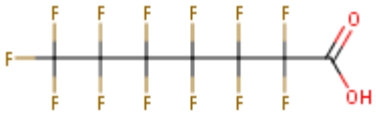
Updated EHS Summary of Perfluoroheptanoic acid for the MA TURA Science Advisory Board Meeting – September 12, 2018

CAS # 375-85-9 	**Perfluoroheptanoic acid** **Synonym[1]s:** Tridecafluoro-1-heptanoic acid; Tridecafluoroheptanoic acid; HSDB 8293 **RTECS #[2]: MJ2415000** **EINECS #[3]: 206-798-9** **Molecular Weight[4]**: 364.0569 **Molecular Formula[5]:** C7-H-F13-O2 **Related CAS #'s:** ***20109-59-5 (hydrochloride salt);*** 6130-43-4 (ammonium salt)
PHYSICAL CHARACTERISTICS	
Primary Use	Long-chain perfluoroalkanecarboxylic acids and their salts are surface-active chemicals (surfactants), which greatly reduce the surface tension (surface energy) of water, aqueous solutions, and organic liquids even at low concentrations. These acids (C6- C12) and derivatives are used as wetting, dispersing, emulsifying, and foaming agents. /Long-chain perfluoroalkanecarboxylic acids/[6]
Physical state, odor at room temperature & pressure	Beige crystalline solid[7]; Low melting solid[8]
Melting point; Boiling point	30 deg C[9]; 175 deg C[10]
Solubility	In water, 3.65 mg/L at 25 deg C (est)[11]; 4.37x10[5] mg/L at 25 deg C (Kwan 2001, as cited in ATSDR 2018)[12]; "Neutral or uncharged perfluoroalkyls or very long chain constituents are expected to form separate layers when mixed with hydrocarbons and water. Conversely, charged species, salts, and ionized species at relevant pH (i.e., PFOS, PFOA, PFHpA, PFNA) and short-chain species (i.e., PFBA, PFBuS) have relatively good solubility in water and alcohol."(ATSDR 2018)[13]
Specific Gravity	1.792 g/cu cm at 20 deg C/4 deg C[14]
SAFETY/PHYSICAL HAZARDS	
Vapor Pressure	0.133 mm Hg at 25 deg C[15]
Flammability	Not found
Flashpoint	> 113.00 deg C (> 235.40 deg F) - closed cup[16]
Flammability Rating	Not available
Auto Ignition Point	Not found
Combustion products	Carbon oxides, Hydrogen fluoride[17]
Explosivity (UEL, LEL, shock sensitive)	Not found
Oxidizer	Not found
Corrosivity	
pH	pKa = -2.29 (est)[18]; -0.15 (estimated)[19]

Reactivity	Incompatible materials: Strong oxidizing agents[20]
Viscosity	Not found
Odor Threshold	Not found
Particle size, shape, respirable fraction	Not found
Other physical hazards associated with process: Heat, gases under pressure, noise, vibration, ergonomic hazard	Not found
HEALTH HAZARDS	
Acute Toxicity	
Oral LD_{50}	"An acute lethal dose of 670 mg/kg bw has been reported for PFHpA. Rats were administered the undiluted liquid in doses ranging from 300 to 3,375 mg/kg. Necrosis of the stomach was observed in animals which died (unpublished study provided by Dupont Co.)."[21]
Dermal LD_{50}	Not found
Inhalation LC_{50}	Not found
Intraperitoneal LD_{50}	Not found
Chronic or Sub-chronic Toxicity	
IARC rating	Not found in the IARC database as of 05/17/18
Carcinogenicity	Not found in the CCRIS database
Neurotoxicity	Not found in Haz-Map
Developmental/Reproductive Toxicity	Not found on the Prop 65 List as of 05/17/18 "Plasma concentrations of perfluoroheptanoic acid (PFHpA), perfluorohexane sulfonic acid (PFHxS) and perfluorononanoic acid (PFNA) were inversely associated with endometriosis-related infertility, but the associations were attenuated in the sensitivity analyses (Wang et al 2017)."[22] See Ecological Toxicity box below – Kim et al 2015
Genotoxicity/Mutagenicity	"This is the first report of the effects of perfluorinated acids on the activity of purified enzymes. The results show these compounds have a very low acute biological activity. The observed effective concentrations lie in the millimole range, which is well above probable intracellular concentrations. A relationship was found between the toxicity of the perfluorinated carboxylic acids and the perfluorocarbon chain length: in every test system applied, the longer the perfluorocarbon chain, the more toxic was the acid. The lowest effective concentrations were thus recorded for perfluorononanoic and perfluorodecanoic acids (Mulkiewicz et al 2007)."[23]

