TECHNICAL MEMORANDUM

PFAS Characterization in Biosolids and TAGRO Soils

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INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made compounds that include perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). Public concern has recently increased with regards to the ubiquity of PFAS in the environment and the potential negative human health impacts of PFOA and PFOS exposure. After being voluntarily phased out in the early 2000s, PFOS and PFOA are no longer manufactured in the United States, but due to their resistance to degradation they continue to persist in the environment. In November 2019, SYLVIS and the City of Tacoma (the City) undertook an investigation to determine the order of magnitude of PFAS in the biosolids produced at the City's Central Wastewater Treatment Plant (WWTP), and the TAGRO products produced with these biosolids.

The City produces Class A biosolids via a dual digestion process at the WWTP, which are then recycled into three different TAGRO soil blends made with biosolids for commercial and residential use. TAGRO Mix is composed of 50% biosolids, 25% screened sand and 25% sawdust. TAGRO Topsoil contains equal parts biosolids, sawdust, screened sand and bark. TAGRO Potting Soil is designed for use in containers and is composed of 20% biosolids, 20% sawdust and 60% screened bark.

This report presents the results of the PFAS sampling and analysis conducted on samples collected from the Central WWTP and compares these results to compiled data from the Northeast Biosolids & Residuals Association (NEBRA) as well as to relevant state and federal guidelines and standards.

BACKGROUND

While PFAS have been used widely in multiple industries for decades, regulation of PFAS is relatively new in the United States, particularly for soil and biosolids. A number of states have established, or are developing, regulatory limits for PFAS in drinking water and/or screening levels for PFAS in soil, but Maine is currently the only state to have regulatory limits on PFAS in biosolids for beneficial use. The US Environmental Protection Agency (EPA) is in the early scoping stages of risk assessment for PFOS and PFOA in biosolids, with completion anticipated for 2020. No preliminary documents for this risk assessment have been released as of January 2020.

Washington state does not currently have guidelines for any PFAS concentrations in biosolids, sewage sludge or soil. In 2016, the Departments of Ecology and Health commenced work on a Chemical Action Plan (CAP) for PFAS. The CAP currently recommends refraining from creating

any regulatory limits for PFAS concentrations in biosolids due to the lack of available relevant data in Washington (Washington Departments of Ecology and Health, 2019a). In a document released in May 2019, the CAP made preliminary recommendations for evaluation of Washington biosolids management with regards to PFAS, including land application (Washington Departments of Ecology and Health, 2019b). For comparison, Table 1 presents examples of some existing regulatory and guidance limits from the USA and Canada for the three most commonly addressed compounds: PFOS, PFOA and perfluorobutanesulfonic acid (PFBS). It is important to note that while Table 1 is current to information available as of January 2020, PFAS legislation is being drafted in many states and draft limits for soil and other media are being revised continually.

While there are no local data in Washington for PFAS concentrations in biosolids, this report includes other sources for comparison and context. NEBRA has been compiling biosolids PFAS data from sources across North America and Europe (NEBRA, 2019). These sources include state-level testing results as well as published peer-reviewed research. Tacoma biosolids testing results will be compared with average PFAS concentrations in biosolids from these sources, as compiled by NEBRA.

SAMPLING METHOD

Due to the widespread presence of PFAS in plastics, clothing and personal care products, the potential for contamination of biosolids samples with PFAS from extraneous sources is high. SYLVIS has developed a Standard Operating Procedure for sampling biosolids for PFAS, adopting a precautionary approach to minimize the potential for sample contamination during all stages of sampling preparation, collection, and submission. Examples of these precautions include avoidance of skincare products on the day of sampling, use of only lab-provided containers, and collecting equipment rinsate blanks using lab-provided, PFAS-free deionized water.

SYLVIS collected biosolids and TAGRO samples on November 26, 2019 at the Central WWTP. Three samples each were taken of biosolids, TAGRO Mix, TAGRO Potting Soil and TAGRO Topsoil. Each sample of biosolids is a composite of 8 equal volume subsamples. Samples were shipped to SGS AXYS laboratory in Sidney, British Columbia, for analysis using Method MLA-110. This method tests for 33 target compounds, including PFOS and PFOA.

