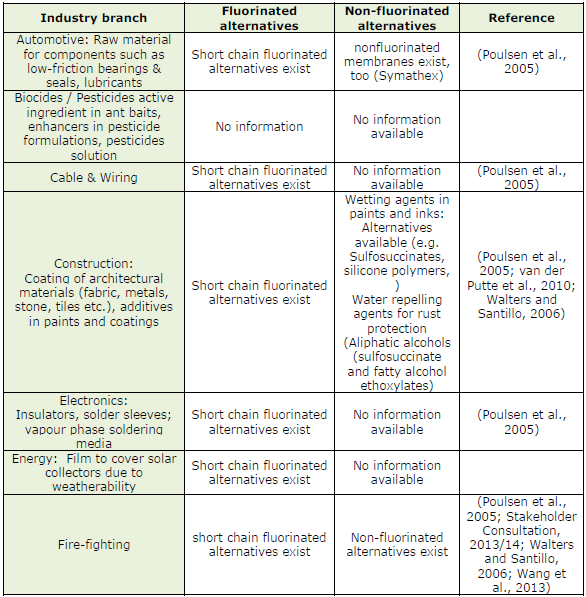
Table 4: Additional Annex E information on releases, such as discharges, losses and emissions

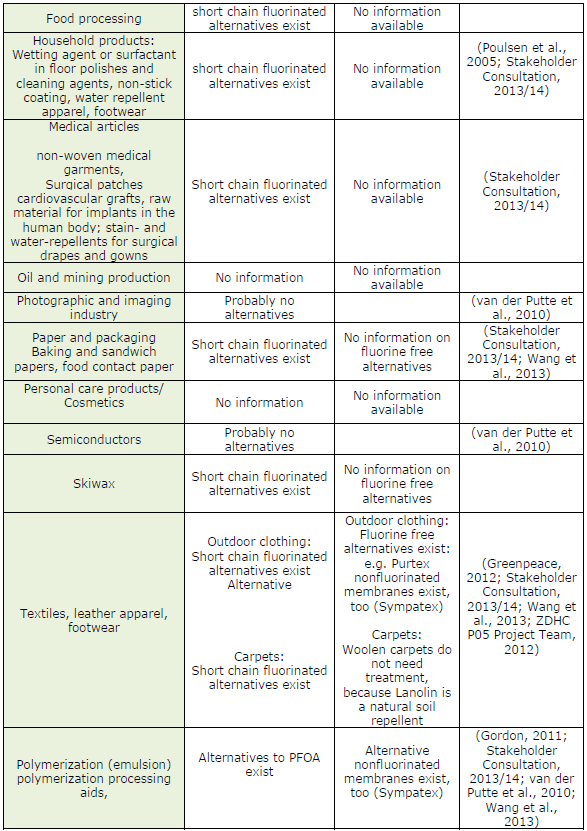
| **Submission** | **Information** |
| --- | --- |
| Australia 2016 | Discharges from use of existing stockpiles of fire-fighting foams is possible.  Chemicals in this group are likely to be present in the environment due to historic use, release from pre-treated articles, or the use of other chemicals. In particular, the use of fluoropolymers (which may contain PFOA residues) has previously been reported in the manufacture of non-stick metal cookware, in paints, in fire-fighting foams, and in textile and carpet protection.  Articles testing undertaken in 2013 found PFOA in a range of imported articles such as carpets, cookware, clothing, umbrellas and fabric. |
| Canada 2016a | Please refer to section 2.2.2 of the Regulatory Impact Analysis Statement (RIAS), Regulations Amending the Prohibition of Certain Toxic Substances Regulations, 2012. Available at: http://www.gazette.gc.ca/rp-pr/p2/2016/2016-10-05/html/sor-dors252-eng.php  "PFOA and LC-PFCAs may be found in the environment due to releases from manufacturing or processing facilities, effluent releases from wastewater treatment plants, landfill leachate, and the degradation and transformation of precursor compounds. No data are available on the actual release of these substances to the Canadian environment."  Please refer to section 2.1 of the Consultation document - Proposed Risk Management Measure for Perfluorooctanoic Acid (PFOA) Its Salts, and Its Precursors and Long-Chain (C9-C20) Perfluorocarboxylic Acids (PFCAs), their Salts, and their Precursors. 2014. Available at: http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=2A11BA77-1#s2\_1  "Both PFOA and LC-PFCAs may be found in the environment due to releases from fluoropolymer manufacturing or processing facilities, effluent releases from wastewater treatment plants, landfill leachates and due to degradation / transformation of PFOA precursors and precursors to LC-PFCAs."  Please refer to Section 3 ‘Comprehensive overview of global and regional emissions of C4-C14 PFCAs’ on page 27 through 45 in OECD/UNEP Global PFC Group, Working towards a Global Emission Inventory of PFASs: Focus on PFCAs – Status Quo and the Way Forward. Available at:  http://www.oecd.org/chemicalsafety/risk-management/Working%20Towards%20a%20Global%20Emission%20Inventory%20of%20PFASS.pdf  Please refer to Section 4.2 ‘Critical data and knowledge gaps that prevent quantification of overlooked sources’ on page 48 thought 49 in OECD/UNEP Global PFC Group, Working towards a Global Emission Inventory of PFASs: Focus on PFCAs – Status Quo and the Way Forward. Available at:  http://www.oecd.org/chemicalsafety/risk-management/Working%20Towards%20a%20Global%20Emission%20Inventory%20of%20PFASS.pdf |
| Monaco 2016 | This chemical is not produced nor used in Monaco |
| Norway 2016 | Long range transport seems to be the main source of PFOA in the Norwegian environment. "Survey of national sources, PFOA in Norway".  http://www.miljodirektoratet.no/old/klif/publikasjoner/2354/ta2354.pdf  Potential PFOA Precursors: Literature study and theoretical assessment of abiotic degradation pathways leading to PFOA. M-231/2014  http://www.miljodirektoratet.no/Documents/publikasjoner/M231/M231.pdf  PFOA isomers salts and precursors- Literature study and evaluation of physico chemical properties (TA-2944/2012):  http://www.miljodirektoratet.no/old/klif/publikasjoner/2944/ta2944.pdf  Investigation of outdoor textiles with respect to determine the content of ionic perfluorinated substances (PFASs)  http://www.miljodirektoratet.no/Documents/publikasjoner/M306/M306.pdf  Analysis of per- and polyfluorinated compounds in articles:  http://www.miljodirektoratet.no/Documents/publikasjoner/M360/M360.pdf  Forest soil were able to degrade precursors to PFOA: Dasu K, Lee LS. Aerobic biodegradation of toluene-2,4-di(8:2 fluorotelomer urethane) and hexamethylene-1,6-di(8:2 fluorotelomer urethane) monomers in soils. Chemosphere. 2016 Feb;144:2482-8. doi: 10.1016/j.chemosphere.2015.11.021. |
| VTB SWT 2016 | PFOA: Approx. 50-75 g/annum in Bavaria (VTB) and Baden-Württemberg (SWT)  Approx. 2-3 kg/annum in Europe |
| IP Europe 2016a | Potential for Environmental Release of PFOA during Manufacturing.  Environmental releases from the manufacturing of conventional photographic products are estimated to be extremely low for a number of reasons including:  1. the small amounts of PFOA related materials added during the coating stage of the photographic product (0.1-0.8 μg/cm2) have beneficial effects throughout the life of the product. Therefore the PFOA related material must predominantly remain in the product for the product to perform adequately;  2. manufacturing facilities for photographic materials either have incineration capability on-site or use incineration facilities available through off-site contracts. Wastes containing PFOA’s may arise from a variety of sources. In all cases, these waste streams are managed appropriately to minimize the potential for exposure and release to the environment.  Wastes from Coating Operations  Wastes from coating are disposed of through high temperature incineration. This waste category has been estimated as 1-3% of the total PFOA material in analogy with former data for PFOS developed in the course of the former regulatory process for PFOS. Coating materials that are unused but excess are sent for silver recovery by incineration at high temperature. This category of waste may account for 5-28% of the total amount of PFOA’s used, again in analogy with former PFOS data.  Some companies may use PFOA related substances in the overcoat layer. Whereas the overcoat does not contain silver (as opposed to photographic emulsion layers), any excess is not sent for silver recovery by incineration but rather treated in a large STP. This quantity of PFOA-related substance is estimated to be well below 1 kg per year and is further declining because of market trends.  Wastes from Finishing Operations  The finishing stage involves slitting the rolls of film that are up to several metres wide into sizes appropriate for the product type. The wastes from this process are all solid and are either incinerated directly or incinerated after recovery of silver and PET (polyethylene terephthalate) film base and other materials. Ultimately, all waste from finishing is incinerated, accounting for an estimated 5-25% of the total of PFOA chemicals.  Wastes from Photo-processing Operations  I&P Europe member companies no longer use PFOA’s in their photo-processing solutions.  During the wet processing of any photographic film or paper containing PFOA’s, we would anticipate very little PFOA chemical being released.  This is confirmed by analytical data yielding a PEC/PNEC of 0.000 24 << 1 in the wash section of a wet film processor for medical film, which constitutes a worst case example, and a PEC/PNEC = 0. 000 000 010 << 1 at the emission point of that processor in a typical hospital setting in Germany (\*\* annex 2).  \*\*: reference “Use of PFOA in critical photographic applications” – presentation at the Workshop on PFOA and its Ammonium salt. Production, use, risk – 4 May 2010, slide 10 (see annex 2)  Potential for Environmental Release of PFOA during Product Use.  Environmental releases originating from photographic products are estimated to be very low. The imaging industry aggressively recycles hundreds of millions of kilograms of manufacturing and post-customer waste annually, including solvents, PET, and silver. Because of the high value of silver, I&P Europe members have developed highly effective processes to recover as much used and waste photographic material as possible in order to recover the precious metal.  Consumer film and paper (except for small amounts of materials returned by photofinishers) are usually not returned to the manufacturer. Consumers typically store their film and printed images indefinitely and usually across generations. Materials that are discarded are usually disposed of in municipal solid waste systems. The proportion of municipal waste that is incinerated will vary considerably on a national and local level.  Recycling of commercial film may be carried out with several goals in mind: recovery of silver; recovery of film base material (PET); and protection of intellectual property or sensitive information. For film that is constructed on a PET base, the emulsion layers are separated using enzymes or chemicals, the PET base is separated and sent for recovery, and the emulsion solutions are either biologically treated or chemically treated with a flocculant, precipitated, dried and are in both cases subsequently incinerated at high temperature to produce an ash that is used for recovery of silver. Film that is not on a PET base is incinerated directly at high temperature to recover the silver. For commercial (e.g., entertainment, industrial x-ray, graphics arts, and printing) and medical imaging industries, film materials are collected by a small number of registered organizations who are responsible for the secure destruction of the film in order to protect private information or intellectual property. The materials are incinerated and the silver and other raw materials are recycled as described above.  Any waste solvents are incinerated in hazardous waste incinerators. To treat wastewaters, most recyclers have primary treatment facilities on-site so as to maximize silver recovery; sludges from primary treatment facilities are collected and used for silver recovery. Recycling operations located at manufacturing sites also have secondary wastewater treatment systems where sludges are collected and incinerated at high temperatures. |
| IPEN 2016 | PFOA is released into the air and water from waste sites, manufacturing facilities, sewerage treatment works and fire-fighting operations. They migrate out of consumer products like all-weather clothing, carpets and camping gear finding their way into household air and dust, soil, ground and surface water and food. Additionally, many PFOA-related substances (e.g. fluoropolymers) can degrade to PFOA under certain conditions. Researchers in 2015[[1]](#footnote-1) concluded that emissions from consumer products imported from China were responsible for 1.5% of PFOA discharges to wastewater.  DuPont is reported to have released approximately 1,136,364 kg of PFOA into the air and water around its West Virginia plant between 1951 and 2003.[[2]](#footnote-2) In 2004, DuPont settled a class-action covering 80,000 people affected by PFOA contamination of their drinking water.  The U.S. military is currently assessing 664 sites where the military has conducted fire or crash training using PFC based firefighting foams.  PFOA has been found in drinking water collected from 34 locations including capital cities and regional centers in Australia. PFOA and PFOS were the most commonly detected; 44% and 49% of all samples respectively. While the maximum concentration in any sample was PFOS at 16 ng /l, the second highest maximums were for PFHxS and PFOA measured at 13 and 9.7 ng/l.[[3]](#footnote-3) In Australian water reclamation and recycling plants, PFOS, PFOA, PFHxS and perfluorohexanoic acid (PFHxA) were the most frequently detected PFCs. Only those recycling plants using reverse osmosis (RO) technology were shown to reduce PFC concentrations to below detection and reporting limits (0.4–1.5 ng/l). [[4]](#footnote-4) In an Australian study of leachate from landfills, evaporation and aeration ponds, PFOA was found in every sample. (0.5-0.88ug/l) with 6 samples returning measurements of PFOA greater than 0.5ug/l. [[5]](#footnote-5)  The use of PFOA in fire-fighting foams has resulted in direct releases to the environment resulting in contamination of groundwater in Germany, Sweden, the US and Australia. In Italy in 2013, surface, groundwater and tap water were found to be contaminated downstream from a PFC/PFAS production plant. As PFOA does not degrade, once released to aquifers they are transported along with the groundwater, [[6]](#footnote-6) with the concentrations decreasing only due to diffusion and dispersion.  In Australia, preliminary sampling of national defence sites, detected PFOA at RAAF Base Townsville in both groundwater (<0.05 – 4.84 ug/l) and surface water (<0.01-1.74ug/l); in surface water at RAAF Base Amberley (<0.01- 0.12 ug/l) and HMAS Creswell, Jervis Bay Range Facility (<0.01 - 0.2 ug/l); and in groundwater at HMAS Stirling WA (<0.02 - 22.6 ug/l). [[7]](#footnote-7)  At the Army Aviation Centre Oakey, 63 groundwater samples returned PFOA detections from <LOR to 45.5 ug/l. Of the 25 surface water samples taken from drainage lines, PFOA ranged from <LOR to 15.5 ug/l. [[8]](#footnote-8)  Groundwater sampling at the regional Gold Coast airport over 6 years has consistently detected PFOA up to 64.6 ug/l. [[9]](#footnote-9)  Airservices Australia have advised that its investigations identified 36 sites that have, or are suspected of having, perfluorinated compounds (PFCs) residues as a result of AFFF use.[[10]](#footnote-10) |
| SIA 2016 | PFOA and related substances are used in both organic and aqueous formulations. For organic formulations, the majority of waste is collected and disposed via incineration or fuel blending; we estimate that approximately 3 percent is emitted to wastewater. This estimate is consistent with the conclusions in the OECD Emission Scenario Document (ESD) on Photoresist Use in Semiconductor Manufacturing and the Opinion of the SEAC and RAC in Europe. Aqueous wastes are incinerated/fuel blended or sent to industrial wastewater. Additional data collection is needed to understand the amount of PFOA from aqueous formulations that may be disposed to industrial wastewater and potentially released to the environment. |

