



17 Additional Information

The following sections will be included in the Additional Information menu item for the web-based document.

17.1 Additional Information for Media-Specific Occurrence

This section includes the tables of information that are summarized in [Section 6](#) and included in the figures that section.

[Table 17-1A](#) and [Figure 6-1A](#), Observed PFAS concentrations in outdoor air

[Table 17-1B](#) and [Figure 6-1B](#), Observed PFAS concentrations in indoor air

[Table 17-2](#) and [Figure 6-2](#), Observed PFAS concentrations in soil and sediment

[Table 17-3](#) and [Figure 6-3](#), Observed PFAS concentrations in groundwater

[Table 17-4](#) and [Figure 6-4](#), Observed PFAS concentrations in surface water

[Table 17-5](#) and [Figure 6-5](#), Observed PFOS concentrations in fish

Table 17-1A. Observed PFAS concentrations in outdoor air

| Location | Information | Concentrations (pg/m ³) |
|--|--|---|
| Japan (Kanazawa and Okinawa), Hong Kong, and Chennai, India (Ge et al. 2017) | Included sampling and analysis of ambient particles at four sites for 24 PFAS (9 PFASs and 15 PFCAs). Ultrafine particles found to be largest contributor to mass fraction of PFCAs, while most PFOS mass was in the coarse-sized fractions. Seasonal differences in PFAS attributed largely to precipitation. | The yearly average PFAS mass concentration, between summer and fall samples, in Chennai was Σ PFAS = 21.5, in Okinawa Σ PFAS = 7, in Kanazawa Σ PFAS = 13. In Hong Kong, the concentration varied from Σ PFAS = 11.5 in the summer to 53 in the winter. |
| North Greenland (Bossi R. 2016) | Measured a range of neutral PFAS and other persistent organic pollutants (POPs) at a research station in North Greenland from 2008 to 2013. | Reported concentrations of PFAS (sum of particle and gaseous phase) [mean (range)]: <ul style="list-style-type: none"> • 6:2 FTOH: 2.82 (<0.45–16.5) • 8:2 FTOH: 4.93 (<0.45–22.4) • 10:2 FTOH: 1.59 (<0.20–9.68) • N-MeFOSA: 0.44 (<0.20–3.41) • N-EtFOSA: 0.33 (<0.22–1.93) • N-MeFOSE: 0.61 (<0.15–7.46) • N-EtFOSE: 0.50 (<0.11–5.96) Average Σ PFAS ranged from 1.82 to 32.1. |
| Northern South China Sea (Lai et al. 2016) | Air samples collected and analyzed for neutral PFAS onboard ship during a cruise campaign over the northern South China Sea in 2013. | Reported concentrations of PFAS [mean (range)]: <ul style="list-style-type: none"> • ΣFTOHs: 53 (17.8–105.8) • ΣFTCAs: mean not reported (0.1–0.4) • ΣFASAs: 1.2 (0.1–3.6) • Overall ΣPFAS: 54.5 (18.0–109.9) |

| Location | Information | Concentrations (pg/m ³) |
|--|--|---|
| Shenzhen China (Liu et al. 2015) | Air samples collected at 13 sites, including industrial areas with many industrial manufacturers, port districts, as well as less industrialized forested and tourist areas. Samples were analyzed for a range of PFCAs and PFSAs. | PFAS concentrations reported as mean \pm standard deviation (SD) (range): <ul style="list-style-type: none"> • PFHxS: 0.31 \pm 0.39 (ND-1.2) • PFOS: 3.1 \pm 1.2 (ND-4.3) • PFBA: 1.9 \pm 1.8 (ND-5.0) • PFPeA: 1.9 \pm 1.4 (ND-4.0) • PFHxA: 1.5 \pm 1.5 (ND-3.6) • PFHpA: 0.042 \pm 0.10 (ND-0.30) • PFOA: 5.4 \pm 3.8 (1.5-15) • PFNA: 0.49 \pm 0.33 (ND-1.0) • PFDA: 0.48 \pm 0.38 (ND-1.2) • PFUDA: 0.018 \pm 0.064 (ND-0.22) • PFDoA: 0.20 \pm 0.19 (ND-0.54) • Overall ΣPFAS: 15 \pm 8.8 (3.4-34) Highest PFAS concentrations found within an industrial district downwind of other industrial cities. |
| Atlantic Ocean from North Atlantic to Antarctic (Wang et al. 2015) | Measured 12 neutral PFAS (4 FTOHs, 3 FOSAs, 3 FOSEs, and 2 FTCAAs) in the atmosphere across the Atlantic from the North Atlantic to the Antarctic, as well as snow from the Antarctic Peninsula. | Total Σ PFAS in air in the gas-phase mean (range): 23.5 (2.8 to 68.8). FTOHs were found to be the dominant compound representing 93% of the total Σ PFAS. |
| Toronto, Canada (Ahrens et al. 2012) | Collected samples from a semi-urban location while investigating an improved technique for measuring the gas-particle partitioning of PFAS using an annular diffusion denuder sampler. | Reported concentration range of gas-phase PFAS: <ul style="list-style-type: none"> • ΣFTOHs (most abundant PFAS in the gas phase): 39-153 • ΣFOSAs: 0.02-1.1 • ΣFOSEs: 0.33-0.79 • ΣFTCAs: 0.87-5.9 • PFBA (dominant PFCA): 4.0-22 |
| Japan Sea to Arctic (Cai et al. 2012) | Neutral PFAS were measured on board ship during an expedition from the Japan Sea to the Arctic Ocean in 2010. | Reported concentrations of PFAS in the gas phase(g)/particle-phase (p) [mean (range)]: <ul style="list-style-type: none"> • ΣFTOHs: 174 (61-358)(g)/3.6 (1-9.9)(p) • ΣFTCAs: 18 (5.2-47.9)(g)/0.3 (0.1-0.5)(p) • ΣFASAs: 1.4 (0.5-2.1)(g)/0.2 (0.1-0.24)(p) • ΣFASEs: 5.8 (1.9-15.0)(g)/1.8 (0.4-4.9)(p) |
| Birmingham and Harwell, United Kingdom (Goosey and Harrad 2012) | Measured atmospheric concentrations of a range of PFAS in homes, offices, and outdoor locations in Birmingham and Harwell, UK during 2008 and 2009. Outdoor sampling included two urban and one semirural locations. (PFAS reported as MeFOSA, EtFOSA, MeFOSE and EtFOSE). | Reported concentrations of PFAS in outdoor air [mean (range)]: <ul style="list-style-type: none"> • PFOS: 2.3 (<1.0-6.1) • PFOA: 3.5 (<1.9-20) • PFHxS: 7.0 (<1.1-30) • MeFOSA: 6.3 (<2.4-41) • EtFOSA: 89 (<5-170) • FOSA: 13 (1.8-27) • MeFOSE: 58 (3.4-130) • EtFOSE: 73 (20-120) |

