

**Occurrence and Distribution of Per- and Polyfluoroalkyl Substances from Multi-Industry Sources to Water, Sediments and Plants along Nairobi River Basin, Kenya**

Chirikona Nyangweso Flora<sup>1\*</sup>, Natalia Soares Quinete<sup>2</sup>, Jesleen Gonzalez<sup>2</sup>, Mutua Gershom<sup>1</sup>,  
Kimosop Selly<sup>1</sup>, Orata Francis<sup>1</sup>

<sup>1</sup>Department of Pure and Applied Chemistry, Masinde Muliro University of Science and Technology. P.O Box 190 Kakamega 50100

<sup>2</sup>Department of Chemistry & Biochemistry Institute of Environment, Freshwater Resources Division Florida International University, 3000 NE 151<sup>st</sup> street, Biscayne Bay Campus North Miami, FL33181, USA

\*Corresponding author E-mail: chirikonaflorey@gmail.com.Tel: +254-723789441

**Supplementary information**

**Table S1:** List of 30 PFAS with their internal standards applied for quantitation and list of 24 PFAS in the secondary standard.

Abbreviation	Compound Name	Molecular Formula	Molecular Weight	I.S.	Secondary Standard
4-2 FTS	Sodium 1H,1H,2H,2H-perfluoro-1-hexanesulfonate	C <sub>6</sub> H <sub>5</sub> F <sub>9</sub> O <sub>3</sub> S	328.15	M2 4-2 FTS	✓
6-2FTS	Sodium 1H,1H,2H,2H-perfluoro-1-octanesulfonate	C <sub>8</sub> H <sub>5</sub> F <sub>13</sub> O <sub>3</sub> S	428.17	M2 6-2FTS	✓
8-2 FTS	Sodium 1H,1H,2H,2H-perfluoro-1-decanesulfonate	C <sub>10</sub> H <sub>5</sub> F <sub>17</sub> O <sub>3</sub> S	528.18	M2 8-2 FTS	✓
ADONA	Sodium dodecafluoro-3H-4,8-dioxanonanoate	C <sub>10</sub> H <sub>11</sub> N <sub>4</sub> NaO <sub>5</sub> S	322.27	M2 6-2FTS	
FBSA	Perfluoro-1-butanesulfonamide	C <sub>4</sub> H <sub>2</sub> F <sub>9</sub> NO <sub>2</sub> S	299.11	M GenX	
FHxSA	Perfluoro-1-hexanesulfonamide	C <sub>6</sub> H <sub>2</sub> F <sub>13</sub> NO <sub>2</sub> S	399.13	M8 PFOA	
FOSA	Perfluoro-1-octanesulfonamide	C <sub>8</sub> H <sub>2</sub> F <sub>17</sub> NO <sub>2</sub> S	499.14	M8 FOSA	
HFPO-DA	2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)-propanoic acid	C <sub>6</sub> HF <sub>11</sub> O <sub>3</sub>	330.05	M GenX	
N-EtFOSAA	N-ethylperfluoro-1-octanesulfonamidoacetic acid	C <sub>12</sub> H <sub>8</sub> F <sub>17</sub> NO <sub>4</sub> S	585.23	d5 N-EtFOSAA	✓
N-MeFOSAA	N-methylperfluoro-1-octanesulfonamidoacetic acid	C <sub>11</sub> H <sub>6</sub> F <sub>17</sub> NO <sub>4</sub> S	571.21	d3 N-MeFOSAA	✓
PFBA	Perfluoro-n-butanoic acid	C <sub>4</sub> HF <sub>7</sub> O <sub>2</sub>	214.04	MPFBA	✓
PFBS	Potassium perfluoro-1-butanesulfonate	C <sub>4</sub> HF <sub>9</sub> O <sub>3</sub> S	300.10	M3 PFBS	✓
PFDA	Perfluoro-n-decanoic acid	C <sub>10</sub> HF <sub>19</sub> O <sub>2</sub>	514.08	M6 PFDA	✓
PFD <sub>o</sub> A	Perfluoro-n-dodecanoic acid	C <sub>12</sub> HF <sub>23</sub> O <sub>2</sub>	614.10	M PFD <sub>o</sub> A	✓
PFDS	Sodium perfluoro-1-decanesulfonate	C <sub>10</sub> HF <sub>21</sub> O <sub>3</sub> S	600.14	M7 PFUdA	✓
PFHpA	Perfluoro-n-heptanoic acid	C <sub>7</sub> HF <sub>13</sub> O <sub>2</sub>	364.06	M4 PFHpA	✓
PFHpS	Sodium perfluoro-1-heptanesulfonate	C <sub>7</sub> HF <sub>15</sub> O <sub>3</sub> S	450.12	M3 PFHxS	✓
PFHxA	Perfluoro-n-hexanoic acid	C <sub>6</sub> HF <sub>11</sub> O <sub>2</sub>	314.05	M5 PFHxA	✓
PFHxS	Potassium perfluorohexanesulfonate	C <sub>6</sub> HF <sub>13</sub> O <sub>3</sub> S	400.11	M3 PFHxS	✓