RESULTS & DISCUSSION

Table 2 through Table 5 summarize the results of PFAS testing for TAGRO soil samples and Tacoma biosolids. Of the 33 compounds targeted, 21 were detected above the laboratory reporting limits in at least one of the nine TAGRO soil samples. All concentrations of PFOS, PFOA and PFBS in TAGRO soil were detected well below the NEBRA data averages for biosolids. In all soil and biosolids samples, concentrations for these three compounds were also below all of the limits for human health listed in Table 1, except for the Maine limits for solid waste.

The biosolids had the highest average concentration of PFOS at 15.27 ppb, approximately 5 to 6 times that of the average PFOS concentrations for the TAGRO soils. However, this is still below the NEBRA average of 21.19 ppb (Table 5). PFBS was not detected above the reporting limit in

either TAGRO Mix or biosolids and was detected in relatively low levels (less than half of the NEBRA average) in TAGRO Topsoil and Potting Soil samples (Table 3 and Table 4). PFOA concentrations, while relatively low for all samples tested, were generally greater in the TAGRO soils than in the biosolids. This may be due to the formation of PFOA in the environment through transformation or degradation of other perfluorinated substances.

Similarly, the concentration of N-methyl perfluorooctanesulfonamidoethanol (N-MeFOSE) in the biosolids versus the concentration of its degradation product, N-methylperfluorooctane sulfonamidoacetic acid (MeFOSAA) in the Mix and Potting Soil samples, suggests that some transformation may occur in TAGRO soils. N-MeFOSE is used primarily in the manufacture of stain-resistant coatings for carpets and textiles. Of all PFAS compounds detected, MeFOSAA held the greatest average concentration for both the TAGRO Mix and Potting Soil samples at approximately 24% and 18% of total PFAS, respectively (Table 2 and Table 4). MeFOSAA concentration was lower in the biosolids, at approximately 12% (Table 5). Conversely, N-MeFOSE held the greatest concentration in the biosolids samples at 42% of total PFAS detected, while in the soil samples, the average concentration of N-MeFOSE was significantly lower at 11 to 19%. The degradation of N-MeFOSE to MeFOSAA has been shown to occur via biotransformation in aerobic soils, with an apparent soil half-life of approximately 14 days (Mejia Avendaño and Liu, 2015).

While TAGRO Topsoil had a similar concentration of MeFOSAA to that of the other soils (17%, Table 3) the greatest average concentration in the Topsoil samples was of perfluorohexanoic acid (PFHxA), at 21.4% of total PFAS detected. For all of the soil samples, PFHxA concentration was 13 to 20 times greater than in the biosolids samples, where the average concentration was just 1.2%. Like PFOA, PFHxA is a degradation product of intermediates used to manufacture other perfluorinated chemicals, so may increase in soils due to degradation.

NEBRA does not supply compiled data for biosolids-amended soil for comparison, but a 2011 study of PFOS and MeFOSAA concentrations of 6 biosolids-amended soils found ranges for PFOS of 2 to 11 ppb and found all MeFOSAA concentrations to be below 4 ppb (Sepulvado et al., 2011). All TAGRO soil samples had PFOS averages on the low end of that range, while MeFOSAA averages were greater than the concentrations found in that study.

In assessing the TAGRO products, the preliminary hypothesis is that the bulk of the PFAS substances would originate in the biosolids. Barring any major transformations, this would result in mathematical reductions of PFAS materials correlating well with the ratios of feedstocks added to the biosolids. For example, a product with a 1:4 ratio of biosolids to feedstocks, would be expected to have approximately 20% of the PFAS of the original biosolids samples.