	"A chain length-EC_{50} dependence has been clearly observed. Estimated values of EC_{50} decreased with elongation of fluorocarbon chain (PFHxA > PFHpA > PFOA > PFNA > PFDA > PFDoA > PFTeDA). Further elongation (C16 and C18) did not deepen the effect but even partially reversed it. The effect was intensified after longer exposure (72 h);… (Kleszczyński 2007)."[24] "The results of our study clearly demonstrate that inductions of stress responsive genes occur for the different compounds and confirm some of the known mechanisms of work for well studied compounds like PFOA and PFOS, and in addition provide new information for less studied compounds. Few inductions were observed after exposure to the low carbon number carboxylic acids, … PFHpA (CF(3)(CF(2))(5)C(O)O(-)) at equimolar concentrations (0.0156-1 mM). …. Overall, the effects seen at the level of gene expression were higher for the sulfonic acids than for the carboxylic acids, but the effect of the chain length is more important than the effect of the functional group (Nobels et al 2010)."[25]
Endocrine Disruption	Added to TEDX List 5/5/11 (information updated 12/6/17)
Thyroid	Bloom 2010 – No values exceeded the LOD, so the substance was not considered further in this paper.
Immunotoxicity	"**Epidemiology Studies**. In general, the two available human immunotoxicity studies did not find associations between serum PFHpA levels and diphtheria or tetanus antibody levels in adults (Kielsen et al. 2016) or risk of asthma diagnosis, eczema, or wheezing in children (Smit et al. 2015). The Smit et al. (2015) study did find an inverse association between maternal PFHpA levels and current wheezing in one subcohort; however, this was not observed in the other subcohort with higher mean maternal PFHpA levels."(ATSDR 2018)[26]
Other organ toxicity	"Wolf et al. (2012) showed an increase in activity of human and mouse PPARa, in vitro with PFHpA (NICNAS 2018)".[27] "Various studies have investigated the effects of PFHpA on liver enzymes. The maximum induction of peroxisomal beta-oxidation was assessed in Wistar rats (Kudo et al., 2000). A slight, but significant increase in liver beta-oxidation was induced by treatment with 160 mg/kg PFHpA, while a significant increase in liver beta-oxidation was detected following 10 mg/kg PFOA. The potency of induction of hepatomegaly, peroxisomal beta-oxidation and microsomal 1-acylglycerophosphocholine acyltransferase in the liver was investigated in mice (Kudo et al., 2006). Similarly to all PFCAs tested, PFHpA induced hepatomegaly and peroxisomal beta-oxidation. The potency of these effects is reported to increase with increasing chain length. The doses

	required to induce an approximately 1.7-fold increase in liver weight relative to body weight in male mice were >150, 50, 5, and 5 mg/kg for PFHxA, PFHpA, PFOA and perfluorononanoic acid (PFNA), respectively. Fischer-344 (F344) rats treated with PFHpA (150 mg/kg) showed no increase in hepatic peroxisomal fatty acyl CoA-oxidase (FAO) activity (an indicator of peroxisome induction) on days three or five post-treatment (Goecke-Flora & Reo, 1996). In Wistar rats, the activity of peroxisomal beta-oxidation was not affected at doses up to 30 mg/kg body weight in either male or female rats (Kudo & Kawashima, 2003). Peroxisomal beta-oxidation induction is considered to depend only on the number of PFCA molecules in hepatocytes, rather than the difference in their chemical structures (Kudo & Kawashima, 2003; Kudo et al., 2006)(NICNAS 2018)".[28] Mattsson et al. (2015) found an increase in the risk of coronary artery disease in individuals with serum PFHpA levels in the 3rd quartile; however, the risk was not increased for those with serum levels in the 4th quartile (ATSDR 2018).[29] "Evidence from acute, intermediate, and/or chronic oral studies in rats, mice, and monkeys indicates that the liver is a sensitive target of …PFHpA toxicity. The effects include increases in liver weight, hepatocellular hypertrophy, and decreases in serum lipid levels. The effects were considered specific to rodents and were not considered relevant to humans. Some degenerative and necrotic effects that are likely relevant to humans have also been observed for PFOA, PFOS, and PFHpA"(ATSDR 2018).[30] "Epidemiology Studies—Serum Lipids. Epidemiology data on PFHpA are limited to a study in adults conducted by Fu et al. (2014a), which found no associations between serum PFHpA and total cholesterol, LDL cholesterol, HDL cholesterol, or triglyceride levels."(ATSDR 2018)[31] "Overall, the epidemiology studies do not provide support for an association between serum perfluoroalkyl levels and increases in the risk of diabetes or related outcomes (e.g., increases in blood glucose, glucose tolerance) for …PFHpA, …"(ATSDR 2018)[32] "Epidemiology Studies. Lind et al. (2014) did not find associations between serum PFHpA levels and the risk of diabetes or HOMA alterations."(ATSDR 2018)[33]
Skin, Eye and Respiratory Effects	
*Irritant – **S**kin, **E**ye, or **R**espiratory*	"…skin irritant and/or corrosive effects cannot be ruled out for PFHpA"(NICNAS 2018).[34]
*Corrosive – **S, E, or R***	Corrosive as concentrated acid; pKa = -2.29 (est)[35]
*Permanent Damage – **S, E, or R***	Not found
*Sensitizer– **S** & **R***	Not found in AOEC database