# Summary of alternatives according to ECHA

1. The following table summarizes some fluorinated and non-fluorinated alternatives for different industry branches (ECHA, 2015a).

Table 5: Fluorinated and non-fluorinated alternatives for different branches





# Information related to adverse effects of alternatives

1. A key consideration for alternatives to PFOA is the Stockholm Convention POPRC “General guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals” (UNEP/POPS/POPRC.5/10/Add.1). The POPRC Guidance deals with the issue of “regrettable substitution”, stating that a safer alternative should not, “have hazardous properties that raise serious concern, such as mutagenicity, carcinogenicity or adverse effects on the reproductive, developmental, endocrine, immune or nervous systems” and that “attention should be paid to the potential for harm under actual conditions of use by consumers and indications that the processing or manufacturing conditions of the alternative might increase health risks of factory workers (IPEN, 2017[[11]](#footnote-11)).
2. Article 3 of the Stockholm Convention is also pertinent to discussion of alternatives and possible exemptions. Article 3, paragraph 3 obligates Parties obligates Parties with regulatory and assessment schemes to take measures to regulate with the aim preventing the production and use of new pesticides or new industrial chemicals that exhibit the characteristics of POPs. Article 3 also obligates Parties to consider POPs characteristics when conducting assessments of pesticides or industrial chemicals currently in use (IPEN, 201711).
3. The following table summarizes information related to adverse effects of alternatives. Information were mainly provided by IPEN. Additional information related to adverse effects of alternatives support the assessment of alternatives performed in the draft risk management evaluation (see chapter 2.3).