| Location | Information | Concentrations (pg/m ³) |
|--|---|--|
| Vancouver, Canada (Shoeib et al. 2011) | Measured a range of ionic and neutral PFAS in indoor air, indoor dust, and clothes dryer lint in 152 homes in Vancouver, Canada in 2007–2008. The study included six outdoor air samples. | Reported concentrations of PFAS in outdoor air were [mean (range)]: <ul style="list-style-type: none"> • Σ FTOHs: 305 (161–906) • Σ FOSA/Es: 18 (8.1–108) • Σ PFCAs: below detection to 35 |
| Atlantic Ocean: Gulf of Mexico to northeast coast of USA; Bermuda, and Nova Scotia (Shoeib et al. 2010) | Air sampling was performed in 2007 in Bermuda and Nova Scotia, and along a cruise track from the Gulf of Mexico to the northeast coast of the USA to assess air concentrations, particle-gas partitioning, and transport of a range of neutral PFAS. | Reported mean concentrations of dominant PFAS (gas + particle-phase): <ul style="list-style-type: none"> • Σ FTOHs: 11–165 • MeFOSE: 1.6–73 |
| Atlantic Ocean, Antarctic Ocean, and Baltic Sea; and Hamburg, Germany (Dreyer et al. 2009) | Air samples were taken onboard several research vessels in the Atlantic Ocean, Antarctic Ocean, and the Baltic Sea as well as at one land-based site close to Hamburg, Germany, in 2007 and 2008 and were analyzed for a range of neutral and ionic PFAS. | Total gas-phase concentrations of ship-based samples (ΣPFAS) ranged from 4.5 in the Antarctic to 335 near source regions. Concentrations of 8:2 FTOH (typically the most dominant PFAS) were between 1.8 and 130. Concentrations of individual particle-bound precursors were usually below 1. Reported overall mean PFAS concentrations for all samples: <ul style="list-style-type: none"> • Σ FTOHs: 47 • Σ FTCAAs: 3.6 • Σ FASAs: 7.6 • Σ FASEs: 3.8 |
| Canadian Rocky and Purcell Mountains, Western Canada (Loewen et al. 2008) | Air and lake water samples were collected along an altitudinal transect across Western Canada during the spring and summer of 2004 and analyzed for a range of PFAS. | The reported ranges of vapor phase PFAS concentrations were estimated as: <ul style="list-style-type: none"> • Σ FTOHs: 0.8–27 • Σ FOSAs: 3.7–19 • Σ FOSEs: <25–88 The concentrations of FTOHs and FOSEs were found to increase with altitude. |
| Parkersburg, West Virginia, USA (Barton, Kaiser and Russell 2007) | Concurrent rain and air samples collected at nine locations at a manufacturing facility during a single precipitation event and analyzed for PFOA. | PFOA predominantly associated with particulates and detected as high as 1,100. |
| Atlantic Ocean from Germany to South Africa (Jahnke et al. 2007) | Air samples were collected on board a research vessel during cruise in the Atlantic Ocean from Germany to South Africa in 2005 and analyzed for a range of neutral and ionic PFAS. | Reported concentration ranges of PFAS: <ul style="list-style-type: none"> • 6:2 FTOH: ND–174 • 8:2 FTOH: 2–190 • 10:2 FTOH: 0.8–48 • N-EtFOSA: ND–2.2 • N-MeFOSA: 0.4–4.2 • N-MeFOSE: ND–22 • N-EtFOSE: ND–11.8 |
| Albany, New York, USA (Kim and Kannan 2007) | Measured PFCAs, PFSAs, and FTSAs in air, rain, snow, surface runoff water, and lake water in an urban area. | Overall range of PFAS concentrations in air: <ul style="list-style-type: none"> • ΣPFAS (gas phase): 5.10–11.6 • ΣPFAS (particle-phase): 2.05–6.04 |