Asthmagen – Initiator or Exacerbator	Not found in AOEC database; "Nearly all study participants had detectable serum concentrations of all PFCs (>94% of PFCs) except for PFDoA (84.4% in children with and without asthma) and PFHpA (53.3% in unasthmatic children, and 70.6% in asthmatic children) (Table 2). Because of the large numbers of samples below the LOQ, we did not conduct further analyses of PFHpA (Dong et al 2013)".[36]
Skin Absorption, Kp	Not found
LOAEL	
NOAEL	
Benchmark Dose Response (BMD)	
Toxicokinetics	"5:3 acid [F(CF2)5CH2CH2COOH] was the most abundant metabolite for 6:2 FTI (3.3-6.3 mol%) and 6:2 FTOH (9-12 mol%). Perfluorobutanoic acid (PFBA), perfluoropentanoic acid (PFPeA), and perfluorohexanoic acid (PFHxA) in sum accounted for 1.3-2.2 mol% from 6:2 FTI and 2.7-4.4 mol% from 6:2 FTOH biotransformation. Perfluoroheptanoic acid (PFHpA) accounted for 0.14-0.36 mol% from 6:2 FTI but only 0.01-0.06 mol% from 6:2 FTOH biotransformation. These results suggest that mammalian systems exposed to 6:2 FTI or 6:2 FTOH would form 5:3 acid, PFBA, PFPeA, PFHxA as the primary stable metabolites, whereas more PFHpA would be expected from 6:2 FTI biotransformation (Ruan et al 2014)."[37] "In a one-day inhalation study of 6:2 FTOH in rats, PFBA, PFHxA, PFHpA and 5:3 Acid were determined to be the major metabolites in plasma with calculated elimination half-lives of 1.3-15.4h and metabolic yields up to 2.7 mol%. In five-day and 23-day inhalation studies and a 90-day oral study of 6:2 FTOH, the plasma or serum concentration profile of 5:3 Acid was several-fold higher than concentrations observed in the single day study, resulting in an estimated elimination half-life of 20-30 d. In contrast, the concentrations of PFBA, PFHxA and PFHpA showed little or no concentration increase with repeated exposure. Elimination half-lives of PFHxA, PFHpA and 5:3 Acid in humans were estimated from a study of professional ski wax technicians who were occupationally exposed to aerosolized and volatilized components of fluorinated glide wax. The resulting human elimination half-life values of PFHxA, **PFHpA** and 5:3 Acid were 32, **70** and 43 d, respectively. Based on a one compartment toxicokinetic model, current environmental air concentrations of 6:2 FTOH are estimated to result in plasma concentrations of PFHxA, PFHpA and 5:3 Acid that are less than or equal to typical LOQ values, in agreement with extant biomonitoring results (Russell et al 2015)."[38]

