

1 **Title:** Effects of fluorinated ski wax bans on per- and polyfluoroalkyl substances (PFAS)
2 concentrations in indoor dust from ski waxing workspaces

3

4 **Authors:** Kathryn A. Crawford,^{1*} Nicola Hartmann,^{2,3} Emilia Andersen,^{2,3} Celeste Alden,⁴
5 Divya Gudur¹, Bharat Chandramouli⁵

6

7 **Author Affiliations:**

8 ¹ Environmental Studies Program, Middlebury College, Middlebury, VT, USA

9 ² Program in Molecular Biology & Biochemistry, Middlebury College, Middlebury, VT, USA

10 ³ Global Health Program, Middlebury College, Middlebury, VT, USA

11 ⁴ Department of Earth and Climate Science, Middlebury College, Middlebury, VT, USA

12 ⁵ SGS AXYS Analytical Services, Ltd. Sidney, British Columbia, Canada

13

14

15

16 **Table S1.** Quality control specification for PFAS analyzed via US EPA Method 1633, SGS AXYS Method MLA-110, in dust wipe
17 samples collected from wax bench workstations before (2020) and after (2023) fluorinated wax bans were implemented. Method
18 LODs represent those established for biosolid samples. SDL ranges reported for all samples in each sampling year. Matrix spike and
19 allowable recovery ranges reported for all procedural blanks analyzed in each sampling year. Abbreviations: CAS = Chemical
20 Abstract Service; LOD = limit of detection; ng/g dw = nanograms per gram wet dry weight; SDL = sample detection limit; ww = wet
21 weight; N/A = not measured. Bolded values reflect those above or below the acceptable recovery range.