Table 6: Information related to adverse effects of alternatives according to information provided by IPEN. The information supports the assessment of alternatives mentioned in the draft risk management evaluation

| **Alternative** | **Information on possible adverse effects** | **Reference** | **Party/observer** |
| --- | --- | --- | --- |
| 6:2 FTOH | Unlike PFOA, which is known to not be metabolized in vivo, 6:2 FTOH has been demonstrated in several rat oral and inhalation metabolism studies to metabolize rapidly. Furthermore, in vitro studies using isolated hepatocytes from mice, rats, and humans showed half-lives of 6:2 FTOH to be 22, 30, and 100 minutes, respectively. Majority of the parent 6:2 FTOH compound is metabolized to 5:3 fluorotelomer acid and the PFCAs (PFBA, PFHxA, and PFHpA). However, there is a lack of data on the excretion of these metabolites, thus not knowing whether these metabolites could cause harm if they remain in the body for an extended period of time. Fluorine retention in liver and fat has been observed in one rat metabolism study via gavage. | ECHA, 2015a |  |
| 6:2 FTOH | One study using isolated rat hepatocytes showed 6:2 FTOH to be less cytotoxic than the other fluorotelomer alcohols (e.g., 4:2 and 8:2 FTOHs) with a LC50 of 3.7±0.54 mM. | Martin et al., 2009 |  |
| 6:2 FTOH | Regarding genotoxicity and mutagenicity, the majority of the studies reported no significant findings. | Oda et al., 2007; Lindeman et al., 2012 |  |
| 6:2 FTOH | At higher concentrations (e.g., 25 mg/kg/day), adverse reproductive and developmental effects such as reduction in pup survival and pup body weight in rodents have been demonstrated. Even though the severity of observed effects was greater in mice compared to rats, the derived NOAELs were identical in both species with 5 mg/kg/day for systemic toxicity and 25 mg/kg/day for offspring viability and growth. | Mukerji et al., 2015 cited by ECHA, 2015a |  |
| 6:2 FTOH | 6:2 FTOH has been shown to stimulate proliferation of resting cells by driving them to enter the S-phase of the cell cycle, and this effect might be mediated via interaction with the estrogen receptor. | Maras et al., 2006; Vanparys et al., 2006 |  |
| 6:2 FTOH | Compared to the endogenous ligand estradiol-17β, 6:2 FTOH appears to have low binding activity to human estrogen receptor α or β | Ishibashi et al., 2007 |  |
| 6:2 FTOH | 6:2 FTOH is considered moderately toxic to aquatic organisms but less than 8:2 FTOH, and it has a notified classification as Aquatic chronic 2. The existing data shows that short-chain PFCAs have low toxicity to aquatic organisms (except fish toxicity of PFPeA). | ECHA, 2015a |  |
| 6:2 FTOH | 6:2 FTOH alters gene expression in the hypothalamic-pituitary-gonadal (HPG) axis and increases plasma estradiol and testosterone levels in zebra fish indicating endocrine disruption. | Liu et al., 2009 | IPEN |
| 6:2 FTOH | In male medaka fish (Oryzias latipes), 6:2 FTOH induces hepatic vitellogenin through activation of the estrogen receptor, indicating endocrine disruption. | Ishibashi et al., 2008 | IPEN |
| 6:2 FTOH | In cultured tilapia hepatocytes, 6:2 FTOH caused a dose-dependent induction of vitellogenin. | Liu et al., 2007 | IPEN |
| 6:2 FTOH | 6:2 FTOH also shows dose-dependent interaction to the human endocrine receptor in vitro. | Ishibashi et al., 2007 | IPEN |
| 6:2 FTOH | 6:2 FTOH is also found in Arctic air and in the Antarctic Peninsula raising concerns about its long-range transport properties | Bossi et al., 2016; Shoeib et al., 2006; Wang Z et al., 2015 | IPEN |
| 6:2 FTOH | 6:2 FTOH is released from textiles and found in indoor air including in office environments and shops selling outdoor clothing. | Schlummer et al., 2013; Fraser et al., 2012 | IPEN |
| 6:2 FTOH | 6:2 FTOH is also widely found in food contact materials and migrates into water and other solvents of varying polarity. | Yuang et al., 2016 | IPEN |
| 6:2 FTOH | A variety of consumer products contain and release 6:2 FTOH and it is also found in house dust. | Vestergren et al., 2015; Liu X et al., 2015; Kotthoff et al., 2015; Liu et al., 2013; Tian et al., 2016; Shoeib et al., 2016; Santen et al., 2016 | IPEN |
| 6:2 FTA | Related compounds 6:2 FTA and 6:2 FTS are not as well characterized, but show some similar characteristics as 6:2 FTOH. 6:2 FTA is found in consumer products and released from them to indoor air. | Langer et al., 2010; Santen et al., 2016 | IPEN |
| 6:2 FTS | 6:2 FTS is persistent, found in maternal and cord serum, found in the effluent of an airport industrial treatment plant, and found in outdoor consumer products. | Wang et al., 2011; Yang et al., 2016; Houtz et al., 2016; Santen et al., 2016 | IPEN |
| 6:2 FTOH | In summary, 6:2 FTOH is persistent; moderately toxic to aquatic organisms; displays a variety of adverse effects including reproductive and developmental effects and endocrine disruption; is degraded to persistent metabolites; is found in the Arctic and Antarctic; and released from products into air and dust. These characteristics are not consistent with criteria for a safer alternative to PFOA. Related compounds 6:2 FTA and 6:2 FTS are not as well-characterized but also raise concerns for their similar properties. | UNEP/POPS/POPRC.5/10/Add.1 | IPEN |
| PFHxS | Perfluorohexane sulfonate (PFHxS) is another common chemical alternative to PFOA and a widespread environmental contaminant, including in drinking water. | Gao et al., 2015; Kunacheva et al., 2011; Chen X et al., 2015; Boiteux et al., 2012; Yeung et al., 2013 | IPEN |
| PFHxS | PFHxS is found in the Arctic, including in wildlife and humans. | Zhao et al., 2012; Verreault et al., 2005; Long et al., 2015; Leter et al., 2014 | IPEN |
| PFHxS | PFHxS bioaccumulates in the food web and is found in gulls, wheat, and earthworms. | Haukås et al., 2007; Letcher et al., 2015; Vicente et al., 2015; Zhao et al., 2014 | IPEN |
| PFHxS | PFHxS causes endocrine disruption in vitro and alters the function of the thyroid hormone receptor. | Webster et al., 2016; Kjeldsen and Bonefeld-Jørgensen, 2013; Long et al., 2013 | IPEN |
| PFHxS | A variety of other PFHxS impacts include inducing apoptosis in brain cells; altering brain proteins essential for development in mice; affecting genes involved in brain development in chickens; and impairing lipoprotein production in rats. | Lee et al., 2014; Lee and Viberg, 2013; Cassone et al., 2012; Bijland et al., 2011 | IPEN |
| PFHxS | PFHxS is found in pregnant women and cord blood; efficiently transferred across the placenta; and associated with decreased birth weight in newborn humans. | Fisher et al., 2016; Lee et al., 2013; Maisonet et al., 2012; Manzano-Salgado et al., 2015; Hanssen et al., 2012 | IPEN |
| PFHxS | PFHxS is transferred to infants during breast feeding, exposing the newborn infant. | Bjermo et al., 2013; Mondal et al., 2014 | IPEN |
| PFHxS | Increasing prevalence of ADHD in children is associated with PFHxS levels. | Stein and Savitz, 2011; Hoffman et al., 2010 | IPEN |
| PFHxS | PFHxS affects blood lipids during pregnancy and alters sperm morphology in humans. | Haug et al., 2014; Toft et al., 2012 | IPEN |
| PFHxS | PFHxS is associated with impaired glucose tolerance and affects blood lipids and chlolesterol ratios in humans. | Shapiro et al., 2016; Fisher et al., 2012; Starling et al., 2014 | IPEN |
| PFHxS | There is a monotonic association between PFHxS levels and earlier menopause in women. | Taylor et al., 2014 | IPEN |
| PFHxS | PFHxS is widely found in children and adults, including in fluorochemical industry workers. | Bao et al., 2014; Alves et al., 2015; Landsteiner et al., 2014; Gyllenhammar et al., 2015; Wan et al., 2013; Cho et al., 2015; Gomez-Canela et al., 2015; Jin et al., 2011; Wang et al., 2012 | IPEN |
| PFHxS | In summary, PFHxS displays a variety of adverse effects and is a widespread environmental and human contaminant which is also found in the Arctic and appears to bioaccumulate in the food web. These characteristics are not consistent with criteria for a safer alternative to PFOA. | UNEP/POPS/POPRC.5/10/Add.1 | IPEN |
| PFHxA | Other C6 alternatives to PFOA also raise concerns. Perfluorohexanoic acid (PFHxA) is found in the Arctic and in an Antarctic marine mammal. | Zhao et al., 2012; Routti et al., 2015 | IPEN |
| PFHxA | PFHxA widely contaminates the environment, including oceans, rivers, landfill leachates, dust and drinking water. | Yamada et al., 2014; Karaskova et al., 2016; Shiwaku et al., 2016; Zafeiraki et al., 2015; Fuertes et al., 2016; Gallen et al., 2016; Houtz et al., 2016; Perkola and Sainio, 2013; Rodriguez-Jorquera et al., 2016; Brumovsky et al., 2016; Sharma et al., 2016; Lu et al., 2015; Yu et al., 2013; Shan et al., 2015; Lorenzo et al., 2016; Campo et al., 2014; Chen X et al., 2015; Sanchez-Vidal et al., 2015; Gonzalez-Gaya et al., 2014; Takemine et al., 2014; Lui et al., 2015; Pan et al., 2014; Liu WX et al., 2015 | IPEN |
| PFHxA | Fluoropolymer plants release PFHxA to drinking water resources. | Dauchy et al., 2012 | IPEN |
| PFHxA | PFHxA is efficiently translocated into plants, raising food contamination concerns. | Bizkarguenaga et al., 2016 | IPEN |
| PFHxA | PFHXA is also found in a variety of outdoor consumer products such as jackets, trousers, and boots. | Santen et al., 2016 | IPEN |
| PFHxA | PFHxA is also found in humans including in amniotic fluid and human milk and in higher concentrations in people with Gilbert Syndrome. | Zhang Tao et al., 2013; Kang et al., 2016; Gebbink et al., 2015; Wan et al., 2013; Fan et al., 2014 | IPEN |
| PFHxA | PFHxA is not well-characterized toxicologically but acts as a developmental toxicant in Xenopus embryos in vitro, decreases survival in female Sprague Dawley rats, and is negatively associated with altered testosterone levels in male adolescents | Kim et al., 2015; Klaunig et al., 2015; Zhou et al., 2016 | IPEN |
| PFBS | C4 compounds such as perfluorobutane sulfonate (PFBS) are also used as PFOA alternatives. Like the C6 compounds, PFBS is found in the Arctic and highly resistant to microbial degradation. | Zhao et al., 2012; Ochoa-Herrera et al., 2016 | IPEN |
| PFBS | PFBS is found in rivers and sediment near manufacturing plants and more widely as a contaminant in rivers and marine biota such as humpback dolphins and finless porpoises. | Chen H et al., 2015; Meng et al., 2015; Wang P et al., 2015; Zhu et al., 2015; Sharma et al., 2016; Gao et al., 2015; Zhang Y et al., 2013; Liu B et al., 2015; Lam et al., 2016; Chen X et al., 2015; Shao et al., 2016; Lorenzo et al., 2016; Pan et al., 2014; Eschauzier et al., 2010 | IPEN |
| PFBS | PFBS is also found in wastewater and drinking water treatment plants along with other PFCs where it is persistent to sludge treatment. | Gómez-Canela et al., 2012; Pan et al., 2016; Campo et al., 2014 | IPEN |
| PBFS | PFBS is readily taken up in maize. | Krippner et al., 2014 | IPEN |
| PBFS | PFBS is also widely found in outdoor consumer products such as ski waxes, jackets, trousers, and boots as well as leather samples. | Kotthoff et al., 2015; Santen et al., 2016 | IPEN |
| PBFS | PFBS contaminates drinking water and is found in humans, including in children. | Zafeiraki et al., 2015; Gyllenhammar et al., 2015; Landsteiner et al., 2014; Glynn et al., 2012; Alves et al., 2015; Bao et al., 2014 | IPEN |
| PBFS | PBFS is not well-characterized toxicologically but has been found to disrupt lipid assemblies, modulate immune response in vitro, inhibit aromatase in human placental cells, and alter heart rates and behavior in zebra fish. | Oldham et al., 2012; Corsini et al., 2012; Ulhaq et al., 2013; Hagennaars et al., 2011; Gorrochategui et al., 2014 | IPEN |
| PFBA | Perfluorobutanoic acid (PFBA) is another C4 fluorinated compound that has been used as an alternative to PFOA. Like PFBS and the C6 compounds, PFBA is found in the Arctic. | Kwok et al., 2013 | IPEN |
| PFBA | PFBA is also found on remote high-altitude glaciers and remote snow mountain snow. | Kirchgeorg et al., 2016; Cobbing et al., 2015; Wang et al., 2014 | IPEN |
| PFBA | PFBA contaminates oceans, lakes, marine fish, rivers, and lakes. | Zhou et al., 2012; Yamada et al., 2014; Lorenzo et al., 2016; Liu WX et al., 2015; Sanchez-Vidal et al., 2015 | IPEN |
| PFBA | PFBA is found in wastewater effluent of sewage treatment plants. | Houtz et al., 2016; Campo et al., 2014 | IPEN |
| PFBA | Like PFBS, PFBA is found in ski waxes, leather samples, and outdoor consumer products such as jackets, trousers, and boots. | Kotthoff et al., 2015; Santen et al., 2016 | IPEN |
| PFBA | Like PBFS, PFBA is also efficiently translocated into plants and it is transferred to crops grown in sewage treatment plant solid-amended soil. | Bizkarguenaga et al., 2016; Blaine et al., 2013; Krippner et al., 2014; Chropenova et al., 2016 | IPEN |
| PFBA | PFBA is found in humans, including in communities with known drinking water contamination. | Gebbink et al., 2015; Landsteiner et al., 2014 | IPEN |
| 4:2 FTOH | 4:2 fluorotelomer alcohol (4:2 FTOH) is another C4 fluorinated compound that has been used as an alternative to PFOA. 4:2 FTOH is not well-characterized but impairs the population growth of Tetrahymena thermophile indicating apoptosis and is toxic to rat hepatocytes in vitro. | Wang et al., 2010; Martin et al., 2009 | IPEN |
|  | A range of fluorocarbon-free, water-repellent finishing agents for textiles include commercial products such as BIONIC-FINISH®ECO and RUCO-DRY® ECO marketed by Rudolf Chemie Ltd., Geretsried/Germany; Purtex® WR, Purtex® WA, Purtex® AP marketed by the Freudenberg Group, Weinheim/Germany; and ecorepel® marketed by Schoeller Techologies AG, Sevelen/Switzerland. |  | IPEN |
|  | The possible alternatives identified for the photographic industry are:   1. Digital techniques; 2. Fluor telomer-based products of various perfluoroalkyl chain length; C3- and C4-perfluorinated compounds; 3. Hydrocarbon surfactants; 4. Silicone products | UNEP/POPS/POPRC.12/INF/15/Rev.1 | IPEN |
|  | There are cosiderable datagaps of siloxane compounds used on the market for photographic applications | UNEP/POPS/POPRC.8/INF/17/Rev.1 | IPEN |