	"The mouse experiment showed that short-chained PFCAs (C6 and C7) were rapidly eliminated in the urine, whereas long-chain PFCAs (C8 to C14) accumulated in the liver and were excreted slowly in feces. Urinary clearance of PFCAs in humans also decreased with increasing alkyl chain lengths, while biliary clearances increased. C9 to C10 had the smallest total clearance for both mice and humans. However, disparities existed in the magnitude of the total clearance between mice and humans. A slightly higher partition ratio (brain/serum) was observed for long-chained PFCAs in mice, but this was not observed in the corresponding partition ratio in humans (CSF/serum) (Fujii et al 2015)."[39] "The half-life for PFHpA in female and male rats was reported as 1.2 and 2.4 hours, respectively, compared with 5.63 and 0.08 days for PFOA (Ohmori et al., 2003)."[40] "In studies in mice and rats, PFHpA was shown to be rapidly eliminated in the urine. Total clearance in animals and humans decreases with increasing chain length, with the clearance rate for PFHpA higher than PFOA, but lower than PFHxA (Han et al., 2012; Fujii et al. 2015). Following intraperitoneal (i.p.) injection in Wistar rats, 92 % of a PFHpA dose was rapidly eliminated in urine within 120 hours after dosing (Kudo et al., 2001). Similar results were seen in NJcl mice administered PFHpA intravenously (i.v.) or by gavage. When administered intravenously, the chemical was rapidly and almost completely eliminated in the urine after 24 hours (99 % for males and 66 % for females) and only a small amount was excreted in faeces (3 % for males and 13 % for females). Gavage-administered animals showed similar clearance patterns to i.v. administered animals (Fujii et al., 2015)(NICNAS 2018)".[41] Summary elimination half-life in humans: PFHpA – Human (n=66), >50 years, M, F = 1.2 years (SE 0.2, GM 0.82); Human (n=20), ≤50 years, F = 1.5 years (SE 0.3, GM 1.0)(Zhang et al 2013[a])(ATSDR 2018)[42]
Metabolites	
Synergistic or Antagonistic Effects	
Environmental and Human Health Exposure and Risk Values	
RfC/RfD	Not in IRIS database as of 05/18/18
ATSDR-MRL	Not on list as of 05/18/18; ATSDR Draft Toxicological Profile notes; "There are insufficient data for derivation of acute-duration inhalation, intermediate-duration inhalation, or chronic-duration inhalation MRLs for PFHpA – Rationale for not deriving MRLs: No inhalation studies in

	laboratory animals were identified for PFHpA".; "There are insufficient data for derivation of acute-duration, intermediate-duration, or chronic-duration oral MRLs for PFHpA - Rationale for Not Deriving MRLs: No oral studies in laboratory animals were identified for PFHpA."(ATSDR 2018)[43]
Adverse Effect Levels: DNEL, PNEC, PNEL	
Health Based Exposure Limits	
NIOSH-REL/IDLH/Ceiling Limits	None exist
OSHA-PEL	None exist
ACGIH TLV-TWA	None exist
TLV-STEL	None exist
Biomonitoring Action Limits	Connecticut DPH set a drinking water Action Level for private wells in 2016 for PFAS that is the same as the EPA Health Advisory (70 ppt) but has added three additional PFAS (PFNA, PFHxS, PFHpA) to the group. The sum of this group of 5 PFAS must be below the target concentration of 70 ppt. These additional PFAS have produced some of the same health effects as PFOS and PFOA (CT DPH 2017).[44]
Drinking Water Standards	
Other	Monitoring requirements for unregulated contaminants: Contaminant, perfluoroheptanoic acid; Minimum reporting level, 0.01 ug/L; Period during which monitoring to be completed, 1/1/2013-12/31/2015.[45] ECHA CLP Database (non-harmonized classifications): H302 – Acute Tox. 4; H314 – Skin Corr. 1B; H290 - Met. Corr. 1; H314 – Skin Corr. 1C; H318 – Eye Dam. 1.[46]
ENVIRONMENTAL & ECO-SYSTEM HAZARDS	
PBT	**Presence in the environment:** "PFOS, PFOA, PFHxS, PFHpA [Median concentration in dust: 10 – 97.3 ng/g] and PFNA were found in all of the vacuum dust samples and dust from eight homes contained all 16 PFCs included in our analysis (Knobeloch et al 2012)."[47] "Among samples with detectable PFAS levels, each additional military site within a watershed's eight-digit hydrologic unit is associated with a 20% increase in PFHxS, a 10% increase in both PFHpA and PFOA, and a 35% increase in PFOS (Hu et al 2016)."[48]
Bioaccumulation	Perfluorinated chemicals have been observed to bioaccumulate by binding to proteins in plasma and liver, rather than the more conventional partitioning to fatty tissue (Ng and Hungerbuhler 2014).[49] "Ericson et al. (2008b) analyzed 14 PFCs in drinking water (tap and bottled) from Tarragona Province (Catalonia, Spain). In 2007, municipal