The results from TAGRO products indicates that this is hypothesis is flawed. While reductions in line with feedstock ratios are noted for some compounds, such as PFOS, others, such as PFOA and PFHxS, show no change, or even a mild increase in concentration in the soil mixes. While this may be a result of degradation of other PFAS compounds, it also indicates that the ubiquity of some PFAS should be assessed across feedstocks in order to understand what an expected concentration of PFAS in a final soil product may be. Based on the results, it is likely that there is a reasonable load of specific PFAS compounds in at least one of the feedstocks, that is adding

to the total concentration of these specific compounds in the TAGRO soil mixes. One feedstock in particular that appears to be a potential source of additional PFOA, is bark. With increasing bark concentrations in the TAGRO mixes, we observe increasing PFOA concentrations. Increased PFOA from bark surfaces is a reasonable hypothesis to further explore feedstock logistics chains to obtain a better understanding of the origins of PFOA, and other PFAS substances.

SUMMARY AND RECOMMENDATIONS

PFAS concentrations in Tacoma biosolids and TAGRO soils were overall below the averages for biosolids and amended soils tested across North America. The biosolids from which TAGRO is produced has reasonably low levels of PFAS, and the TAGRO products themselves reflect both dilution of these substances, or ubiquitously low concentrations of the substances that may be present in the other TAGRO feedstocks as well. The TAGRO feedstocks and their supply chain should be assessed, and the feedstocks analyzed, to better understand the sources of PFAS.

The quantities of PFAS substances in TAGRO products are very low. They fall below all science-based benchmarks, and most additional indicator guidelines or regulatory benchmarks for soils that are currently available for comparison.

The PFAS concentrations observed are not likely to pose any acute or chronic environmental or health concerns for TAGRO users with regards to the use of TAGRO products; health risks have not been observed at the low concentrations of PFAS which are present in TAGRO products.

The study and comprehension of the health and environmental implications of PFAS in biosolids and the environment continues to evolve. A robust pool of data does not yet exist for this issue, but the foresight and participation of concerned municipal governments operating biosolids management plans allows for the continued evolution of this area of research. The purpose of this study was to provide a baseline of knowledge for the City of Tacoma in regard to its TAGRO products. Remaining informed of the ongoing development of knowledge and policy through science is required to ensure that the understanding of the potential risk that PFAS presents to TAGRO products remains low.

Table 1: Summary of selected PFAS regulatory and guidance limits for soil in the United States and Canada.

Source	Purpose	Media	Standard	PFOS	PFOA	PFHxS	PFBS	Units
United States								
Environmental Protection Agency - Regional Screening Levels (RSL) [a]	Surface and Groundwater Protection	Soil	Guidance	0.378	0.172	none	130	ppb
Environmental Protection Agency - RSL [a]	Human Health	Soil	Guidance	1,260	1,260	none	1.30E+06	ppb
Maine Department of Environmental Protection - Screening Levels for Beneficial Use [b]	Human Health	Solid Waste	Regulatory	5.2	2.5	none	1,900	ppb
Minnesota Pollution Control Agency - Soil Reference Value [c]	Human Health	Soil	Guidance	41	240	130	5,700	ppb
Nevada Division of Environmental Protection - Basic Comparison Levels [d]	Human Health	Soil	Guidance	1,560	1,560	none	1.25E+05	ppb
Vermont Department of Environmental Conservation - RSL [e]	Human Health	Soil	Regulatory	1,220	1,220	1,220	none	ppb
Canada and British Columbia								
BC Contaminated Sites Regulation - Numerical Standards for Agricultural Land	Groundwater Protection [e]	Soil	Regulatory	3.50E+05	none	none	none	ppb
BC Contaminated Sites Regulation - Numerical Standards for Agricultural Land	Human Health	Soil	Regulatory	1000	none	none	3.00E+05	ppb

[a] PFOS and PFOA RSLs calculated using the EPA RSL calculator, with residential exposure assumptions (Interstate Technology Regulatory Council, 2019). PFBS RSL as presented in the EPA's RSL Summary Table (EPA, 2019).

[b] Can apply to biosolids at Department's discretion (Maine Department of Environmental Protection, 2018).