# References considered for adverse effects of alternatives as summarized in Table 6

Alves A, Jacobs G, Vanermen G, Covaci A, Voorspoels S (2015) New approach for assessing human perfluoroalkyl exposure via hair. Talanta 144:575-583

Bao J, Lee YL, Chen PC, Jin YH, Dong GH (2014) Perfluoroalkyl acids in blood serum samples from children in Taiwan. Environ Sci Pollut Res Int 21:7650-7655

Bijland S, Rensen PC, Pieterman EJ, Maas AC, van der Hoorn JW, van Erk MJ, Havekes LM, Willems van Dijk K, Chang SC, Ehresman DJ, Butenhoff JL, Princen HM (2011) Perfluoroalkyl sulfonates cause alkyl chain length-dependent hepatic steatosis and hypolipidemia mainly by impairing lipoprotein production in APOE\*3-Leiden CETP mice. Toxicol Sci 123:290-303

Bizkarguenaga E, Zabaleta I, Prieto A, Fernandez LA, Zuloaga O (2016) Uptake of 8:2 perfluoroalkyl phosphate diester and its degradation products by carrot and lettuce from compost-amended soil. Chemosphere 152:309-317

Bjermo H, Darnerud PO, Pearson M, Barbieri HE, Lindroos AK, Nalsen C, Lindh CH, Jonsson BA, Glynn A (2013) Serum concentrations of perfluorinated alkyl acids and their associations with diet and personal characteristics among Swedish adults. Mol Nutr Res 57:2206-2215

Blaine AC, Rich CD, Hundal LS, Lau C, Mills MA, Harris KM, Higgins CP (2013) Uptake of perfluoroalkyl acids into edible crops via land applied biosolids: field and greenhouse studies. Environ Sci Technol 47:14062-14069

Boiteux V, Dauchy X, Rosin C, Munoz JF (2012) National screening study on 10 perfluorinated compounds in raw and treated tap water in France. Arch Environ Contam Toxicol 63:1-12

Bossi R, Vorkamp K, Skov H (2016) Concentrations of organochlorine pesticides, polybrominated diphenyl ethers and perfluorinated compounds in the atmosphere of North Greenland. Environ Pollut 217:4-10

Brumovsky M, Karaskova P, Borghini M, Nizzetto L (2016) Per- and polyfluoroalkyl substances in the Western Mediterranean Sea waters, Chemosphere. 159:308-316. doi: 10.1016/j.chemosphere.2016.06.015