| Location | Information | Concentrations (pg/m ³) |
|---|--|--|
| Okinawa, Japan, and Central Oregon, USA (Piekarz et al. 2007) | Air samples were collected and analyzed for a range of neutral PFAS from locations in Okinawa, Japan, and central Oregon, USA, between 2004 and 2006. (PFAS reported as MeFOSE and EtFOSE). | Reported PFAS concentration in the gas phase (g)/particle-phase (p): <ul style="list-style-type: none"> • ΣFTOHs: <0.4-32 • MeFOSE: <1-25 (g)/<1-21 (p) • EtFOSE: <1-8.7 (g)/<1-6.9 (p) • N-EtFOSA: <0.4-12 (g)/<0.4-12 (p) |
| Parkersburg, West Virginia USA (Barton et al. 2006) | This study included six sampling events over a 10-week period during 2003-2004. Air samples were collected along the fence line of a fluoropolymer manufacturer and analyzed for PFOA. | The measured concentration of PFOA ranged from 120,000-900,000. |
| Canada (Shoeib et al. 2004) | Indoor and outdoor air was collected from laboratories and homes in Canada from 2001-2003 and analyzed for several PFAS. The study included two outdoor sample locations. | Reported range of PFAS concentrations in outdoor air (gas + particle-phase): <ul style="list-style-type: none"> • MeFOSE: 16.0-31.7 • EtFOSE: 8.47-9.79 |
| North American cities (Stock et al. 2004) | Air samples were collected in six North American cities (Reno, NV; Griffin, GA; Cleves, OH; Winnipeg, MB; Long Point, ON; and Toronto, ON) and analyzed for three FTOHs (6:2, 8:2, and 10:2) and three polyfluorinated sulfonamides (NEtFOSA, NEtFOSE, and NMeFOSE). | Reported PFAS concentration range: <ul style="list-style-type: none"> • ΣFTOHs: 11-165 • Σ(N-EtFOSA, N-EtFOSE, and N-MeFOSE): 22-403 |
| ND = Nondetect | | |

Table 17-1B. Observed PFAS concentrations in indoor air

| Location | Information | Concentrations (pg/m ³) |
|---|--|---|
| Northern Germany (Fromme et al. 2015) | Measured volatile PFAS in residences and schools in Northern Germany in 2014. | In schools, reported concentrations of PFAS [mean (range)]: <ul style="list-style-type: none"> • 6:2 FTOH: 7,853 (1,428-46,867) • 8:2 FTOH: 5,717 (2,480-13,888) • 10:2 FTOH: 2,066 (1,166-4,774) • 8:2 FTCA: 4,554 (128-47,739) • 10:2 FTCA: 1,800 (47-17,360) • N-EtFOSA: 274 (62-692). In residences, reported concentrations of PFAS [mean (range)]: <ul style="list-style-type: none"> • 6:2 FTOH: 2,058 (289-5,424) • 8:2 FTOH: 9,007 (4,702-21,698) • 10:2 FTOH: 3,296 (759-10,306) • 8:2 FTCA: 422 (58-1,040) • 10:2 FTCA: 205 (27-560) • N-EtFOSE: 69 (27-155) • N-MeFOSE: 552 (27-3,796) |
| Boston, USA (Fraser et al. 2012) | Indoor office air was sampled in the winter of 2009 in 31 offices in Boston, MA. | Reported mean concentrations of select PFAS: <ul style="list-style-type: none"> • 8:2 FTOH: 9,920 • N-MeFOSE: 289 |

| Location | Information | Concentrations (pg/m ³) |
|---|--|---|
| Birmingham and Harwell, United Kingdom (Goosey and Harrad 2012) | This study reports atmospheric concentrations of a range of PFAS in homes, offices, and outdoor locations in Birmingham and Harwell, UK, during 2008 and 2009. (PFAS reported as MeFOSA, EtFOSA, MeFOSE and EtFOSE). | <p>In homes, reported concentrations of PFAS [mean (range)]:</p> <ul style="list-style-type: none"> • PFOS: 38 (<1-400) • PFOA: 52 (<1.9-440) • PFHxS: 36 (<1.1-220) • MeFOSA: <2.5 (<2.5-19) • EtFOSA: 120 (14-350) • MeFOSE: 950 (77-3,100) • EtFOSE: 600 (80-1,900). <p>In offices, reported concentration of PFAS [mean (range)]:</p> <ul style="list-style-type: none"> • PFOS: 56 (12-89) • PFOA: 58 (<1.9-200) • PFHxS: 94 (<1.1-330) • MeFOSA: 6 (<2.5-50) • EtFOSA: 59 (12-150) • MeFOSE: 480 (39-1,200) • EtFOSE: 490 (180-950) |
| Vancouver, Canada (Shoeib et al. 2011) | Measured a range of ionic and neutral PFAS in indoor air, indoor dust, and clothes dryer lint in 152 homes in Vancouver, Canada, in 2007-2008. | <p>Reported concentration range for ΣFTOHs in homes was 890-47,000. The geometric mean concentrations for other PFAS:</p> <ul style="list-style-type: none"> • MeFOSE: 380 • EtFOSE: 60 • MeFOSA: 30 • EtFOSA: 20 • PFOA: 28 • PFHxA: 9.7 • PFHpA: 5.1 |
| Hamburg, Germany (Langer, Dreyer, and Ebinghaus 2010) | Air samples were collected in 16 residential and commercial buildings in Hamburg, Germany, in 2009-2010 and analyzed for a range of neutral PFAS. | <p>Reported concentrations of PFAS ranged from:</p> <ul style="list-style-type: none"> • ΣFTOHs: 3,300-307,000 • ΣFTCAs: 200-15,2000 • Σ(FASAs + FASEs): 4,400-148,000 |