[c] Risk-based Site Evaluation Guidance, Draft SRV Technical Support Document and SRV Spreadsheets (Minnesota Pollution Control Agency, 2009, as cited in Interstate Technology Regulatory Council, 2019).

[d] (Nevada Division of Environmental Protection, 2017).

[e] Criteria for individual compounds or sum of five PFAS: PFHpA, PFHxS, PFNA, PFOS and PFOA (State of Vermont et al., 2019).

Table 2: Results of PFAS testing of TAGRO Mix.

Analytes	TAGRO Mix - Sample 1		TAGRO Mix - Sample 2		TAGRO Mix - Sample 3		Mean Concentration (ppb)	Mean Percentage of Total PFAS Detected
	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)		
Perfluoroalkyl carboxylates								
PFBA	ND [a] H [b]	0.57	ND H	0.377	ND H	0.589	-	-
PFPeA	0.322	0.158	0.297	0.148	0.239	0.164	0.29	1%
PFHxA	4.88	0.103	4.89	0.0738	4.13	0.0822	4.63	14%
PFHpA	0.164	0.0788	0.2	0.0738	0.198	0.0822	0.19	1%
PFOA	1.9	0.0788	2.08	0.0738	1.62	0.0822	1.87	6%
PFNA	0.466	0.0788	0.537	0.0738	0.524	0.0822	0.51	2%
PFDA	0.908	0.0788	0.901	0.0738	0.75	0.0822	0.85	3%
PFUnA	0.383	0.0788	0.224	0.0738	0.368	0.0822	0.33	1%
PFDoA	0.418	0.0788	0.356	0.0738	0.33	0.0822	0.37	1%
PFTrDA	0.211	0.0788	0.211	0.0738	0.198	0.0822	0.21	1%
PFTeDA	0.184	0.0788	0.155	0.0738	0.172	0.0822	0.17	1%
Perfluoroalkyl sulfonates								
PFBS	ND	0.0788	ND	0.0738	ND	0.0822	-	-
PFPeS	ND	0.0788	ND	0.0738	ND	0.0822	-	-
PFHxS	ND	0.0788	ND	0.0738	ND	0.0822	-	-
PFHpS	ND	0.0788	ND	0.0738	ND	0.0822	-	-
PFOS	2.69	0.126	2.69	0.0738	2.36	0.111	2.58	8%
PFNS	ND	0.298	ND	0.0738	ND	0.0822	-	-
PFDS	0.149	0.0788	0.205	0.0738	0.264	0.0822	0.21	1%
PFDoS	ND	0.0788	ND	0.0738	ND	0.0822	-	-
Fluorotelomer sulfonates								
4:2 FTS	ND	0.315	ND	0.295	ND	0.329	-	-
6:2 FTS	1.22	0.567	1.15	0.531	0.989	0.592	1.12	3%
8:2 FTS	0.658	0.315	0.876	0.295	0.871	0.329	0.80	2%
Perfluorooctane sulfonamides								
PFOSA	0.551	0.0788	0.55	0.0738	0.494	0.0822	0.53	2%
N-MeFOSA	ND	0.0906	0.118	0.0848	ND	0.0945	n/a [c]	-
N-EtFOSA	ND	0.197	ND	0.184	ND	0.205	-	-
Perfluorooctane sulfonamideacetic acids								
MeFOSAA	7.61	0.0788	8.05	0.0738	8.34	0.0822	8.00	24%
EtFOSAA	2.9	0.158	2.9	0.148	2.61	0.164	2.80	8%
Perfluorooctane sulfonamide ethanols								
N-MeFOSE	6.23	0.788	7.48	0.738	5.09	0.822	6.27	19%
N-EtFOSE	1.99	0.591	1.93	0.553	1.95	0.616	1.96	6%
Ether carboxylates								
HFPO-DA	ND	0.315	ND	0.295	ND	0.329	-	-
ADONA	ND	0.315	ND	0.295	ND	0.329	-	-
Ether sulfonates								
9Cl-PF3ONS	ND	0.315	ND	0.295	ND	0.329	-	-
11Cl-PF3OUdS	ND	0.315	ND	0.295	ND	0.329	-	-

[a] ND = substance not detected at laboratory's reporting limit.