Campo J, Masia A, Pico Y, Farre M, Barcelo D (2014) Distribution and fate of perfluoroalkyl substances in Mediterranean Spanish sewage treatment plants. Sci Total Environ 472:912-922

Cassone C, Taylor J, O'Brien J, Williams A, Yauk C, Crump D, Kennedy S (2012) Transcriptional profiles in the cerebral cortex of chicken embryos following in ovo perfluorohexane sulfonate exposure. Toxicol Sci 129:380-391

Chen H, Zhang C, Han J, Sun R, Kong X, Wang X, He X (2015) Levels and spatial distribution of perfluoroalkyl substances in China Liaodong Bay basin with concentrated fluorine industry parks. Mar Pollut Bull 101:965-971

Chen X, Zhu L, Pan X, Fang S, Zhang Y, Yang L (2015) Isomeric specific partitioning behaviors of perfluoroalkyl substances in water dissolved phase, suspended particulate matters and sediments in Liao River Basin and Taihu Lake, China. Water Res 80:235-244

Cho CR, Lam NH, Cho BM, Kannan K, Cho HS (2015) Association of polyfluoroalkyl chemical exposure with serum lipids in children. Sci Total Environ 512-513:397-405

Chropenova M, Karaskova P, Kallenborn R, Greguskova EK, Cupr P (2016) Pine Needles for the Screening of Perfluorinated Alkylated Substances (PFASs) along Ski Tracks. Environ Sci Technol 50:9487-9496

Cobbing M, Jacobson T, Santen M (2015) Footprints in the snow: Hazardous PFC in remote locations around the globe. Greenpeace

Corsini E, Sangiovanni E, Avogadro A, Galbiati V, Viviani B, Marinovich M, Galli CL, Dell'Agli M, Germolec DR (2012) In vitro characterization of the immunotoxic potential of several perfluorinated compounds (PFCs). Toxicol Appl Pharmacol 258:248-255

Dauchy X, Boiteux V, Rosin C, Munoz JF (2012) Relationship between industrial discharges and contamination of raw water resources by perfluorinated compounds. Part I: Case study of a fluoropolymer manufacturing plant. Bull Environ Contam Toxicol 89:525-530

ECHA (2015a) Background document to the Opinion on the Annex XV dossier proposing restrictions on Perfluorooctanoic acid (PFOA), PFOA salts and PFOA-related substances. 4 December 2015. Available from: https://echa.europa.eu/documents/10162/61e81035-e0c5-44f5-94c5-2f53554255a8.

Eschauzier C, Haftka J, Stuyfzand PJ, de Voogt P (2010) Perfluorinated compounds in infiltrated river rhine water and infiltrated rainwater in coastal dunes. Environ Sci Technol 44:7450-7455

Fan H, Ducatman A, Zhang J (2014) Perfluorocarbons and Gilbert syndrome (phenotype) in the C8 Health Study Population. Environ Res 135:70-75

Fisher M, Arbuckle TE, Liang CL, LBlanc A, Gaudreau E, Foster WG, Haines D, Davis K, Fraser WD (2016) Concentrations of persistent organic pollutants in maternal and cord blood from the maternal-infant research on environmental chemicals (MIREC) cohort study. Environ Health 15:59 doi: 10.1186/s12940-016-0143-y

Fisher M, Arbuckle TE, Wade M, Haines DA (2012) Do perfluoroalkyl substances affect metabolic function and plasma lipids?-Analysis of the 2007-2009, Canadian Health Measures Survey (CHMS) Cycle 1. Environ Res 121:95-103

Fraser AJ, Webster TF, Watkins DJ, Nelson JW, Stapleton HM, Calafat AM, Kato K, Shoeib M, Vieira VM, McClean MD (2012) Polyfluorinated compounds in serum linked to indoor air in office environments. Environ Sci Technol 46:1209-1215

Fuertes I, Gomez-Lavin S, Elizalde MP, Urtiaga A (2016) Perfluorinated alkyl substances (PFASs) in northern Spain municipal solid waste landfill leachates. Chemosphere 168:399-407

Gallen C, Drage D, Kaserzon S, Baduel C, Gallen M, Banks A, Broomhall S, Mueller JF (2016) Occurrence and distribution of brominated flame retardants and perfluoroalkyl substances in Australian landfill leachate and biosolids. J Hazard Mater 312:55-64

Gao Y, Fu J, Meng M, Wang Y, Chen B, Jiang G (2015) Spatial distribution and fate of perfluoroalkyl substances in sediments from the Pearl River Estuary, South China. Mar Pollut Bull 96:226-234

Gebbink WA, Berger U, Cousins IT (2015) Estimating human exposure to PFOS isomers and PFCA homologues: the relative importance of direct and indirect (precursor) exposure. Environ Int 74:160-169

Glynn A, Berger U, Bignert A, Ullah S, Aune M, Lignell S, Sarnerud PO (2012) Perfluorinated alkyl acids in blood serum from primiparous women in Sweden: serial sampling during pregnancy and nursing, and temporal trends 1996-2010. Environ Sci Technol 46:90719079

Gómez-Canela C, Barth JA, Lacorte S (2012) Occurrence and fate of perfluorinated compounds in sewage sludge from Spain and Germany. Environ Sci Pollut Res Int 19:4109-4119

Gomez-Canela C, Fernandez-Sanjuan M, Farres M, Lacorte S (2015) Factors affecting the accumulation of perfluoroalkyl substances in human blood. Environ Sci Pollut Res 22:1480-1486

Gonzalez-Gaya B, Dachs J, Roscales JL, Caballero G, Jimenez B (2014) Perfluoroalkylated substances in the global tropical and subtropical surface oceans. Environ Sci Technol 48:13076-13084

Gorrochategui E, Perez-Albaladejo E, Casas J, Lacorte S, Porte C (2014) Perfluorinated chemicals: differential toxicity, inhibition of aromatase activity and alteration of cellular lipids in human placental cells. Toxicol Appl Pharmacol 277:124-130

Gyllenhammar I, Berger U, Sundstrom M, McCleaf P, Euren K, Eriksson S, Ahlgren S, Lignell S, Aune M, Kotova N, Glynn A (2015) Influence of contaminated drinking water on perfluoroalkyl acid levels in human serum--A case study from Uppsala, Sweden. Environ Res 140-673-683

Hagennaars A, Vergauwen L, De Coen W, Knapen D (2011) Structure-activity relationship assessment of four perfluorinated chemicals using a prolonged zebrafish early life stage test. Chemosphere 82:764-772

Hanssen L, Röllin H, Odland JØ, Moe MK, Sandanger TM (2010) Perfluorinated compounds in maternal serum and cord blood from selected areas of South Africa: results of a pilot study. J Environ Monit 12:1355-1361

Haug LS, Eggesbø M, Becher G, Sabaredzovic A, Thomsen C, Wilson RE, Travlos GS, Hoppin JA, Baird DD, Longnecker MP. (2014) Perfluoroalkyl substances and lipid concentrations in plasma during pregnancy among women in the Norwegian Mother and Child Cohort Study. Environ Int. 62:104-112

Haukås M, Berger U, Hop H, Gulliksen B, Gabrielsen GW (2007) Bioaccumulation of per- and polyfluorinated alkyl substances (PFAS) in selected species from the Barents Sea food web. Environ Pollut148:360-371

Hoffman K, Webster TF, Weisskopf MG, Weinberg J, Vieira VM (2010) Exposure to polyfluoroalkyl chemicals and attention deficit/hyperactivity disorder in U.S. children 12-15 years of age. Environ Health Perspect118:1762-1767

Houtz EF, Sutton R, Park JS, Sedlak M (2016) Poly- and perfluoroalkyl substances in wastewater: Significance of unknown precursors, manufacturing shifts, and likely AFFF impacts. Water Res 95:142-149

Ishibashi H, Ishida H, Matsuoka M, Tominaga N Arizono K (2007) Estrogenic effects of fluorotelomer alcohols for human estrogen receptor isoforms alpha and beta in vitro. Bio Pharm Bull 30:1358-1359

Ishibashi H, Yamauchi R, Matsuoka M, Kim JW, Hirano M, Yamaguchi A, Tominaga N, Arizono K (2008) Fluorotelomer alcohols induce hepatic vitellogenin through activation of the estrogen receptor in male medaka (Oryzias latipes). Chemosphere 71:1853-1859

Jin C, Sun Y, Islam A, Qian Y, Ducatman A (2011) Perfluoroalkyl acids including perfluorooctane sulfonate and perfluorohexane sulfonate in firefighters. J Occup Environ Med 53:324-328