| Location | Information | Concentrations (pg/m ³) |
|--|--|---|
| Canada (Shoeib et al. 2004) | Indoor and outdoor air was collected from laboratories and homes in Canada from 2001-2003 and analyzed for several PFAS. | Reported total air concentrations (gas phase + particle phase) [mean (range)]: <ul style="list-style-type: none"> • MeFOSE: 2590 (11.1-8,315) • EtFOSE: 770 (4.75-1,917) |
| ND = Nondetect | | |

Table 17-2. Observed PFAS concentrations in soil and sediment

| Location | Information | Concentrations (µg/kg) |
|--|--|--|
| Global Distribution | | |
| Global distribution (Rankin et al. 2016) | Worldwide survey of 62 soils samples, PFOA and PFHxA detected in all samples, and PFOS detected in all but one sample; PFOS and PFOA the most frequently detected. | <ul style="list-style-type: none"> • ΣPFCA: 0.029-14.3 • ΣPFSA: ND-3.27 (only one sample was ND) Remote area (Lake Bonney, Antarctica): <ul style="list-style-type: none"> • PFOA = 0.048 • PFOS = 0.007 |
| Global, locations not associated with known PFAS sources (Strynar et al. 2012) | Evaluated 60 soil samples from six countries and reported global median concentrations. PFOS detected in 48% and PFOA detected in 28% of the samples. Note that concentrations < LOQ (~0.5 µg/kg) were assigned a value of LOQ/√2 for the median calculations. | Global median concentrations: <ul style="list-style-type: none"> • PFOA: 0.124 • PFOS: 0.472 |
| Point Sources | | |

| Location | Information | Concentrations (µg/kg) |
|--|--|---|
| Location near industrial PFAS source (Davis et al. 2007) | Concentrations of ammonium perfluorooctanoate (APFO) in two soil borings located within an impacted well field; concentrations decreased rapidly with depth. | APFO: 110-170 |
| Fire Training/Fire Response (Houtz et al. 2013) | PFOS and PFOA in soils at an unlined fire training area. | Median concentrations: • PFOS: 2,400 • PFOA: 21 |
| Fire Training/Fire Response (Anderson et al. 2016) | In a survey of 40 sites impacted by PFAS, the most frequently detected compounds were PFOS (99% of surface samples), PFHxS (77%), and PFOA (79%). PFOS was detected at the highest concentrations. | PFOS: • Median: 53 • Max: 9,700 |
| Industrial Areas (Zareitalabad et al. 2013) | PFOA and PFOS concentrations in soil were compiled. | Max: • PFOS: 48 • PFOA: 10 |
| Sludge-Biosolids Application | | |
| Soil, groundwater, and tile water sampled after a single high-rate application of municipal biosolids (Gottschall et al. 2017) | Soil cores collected from 0-0.3 meters, entire interval homogenized; (values picked from concentrations plots). | PFOA: 0.4-0.8 PFOS: 0.2-0.4 PFNA: 0.1-0.22 PFDA: 0.05-0.33 PFUDA: 0.07-0.12 |
| Municipal Biosolids (Sepulvado et al. 2011) | Six municipal biosolids and biosolids-amended surface soils. Soil concentrations decreased with depth. Values approximated from plots in supplemental information. | Biosolids: • PFOS: 80-219 • N-MeFOSAA: 63-143 • N-EtFOSAA: 42-72 • PFOA: 8-68 Biosolid amended soil <10 cm depth: • PFOS: 2,438 • PFOA: ~8-38 • PFNA: ~2-7 • PFHpA: ~2-8 • PFHxS: ~3-12 |
| Sediment | | |

| Location | Information | Concentrations (µg/kg) |
|--|---|--|
| Lake Ontario, Yangtze & Mississippi Rivers (Qi et al. 2016 ; Yeung et al. 2013 ; Oliaei et al. 2013 ; Pan et al. 2014) | Maximum sediment concentrations of PFOA, PFOS, and other PFAAs. | 10s-100s |
| Estuarine sediments-South Carolina (White et al. 2015) | Analysis of 11 PFAS. | Average of 3.79 (ΣPFAS) |
| Surface sediments-China (Qi et al. 2016) | Analysis of 17 PFAS. Dominant PFAS: PFOA, PFOS, and PFUDA. | 0.086-5.79 dry weight and an average of 1.15 (ΣPFAS) |
| Surface sediments and cores-Great Lakes (Codling et al. 2018) | 22 PFAS analyzed, surface sediment averaged for 3 different lakes, and dated cores used to approximate depositional trends over time. | 1.5, 3.1, and 4.6 (surface sediment average for ΣPFAS 3 lakes) |
| ND = Nondetect LOQ = Limit of quantitation | | |