[b] H = percent recovery was less than 50% of the lab method lower control limits, but greater than 1%; concentration is reported as estimated.

[c] n/a = insufficient quantity of values to calculate an average.

Table 3: Results of PFAS testing of TAGRO Topsoil.

Analytes	TAGRO Topsoil - Sample 1		TAGRO Topsoil - Sample 2		TAGRO Topsoil - Sample 3		Mean Concentration (ppb)	Mean Percentage of Total PFAS Detected
	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)		
Perfluoroalkyl carboxylates								
PFBA	1.06	0.292	1.07	0.326	1.1	0.282	1.08	4%
PFPeA	0.604	0.146	0.651	0.163	0.465	0.141	0.57	2%
PFHxA	6.52	0.13	6.47	0.101	6.02	0.162	6.34	21%
PFHpA	0.202	0.0731	0.284	0.0816	0.24	0.0705	0.24	1%
PFOA	3.19	0.0731	3.4	0.0816	2.64	0.0705	3.08	10%
PFNA	0.589	0.0731	0.634	0.0816	0.611	0.0705	0.61	2%
PFDA	1.04	0.0731	1.02	0.0816	0.879	0.0705	0.98	3%
PFUnA	0.323	0.0731	0.308	0.0816	0.33	0.0705	0.32	1%
PFDoA	0.349	0.0731	0.379	0.0816	0.333	0.0705	0.35	1%
PFTrDA	0.188	0.0731	0.205	0.0816	0.212	0.0705	0.20	1%
PFTeDA	0.152	0.0731	0.165	0.0816	0.143	0.0705	0.15	1%
Perfluoroalkyl sulfonates								
PFBS	1.18	0.0731	1.28	0.0816	1.09	0.0705	1.18	4%
PFPeS	ND [(b)]	0.0731	ND	0.0816	ND	0.0705	-	-
PFHxS	ND	0.0731	ND	0.0816	ND	0.0705	-	-
PFHpS	ND	0.0731	ND	0.0816	ND	0.0705	-	-
PFOS	2.46	0.123	2.68	0.111	2.88	0.0943	2.67	9%
PFNS	ND	0.123	ND	0.0816	ND	0.0781	-	-
PFDS	0.39	0.0731	0.335	0.0816	0.363	0.0705	0.36	1%
PFDoS	ND	0.0731	ND	0.0816	ND	0.0705	-	-
Fluorotelomer sulfonates								
4:2 FTS	ND	0.292	ND	0.326	ND	0.282	-	-
6:2 FTS	0.909	0.526	1.1	0.588	0.852	0.507	0.95	3%
8:2 FTS	0.644	0.292	0.69	0.326	0.498	0.282	0.61	2%
Perfluorooctane sulfonamides								
PFOSA	0.326	0.0731	0.386	0.0816	0.335	0.0705	0.35	1%
N-MeFOSA	0.109	0.084	ND	0.0938	ND	0.081	n/a	0%
N-EtFOSA	ND	0.183	ND	0.204	ND	0.176	-	-
Perfluorooctane sulfonamideacetic acids								
MeFOSAA	4.54	0.0731	5.59	0.0816	5.17	0.0705	5.10	17%
EtFOSAA	1.91	0.146	1.73	0.163	1.35	0.141	1.66	6%
Perfluorooctane sulfonamide ethanols								
N-MeFOSE	3.21	0.731	3.26	0.816	3.68	0.705	3.38	11%
N-EtFOSE	1.58	0.548	1.7	0.612	1.67	0.528	1.65	6%
Ether carboxylates								
HFPO-DA	ND	0.292	ND	0.326	ND	0.282	-	-
ADONA	ND	0.292	ND	0.326	ND	0.282	-	-
Ether sulfonates								
9Cl-PF3ONS	ND	0.292	ND	0.326	ND	0.282	-	-
11Cl-PF3OUdS	ND	0.292	ND	0.326	ND	0.282	-	-

[(a)] ND = substance not detected at laboratory's reporting limit.