PFNA	Perfluoro-n-nonanoic acid	$C_9HF_{17}O_2$	464.08	M3 PFHxS	✓
PFNS	Sodium perfluoro-1-nonanesulfonate	$C_9HF_{19}O_3S$	550.14	M8 PFOS	✓
PFOA	Perfluoro-n-octanoic acid	$C_8HF_{15}O_2$	414.07	M8 PFOA	✓
PFONS	Potassium 9-chlorohexadecafluoro-3-oxanonane-1-sulfonate	$C_8ClF_{16}KO_4S$	570.67	M8 PFOS	
PFOS	Potassium perfluorooctanesulfonate	$C_8HF_{17}O_3S$	500.13	M8 PFOS	✓
PFOUdS	Potassium 11-chloroeicosafluoro-3-oxaundecane-1-sulfonate	$C_{10}ClF_{20}KO_4S$	670.69	M PFDoA	
PFPeA	Perfluoro-n-pentanoic acid	$C_5HF_9O_2$	264.05	M5 PFPeA	✓
PFPeS	Sodium perfluoro-1-pentanesulfonate Potassium	$C_5HF_{11}O_3S$	350.11	M GenX	✓
PFTeDA	Perfluoro-n-tetradecanoic acid	$C_{14}HF_{27}O_2$	714.11	M2 PFTeDA	✓
PFTTrDA	Perfluoro-n-tridecanoic acid	$C_{13}HF_{25}O_2$	664.11	M2 PFTeDA	✓
PFUdA	Perfluoro-n-undecanoic acid	$C_{11}HF_{21}O_2$	564.09	M7 PFUdA	✓

**Table S2:** The LC gradient conditions

Time (Min)	A [%]	B %	Flow mL/min
0.00	90	10	0.4
8.00	5	95	0.4
11.00	5	95	0.4
12.00	90	10	0.4

**Table S3** Ms parameters for LC- MS/MS Analysis

Parameters	Settings
Ms Aquisition	Dynamic MRM
Cycle time	500 ms
Ion source	ESI negative
Drying gas Temperature and Flow	150 0c and 10L/Min
Sheath gas temperature and flow	300 and 10L/Min
Capillary	2000
Nozzle Voltage	0 V

**Table S4.** Summary of the MRM method for the analysis of PFAS

Compound Name	IST D	Precursor Ion	Product Ions	Retention Time (min)	Delta Retention Time	Fragmentor	Collision Energy	Cell Accelerator Voltage
4-2 FTS		327	80.9	5.69	3	125	32	5
6-2FTS		427	406.8; 79.9	6.95	3	125	24	5
8-2 FTS		527	506.8; 80.9	7.65	3	170	28	5
Adona		377	250.9	6.54	3	70	10	5
d3 N-MeFOSAA	✓	573	419	8.1	3	115	20	5
d5 N-EtFOSAA	✓	589	419	8.18	3	115	20	5
FBSA		298	77.9	6.83	3	100	28	5
FHxSA		398	77.9	7.95	3	100	28	5
FOSA		497.9	77.9	8.63	3	125	36	5
GenX		285	169	5.88	3	108	12	5
M GenX	✓	287	185	5.88	3	108	20	5
M PFDoA	✓	615	570	8.21	3	79	8	5
M2 4-2 FTS	✓	329	81	5.66	3	125	28	5
M2 6-2FTS	✓	429	81	6.94	3	125	32	5
M2 8-2 FTS	✓	529	81	7.66	3	170	36	5
M2 PFTeDA	✓	715	670	8.72	5	100	13	5
M3 PFBS	✓	302	99	4.99	3	100	33	5
M3 PFHxS	✓	402	99	6.57	3	100	41	5
M4 PFHpA	✓	367	322	6.52	3	72	8	5
M5 PFHxA	✓	318	273	5.79	3	70	8	5
M5 PFPeA	✓	268	223	4.35	3	60	4	5
M6 PFDA	✓	519	474	7.7	3	81	8	5
M7 PFUDa	✓	570	525	7.98	3	73	8	5
M8 FOSA	✓	506	78	8.63	3	125	36	5