Table 17-3. Observed PFAS concentrations in groundwater

| Location | Information | Concentrations (ng/L) |
|--|---|---|
| Firefighting Foam Sites | | |
| AFFF Release Sites other than Fire Training Areas (Anderson et al. 2016) | Tested 149 groundwater samples; most commonly detected PFAAs: PFHxS (95%); PFHxA (94%), PFOA (90%), PFPeA (88%), PFBA and PFHpA (85%), PFOS (84%). The frequency of detections for PFSAs in groundwater was generally higher than those of PFCAs, which has been attributed to the use of specific AFFF formulations. | Median (maximum): <ul style="list-style-type: none"> • PFHxS: 870 (290,000) • PFHxA: 820 (120,000) • PFOS: 4,220 (4,300,000) • PFOA: 405 (250,000) • PFPeA: 530 (66,000) • PFBA: 180 (64,000) • PFHpA: 235 (75,000) |
| Fire Training/Fire Response (Moody and Field 1999 ; Moody et al. 2003 ; Houtz et al. 2013) | Studies at U.S. military installations and other AFFF release areas have documented relatively high detection frequencies of PFAAs in underlying groundwater. | Maximum: <ul style="list-style-type: none"> • PFOA: 6,570,000 • PFOS: 2,300,000 |
| Landfill Impacts | | |

| Location | Information | Concentrations (ng/L) |
|--|---|---|
| Firefighting Foam Sites | | |
| Raw and Treated Landfill Leachates (Yan et al. 2015) | 5 municipal landfill sites in China were included in a study of 14 PFAAs concentrations in raw and treated leachate. Total PFAAs ranged from 7.28 to 292 µg/L in raw and 0.1 to 282 µg/L in treated. Dominant compounds included PFOA (28.8% of raw and 36.8% of treated) and PFBS (26.1% of raw and 40.8% of treated). | <p>Raw leachate Range (mean contribution %):</p> <ul style="list-style-type: none"> • PFOA: 281–217,000 (28.8) • PFBS: 1,600–41,600 (26.1) • PFPeA: 640–10,000 (15.9) • PFOS: 1,200–6,00 <p>Treated leachate Range (mean contribution %):</p> <ul style="list-style-type: none"> • PFOA: 30–206,000 (36.8) • PFBS: 20–55,300 (40.8) |
| Landfill Leachates (Eggen, Moeder, and Arukwe 2010) | Leachates from two landfills were analyzed for different emerging pollutants, including PFAS. Landfills had clay liners and tubing system to collect the leachate. Data presented include PFAS concentrations in water and particle phases. | <p>Water maximum:</p> <ul style="list-style-type: none"> • PFHxS: 281 • PFOS: 2,920 • PFHxA: 757 • PFHpA: 277 • PFOA: 767 • PFNA: 539 <p>Particle maximum:</p> <ul style="list-style-type: none"> • PFHxS: 0.15 • PFOS: 339 • PFOA: 4.05 • PFOSA: 0.44 |
| Landfill Leachate and Groundwater (NY DEC 2017) | PFOA was detected in public and private drinking water in Petersburg, NY. In the site investigation groundwater and leachate from the Petersburg/Berlin landfill was tested. | <p>PFOA groundwater range:</p> <ul style="list-style-type: none"> • 1.4–1,600 <p>PFOA leachate:</p> <ul style="list-style-type: none"> • 4,200 |
| Landfill Groundwater (NY DEC 2016) | The City of Newburgh, NY, identified PFAS in their water in 2016. Included in their investigation was the Town of New Windsor landfill, which had its monitoring wells tested for PFAS compounds. | <p>Range:</p> <ul style="list-style-type: none"> • PFOS: 2.59–50.3 • PFOA: 4.0–40.4 • PFHxS: 3.72–86.6 • PFHpA: 2.36–5.93 • PFBS: 8.08–23.9 |
| Landfill Groundwater (VT DEC 2018) | Analysis of groundwater monitoring wells around landfills in Bennington, VT, for PFOS and PFOA. Nine locations were tested in 2016. | <p>Median (maximum):</p> <ul style="list-style-type: none"> • PFOA: 18 (900) • PFOS: 4.98 (140) |
| MSW Landfill Leachate | | |

| Location | Information | Concentrations (ng/L) |
|--|--|--|
| Firefighting Foam Sites | | |
| Raw and Treated Landfill Leachates (Busch et al. 2010) | 22 landfill sites in Germany were included in a study of 43 PFAS in treated and untreated landfill leachate | <p>Raw leachate</p> <p>Mean contribution (%):</p> <ul style="list-style-type: none"> • PFBA: 27% • PFBS: 24% • PFHxA 15% • PFOA 12% • PFPeA 6.0% • PFHpA 4.0% • 6:2 FTS 3.7% • PFOS 2.7% • PFHxS 2.3% <p>Treated leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFBA: ND-2,968 • PFBS: ND-1,356 • PFHxA ND-2,509 • PFOA: ND-926 • PFPeA: ND-829 • PFHpA: ND-280 • 6:2 FTS: ND-82 • PFOS: 0.01-235 • PFHxS: ND-178 |
| Raw Landfill Leachates (Huset et al. 2011) | Concentrations of 24 PFAS were measured in six leachate samples collected from four US MSW landfills prior to leachate treatment | <p>Raw leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFBA: 170-1,700 • PFPA: 120-1,500 • PFHxA: 270-790 • PFHpA: 100-340 • PFOA: 380-1,000 • PFBS: 280-890 • PFHxS: 160-700 • PFOS: 56-160 • 6:2 FtS: 29-370 • 8:2 FtS: 11-120 • Me-FBSAA: 58-440 • Me-FOSAA: 16-290 • Et-FOSAA: 21-480 |