Table 4: Results of PFAS testing of TAGRO Potting Soil.

Analytes	TAGRO Potting Soil - Sample 1		TAGRO Potting Soil - Sample 2		TAGRO Potting Soil - Sample 3		Mean Concentration (ppb)	Mean Percentage of Total PFAS Detected
	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)		
Perfluoroalkyl carboxylates								
PFBA	1.56	0.307	1.36	0.292	1.57	0.314	1.50	4%
PFPeA	0.909	0.154	0.882	0.146	1.18	0.157	0.99	3%
PFHxA	5.89	0.143	5.91	0.145	6.48	0.0996	6.09	18%
PFHpA	0.468	0.0768	0.374	0.0752	0.487	0.0785	0.44	1%
PFOA	3.29	0.0768	3.23	0.0731	4.28	0.0785	3.60	10%
PFNA	0.881	0.0768	0.906	0.0731	0.939	0.0785	0.91	3%
PFDA	1.31	0.0768	1.38	0.0731	1.5	0.0785	1.40	4%
PFUnA	0.406	0.0768	0.442	0.0731	0.365	0.0785	0.40	1%
PFDoA	0.366	0.0768	0.5	0.0731	0.414	0.0785	0.43	1%
PFTrDA	0.285	0.0768	0.288	0.0731	0.273	0.0785	0.28	1%
PFTeDA	0.187	0.0768	0.197	0.0731	0.233	0.0785	0.21	1%
Perfluoroalkyl sulfonates								
PFBS	2.21	0.0768	2.45	0.0731	2.48	0.0785	2.38	7%
PFPeS	ND [(a)]	0.0994	ND	0.0731	ND	0.0785	-	-
PFHxS	ND	0.0768	ND	0.0731	ND	0.0785	-	-
PFHpS	ND	0.0768	ND	0.0731	ND	0.0785	-	-
PFOS	2.8	0.25	2.87	0.188	2.63	0.0785	2.77	8%
PFNS	ND	0.147	ND	0.124	ND	0.311	-	-
PFDS	0.544	0.0768	0.49	0.0731	0.537	0.0785	0.52	2%
PFDoS	ND	0.0768	ND	0.0731	ND	0.0785	-	-
Fluorotelomer sulfonates								
4:2 FTS	ND	0.307	ND	0.292	ND	0.314	-	-
6:2 FTS	0.77	0.553	0.627	0.526	ND	0.565	0.70	2%
8:2 FTS	0.694	0.307	0.63	0.292	0.505	0.314	0.61	2%
Perfluorooctane sulfonamides								
PFOSA	0.431	0.0768	0.457	0.0731	0.453	0.0785	0.45	1%
N-MeFOSA	ND	0.0883	0.108	0.0841	0.112	0.0902	0.11	0%
N-EtFOSA	ND	0.192	ND	0.183	ND	0.196	-	-
Perfluorooctane sulfonamideacetic acids								
MeFOSAA	5.52	0.0768	6.38	0.0731	6.62	0.0785	6.17	18%
EtFOSAA	2.32	0.154	2.35	0.146	2.14	0.157	2.27	7%
Perfluorooctane sulfonamide ethanols								
N-MeFOSE	4.27	0.768	4.27	0.731	4.54	0.784	4.36	13%
N-EtFOSE	2.03	0.576	2.07	0.548	2.37	0.588	2.16	6%
Ether carboxylates								
HFPO-DA	ND	0.307	ND	0.292	ND	0.314	-	-
ADONA	ND	0.307	ND	0.292	ND	0.314	-	-
Ether sulfonates								
9Cl-PF3ONS	ND	0.307	ND	0.292	ND	0.314	-	-
11Cl-PF3OUdS	ND	0.307	ND	0.292	ND	0.314	-	-

[(a)] ND = substance not detected at laboratory's reporting limit.

Table 5: Results of PFAS testing of Tacoma biosolids from Central WWTP.