M8 PFOA	✓	421	376	7.01	3	69	8	5
M8 PFOS	✓	507	99	7.37	3	100	46	5
M9 PFNA	✓	472	427	7.39	3	66	8	5
MPFBA	✓	217	172	2.18	3	60	8	5
N-EtFOSAA		584	525.9; 418.9	8.18	3	115	20	5
N-MeFOSAA		570	482.9;418.9	8.09	3	115	16	5
PFBA		213	168.9	2.18	3	60	8	5
PFBS		298.9	98.9;80	4.98	3	100	33	5
PFDA		513	469	7.7	3	81	8	5
PFDoA		613	569; 268.7	8.21	3	79	8	5
PFDS		598.9	99	7.93	3	100	56	5
PFDS		598.9	80	7.93	3	100	88	5
PFHpA		362.9	319; 169	6.52	3	72	5	5
PFHpS		448.9	98.7; 79.7	7.01	3	100	44	5
PFHxA		313	268.9	5.79	3	70	4	5
PFHxS		398.9	99;80	6.56	3	100	41	5
PFNA		463	419;169	7.39	3	66	8	5
PFNS		548.9	98.9; 79.9	7.67	3	165	48	5
PFOA		413	369;169	7.01	3	69	8	5
PFONS		530.9	350.9	7.44	3	100	17	5
PFOS		498.9	99; 80	7.37	3	100	46	5
PFOUDS		630.9	450.9	7.97	3	100	17	5
PFPeA		263	218.9	4.3	3	60	4	5
PFPeS		348.9	98.9;79.9	5.97	3	135	36	5
PFTeDA		713	669;169	8.6	3	100	13	5
PFTTrDA		663	619;169	8.41	3	91	9	5
PFUdA		563	519	7.97	3	73	8	5
4-2 FTS		327	306.9	5.69	3	125	20	5

**Table S5.** Method Validation results for PFAS.

<b>Compounds</b>	<b>MDL (ng/L) water</b>	<b>MDL (ng/g) sediments and plants</b>
PFBA	0.001	0.1
FBSA	0.01	0.1
PFBS	0.01	0.2
PFPeA	0.05	2
PFPeS	0.003	0.4
PFHxA	0.01	0.4
FHxSA	0.02	0.4
PFHxS	0.01	0.1
4-2 FTS	0.03	0.4
Adona	0.01	0.4
GenX	0.03	0.1
PFHpA	0.08	0.2
PFHpS	0.04	0.4
PFOA	0.01	0.2
FOSA	0.03	0.2
PFOS	0.01	0.2
6-2 FTS	0.22	0.1
PFONS	0.01	0.4
PFNA	0.02	0.1
N-MeFOSAA	0.49	0.2
N-EtFOSAA	0.27	
PFNS	0.01	0.2
PFDA	0.02	0.1
PFDS	0.09	
8-2 FTS	0.002	1
PFUdA	0.21	1
PFDoA	0.04	
PFTTrDA	0.54	0.4

**Table S6.** PFAS abbreviation list. Long chain PFAS are characterized by a carbon chain greater than or equal to 8 whereas with short-chain PFAS are defined as the ones with a carbon chain less than 8.

Compound Class	Compound Name	Abbreviation	Structure	Chain Length
<b>Perfluoroalkyl carboxylic acid (PFCA)</b>	Perfluorobutanoic acid	PFBA	C <sub>3</sub> F <sub>7</sub> COOH	Short
	Perfluoropentanoic acid	PFPeA	C <sub>4</sub> F <sub>9</sub> COOH	Short
	Perfluorohexanoic acid	PFHxA	C <sub>5</sub> F <sub>11</sub> COOH	Short
	Perfluoroheptanoic acid	PFHpA	C <sub>6</sub> F <sub>13</sub> COOH	Short
	Perfluorooctanoic acid	PFOA	C <sub>7</sub> F <sub>15</sub> COOH	Long
	Perfluorononanoic acid	PFNA	C <sub>8</sub> F <sub>17</sub> COOH	Long
	Perfluorodecanoic acid	PFDA	C <sub>9</sub> F <sub>19</sub> COOH	Long