| Location | Information | Concentrations (ng/L) |
|--|--|---|
| Firefighting Foam Sites | | |
| <p>Raw MSW Landfill Leachate and a Evaporation Pond (Allred et al. 2014)</p> | <p>Concentrations of 70 PFASs were measured in seven landfill leachate samples from six landfills</p> | <p>Raw leachate Range: <ul style="list-style-type: none"> • PFBA: 69-3,700 • PFPeA: 54-3,200 • PFHxA: 190-8,900 • PFHpA: 62-3,100 • PFOA: 150-5,000 • 6:2 FTCA: 230-2,000 • 5:3 FTCA: 320-18,000 • 7:3 FTCA: 22-1,700 • PFBS: 38-3,200 • PFHxS: 45-1,100 • PFOS: 25-590 • MeFBSAA: 41-2,900 • MeFHxSAA: 16-1,900 Evaporation Pond Concentration: <ul style="list-style-type: none"> • PFBA: 24,000 • PFPeA: 39,000 • PFHxA: 50,000 • PFHpA: 14,000 • PFOA: 9,200 • 6:2 FTCA: 300 • 5:3 FTCA: 3,200 • 7:3 FTCA: 60 • PFBS: 830 • PFHxS: 3900 • PFOS: 14 • MeFBSAA: 8,000 • MeFHxSAA: 44 </p> |
| <p>Raw and Treated Landfill Leachates (Yan et al. 2015)</p> | <p>Five municipal landfill sites in China were included in a study of 14 PFAAs concentrations in raw and treated leachate.</p> | <p>Raw leachate Range (mean contribution %): <ul style="list-style-type: none"> • PFOA: 281–217,000 (28.8) • PFBS: 1,600–41,600 (26.1) • PFPeA: 640–10,000 (15.9) • PFOS: 1,200–6,000 Treated leachate Range (mean contribution %): <ul style="list-style-type: none"> • PFOA: 30–206,000 (36.8) • PFBS: 20–55,300 (40.8) </p> |

| Location | Information | Concentrations (ng/L) |
|--|--|---|
| Firefighting Foam Sites | | |
| Raw MSW Landfill Leachate (Lang et al. 2017) | 70 PFASs were included in a study of 95 leachate samples from U.S. landfills | <p>Raw leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFBA: 30-4,791 • PFPeA: 23-3,194 • PFHxA: 41-8,858 • PFHpA: 32-3,133 • PFOA: 30-4,989 • FHEA: 30-6,547 • FOEA: <LOQ-1,150 • FPePA: <LOQ-41,309 • FHpPA: <LOQ-5,331 • PFBS: <LOQ-3,410 • PFHxS: <LOQ-1,328 • 6:2 FtS: <LOQ-2,248 • MeFBSAA: <LOQ-2,932 1. MeFHxSAA: <LOQ-1,898 |
| Non-MSW Landfill Leachate | | |
| Industrial Impacted Raw Landfill Leachate (Oliaei, Kessler, and Kriens 2006) | 14 PFAAs were measured in leachate and gas condensate sampled from 3M-impacted landfills, Minnesota, USA | <p>Raw Leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFBA: 1,400-2,200 • PFPeA: 2,700-9,200 • PFHxA: 13,100-28,900 • PFHpA: 4,000-14,700 • PFOA: 14,200-81,800 • PFBS: 1,800-4,800 • PFHxS: 2,200-7,400 • PFOS: 3,100-31,400 <p>Gas Condensate</p> <p>Concentration:</p> <ul style="list-style-type: none"> • PFBA: 4,570 • PFPeA: 5,480 • PFHxA: 37,900 • PFHpA: 15,100 • PFOA: 83,800 • PFBS: 6,300 • PFHxS: 9,480 • PFOS: 29,900 |

