Article

PER-AND POLYFLUOROALKYL SUBSTANCES (PFAS) OCCURRENCE IN GUNPOWDER RIVER WATERSHED IN MARYLAND UNITED STATES

Chichedo I Duru[1], Theaux M. Le Gardeur[2], Isabel N Ryen[2], Jennifer A. Galler[2], Samendra Sherchan*[1,]

[1] Center of Research Excellence in Wastewater Based Epidemiology, Morgan State University, Baltimore, MD 21251, USA

[2] Gunpowder RIVERKEEPER, 16829 York RD, Monkton, MD 21111, USA

* Correspondence: Dr. Samendra Sherchan Samendra.sherchan@morgan.edu)

Table S1: List of Streams Sampled During the Study

Above Loch Raven				
S/N	**River Name**	**Location**	**Longitude**	**Latitude**
1	Loch Raven Reservoir	Loch Raven	-76.5666	39.46296
2	Prettyboy Reservoir	Hampstead	-76.74252	39.65208
3	Little Falls	White Hall	-76.62908	39.62151
4	Green Branch	Jacksonville	-76.58621	39.5129
5	Beaverdam Run	Cockeysville	-76.6459	39.48548
6	Piney Run	Upperco	-76.81133	39.57558
Below Loch Raven				
7	Winters Run	Joppa	-76.31682	39.44389
8	Gunpowder Falls	Perry Hall	-76.428022	39.417515
9	Bird River	White Marsh	-76.394915	39.382405
10	Upstream Little Gunpowder Falls	Joppa	-76.3729	39.4211
11	Downstream Little Gunpowder Falls	Joppa	-76.36735	39.41059

Table S2: PFAS in Non-drinking Water Sources

Sampling Locations					
Compounds	Little Gunpowder River Upstream	Little Gunpowder River Downstream	Bird River (White Marsh)	Gunpowder Falls (Perry Hall)	Winters Run (Joppa)
PFBS	1.6	1.7	1.8	< 1 ng/l	2
PFNA	< 1 ng/l	< 1 ng/l	1	< 1 ng/l	< 1 ng/l
PFHpA	< 1 ng/l	1.1	1.7	< 1 ng/l	1.1
PFHxA	1.6	2.2	2.2	3.6	1.4
PFHxS	< 1 ng/l	< 1 ng/l	1.8	< 1 ng/l	2.1
PFOA	1.9	2.3	3.1	1.1	2.4
PFOS	1.5	3.1	4.7	1	3.1
PFPeA	< 1 ng/l	2	2.1	< 1 ng/l	1
5:3 FTCA	< 1 ng/l	< 1 ng/l	< 1 ng/l	1	< 1 ng/l
HFPO-DA (GenX)	< 2 ng/l	< 2 ng/l	< 2 ng/l	< 2 ng/l	< 2 ng/l
N-MeFOSA	< 1 ng/l	< 1 ng/l	<1 ng/l	3.9	
Total PFAS (All Detected)	6.6 ng/l	12.4 ng/l	18.4 ng/l	10.6 ng/l	13.1 ng/l

Table S3: PFAS in Drinking Water Sources

Sampling Locations						
Compounds	Loch Raven reservoir (Loch Raven)	Breen branch (Jacksonville)	Prettyboy Reservoir (Hampstead)	Piney Run (Upperco)	Beaverdam Run (Cockeysville)	Little Falls (White Hall)
PFBA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l
PFPeA	< 1 ng/l	2.8	< 1 ng/l	2.6	1.4	1.3
PFHxA	1.2	4.6	< 1 ng/l	2.4	2.3	1.7
PFHpA	< 1 ng/l	2	< 1 ng/l	1	1.8	1.3
PFOA	1.4	4.8	1.1	1.5	3.1	1.6
PFNA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l
PFDA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l
HFPO-DA (GenX)	< 2 ng/l	< 2 ng/l	< 2 ng/l	< 2 ng/l	< 2 ng/l	< 2 ng/l
PFBS	1.1	2.8	< 1 ng/l	1.1	3.6	1
PFHxS	< 1 ng/l	2.2	< 1 ng/l	< 1 ng/l	1.4	< 1 ng/l
PFOS	1.3	2.1	1	< 1 ng/l	3.3	< 1 ng/l
5:3 FTCA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l
FBSA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	1	< 1 ng/l
N-MeFOSAA	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l	< 1 ng/l
Total PFAS (All detected)	5	21.3	2.1	8.6	17.9	6.9