	Perfluoroundecanoic acid	PFUdA	C <sub>10</sub> F <sub>21</sub> COOH	Long
	Perfluorododecanoic acid	PFDdA	C <sub>11</sub> F <sub>23</sub> COOH	Long
	Perfluorotridecanoic acid	PFTTrDA	C <sub>12</sub> F <sub>25</sub> COOH	Long
	Perfluorotetradecanoic acid	PFTeDA	C <sub>13</sub> F <sub>27</sub> COOH	Long
<b>Perfluoroalkyl sulfonic acid (PFSA)</b>	Perfluorobutane sulfonic acid	PFBS	C <sub>4</sub> F <sub>9</sub> SO <sub>3</sub> H	Short
	Perfluoropentane sulfonic acid	PFPeS	C <sub>5</sub> F <sub>11</sub> SO <sub>3</sub> H	Short
	Perfluorohexane sulfonic acid	PFHxS	C <sub>6</sub> F <sub>13</sub> SO <sub>3</sub> H	Short
	Perfluoroheptane sulfonic acid	PFHpS	C <sub>7</sub> F <sub>15</sub> SO <sub>3</sub> H	Short
	Perfluorooctane sulfonic acid	PFOS	C <sub>8</sub> F <sub>17</sub> SO <sub>3</sub> H	Long

	Perfluorononane sulfonic acid	PFNS	$C_9F_{19}SO_3H$	Long
	Perfluorodecane sulfonic acid	PFDS	$C_{10}F_{21}SO_3H$	Long
<b>Fluorotelomer sulfonic acid (FTS)</b>	4:2 Fluorotelomer sulfonic acid	4-2 FTS	$C_4F_9C_2H_4SO_3H$	Short
	6:2 Fluorotelomer sulfonic acid	6-2 FTS	$C_6F_{13}C_2H_4SO_3H$	Long
	8:2 Fluorotelomer sulfonic acid	8-2 FTS	$C_8F_{17}C_2H_4SO_3H$	Long
<b>Perfluoroether carboxylic acid (PFECA)</b>	Perfluoro-2-methyl-3-oxahexanoic acid	GenX	$C_6F_{11}O_3H$	Short
	4,8-Dioxa-3H-perfluorononanoic acid	Adona	$C_7H_2F_{12}O_4$	Short

<b>Perfluoroalkane sulfonamido acetic acid (FOSAA)</b>	N-Methyl perfluorooctane sulfonamido acetic acid	N-MeFOSAA	$\text{C}_8\text{F}_{17}\text{SO}_2\text{N}[\text{CH}_3]\text{CH}_2\text{COOH}$	Long
	N-Ethyl perfluorooctane sulfonamido acetic acid	N-EtFOSAA	$\text{C}_8\text{F}_{17}\text{SO}_2\text{N}[\text{C}_2\text{H}_5]\text{CH}_2\text{COOH}$	Long
<b>Perfluoroalkane sulfonamide (PFOSA)</b>	Perfluorobutanesulfonamide	FBSA	$\text{C}_4\text{F}_9\text{SO}_2\text{NH}_2$	Short
	Perfluorohexanesulfonamide	FH <sub>x</sub> SA	$\text{C}_6\text{F}_{13}\text{SO}_2\text{NH}_2$	Short
	Perfluorooctanesulfonamide	FOSA	$\text{C}_8\text{F}_{17}\text{SO}_2\text{NH}_2$	Long

Table S7: Range, mean, total concentration and the detection frequency of PFAS in water in the eight sampling points along the Nairobi River.

PFAS	Range	Mean	Total ng/L	Detection frequency
PFBA	0.74-4.79	1.69	13.52	100%
PFPeA	0.28-3.92	1.13	9.07	100%
PFBS	0.01- 1.0	0.15	1.23	100%
4-2 FTS	0.01- 0.05	0.02	0.18	100%
PFHxA	0.15- 3.0	0.74	5.9	100%
PFPeS	0.05- 0.11	0.06	0.12	25%
GenX	0.01- 0. 12	0.06	0.53	100%
PFHpA	0.13- 2.41	0.60	4.80	100%
Adona	<LOD- 0.01	0.01	0.02	50%
PFHxS	<LOD- 0.47	0.11	0.11	62.5%
FBSA	0.01- 0.06	0.03	0.23	100%
6 – 2 FTS	0.77- 5.53	3.66	29.31	100%
PFOA	0.16- 3.01	0.74	5.90	100%
PFHpS	<LOD- 0.01	0.01	0.01	75%
PFOS	0.01-1.37	0.23	1.83	100%
PFNA	0.06- 1.39	0.34	2.69	100%
PFONs	<LOD- 0.02	0.01	0.06	75%
PFNs	<LOD- 0.09	0.01	0.01	12.5%
8-2 FTs	0.02- 30.11	0.03	0.24	100%
PFDA	0.04- 0.67	0.19	1.50	100%
PFDS	0.01- 1.30	0.22	1.78	100%
PFOUDS	<LOD- 0.38	0.15	0.50	37.5%
PFUdA	0.05- 13. 22	4.9	39.19	100%
FH <sub>x</sub> SA	0.002-0.013	0.01	0.06	87.5%
N-MeFOSAA	<LOD-0.22	0.06	0.39	87.5%