Kang H, Choi K, Lee HS, Kim DH, Park NY, Kim S, Kho Y (2016) Elevated levels of short carbon-chain PFCAs in breast milk among Korean women: Current status and potential challenges. Environ Res 148:351-359

Karaskova P, Venier M, Melymuk L, Becanova J, Voja S, Prokes R, Diamond ML, Klanova J (2016) Perfluorinated alkyl substances (PFASs) in household dust in Central Europe and North America. Environ Int 94:315-324

Kim M, Park MS, Son J, Park I, Lee HK, Kim C, Min BH, Ryoo J, Choi KS, Lee DS, Lee HS (2015) Perfluoroheptanoic acid affects amphibian embryogenesis by inducing the phosphorylation of ERK and JNK. In J Mol Med 36:1693-1700

Kirchgeorg T, Dreyer A, Gabrielli P, Gabrieli J, Thompson LG, Barbante C, Ebinghaus R (2016) Seasonal accumulation of persistent organic pollutants on a high altitude glacier in the Eastern Alps. Environ Pollut 218:804-812

Kjeldsen LS1, Bonefeld-Jørgensen EC (2013) Perfluorinated compounds affect the function of sex hormone receptors. Environ Sci Pollut Res Int. 20:8031-8044

Klaunig JE, Shinohara M, Iwai H, Chengelis CP, Kirkpatrick JB, Wang Z, Bruner RH (2015) Evaluation of the chronic toxicity and carcinogenicity of perfluorohexanoic acid (PFHxA) in Sprague-Dawley rats. Toxicol Pathol 43:209-220

Kotthoff M, Muller J, Jurling H, Schlummer M, Fiedler D (2015) Perfluoroalkyl and polyfluoroalkyl substances in consumer products. Environ Sci Pollut Res Int 22:14546-14559

Krippner J, Brunn H, Falk S, Georgii S, Schubert S, Stahl T (2014) Effects of chain length and pH on the uptake and distribution of perfluoroalkyl substances in maize (Zea mays). Chemosphere 94:85-90

Kunacheva C, Tanaka S, Fuji S, Boontanon SK, Musirat C, Wongwattana T, Shivakoti BR (2011) Mass flows of perfluorinated compounds (PFCs) in central wastewater treatment plants of industrial zones in Thailand. Chemosphere 83:737-744

Kwok KY, Yamazaki E, Yamashita N, Taniyasu S, Murphy MB, Horii Y, Petrick G, Kallerborn R, Kannan K, Murano K, Lam PK (2013) Transport of perfluoroalkyl substances (PFAS) from an arctic glacier to downstream locations: implications for sources. Sci Total Environ 447:46-55

Lam JC, Lyu J, Kwok KY, Lam PK (2016) Perfluoroalkyl Substances (PFASs) in Marine Mammals from the South China Sea and Their Temporal Changes 2002-2014: Concern for Alternatives of PFOS? Environ Sci Technol 50:6728-6736

Landsteiner A, Huset C, Johnson J, Williams A (2014) Biomonitoring for perfluorochemicals in a Minnesota community with known drinking water contamination. J Environ Health 77:14-19

Langer V, Dreyer A, Ebinghaus R (2010) Polyfluorinated compounds in residential and nonresidential indoor air. Enivron Sci Technol 44:8075-8081

Lee I, Viberg H (2013) A single neonatal exposure to perfluorohexane sulfonate (PFHxS) affects the levels of important neuroproteins in the developing mouse brain. Neurotoxicology 37:190-196

Lee YJ, Choi SY, Yang JH (2014) PFHxS induces apoptosis of neuronal cells via ERK1/2-mediated pathway. Chemosphere 94:121-127

Lee YJ, Kim MK, Bae J, Yang JH (2013) Concentrations of perfluoroalkyl compounds in maternal and umbilical cord sera and birth outcomes in Korea. Chemosphere 90:1603-1609

Letcher RJ, Su G, Moore JN, Williams LL, Martin PA, de Solla SR, Bowerman WW (2015) Perfluorinated sulfonate and carboxylate compounds and precursors in herring gull eggs from across the Laurentian Great Lakes of North America: Temporal and recent spatial comparisons and exposure implications. Sci Total Environ 538:468-477

Leter G, Consales C, Eleuteri P, Uccelli R, Specht IO, Toft G, Moccia T, Budillon A, Jönsson BA, Lindh CH, Giwercman A, Pedersen HS, Ludwicki JK, Zviezdai V, Heederik D, Bonde JP, Spanò M. (2014) Exposure to perfluoroalkyl substances and sperm DNA global methylation in Arctic and European populations. Environ Mol Mutagen 55:591-600

Lindemann et al. (2012) Effects of per- and polyfluorinated compounds on adult rat testicular cells following in vitro exposure. Reprod Toxicol 33: 531-7.

Liu C, Du Y, Zhou B (2007) Evaluation of estrogenic activities and mechanism of action of perfluorinated chemicals determined by vitellogenin induction in primary cultured tilapia hepatocytes. Aquat Toxicol 85:267-277

Liu C, Yu L, Deng J, Lam PK, Wu RS, Zhou B (2009) Waterborne exposure to fluorotelomer alcohol 6:2 FTOH alters plasma sex hormone and gene transcription in the hypothalamic-pituitary-gonadal (HPG) axis of zebrafish. Aquat Toxicol 93:131-137

Liu W, Takahashi S, Sakuramachi Y, Harada KH, Koizumi A (2013) Polyfluorinated telomers in indoor air of Japanese houses. Chemosphere 90:1672-1677

Liu WX, He W, Qin N, Kong XZ, He Qs, Yang B, Yang C, Jorgensen SE, Xu FL (2015) Temporal-spatial distributions and ecological risks of perfluoroalkyl acids (PFAAs) in the surface water from the fifth-largest freshwater lake in China (Lake Chaohu). Environ Pollut 200:24-34

Liu X, Guo Z, Folk EE 4th, Roache NF (2015) Determination of fluorotelomer alcohols in selected consumer products and preliminary investigation of their fate in the indoor environment. Chemosphere 120:81-86

Long M, Ghisari M, Bonefeld-Jorgensen EC (2013) Effects of perfluoroalkyl acids on the function of the thyroid hormone and the aryl hydrocarbon receptor. Environ Sci Pollut 20:8045-8056

Long M, Knudsen AK, Pedersen HS, Bonefeld-Jørgensen EC (2015) Food intake and serum persistent organic pollutants in the Greenlandic pregnant women: The ACCEPT sub-study. Sci Total Environ 529:198-212

Lorenzo M, Campo J, Farre M, Perez F, Pico Y, Barcelo D (2016) Perfluoroalkyl substances in the Ebro and Guadalquivir river basins (Spain). Sci Total Environ 540:191-199

Lu Z, Song L, Zhao Z, Ma Y, Wang J, Yang H, Ma H, Cai M, Codling G, Ebinghaus R, Xie Z, Giesy JP (2015) Occurrence and trends in concentrations of perfluoroalkyl substances (PFASs) in surface waters of eastern China. Chemosphere 119:820-827

Lui B, Zhang H, Xie L, Li J, Wang X, Zhao L, Wang Y, Yang B (2015) Spatial distribution and partition of perfluoroalkyl acids (PFAAs) in rivers of the Pearl River Delta, southern China. Sci Total Environ 524-525:1-7

Maisonet M, Terrell ML, McGeehin MA, Christensen KY, Holmes A, Calafat AM, Marcus M (2012) Maternal concentrations of polyfluoroalkyl compounds during pregnancy and fetal and postnatal growth in British girls. Environ Health Perspect 120:1432-1437

Manzano-Salgado CB, Casas M, Lopez-Espinosa MJ, Ballester F, Basterrechea M, Grimalt JO, Jimenez AM, Kraus T, Schettgen T, Sunyer J, Vrijheid M (2015) Transfer of perfluoroalkyl substances from mother to fetus in a Spanish birth cohort. Environ Res 142:471-478

Maras et al. (2006) Estrogen-like properties of fluorotelomer alcohols as revealed by mcf-7 breast cancer cell proliferation. Environ Health Perspect 114:100-105.