PFAS Compound	Abbreviation	CAS Registry #	Method LOD (ng/g dw)	Allowable Recovery (%)	2020		2023	
					SDL (ng/g ww)	Matrix Spike Recovery (%)	SDL (ng/g ww)	Matrix Spike Recovery (%)
Perfluorobutanoic acid	PFBA	375-22-4	6.4	70-140	0.228 - 8.83	104 - 107	0.316 - 2.89	94.9 - 144
Perfluoropentanoic acid	PFPeA	2706-90-3	3.2	60-150	0.114 - 4.42	97.4 - 110	0.158 - 1.44	93.0 - 140
Perfluorohexanoic acid	PFHxA	307-24-4	1.6	65-140	0.057 - 2.21	75.9 - 104	0.079 - 0.721	92.8 - 106
Perfluoroheptanoic acid	PFHpA	375-85-9	1.6	65-145	0.057 - 2.21	102 - 107	0.079 - 0.721	102 - 115
Perfluorooctanoic acid	PFOA	335-67-1	1.6	70-150	0.057 - 2.21	94.0 - 105	0.087 - 0.721	94.3 - 108
Perfluorononanoic acid	PFNA	375-95-1	1.6	70-155	0.084 - 2.21	97.8 - 107	0.079 - 0.721	97.3 - 108
Perfluorodecanoic acid	PFDA	335-76-2	1.6	70-155	0.057 - 2.21	103 - 111	0.079 - 0.721	85.2 - 105
Perfluoroundecanoic acid	PFUNA	2058-94-8	1.6	70-155	0.057 - 2.21	94.6 - 99.4	0.079 - 0.721	92.2 - 109
Perfluorododecanoic acid	PFDoA	307-55-1	1.6	70-150	0.057 - 2.21	104 - 112	0.063 - 0.577	98.0 - 111
Perfluorotridecanoic acid	PFTTrDA	72629-94-8	1.6	65-150	0.057 - 9.00	104 - 123	0.079 - 0.721	99.7 - 109
Perfluorotetradecanoic acid	PFTTeDA	376-06-7	1.6	65-150	0.169 - 5.83	104 - 110	0.079 - 0.721	95.1 - 108
Perfluorobutanesulfonic acid	PFBS	375-73-5	1.6	65-145	0.057 - 2.21	93.3 - 122	0.079 - 0.721	91.3 - 110
Perfluoropentanesulfonic acid	PFPeS	2706-91-4	1.6	55-160	0.057 - 2.22	96.0 - 105	0.080 - 0.725	95.6 - 109
Perfluorohexanesulfonic acid	PFHxS	355-46-4	2.4	60-150	0.057 - 2.21	93.1 - 101	0.079 - 0.721	87.1 - 100
Perfluoroheptanesulfonic acid	PFHpS	375-92-8	1.6	65-155	0.057 - 2.21	96.7 - 108	0.079 - 0.721	93.8 - 109
Perfluorooctanesulfonic acid	PFOS	1763-23-1	1.6	65-160	0.057 - 2.21	97.2 - 97.9	0.079 - 0.721	87.5 - 106
Perfluorononanesulfonic acid	PFNS	68259-12-1	1.6	55-140	0.057 - 2.21	90.1 - 119	0.079 - 0.721	81.6 - 95.1
Perfluorodecanesulfonic acid	PFDS	335-77-3	1.6	40-155	0.057 - 2.21	95.6 - 115	0.079 - 0.722	87.5 - 113
Perfluorododecanesulfonic acid	PFDoS	79780-39-5	1.6	25-160	0.057 - 2.21	89.2 - 118	0.079 - 0.721	86.5 - 97.1
3:3 Fluorotelomer carboxylic acid	3:3 FTCA	356-02-5	6.4	45-130	0.228 - 8.83	102 - 112	0.316 - 2.89	88.9 - 106
5:3 Fluorotelomer carboxylic acid	5:3 FTCA	914637-49-3	40	60-130	1.42 - 55.2	97.0 - 106	1.98 - 18.0	86.2 - 108
7:3 Fluorotelomer carboxylic acid	7:3 FTCA	812-70-4	40	60-150	1.42 - 55.2	104 - 112	1.98 - 18.0	90.1 - 101
4:2 Fluorotelomer sulfonic acid	4:2 FTS	757124-72-4	6.4	60-150	0.228 - 8.83	105 - 106	0.316 - 2.89	92.5 - 106
6:2 Fluorotelomer sulfonic acid	6:2 FTS	27619-97-2	22.1	55-200	0.205 - 7.96	102 - 104	0.285 - 2.60	99.4 - 116
8:2 Fluorotelomer sulfonic acid	8:2 FTS	39108-34-4	6.4	70-150	0.228 - 8.83	103 - 118	0.269 - 2.45	83.3 - 111
Perfluorooctanesulfonamide	PFOSA	754-91-6	1.6	70-140	0.057 - 2.21	84.1 - 102	0.079 - 0.721	76.4 - 104
N-Methylperfluorooctanesulfonamide	N-MeFOSA	31506-32-8	1.6	70-155	0.066 - 2.54	94.8 - 99.8	N/A	82.5 - 105
N-Ethylperfluorooctanesulfonamide	N-EtFOSA	4151-50-2	1.6	70-140	0.142 - 5.52	102 - 108	N/A	95.9 - 107
N-Methylperfluoro-1-octanesulfonamidoacetic acid	N-MeFOSAA	2355-31-9	1.6	65-155	0.057 - 2.21	111 - 119	0.079 - 0.721	80.1 - 107
N-Ethylperfluoro-1-octanesulfonamidoacetic acid	N-EtFOSAA	2991-50-6	1.6	65-165	0.057 - 2.21	93.3 - 116	0.079 - 0.721	90.8 - 108
N-Methylperfluoro-1-octanesulfonamidoethanol	N-MeFOSE	24448-09-7	16	70-140	0.570 - 22.1	102 - 105	0.791 - 7.21	82.6 - 133
N-Ethylperfluoro-1-octanesulfonamidoethanol	N-EtFOSE	1691-99-2	16	70-135	0.426 - 16.5	102 - 114	0.791 - 7.21	84.8 - 108
Hexafluoropropylene oxide dimer acid	HFPO-DA	13252-13-6	6.4	70-145	0.319 - 8.39	94.9 - 97.9	0.316 - 2.89	74.7 - 106
4,8-Dioxa-3H-perfluorononanoic acid	ADONA	919005-14-4	6.4	70-160	0.228 - 8.83	84.5 - 100	0.316 - 2.89	79.7 - 110
Nonafluoro-3,6-dioxahexanoic acid	NFDHA	151772-58-6	3.2	60-155	0.114 - 4.42	85.3 - 106	0.158 - 1.44	96.3 - 103
Perfluoro-4-methoxybutanoic acid	PFMBA	863090-89-5	1.6	30-140	0.057 - 2.21	73.1 - 100	0.079 - 0.721	67.7 - 90.5
Perfluoro-3-methoxypropanoic acid	PFMPA	377-73-1	3.2	70-130	0.114 - 4.42	108 - 112	0.158 - 1.44	88.5 - 114
9-chlorohexadecafluoro-3-oxanone-1-sulfonate	9Cl-PF3ONS	756426-58-1	6.4	70-150	0.228 - 8.86	92.2 - 107	0.317 - 2.89	86.8 - 103
11-chloroeicosafluoro-3-oxaundecane-1-sulfonate	11Cl-PF3OUdS	763051-92-9	6.4	45-160	0.228 - 8.85	98.3 - 106	0.317 - 2.89	85.8 - 107
Perfluoro(2-ethoxyethane) sulfonic acid	PFEESA	113507-82-7	1.6	70-140	0.057 - 2.21	104 - 109	0.079 - 0.723	78.5 - 110