N-EtFOSAA	<LOD-0.24	0.06	0.31	37.5%
PFD <sub>o</sub> A	0.03- 2.40	0.76	6.06	100%
PFT <sub>r</sub> DA	<LOD-0.02	0.001	0.02	87.5%
PFT <sub>e</sub> DA	<LOD-0.54	0.31	2.17	75%
FOSA	0.01-0.1	0.04	0.023	100%

Table S8: Range, mean, total concentration and the detection frequency of PFAS in sediments

PFAS	Range	Mean	Total ng/g	Detection frequency
PFBA	0.55 - 5.47	2.85	22.81	100%
PFPeA	1.58 - 10.91	4.75	37.98	100%
PFBS	0.12 - 6.18	2.0	16.01	100%
4-2 FTS	< MDL	0.00	0.00	0%
PFHxA	0.46 - 1.50	0.81	6.51	100%
PFHxS	0 - 3.70	1.49	10.42	85.5%
PFHpA	0.17- 0.84	0.42	3.40	100%
ADONA	0 - 0.77	0.25	1.49	75%
6-2 FTS	1.62	1.62	1.62	12.5%
PFHpS	1.69	1.69	1.69	12.5%
PFOA	0.88 - 13.60	4.95	39.62	100%
FBSA	0- 0.21	0.17	1.19	85.5%
PFOS	2.44- 11.74	5.15	41.16	100%
PFONS	0 - 0.2741	0.20	0.80	50%
PFNA	0.053 -1.05	0.40	3.16	100%
PFNS	0 -7.17	5.17	31.03	75%
8-2 FTS	0.03- 0.87	0.36	2.88	100%
PFDA	0.47- 3.76	1.43	11.43	100%
PFDS	1.55	1.56	1.56	12.5%
PFOUDS	0.20- 0.36	0.26	0.52	25%
PFUdA	0.33- 1.65	1.00	8.01	100%
FHxSA	0- 0.02	0.09	0.68	100%
PFDoA	0.30- 1.35	0.79	6.31	100%
N.MeFOSAA	0.52 -1.66	1.00	8.03	100%
N-EtFOSAA	0.44- 1.51	0.87	6.94	100%
PFTTrDA	0.21- 1.01	0.41	3.31	100%
PFTeDA	0.10- 0.75	0.40	3.18	100%
FOSA	0- 0.60	0.39	3.17	100%

Table S9: Range, mean, total concentration and the detection frequency of PFAS in plants

PFAS	Range	Mean	Total	Detection frequency
PFBA	<MDL- 15	4.71	28.23	83.33%
PFPeA	2.75 -9.00	5.41	32.47	100%
PFBS	<MDL -2.3	0.11	0.71	83.33%
4-2 FTS	<MDL- 0.8	0.13	0.80	16.67%
PFHxA	<MDL- 2.8	0.87	5.21	83.33%
PFHxS	<MDL- 2.04	0.85	3.79	33.33%
PFHpA	0.20-1.14	0.61	3.67	100%
ADONA	<MDL- 0.12	0.11	0.14	33.33%
6-2 FTS	<MDL-2.90	0.48	2.90	16.67%
PFHpS	<MDL	0	0	0%
PFOA	2.85- 5.60	4.89	29.33	100%
FBSA	<MDL – 0.19	0.03	0.19	16.67%
PFOS	0.02- 2.66	0.95	5.68	100%
PFONS	<MDL – 0.21	0.09	0.56	50%
PFNA	<MDL – 1.04	0.26	1.53	33.33%
PFNS	<MDL- 0.53	0.09	0.54	16.67%
8-2FTS	<MDL -0.86	0.24	1.45	16.67%
PFDA	<MDL -1.29	0.41	2.48	83.33%
PFDS	<MDL- 0.91	0.15	0.91	16.67%
PFOUDS	<MDL	0	0	0
PFUdA	<MDL -1.32	0.38	2.25	66.67%
FHxSA	<MDL – 0.12	0.02	0.12	16.67%
PFDoA	0.05 – 0.37	0.20	1.22	100%
N.MeFOSAA	<MDL-0.20	0.28	1.67	66.67%
N-EtFOSAA	<MDL -0.003	0.0004	0.003	16.67%
PFTTrDA	<MDL- 1.92	0.42	2.53	66.67%
PFTeDA	<MDL- 0.20	0.12	0.71	83.33%
FOSA	<MDL- 1.02	0.17	1.02	16.67%