	drinking (tap) water was obtained in public fountains of the three most populated towns in Tarragona Province. The bottled water samples from four commercial companies, whose water spring has different origins, were purchased from a supermarket. This is, to the best of our knowledge, the first study in which bottled water was analyzed. The PFC levels in tap water varied among the four places. In the Valls sample, the highest PFC levels were found; PFHpA (3.02 ng/L), PFOS (0.44 ng/L), and PFOA (6.28 ng/L)(D'Hollander et al 2010)."[50] "Perfluoroalkyl and polyfluoroalkyl substances (PFASs) are commonly used in industrial applications and consumer products, and their potential health impacts are of concern, especially for vulnerable population like fetuses. However, in utero exposure to PFASs and health implications are far from fully characterized in China. To fill in the gap, we analyzed 10 PFASs in cord plasma samples (N=687) collected in Shanghai between 2011 and 2012, one of the regions widely polluted with PFASs in China. A questionnaire survey on maternal and diet-related factors was conducted. Except for perfluoroheptanoic acid (PFHpA) [detected in 30% of the samples] and perfluorooctane sulfonamide (PFOSA), all other PFASs were detected in >90% of the samples (Wang et al 2016c)."[51] *Percent detection and level of PFHpA in:* **U.S. NHANES (ages 12-19)(**various years from 1999-2010 – see Table 5-25 in ATSDR draft profile): 6.2 (Geometric mean <0.3 ng/mL) - 10%. **Percent detection not specified for the adolescent age group samples. Percentage listed here is for the total sample population. **U.S. children (ages 2-12)(**1994-1995): Not detected above LLOQ. **Umbilical Cord Serum** (Baltimore): 2% >LOD, Min = <0.4 ng/mL, Max= 2.6 ng/mL. (Japan): Not detected. **Breast Milk** (MA): <1% >LOQ, Min = <0.010 ng/mL, Max = 0.0234 ng/mL. Not detected in study from Sweden. **Maternal Serum** (China): 37% > LOD, Min = <0.005 ng/mL, Max = 0.0067 ng/mL. Not detected in study from Sweden. **For additional information see ATSDR draft profile pages 616-620 (ATSDR 2018).[52]** "PFHpA was detected in pizza and microwave popcorn at 1.5–2.0 ng/g, wet weight. (ATSDR 2018)"[53]

	"there is evidence that PFHpA bioaccumulates in earthworms (Zhao et al., 2013[c]) and humans (Freberg et al., 2010, Nilsson et al., 2010) with a geometric mean elimination half-life in ski-wax technicians of 98 day (range 23 to 599 days). In addition, it has also been shown that PFHpA is maternally transferred in polar bears (Bytingsvik et al., 2012) and humans (Zhang et al., 2013b). In contrast, trophic magnification of PFHpA was investigated but not observed in an artic (Kelly et al., 2009), a subtropical pelagic (Loi et al., 2011), nor a remote terrestrial (Muller et al., 2011) food web. Also, there are human maternal transfer studies that did not detect PFHpA in maternal and/or cord blood (Monroy et al., 2008, Kim et al., 2011, Gutzkow et al., 2012). Thus, data from public literature on the bioaccumulation potential of PFHpA are equivocal, and at this moment it is too premature to conclude upon the B-criterion." (ECHA 2015a)[54] In earthworm study, $BSAF_{kinetic}$ =0.122 ± 0.006 (g_{oc}/g_{dw}); BSAF measured based on wet wt of organisms at three exposure concentrations: at 100 ng/g: 0.040 ± 0.023; at 200 ng/g: 0.019 ± 0.002; at 500 ng/g: 0.008 ± 0.001. "According to our study, PFHxA, PFHpA, PFOA, PFBS and PFHxS, which have seven or less fluorinated carbons, displayed distinct bioaccumulative ability. This could be due to the active ingestion of soil through the gut and the high protein content of the earthworms. (Zhao et al 2013)"[55] In Zhang, et al, 2013, a coefficient, T_{MB-CB} was calculated to indicate maternal transfer efficiency of each PFAS between maternal blood and cord blood. A U-shaped trend was observed for PFCAs: "the highest T_{MB-CB} among all the measured PFCAs was for PFHpA (C7). A descending trend in T_{MB-CB} was observed with the increasing carbon chain length from PFHpA (C7) to PFDA (C10); the T_{MB-CB} reached a minimum value for PFDA (C10, T_{MB-CB} = 0.25), and then increased with the increasing carbon chain length from PFDA (C10) to PFDoDA (C12)".[56] Phytoaccumulation – PFHpA, PFOA, PFNA and PFBS were taken up by yam root, maize cob and sugarcane stem (Dalahmeh et al 2018).[57] "In blood of the Gdańsk Coast inhabitants…PFHpA, were found (Falandysz 2006 – Article in Polish)." Effects of perfluorobutanesulfonic acid (PFBS), perfluorohexanesulfonic acid (PFHxS), perfluorononanoic acid (PFNA), and perfluoroheptanoic acid (PFHpA) on earthworms (Eisenia fetida) in soils contaminated with