23 **Table S2.** Range of allowed (biosoloids) and measured surrogate standard recoveries in samples
 24 and process blanks for PFAS analyzed via US EPA Method 1633, SGS AXYS Method MLA-
 25 110, in dust wipe samples collected from wax bench workstations before (2020) and after (2023)
 26 fluorinated wax bans were implemented. Bolded values reflect those above or below the
 27 acceptable recovery range.
 28

PFAS Compound	Allowable Recovery (%)	Sample Surrogate Recovery (%)		Blank Surrogate Recovery (%)	
		2020	2023	2020	2023
13C4-PFBA	5-130	52.6 - 91.8	46.4 - 96.1	91.5 - 98.3	82.2 - 99.7
13C5-PFPeA	35-130	47.8 - 117	49.8 - 108	84.4 - 86.6	92.4 - 109
13C5-PFHxA	40-130	46.6 - 122	48.1 - 95.8	77.6 - 88.4	87.9 - 100
13C4-PFHpA	40-130	51.1 - 100	44.5 - 90.9	84.3 - 97.2	78.5 - 96.6
13C8-PFOA	40-130	52.2 - 85.6	45.2 - 92.6	87.2 - 96.2	83.3 - 95.0
13C9-PFNA	40-145	49.2 - 99.9	50.3 - 102	87.9 - 98.0	94.6 - 101
13C6-PFDA	40-130	45.0 - 95.8	48.0 - 95.2	94.9 - 96.4	80.9 - 96.0
13C7-PFUnA	40-130	56.3 - 105	50.9 - 106	98.0 - 131	90.2 - 101
13C2-PFDoA	40-130	55.1 - 97.4	47.4 - 113	93.0 - 118	80.4 - 94.8
13C2-PFTeDA	10-160	77.9 - 154	32.4 - 97.1	82.7 - 126	73.5 - 80.3
13C3-PFBS	40-150	46.4 - 97.0	40.9 - 94.8	85.0 - 98.4	79.7 - 96.3
13C3-PFHxS	40-140	48.9 - 93.7	44.8 - 103	90.5 - 103	89.8 - 100
13C8-PFOA	40-130	48.0 - 99.7	51.7 - 105	86.1 - 95.7	96.7 - 105
13C2-4:2 FTS	40-300	55.1 - 106	51.8 - 115	95.6 - 96.7	91.3 - 131
13C2-6:2 FTS	40-300	39.0 - 104	42.8 - 94.4	73.2 - 91.0	82.3 - 95.4
13C2-8:2 FTS	40-300	38.3 - 105	40.1 - 80.1	80.6 - 97.4	75.0 - 88.8
13C8-PFOA	20-140	62.4 - 107	64.2 - 157	74.4 - 87.4	87.4 - 115
D3-N-MeFOSA	20-130	53.0 - 86.6	1.07 - 90.4	61.2 - 61.9	30.7 - 83.1
D5-N-EtFOSA	20-130	49.3 - 72.6	1.27 - 87.9	49.0 - 53.8	18.6 - 80.1
D3-MeFOSAA	30-150	51.3 - 101	44.2 - 98.1	63.8 - 104	74.2 - 109
D5-EtFOSAA	20-140	58.8 - 103	48.2 - 106	71.3 - 105	73.7 - 118
d7-NMe-FOSE	25-130	57.1 - 100	5.88 - 134	64.5 - 87.0	49.8 - 108
d9-NEt-FOSE	20-130	56.4 - 112	6.11 - 157	57.2 - 100	56.0 - 121
13C3-HFPO-DA	40-130	33.0 - 117	39.8 - 87.4	83.1 - 88.6	73.9 - 109