Table S4: All PFAS Analyzed

Compounds	Abbreviation	Formula
N-Methyl Perfluorooctane Sulfonamido Acetic Acid	N-MeFOSAA	$C_9H_6F_{17}NO_4S$
N-methyl perfluorooctanesulfonamidoethanol	NMeFOSE	$C_{11}H_8F_{17}NO_3S$
Perfluorobutanoic Acid	PFBA	$C_4HF_7O_2$
Perfluorobutane Sulfonic Acid	PFBS	$C_4HF_9O_3S$
Perfluorodecanoic Acid	PFDA	$C_{10}HF_{19}O_2$
Perfluorododecanoic Acid	PFDoA	$C_{12}HF_{23}O_2$
Perfluorododecane Sulfonic Acid	PFDoS	$C_{12}HF_{25}O_3S$
Perfluorodecane Sulfonic Acid	PFDS	$C_{10}HF_{21}O_3S$
Perfluoro-4-ethylcyclohexane Sulfonic Acid	PFECHS	$C_8HF_{15}O_3S$
Perfluoro(2-ethoxyethane) Sulfonic acid	PFEESA	$C_4HF_9O_4S$
Perfluoroheptanoic Acid	PFHpA	$C_7HF_{13}O_2$
Perfluoroheptane Sulfonic Acid	PFHpS	$C_7HF_{15}O_3S$
Perfluorohexanoic Acid	PFHxA	$C_6HF_{11}O_2$
Perfluorohexane Sulfonic Acid	PFHxS	$C_6HF_{13}O_3S$
Perfluoro-4-Methoxybutanoic Acid	PFMOBA	$C_5HF_9O_3$
Perfluoro-3-Methoxypropanoic Acid	PFMOPrA	$C_4HF_7O_3$
Perfluorononanoic Acid	PFNA	$C_9HF_{17}O_2$
Perfluorononane Sulfonic Acid	PFNS	$C_9HF_{19}O_3S$
Perfluorooctanoic Acid	PFOA	$C_8HF_{15}O_2$
Perfluorooctane Sulfonic Acid	PFOS	$C_8HF_{17}O_3S$
Perfluorooctane Sulfonamide	PFOSA	$C_8H_2F_{17}NO_2S$
Perfluoropentanoic Acid	PFPeA	$C_5HF_9O_2$
Perfluoropentane Sulfonic Acid	PFPeS	$C_5HF_{11}O_3S$
Perfluoropropane Sulfonic Acid	PFPrS	$C_3F_7SO_3H$
Perfluorotetradecanoic Acid	PFTeA	$C_{14}HF_{27}O_2$
Perfluorotridecanoic Acid	PFTrDA	$C_{13}HF_{25}O_2$
Perfluoroundecanoic Acid	PFUnA	$C_{11}HF_{21}O_2$
10:2 Fluorotelomer Sulfonate	10:2 FTS	$C_{12}H_4F_{21}NaO_3S$
11-Chloroeicosafluoro-3-Oxanonane-1-Sulfonic Acid	11CL-PF3OUdS	$C_{10}HClF_{20}O_4S$
3-Perfluoropropyl Propanoic Acid	3:3 FTCA	$C_6H_5F_7O_2$
4:2 Fluorotelomer Sulfonate	4:2 FTS	$C_6H_5F_9O_3S$
2h,2h,3h,3h-Perfluorooctanoic Acid	5:3 FTCA	$C_8H_5F_{11}O_2$
6:2 Fluorotelomer Sulfonate	6:2 FTS	$C_8H_5F_{13}O_3S$
Bis(perfluorohexyl)phosphinic acid	6:6PFPi	$C_{12}HF_{26}O_2P$
(Heptadecafluorooctyl)(tridecafluorohexyl) Phosphinic Acid	6:8PFPi	$C_{14}HF_{30}O_2P$
3-Perfluoroheptyl propanoic acid	7:3 FTCA	$C_{10}H_5F_{15}O_2$
8:2 Fluorotelomer Sulfonate	8:2 FTS	$C_{10}H_5F_{17}O_3S$
8-Chloroperfluoro-1-Octanesulfonic Acid	8Cl-PFOS	$C_8HClF_{16}O_3S$
9-Chlorohexadecafluoro-3-Oxanone-1-Sulfonic Acid	9Cl-PF3ONS	$C_8HClF_{16}O_4S$
4,8-Dioxa-3H-Perfluorononanoate	ADONA	$C_{10}H_{11}N_4NaO_5S$
Perfluorobutane Sulfonamide	FBSA	C_6H_5FOS