	these compounds at 0.1, 1, 10, 1,000, and 100,000 µg kg-1 dry weight, covering concentration levels found in background, biosolid-amended, and facility-surrounding soils, were investigated. Earthworms were exposed to spiked soil for 21 days. Concentrations of these compounds in earthworms after 21-d exposure ranged from below detection to 127 mg kg-1 wet weight with the rank order of PFNA > PFHxS > PFHpA > PFBS; no mortality of earthworms was observed in all treatments including controls, except PFBS at 1,000 µg kg-1 and all PFASs at 100,000 µg kg-1. The highest weight loss (29%) was observed for earthworms exposed to PFNA at 100,000 µg kg-1, which was significantly different from all other treatments except PFHpA at 100,000 µg kg-1. These results are expected to fill some data gaps in toxicity of PFASs in terrestrial environments and provide helpful information on the potential for trophic transport of PFASs from soil to higher organisms (Karnjanapiboonwong 2018).[58]
BAF	Aquatic food web study, estuary of Ariake Sea, Japan log BAF = 2.1 ± 0.3 (Kobayashi et al 2018)[59]
BCF	
BMF	
Ecological Toxicity	"The present study assessed the transactivation potencies of the Baikal seal (*Pusa sibirica*) peroxisome proliferator-activated receptor α (BS PPARα) by perfluorochemicals (PFCs) having various carbon chain lengths (C4-C12) using an in vitro reporter gene assay. Among the twelve PFCs treated with a range of 7.8-250 µM concentration, eight perfluoroalkyl carboxylates (PFCAs) and two perfluoroalkyl sulfonates (PFSAs) induced BS PPARα-mediated transcriptional activities in a dose-dependent manner. To compare the BS PPARα transactivation potencies of PFCs, the present study estimated the PFOA induction equivalency factors (IEFs), a ratio of the 50% effective concentration of PFOA to the concentration of each compound that can induce the response corresponding to 50% of the maximal response of PFOA. The order of IEFs for the PFCs was as follows: PFOA (IEF: 1)>PFHpA (0.89)>PFNA (0.61)>PFPeA (0.50)>PFHxS (0.41)>PFHxA (0.38)≈PFDA (0.37)>PFBA (0.26)=PFOS (0.26)>PFUnDA (0.15)≫PFDoDA and PFBuS (not activated). The structure-activity relationship analysis showed that PFCAs having more than seven perfluorinated carbons had a negative correlation (r=-1.0, p=0.017) between the number of perfluorinated carbons and the IEF of PFCAs, indicating that the number of perfluorinated carbon of PFCAs is one of the factors determining the transactivation potencies of the BS PPARα. The analysis also indicated that PFCAs were more potent than PFSAs with the same number of