Martin JW, Chan K, Mabury SA, O’Brien PJ (2009) Bioactivation of fluorotelomer alcohols in isolated rat hepatocytes. Chem Bio Interact 177:196-203

Meng J, Wang T, Wang P, Zhu Z, Li Q, Lu Y (2015) Perfluoroalkyl substances in Daling River adjacent to fluorine industrial parks: implication from industrial emission. Bull Environ Contam Toxicol 94:34-40

Mondal D, Weldon RH, Armstrong BG, Gibson LJ, Lopez-Espinosa MJ, Shin HM, Fletcher T. (2014) Breastfeeding: a potential excretion route for mothers and implications for infant exposure to perfluoroalkyl acids. Environ Health Perspect 122:187-92

Ochoa-Herrera V, Field JA, Luna-Velasco A, Sierra-Alvarez R (2016) Microbial toxicity and biodegradability of perfluorooctane sulfonate (PFOS) and shorter chain perfluoroalkyl and polyfluoroalkyl substances (PFASs). Environ Sci Process Impacts 18:1236-1246

Oda et al. (2007) Negative results of umu genotoxicity test of fluorotelomer alcohols and perfluorinated alkyl acids. Environ Health Perspect 12:217-9.

Oldham ED, Xie W, Farnoud AM, Fiegel J, Lehmler HJ (2012) Disruption of phosphatidylcholine monolayers and bilayers by perfluorobutane sulfonate. J Phys Chem B 116:9999-10007

Pan CG, Liu YS, Ying GG (2016) Perfluoroalkyl substances (PFASs) in wastewater treatment plants and drinking water treatment plants: Removal efficiency and exposure risk. Water Res 106: 562-570

Pan CG, Ying GG, Zhao JL, Liu YS, Jiang YX, Jiang YX, Zhang QQ (2014) Spatiotemporal distribution and mass loadings of perfluoroalkyl substances in the Yangtze River of China. Sci Total Environ 493:580-587

Perkola N, Sainio P (2013) Survey of perfluorinated alkyl acids in Finnish effluents, storm water, landfill leachate and sludge. Environ Sci Pollut Res Int (2013) 20:7979-7987

Rodriguez-Jorquera IA, Silva-Sanchez C, Strynar M, Denslow ND, Toor GS (2016) Footprints of Urban Micro-Pollution in Protected Areas: Investigating the Longitudinal Distribution of Perfluoroalkyl Acids in Wildlife Preserves. Water Res 11(2):e0148654. doi: 10.1371/journal.pone.0148654

Routti H, Krafft BA, Herzke D, Eisert R, Oftedal O (2015) Perfluoroalkyl substances detected in the world's southernmost marine mammal, the Weddell seal (Leptonychotes weddellii). Environ Pollut 197:62-67

Sanchez-Vidal A, Llorca M, Farre M, Canals M, Barcelo D, Puig P, Calafat A (2015) Delivery of unprecedented amounts of perfluoroalkyl substances towards the deep-sea. Sci Total Environ 526:41-48

Santen M, Brigden K, Cobbing M (2016) Leaving Traces: The hidden hazardous chemicals in outdoor gear. Greenpeace

Schlummer M, Gruber L, Fiedler D, Kizlauskas M, Muller J (2013) Detection of fluorotelomer alcohols in indoor environments and their relevance for human exposure. Environ Int 57-58:42-49

Shan G, Chen X, Zhu L (2015) Occurrence, fluxes and sources of perfluoroalkyl substances with isomer analysis in the snow of northern China. J Hazard Mater 299:639-646

Shao M, Ding G, Zhang J, Wei L, Xue H, Zhang N, Li Y, Chen G, Sun Y (2016) Occurrence and distribution of perfluoroalkyl substances (PFASs) in surface water and bottom water of the Shuangtaizi Estuary, China. Environ Pollut 216:675681

Shapiro GD, Dodds L, Arbuckle TE, Ashley-Martin J, Ettinger AS, Fisher M, Taback S, Bouchard MF, Monnier P Dallaire R, Morisset P, Dallaire R, Morisset AS, Fraser W (2016) Exposure to organophosphorus and organochlorine pesticides, perfluoroalkyl substances, and polychlorinated biphenyls in pregnancy and the association with impaired glucose tolerance and gestational diabetes mellitus: The MIREC Study. Environ Res. 147:71-81

Sharma BM, Bharat GK, Tayal S, Larssen T, Becanova J, Karaskova P, Whitehead PG, Futter MN, Butterfield D, Nizzetto L (2016) Perfluoroalkyl substances (PFAS) in river and ground/drinking water of the Ganges River basin: Emissions and implications for human exposure. Environ Pollut 208(PtB):704-713

Shiwaku Y, Lee P, Thepaksorn P, Zheng B, Koizumi A, Harada KH (2016) Spatial and temporal trends in perfluorooctanoic and perfluorohexanoic acid in well, surface, and tap water around a fluoropolymer plant in Osaka, Japan. Chemosphere 164:603-610

Shoeib M, Harner T, Vlahos P (2006) Perfluorinated Chemicals in the Arctic Atmosphere. Environ Sci Technol 40:7577-7583

Shoeib T, Hassan Y, Rauert C, Harner T (2016) Poly- and perfluoroalkyl substances (PFASs) in indoor dust and food packaging materials in Egypt: Trends in developed and developing countries. Chemosphere 144:1573-1581

Starling AP, Engel SM< Whitworth KW, Richardson DB, Stuebe AM, Daniels JL, Haug LS, Eggesbo M, Becher G, Sabaredzovic A, Thomsen C, Wilson RE, Travlos GS, Hoppin JA, Baird DB, Longnecker (2014) Perﬂuoroalkyl substances and lipid concentrations in plasma during pregnancy among women in the Norwegian Mother and Child Cohort Study. Environ Int 62:104-112

Stein CR, Savitz DA (2011) Serum perfluorinated compound concentration and attention deficit/hyperactivity disorder in children 5-18 years of age. Environ Health Perspect119:1466-1471

Stockholm Convention POPRC “Consolidated guidance on alternatives to perfluorooctane sulfonic acid and its related chemicals” (UNEP/POPS/POPRC.12/INF/15/Rev.1)

Stockholm Convention POPRC “General guidance on considerations related to alternatives and substitutes for listed persistent organic pollutants and candidate chemicals” (UNEP/POPS/POPRC.5/10/Add.1)

Stockholm Convention POPRC “Technical paper on the identification and assessment of alternatives to the use of perfluorooctane sulfonic acid, its salts, perfluorooctane sulfonyl fluoride and their related chemicals in open applications” (UNEP/POPS/POPRC.8/INF/17/Rev.1)

Takemine S, Matsumura C, Yamamoto K, Suzuki M, Tsurukawa M, Imaishi H, Nakano T, Kondo A (2014) Discharge of perfluorinated compounds from rivers and their influence on the coastal seas of Hyogo prefecture, Japan. Environ Pollut 184:397-404

Taylor KW, Hoffman K, Thayer KA, Daniels JL (2014) Polyfluoroalkyl chemicals and menopause among women 20-65 years of age (NHANES). Environ Health Perspect 122:145-150

Tian Z, Kim SK, Shoeib M, Oh JE, Park JE (2016) Human exposure to per- and polyfluoroalkyl substances (PFASs) via house dust in Korea: Implication to exposure pathway. Sci Total Environ 553:266-275

Toft G, Jönsson BA, Lindh CH, Giwercman A, Spano M, Heederik D, Lenters V, Vermeulen R, Rylander L, Pedersen HS, Ludwicki JK, Zviezdai V, Bonde JP (2012) Exposure to perfluorinated compounds and human semen quality in Arctic and European populations. Hum Reprod 27:2532-2540

Ulhaq M, Orn S, Carlsson G, Morrison DA, Norrgren L (2013) Locomotor behavior in zebrafish (Danio rerio) larvae exposed to perfluoroalkyl acids. Aquat Toxicol 144-145:332-340

Vanparys et al. (2006) Flow cytometric cell cycle analysis allows for rapid screening of estrogenicity in MCF-7 breast cancer cells. Toxicol. in vitro 20: 1238-48.

Verreault J, Houde M, Gabrielsen GW, Berger U, Haukås M, Letcher RJ, Muir DC (2005) Perfluorinated alkyl substances in plasma, liver, brain, and eggs of glaucous gulls (Larus hyperboreus) from the Norwegian arctic. Environ Sci Technol 39:7439-45.

Vestergren R, Herzke D, Wang T, Cousins IT (2015) Are imported consumer products an important diffuse source of PFASs to the Norwegian environment? Environ Pollut 198:223-230

Vicente J, Sanpera C, Garcia-Tarrason M, Perez A, Lacorte S (2015) Perfluoroalkyl and polyfluoroalkyl substances in entire clutches of Audouin's gulls from the Ebro Delta, Chemosphere 119 Suppl:S62-8. doi: 10.1016/j.chemosphere.2014.04.041.