| Location | Information | Concentrations (ng/L) |
|--|---|---|
| Firefighting Foam Sites | | |
| Raw and Treated MSW/C&D/Ash Landfill Leachate (Solo-Gabriele et al. 2020) | 12 samples were collected at five different landfill facilities within Florida, USA, and analyzed for concentrations of 11 PFAS species (7 carboxylic acids, 3 sulfonic acids, and 5:3 fluorotelomer carboxylic acid) | <p>C&D leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFOS: 874-1,000 • PFOA: 1,680-1,720 • 5:3 FTCA: 1,650-1,930 <p>C&D MSW (25:75) leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFOS: 557-770 • PFOA: 2,200-2,860 • 5:3 FTCA: 2,540-3,050 <p>MSW Ash Monofill (930-980C) leachate</p> <p>Range:</p> <ul style="list-style-type: none"> • PFOS: 120-166 • PFOA: 259-387 • 5:3 FTCA: ND |
| Biosolids/Sludge | | |
| Soil, Groundwater, and Tile Water Sampled after a Single High-Rate Application of Municipal Biosolids (Gottschall et al. 2017) | Shallow groundwater (2-meter depth) sampled at 2, 7, and 10 months after application. Values picked from concentrations plots. Tile water was similar except PFOA range nondetect to 23. | <p>PFOA: 1.5-3</p> <p>PFOS: nondetect-0.8</p> <p>PFNA: nondetect-1.1</p> <p>PFHpA: nondetect-6</p> |
| Contaminated Biosolid Application Effects on Groundwater in Decatur, Alabama (Lindstrom et al. 2011) | Fluorochemical industry contaminated biosolids were applied on local agricultural fields for as much as 12 years in Decatur, Alabama. Sampling of well water near the fields showed elevated PFAS concentrations. | <p>Range:</p> <ul style="list-style-type: none"> • PFNA: 25.7 • PFOA: 149-6,410 • PFHpA: 77.2-5,220 • PFHxA: 9.7-3,970 • PFPeA: 12.2-2,330 • PFBA: 10.4-1,260 • PFOS: 12-151 • PFHxS: 12.7-087.5 • PFBS: 10.1-76.6 |
| Industrial Sites | | |
| Industrial Use Contamination (Procopio et al. 2017) | Study by NJDEP and the NJ Brick Township Municipalities Authority on concentrations of PFAS compounds in various water sources. A plume of contamination was detected and attributed to a small manufacturer using materials containing PFOA. | <p>Maximum:</p> <ul style="list-style-type: none"> • PFOA: 70,000 • PFBA: 2,000 • PFPA: 560 • PFHxA: 3,800 • PFHpA: 4,300 • PFNA: 63 • PFDA: 560 • PFHxS: 6 • PFOS: 50 |
| Fluorochemical Industrial Facility (Davis et al. 2007) | Environmental media (soil and water) were investigated in a PWS well field near a fluoropolymer manufacturing facility for the presence of PFOA. | <p>Maximum:</p> <ul style="list-style-type: none"> • PFOA: 78,000 |

| Location | Information | Concentrations (ng/L) |
|--|--|--|
| Firefighting Foam Sites | | |
| Teflon Fabric Coating Facility (VT DEC 2018) | 2016 investigation of PFAS contamination in relation to a former Teflon coating factory in North Bennington, VT. Over 600 drinking water wells tested and more than 300 wells exceeded the state's PFOA/PFOS standard of 20 ppt. | Maximum: • PFOA: 4,600 |
| Fluorochemical Industrial Facility (3M Company 2007) | Study completed at the 3M Company's Cottage Grove, Minnesota, plant. 8 groundwater monitoring wells were installed and sampled throughout the site for the presence of FCs. | Maximum: • PFOA: 619,000 • PFBA: 318,000 • PFBS: 26,100 • PFHxS: 40,000 • PFOS: 26,000 |
| Water Supplies-Nonsite-Related | | |
| Domestic Drinking Water Wells on Cape Cod, Massachusetts (Schaidler, Ackerman, and Rudel 2016) | 20 domestic drinking water wells in Cape Cod, MA, were investigated for the presence of organic wastewater compounds, including PFAS. All wells were located in areas served exclusively by onsite wastewater treatment systems. | Maximum: • PFBS: 23 • PFHxA: 2 • PFHpA: 1 • PFHxS: 41 • PFOS: 7 |
| Survey across European Countries (Loos et al. 2010) | 164 groundwater samples tested from 23 European countries. Sampling sites were not chosen to be "representative" or "contaminated," but most were from official monitoring stations also used for drinking water monitoring. | Median (maximum) [freq. %]: • PFOA: 1 (39) [65.9] • PFOS: 0 (135) [48.2] • PFHxS: 0 (19) [34.8] • PFHpA: 0 (21) [29.9] • PFDA: 0 (11) [23.8] • PFBS: 0 (25) [15.2] • PFNA: 0 (1) [15.2] |
| Public Drinking Water Sources across the U.S. (USEPA 2017) | Results from finished groundwater testing by the EPA under UCMR3. | Range (freq. %): • PFBS: 90–220 (0.05) • PFHpA: 10–410 (0.64) • PFHxS: 30–1,600 (0.56) • PFNA: 22–56 (0.05) • PFOA: 20–350 (1.03) • PFOS: 40–7,000 (0.79) |

Table 17-4. Observed PFAS concentrations in surface water

| Location | Information | Concentrations (ng/L) |
|---|---|--|
| Freshwater | | |
| Remote Areas (Filipovic et al. 2015 ; Eriksson et al. 2013 ; Stock et al. 2007 ; Lescord et al. 2015) | PFOS and PFOA concentrations in the Faroe Islands and remote areas of Sweden have been measured in the 100s of picograms per liter range, while concentrations in the Canadian Arctic have been measured up to single nanogram per liter range. | Range: PFOS/PFOA ND to <10 |
| Industrial Areas, Japan, and Tennessee River, USA (Saito et al. 2004 ; Hansen et al. 2002) | Concentrations of PFOS and PFOA as high as 144 ng/L and 67,000 ng/L, respectively, have been measured. | Maximums: PFOS: 144 PFOA: 67,000 |