	perfluorinated carbons. Treatment with a mixture of ten PFCs showed an additive action on the BS PPARα activation. Using IEFs of individual PFCs and hepatic concentrations of PFCs in the liver of wild Baikal seals, the PFOA induction equivalents (IEQs, 5.3-58 ng IEQ/g wet weight) were calculated. The correlation analysis revealed that the hepatic total IEQs showed a significant positive correlation with the hepatic expression levels of cytochrome P450 4A-like protein (r=0.53, p=0.036). This suggests that our approach may be useful for assessing the potential PPARα-mediated biological effects of complex mixtures of PFCs in wild Baikal seal population (Ishibashi et al 2011)."[60] "Whole-mount in situ hybridization, reverse transcriptase-polymerase chain reaction (RT-PCR), and histologic analyses detected severe defects in the liver and heart following exposure to PFHxA or PFHpA. In addition, immunoblotting revealed that PFHpA significantly increased the phosphorylation of extracellular signal-regulated kinase (ERK) and c-Jun N-terminal kinase (JNK), while PFHxA slightly increased these, as compared with the control. These results suggest that PFHxA and PFHpA are developmental toxicants and teratogens, with PFHpA producing more severe effects on liver and heart development through the induction of ERK and JNK phosphorylation (Kim et al 2015)."[61] "Earthworms were exposed to spiked soil for 21 days. Concentrations of these compounds in earthworms after 21-d exposure ranged from below detection to 127 mg kg-1 wet weight with the rank order of PFNA > PFHxS > PFHpA > PFBS; no mortality of earthworms was observed in all treatments including controls, except PFBS at 1,000 µg kg-1 and all PFASs at 100,000 µg kg-1. The highest weight loss (29%) was observed for earthworms exposed to PFNA at 100,000 µg kg-1, which was significantly different from all other treatments except PFHpA at 100,000 µg kg-1 (Karnjanapiboonwong et al 2018)."[62]
Aquatic Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC	EC_{50}; Species: *Geitlerinema amphibium* (Blue-green Algae) Exponential Growth Phase BA-13; Conditions: saltwater, static, 20 deg C, pH 7.6-7.8; Concentration: 1.42 mM for 72 hr; Effect: decreased population growth /formulation/[63] EC_{50}; Species: *Skeletonema marinoi* (Diatom) Exponential Growth Phase BA-98; Conditions: saltwater, static, 20 deg C, pH 7.6-7.8; Concentration: 2.4 mM for 72 hr; Effect: decreased population growth /formulation/[64] EC_{50}; Species: *Chlorella vulgaris* (Green Algae) Exponential Growth Phase BA-02; Conditions: saltwater, static, 20 deg C, pH 7.6-7.8; Concentration: 5.21 mM for 72 hr; Effect: decreased population growth

	/formulation/[65] LC_{50} = 108.6 mg/L/48H (other fish)[66]
Mammalian Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC	
Wildlife Toxicity: LC_{50}, EC_{50}, ErC_{50}, NOAEC/NOEC	
Breakdown/degradation /combustion products	
Anaerobic degradation	
Aerobic degradation	
Other observable ecological effects (e.g. BOD)	
Fate and Transport: Aquatic	"Of the PFCs measured, PFOS, PFHxS, PFBS, PFPrS, PFEtS, PFOSA, N-EtFOSAA, PFDoDA, PFUnDA, PFDA, PFNA, PFHpA, PFHxA, PFPeA, PFBA, and PFPrA were found at detectable concentrations in the tap water samples. The water samples from Shanghai (China) contained the greatest concentrations of total PFCs (arithmetic mean = 130 ng/L), whereas those from Toyama (Japan) contained only 0.62 ng/L (Mak et al 2009)."[67] "In tap water, PFOS and PFOA levels ranged between 0.39 and 0.87 ng/L (0.78 and 1.74 pmol/L) and between 0.32 and 6.28 ng/L (0.77 and 15.2 pmol/L), respectively. PFHpA, PFHxS, and PFNA were also other detected PFCs. PFC levels were notably lower in bottled water, where PFOS could not be detected in any sample. Moreover, PFHpA, PFHxS, PFOA, PFNA, PFOS, PFOSA, and PFDA could be detected in the river water samples. PFOS and PFOA concentrations were between <0.24 and 5.88 ng/L (<0.48 and 11.8 pmol/L) and between <0.22 and 24.9 ng/L (<0.53 and 60.1 pmol/L), respectively (Ericson 2008)."[68] Long-range transport: Measurement of PFHpA in Antarctic peninsula: Detected in all seabird feather samples (range = 1.60−2.85 ww ng/g; Table 3), and in 47% of penguin feces, ranging 0.37−22 ng/g ww (Alava et al 2015)[69]
Fate and Transport: Terrestrial	
Fate and Transport: Atmospheric	
Transport Issues	
Factors affecting bioavailability	
Global Environmental Impacts	
Ozone Depletion Potential (ODP)	

Global Climate Change	
Greenhouse Gas Production	
Acid Rain Formation	
Special Reports	
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