Wan HT, Leung PY, Zhao YG, Wei X, Wong MH, Wong CK (2013) Blood plasma concentrations of endocrine disrupting chemicals in Hong Kong populations. J Hazard Mater 261:763-769

Wang J, Zhang Y, Zhang W, Jin Y, Dai J (2012) Association of perfluorooctanoic acid with HDL cholesterol and circulating miR-26b and miR-199-3p in workers of a fluorochemical plant and nearby residents. Environ Sci Technol 46:9274-9281

Wang N, Liu J, Buck RC, Korzeniowski SH, Wolstenholm BW, Folsom PW, Sulecki LM (2011) 6:2 fluorotelomer sulfonate aerobic biotransformation in activated sludge of waste water treatment plants. Chemosphere 82:853-858

Wang P, Lu Y, Wang T, Zhu Z, Li Q, Zhang Y, Fu Y, Xiao Y, Giesy JP (2015) Transport of short-chain perfluoroalkyl acids from concentrated fluoropolymer facilities to the Daling River estuary, China. Environ Sci Pollut Res Int 22:9626-9636

Wang X, Halsall C, Codling G, Xie Z, Xu B, Zhao Z, Xue Y, Ebinghaus R, Jones KC (2014) Accumulation of perfluoroalkyl compounds in tibetan mountain snow: temporal patterns from 1980 to 2010. Environ Sci Technol 48:173-181

Wang Z, Ud-Daula A, Fiedler S, Schramm KW (2010) Impact of fluorotelomer alcohols (FTOH) on the molecular and macroscopic phenotype of Tetrahymena thermophile. Environ Sci Pollut Res Int 17:154-164

Wang Z, Xie Z, Mi W, Moller A, Wolschke H, Ebinghaus R (2015) Neutral Poly/Per-Fluoroalkyl Substances in Air from the Atlantic to the Southern Ocean and in Antarctic Snow. Environ Sci Technol 49:7770-7775

Webster GM, Rauch SA, Ste Marie N, Mattman A, Lanphear BP, Venners SA (2016) Cross-Sectional Associations of Serum Perfluoroalkyl Acids and Thyroid Hormones in U.S. Adults: Variation According to TPOAb and Iodine Status (NHANES 2007-2008). Environ Health Perspect. 124:935-942

Yamada A, Bemrah N, Veyrand B, Pollono C, Merlo M, Desvignes V, Sirot V, Oseredczuk M, Marchand P, Cariou R, Antignac JP, Le Bizec B, Leblanc JS (2014) Perfluoroalkyl acid contamination and polyunsaturated fatty acid composition of French freshwater and marine fishes. J Agric Food Chem 62:7593-7603

Yang L, Wang Z, Shi Y, Li J, Wang Y, Zhao Y, Wu Y, Cai Z (2016) Human placental transfer of perfluoroalkyl acid precursors: Levels and profiles in paired maternal and cord serum. Chemosphere 144:1631-1638

Yeung LW, De Silva AO, Loi El, Marvin CH, Taniyasu S, Yamashita N, Mabury SA, Muir DC, Lam PK (2013) Perfluoroalkyl substances and extractable organic fluorine in surface sediments and cores from Lake Ontario. Environ Int 59:389-397

Yu N, Shi W, Zhang B, Su G, Feng J, Zhang X, Wei S, Yu H (2013) Occurrence of perfluoroalkyl acids including perfluorooctane sulfonate isomers in Huai River Basin and Taihu Lake in Jiangsu Province, China. Environ Sci Technol 47:710-717

Yuan G, Peng H, Huang C, Hu J (2016) Ubiquitous Occurrence of Fluorotelomer Alcohols in Eco-Friendly Paper-Made Food-Contact Materials and Their Implication for Human Exposure. Environ Sci Technol 50:942-950

Zafeiraki E, Costopoulou D, Vassiliadou I, Leondiadis L, Dassenakis E, Traag W, Hoogenboom RL, van Leeuwen SP (2015) Determination of perfluoroalkylated substances (PFASs) in drinking water from the Netherlands and Greece. Food Addit Contam Part A Chem Anal Control Expo Risk Asses 32:2048-2057

Zhang Tao, Sun H, Lin Y, Qin X, Zhang Y, Gen X, Kannan K (2013) Distribution of poly- and perfluoroalkyl substances in matched samples from pregnant women and carbon chain length related maternal transfer. Environ Sci Technol 47:7974-7981

Zhang Y, Lai S, Zhao Z, Liu F, Chen H, Zou S, Xie Z, Ebinghaus R (2013) Spatial distribution of perfluoroalkyl acids in the Pearl River of southern China. Chemosphere 93:1519-1525

Zhao S, Fang S, Zhu L, Liu L, Liu Z, Zhang Y (2014) Mutual impacts of wheat (Triticum aestivum L.) and earthworms (Eisenia fetida) on the bioavailability of perfluoroalkyl substances (PFASs) in soil. Environ Pollut 184:495-501

Zhao Z, Xie Z, Möller A, Sturm R, Tang J, Zhang G, Ebinghaus R (2012) Distribution and long-range transport of polyfluoroalkyl substances in the Arctic, Atlantic Ocean and Antarctic coast, Environ Pollut170:71-77

Zhou Y, Hu LW, Qian ZM, Chang JJ, King C, Paul G, Lin S, Chen PC, Lee YL, Dong GH (2016) Association of perfluoroalkyl substances exposure with reproductive hormone levels in adolescents: By sex status..Environ Int 94:189-195

Zhou Z, Shi Y, Li W, Xu L, Cai Y (2012) Perfluorinated compounds in surface water and organisms from Baiyangdian Lake in North China: source profiles, bioaccumulation and potential risk, Bull Environ Contam Toxicol 89:519-524

Zhu Z, Wang T, Meng J, Wang P, Li Q, Lu Y (2015) Perfluoroalkyl substances in the Daling River with concentrated fluorine industries in China: seasonal variation, mass flow, and risk assessment. Environ Sci Pollut Int 22:100009-100018

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1. Vestergren et al., Are imported consumer products an important diffuse source of PFASs to the Norwegian environment? *Environmental Pollution*. 2015; 198, 223-30. [↑](#footnote-ref-1)
2. Paustenbach et al 2007 A methodology for estimating human exposure to perfluorooctanoic acid (PFOA) : a retrospective exposure assessment of a community (1951-2003). *J Toxicol Environ Health* 70 :28-57. [↑](#footnote-ref-2)
3. Jack Thompson, Geoff Eaglesham, Jochen Mueller (2011) Concentrations of PFOS, PFOA and other perfluorinated alkyl acids in Australian drinking water. *Chemosphere*, Vol. 83/10, 1320–1325 [↑](#footnote-ref-3)
4. Thompson J, Eaglesham G, Reungoat J, Poussade Y, Bartkow M, Lawrence M, Mueller JF (2011) Removal of PFOS, PFOA and other perfluoroalkyl acids at water reclamation plants in South East Queensland Australia, *Chemosphere* Vol 82: 9–17 [↑](#footnote-ref-4)
5. Perfluorinated Compounds (PFCs) in Landfill leachate, <http://www.alsglobal.com/~/media/Files/Divisions/Life%20Sciences/Environmental/Environmental%20Resources/Australia/Enviromail%20Technical%20Newsletters/EnviroMail-86-Perfluorinated-Compounds-PFCs-in-the-Landfill-leachate-February-2015.pdf> [↑](#footnote-ref-5)
6. Stage 3 Risk Assessment and Remediation Design at Army Aviation Centre Oakey Remediation Action Plan - Perfluorocarbons in Groundwater, June 2013 Department of Defence. Available at <http://www.defence.gov.au/id/_Master/docs/Oakey/0207AACOakey2013EI2-RAP-PFOSGroundwater-PBJun2013.pdf> [↑](#footnote-ref-6)
7. Defence per- and poly-fluoroalkyl Substances (PFAS) environmental Management Preliminary Sampling Program, final Report September 2016, Jones Lang LaSalle, GHD, Available at http://www.defence.gov.au/ID/PFOSPFOA/\_master/docs/PSPReports/PreliminarySamplingProgramReportMainReportLessAppendices.pdf [↑](#footnote-ref-7)
8. Stage 2C Environmental Site Assessment, Army Aviation Centre Oakey, Dept. of Defence 26 July 2016: <http://www.defence.gov.au/id/_Master/docs/Oakey/0207AACOakeyEI2-2016Stage2C-ESAFullReport.pdf> [↑](#footnote-ref-8)
9. Air Services Australia, Gold Coast Airport Preliminary Site Investigation 2016 <http://www.airservicesaustralia.com/wp-content/uploads/251713_Final_PSI-Report.pdf> [↑](#footnote-ref-9)
10. Airservices Australia, *Submission 113 to the* The Senate Foreign Affairs, Defence and Trade References Committee, Firefighting foam contamination Part B – Army Aviation Centre Oakey and other Commonwealth, state and territory sites, p. 4. [↑](#footnote-ref-10)
11. Comment by IPEN. [↑](#footnote-ref-11)