Perfluorodecane Sulfonamide	FDSA	$C_{10}H_2F_{21}NO_2S$
2H-Perfluoro-2-dodecenoic acid	FDUEA	$C_{12}H_2F_{20}O_2$
Perfluorohexane Sulfonamide	FHxSA	$C_6H_2F_{13}NO_2S$
Perfluorooctane Sulfonamido Acetic Acid	FOSAA	$C_{10}H_4F_{17}NO_4S$
2H-perfluoro-2-decenoic acid	FOUEA	$C_{10}H_2F_{16}O_2$
Hexafluoropropylene Oxide Dimer Acid	HFPO-DA (GenX)	$C_4HF_7O_3$
N-Methylperfluorobutanesulfonamide	MeFBSA	$C_5H_4F_9NO_2S$
N-AP-FHxSA	N-AP-FHxSA	$C_{11}H_{13}F_{13}N_2O_2S$
N-Ethylperfluorooctane-1-Sulfonamide	N-EtFOSA	$C_{10}H_6F_{17}NO_2S$
N-Ethyl Perfluorooctane Sulfonamido Acetic Acid	N-EtFOSAA	$C_{12}H_8F_{17}NO_4S$
N-ethyl perfluorooctanesulfonamidoethanol	NEtFOSE	$C_{12}H_6F_{21}NO_3S$
Perfluoro-3,6-Dioxaheptanoic Acid	NFDHA	$C_5HF_9O_4$
N-Methylperfluorooctane-1-Sulfonamide	N-MeFOSA	$C_9H_4F_{17}NO_2S$

Table S5: PFAS Levels in States in the United States (Source [32])

State	PFAS	Level	Regulation Status
Alaska	PFOA and PFOS combined	70 ng/l	Notification
California	PFOA, PFOS; PFHxS and PFBS	5.1 ng/l; 6.5 ng/l;3 ng/l and 500 ng/l	Notification
Colorado	3 PFAS combined (PFOA, PFOS, PFNA); PFHxS; PFBS	70 ng/l; 700 ng/l; 400,000 ng/l	Guidance
Connecticut	5 PFAS combined (PFOA, PFOS, PFHxS, PFHpA and PFNA)	70 ng/l	Notification
Delaware	PFOA and PFOS combined	70 ng/l	Guidance
Hawaii	PFOA and PFOS; 16 other PFAS substances	40 ng/l	Guidance
Maine	6 PFAS combined (PFOA, PFOS, PFHxS, PFHpA, PFNA, and PFDA)	20 ng/l	Notification
Maryland	PFHxS	140 ng/l	Guidance
Massachusetts	6 PFAS combined (PFOS, PFOA, PFHxS, PFNA, PFDA and PFHpA)	20 ng/l	MCL
Michigan	PFOA; PFNA; PFHxS; HFPO-DA; PFHxA	8 ng/l; 6 ng/l; 51 ng/l; 370 ng/l and 400,000 ng/l	MCL
Minnesota	PFOS; PFOA; PFHxS; PFBS and PFBA	15 ng/l; 35 ng/l; 47 ng/l; 20,000 ng/l and 70,000 ng/l	Guidance
Nevada	PFOA and PFOS; PFBS	667,000 ng/l; 667,000,000 ng/l	Guidance
New Hampshire	PFOA; PFNA	12 ng/l; 11 ng/l	MCL
New Jersey	PFOA; PFOS; PFNA	14 ng/l; 13 ng/l; 13 ng/l	MCL
New Mexico	PFAS	70 ng/l	
New York	PFAS; PFOA	10 ng/l	MCL
North Carolina	HFPO-DA(GenX)	140 ng/l	Guidance
Ohio	PFOA and PFOS combined; PFNA; PFBS and HFPO-DA	70 ng/l; 21 ng/l; 140,000 ng/l, 700 ng/l	Guidance
Oregon	4 PFAS combined (PFOA, PFOS, PFHxS and PFNA)	30 ng/l	Guidance
Pennsylvania	PFOA	14 ng/l	MCL
Rhode Island	6 PFAS combined (PFOA, PFOS, PFHxS, PFNA, PFHpA, and PFDA)	20 ng/l	Notification
Vermont	5 PFAs combined (PFOA, PFOS, PFHxS, PFHpA and PFNA)	20 ng/l	MCL
Washington	PFOA; PFOS; PFNA	10 ng/l;15 ng/l; 9 ng/l	Notification