Analytes	Biosolids - Sample 1		Biosolids - Sample 2		Biosolids - Sample 3		Mean Concentration (ppb)	NEBRA Compiled Average [a] (ppb)	Mean Percentage of Total PFAS Detected
	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)	Concentration (ppb)	Reporting Limit (ppb)			
Perfluoroalkyl carboxylates									
PFBA	ND [b]	3.95	ND	6.29	ND	2.94	-	3.07	-
PFPeA	ND	1.48	ND	1.47	ND	1.13	-	7.63	-
PFHxA	1.72	0.74	1	0.736	1.37	0.565	1.36	41.83	1%
PFHpA	ND	0.74	ND	0.736	ND	0.565	-	0.70	-
PFOA	2.09	0.74	2.02	0.736	1.87	0.565	1.99	7.40	2%
PFNA	1.11	0.74	ND	0.736	0.905	0.565	1.01	8.50	1%
PFDA	2.21	0.74	2.42	0.736	1.87	0.565	2.17	5.85	2%
PFUnA	1.07	0.74	ND	0.736	1.34	0.565	1.21	*2.70*	1%
PFDoA	1.91	0.74	1.84	0.736	1.58	0.565	1.78	*3.60*	2%
PFTrDA	1.16	0.74	0.955	0.736	0.751	0.565	0.96	-	1%
PFTeDA	0.802	0.74	1.19	0.736	1.06	0.565	1.02	-	1%
Perfluoroalkyl sulfonates									
PFBS	ND	0.74	ND	0.736	ND	0.565	-	4.30	-
PFPeS	ND	0.74	ND	0.855	ND	0.565	-	-	-
PFHxS	ND	0.74	ND	0.736	ND	0.565	-	1.59	-
PFHpS	ND	0.74	ND	0.736	ND	0.565	-	-	-
PFOS	16.5	0.911	15.4	0.736	13.9	0.584	15.27	21.19	14%
PFNS	ND	0.74	ND	0.736	ND	0.565	-	-	-
PFDS	2.25	0.74	1.96	0.736	1.06	0.565	1.76	*4.30*	2%
PFDoS	ND	0.74	ND	0.736	ND	0.565	-	-	-
Fluorotelomer sulfonates									
4:2 FTS	ND	2.96	ND	2.95	ND	2.26	-	-	-
6:2 FTS	ND	5.33	ND	5.3	ND	4.07	-	-	-
8:2 FTS	ND	2.96	ND	2.95	ND	2.26	-	-	-
Perfluorooctane sulfonamides									
PFOSA	1.42	0.74	1.58	0.736	1.3	0.565	1.43	*0.50*	1%
N-MeFOSA	1.45	0.851	1.12	0.847	1.11	0.65	1.23	-	1%
N-EtFOSA	ND	1.85	ND	1.84	ND	1.41	-	-	-
Perfluorooctane sulfonamideacetic acids									
MeFOSAA	11.2	0.74	13.3	0.736	14.3	0.565	12.93	-	12%
EtFOSAA	11.9	1.48	12.6	1.47	10.2	1.13	11.57	-	10%
Perfluorooctane sulfonamide ethanols									
N-MeFOSE	46.8	7.4	48	7.36	45.2	5.65	46.67	-	42%
N-EtFOSE	10.8	5.55	7.42	5.52	8.74	4.24	8.99	-	8%
Ether carboxylates									
HFPO-DA	ND	2.96	ND	2.95	ND	2.26	-	-	-
ADONA	ND	2.96	ND	2.95	ND	2.26	-	-	-
Ether sulfonates									
9Cl-PF3ONS	ND	2.96	ND	2.95	ND	2.26	-	-	-
11Cl-PF3OUdS	ND	2.96	ND	2.95	ND	2.26	-	-	-

[a] Averages calculated from select, relevant data compiled by NEBRA. Sources include government testing well as scientific peer-reviewed research (NEBRA, 2019). Values in *italics* are not averages but are single values from Gottshall, 2016, (as cited in NEBRA, 2019)

[b] ND = substance not detected at laboratory's reporting limit.

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