| Location | Information | Concentrations (ng/L) |
|---|--|---|
| Fire Training/Fire Response (Saito et al. 2004 ; Anderson et al. 2016) | Concentrations of PFOS and PFOA as high as 8,970 ng/L and 3,750 ng/L, respectively, have been measured in AFFF-impacted surface water. | Maximums: PFOS: 8,970 PFOA: 3,750 |
| Municipal Wastewater Treatment Facilities (Becker, Gerstmann, and Frank 2008 ; Boulanger 2005 ; Wilkinson et al. 2017 ; MDH 2008) | Data presented typically for upstream, downstream, and effluent wastewater. Generally low frequency of detection upstream. Some treatment facilities show evidence for precursors with greater PFAS in effluent than influent. | PFOA: ND-220 PFOS: ND-814 PFHxS: ND-26 PFBS: ND-115 PFNA: ND-209 |
| Public Drinking Water Sources across the US (USEPA 2017) | Results from finished water testing with surface water source by the EPA under UCMR3. | Range: PFBS: 90-370 PFHpA: 10-60 PFHxS: 30-190 PFNA: 20-54 PFOA: 20-100 PFOS: 40-400 |
| Marine Water | | |
| Open Water (Benskin et al. 2012 ; Cai et al. 2012 ; Zhao et al. 2012) | The sum of PFAA concentrations in the mid-Northwest Atlantic ranged from 0.077 to 0.19 ng/L, while PFAAs in the Northeast Atlantic ranged from 0.28 to 0.98 ng/L. The sum of PFAS in the North Atlantic ranged from 0.13 to 0.65 ng/L, and in the Greenland Sea from 0.045 to 0.28 ng/L. | Range: ΣPFAA 0.077-0.98 ΣPFAS 0.045-0.65 |
| Coastal Areas (Benskin et al. 2012 ; Cai et al. 2012 ; Zhao et al. 2012) | Along the Rhode Island coast the sum of PFAAs ranged up to 5.8 ng/L. Along the coast of Antarctica the sum of PFAS ranged from 0.59 to 15.3 ng/L, and along the southern Atlantic coast of South America the sum of PFAA ranged from <0.21 to 0.54 ng/L. | Range: ΣPFAA <0.21 to 5.8 ΣPFAS 0.59-15.3 |
| Stormwater | | |
| Residential/Undeveloped (Xiao, Simcik, and Gulliver 2012 ; Wilkinson et al. 2016 ; Zhao et al. 2013) | PFAS concentrations measured in residential, campus, and field settings in Minnesota, China, and England, respectively. | Maximums: • PFOS: 15.5 • PFOA: 19.1 • PFHxA: 4 • PFHpA: 22.5 • PFNA: 23 |
| Commercial/Heavy Traffic–Minneapolis/St. Paul, MN; Eastern and Central China cities; and England (Xiao, Simcik, and Gulliver 2012 ; Zhao et al. 2013 ; Wilkinson et al. 2016) | PFOS and PFOA measured in stormwater runoff from streets in areas not related to specific releases, but unidentified local or consumer sources may be responsible for higher concentrations detected. | Range: • PFOS: <LOQ-590 • PFOA: 3.5-1,160 • PFHpA: ND-6.8 • PFNA: ND-648 • PFDA: ND-10.6 • PFUnDA: ND-2.9 |
| Industrial Areas–Minneapolis and St. Paul, MN (Xiao, Simcik, and Gulliver 2012) | PFOS measured in stormwater in an industrial area with suspected PFAS. | Range: • PFOS: 8.7-156 |
| Airport Ditch, Likely Impacted by AFFF, Korea (Kim et al. 2014) | PFAAs measured, predominately PFHxS and PFOS. | • Total PFAAs: 6.42-804 |

Table 17-5. Observed PFOS concentrations in fish (µg/kg)

| Location | Information | Mean (max) |
|--|--|--|
| Industrial (Oliaei et al. 2013 ; Delinsky et al. 2010) | Near PFAS production plants, individual fish tissues such as liver, blood, and muscle have been reported to have elevated PFOS. | PFOS: <ul style="list-style-type: none"> • Liver: (6,350) • Blood: (29,600) • Muscle: <3-100 (2,000) |
| AFFF Release (Moody et al. 2002 ; Gewurtz et al. 2014 ; Lanza et al. 2017) | PFOS in fish liver, muscle, and whole fish samples were detected following a release of AFFF during emergency or fire training activities. | PFOS: <ul style="list-style-type: none"> • Liver: (100) 72,900 • Muscle: (6,160) • Whole fish: ~200-2,000 (15,000) |
| Wastewater Treatment Plant (Becker, Gerstmann, and Frank 2010 ; Li et al. 2008 ; Schuetze et al. 2010) | PFOS concentrations have been detected in fish collected near the outfall of wastewater treatment plants. | PFOS: Liver: (400) Serum: (64) Muscle tissue: 7-250 (400) |
| Freshwater fish from New Jersey (NJDEP 2018) | PFOS concentrations in 12 species of freshwater fish from New Jersey. | PFOS: 1.4-119 (162.5) |
| Freshwater fish from U.S. urban rivers and the Great Lakes (Stahl et al. 2014) | PFOS concentrations in freshwater fish from U.S. urban rivers (25 species) and the Great Lakes (18 species). | PFOS: 10.7 (127) |

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