29

30 **Table S3.** Concentrations of individual PFAS compounds (ng/cm²) detected in each dust wipe sample in 2020 and 2023. The Σ PFAS
 31 concentration for each sample was calculated as the sum of individual PFAS compounds accumulated during the course of a workday.
 32 PFBA, PFPeA, and 6:2 FTS were removed from 2023 analyses for QA/QC purposes. PFAS compounds analyzed, but not detected in
 33 any dust wipe sample from either year include: PFPeS, PFHpS, PFNS, PFDS, PFDoS, 3:3 FTCA, 5:3 FTCA, 7:3 FTCA, 4:2 FTS,
 34 PFOSA, N-EtFOSEA, MeFOSAA, EtFOSAA, N-MeFOSE, ADONA, NFDHA, PFMBA, 9Cl-PF3ONS, 11Cl-PF3OUdS, PFEESA.
 35

PFAS Analyte	2020						2023														
	A1	A2	B1	B2	C1	C2	D1	D2	D3	D4	E1	E2	F1	F2	F3	F4	G1	G2	G3	G4	
PFBA	0.119	0.034	0.016	0.009	0.070	0.558	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PFPeA	0.130	0.031	0.005	0.012	0.092	0.540	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PFHxA	0.331	0.164	0.103	0.060	0.646	2.77	0.020	0.007	0.007	0.001	0.016	0.003	0.039	0.007	0.007	0.009	0.011	0.011	0.007	0.004	0.004
PFHpA	0.307	0.102	0.024	0.038	0.674	1.788	0.021	0.008	0.009	0.001	0.014	0.003	0.088	0.015	0.017	0.019	0.009	0.011	0.006	0.004	0.004
PFOA	0.458	1.06	0.158	0.642	1.09	11.9	0.038	0.009	0.017	0.002	0.037	0.007	0.032	0.007	0.008	0.006	0.023	0.022	0.009	0.005	0.005
PFNA	0.715	0.219	0.048	0.109	0.267	1.55	0.013	--	0.003	--	0.012	0.001	0.008	0.002	0.003	0.002	0.006	0.012	--	--	--
PFDA	4.27	42.4	1.25	1.95	2.61	28.9	0.068	0.016	0.013	0.003	0.060	0.010	0.038	0.009	0.010	0.008	0.017	0.070	0.016	0.008	0.008
PFUnA	0.247	0.281	0.005	0.062	0.293	4.12	0.015	--	0.003	--	0.015	0.001	0.016	0.005	0.004	0.003	0.005	0.006	0.003	--	--
PFDoA	1.08	24.6	1.26	1.72	5.19	39.9	0.060	0.013	0.014	0.003	0.049	0.009	0.041	0.011	0.011	0.009	0.017	0.041	0.023	0.010	0.010
PFTrDA	0.052	0.451	0.002	0.084	0.622	5.62	0.021	--	0.004	--	0.020	0.002	0.017	0.005	0.005	0.004	0.008	0.010	0.007	0.002	0.002
PFTeDA	0.581	12.3	0.355	2.081	12.7	46.3	0.092	0.019	0.021	0.004	0.091	0.016	0.092	0.027	0.026	0.018	0.039	0.052	0.048	0.023	0.023
PFBS	--	--	0.001	0.000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
PFHxS	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.017	--	--
PFOS	--	--	0.000	--	--	--	--	--	--	--	--	--	0.003	--	--	--	--	--	--	--	--
6:2 FTS	--	--	0.000	0.002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8:2 FTS	--	--	0.000	0.003	0.145	0.123	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N-MeFOSA	--	--	0.000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
N-EtFOSE	--	--	0.003	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HFPO-DA	--	--	9.00	1.30	1.55	2.21	--	--	--	--	--	--	0.343	0.043	0.053	0.076	--	--	--	--	
PFMPA	0.018	0.242	0.030	0.015	0.518	4.07	0.009	--	--	--	0.006	0.001	0.021	0.003	0.003	0.004	0.005	--	--	--	
36 Total	8.30	81.9	12.3	8.08	26.5	150	0.357	0.072	0.092	0.013	0.320	0.054	0.735	0.139	0.147	0.158	0.139	0.236	0.135	0.056	