

Chemical profiles of PM_{2.5} emitted from various anthropogenic sources of the Eastern Mediterranean: cooking, wood burning, and diesel generators

*Marc Fadel^{1,2}, Frédéric Ledoux², Marianne Seigneur², Konstantina Oikonomou³, Jean Sciare³,
Dominique Courcot², Charbel Afif^{1,3, *}.*

¹Emissions, Measurements, and Modeling of the Atmosphere (EMMA) Laboratory, CAR,
Faculty of Sciences, Saint Joseph University, Beirut, Lebanon

²Unité de Chimie Environnementale et Interactions sur le Vivant, UCEIV UR4492, FR CNRS
3417, University of Littoral Côte d'Opale (ULCO), Dunkerque, France

³Climate and Atmosphere Research Center, The Cyprus Institute, Nicosia, Cyprus

*Corresponding author: charbel.afif@usj.edu.lb

Supplementary information

Table S1 : Carbonaceous fractions, water-soluble ions and elements in PM_{2.5} emitted by the different sources – (mg/g of sum of analyzed species)

Species		Wood burning (WB)	Diesel generator (DG)	Cooking		
				Beef charcoal grilling (BG)	Chicken charcoal grilling (CG)	General cooking activities (GCA)
Number of samples		3	4	1	1	5
Carbonaceous fraction	OC	537 ± 109	633 ± 50	817	967	605 ± 121
	EC	181 ± 95	226 ± 51	18	1.55	34 ± 8
Total carbon (TC)		718 ± 168	859 ± 40	835	969	639 ± 121
Water-soluble ions	Cl ⁻	65.2 ± 45.6	<D.L	15.2	1.31	<D.L
	NO ₃ ⁻	3.01 ± 2.02	16.9 ± 5.0	6.51	1.34	28.5 ± 1.4
	SO ₄ ²⁻	16.5 ± 5.9	19.5 ± 4.8	11.4	3.61	121 ± 67
	Na ⁺	2.31 ± 1.38	3.25 ± 1.74	2.83	0.48	3.56 ± 1.62
	NH ₄ ⁺	8.15 ± 6.07	6.51 ± 1.61	0.90	0.30	41.0 ± 24.5
	K ⁺	65.8 ± 45.7	1.98 ± 1.21	23.7	5.61	4.05 ± 1.29
	Mg ²⁺	1.32 ± 0.36	0.67 ± 0.28	1.62	0.57	1.11 ± 0.28
	Ca ²⁺	16.6 ± 6.7	22.5 ± 9.2	8.43	1.69	23.8 ± 13.4
Total water-soluble ions		179 ± 112	71 ± 21	71	15	223 ± 58
Elements	Mg	2.16 ± 0.74	2.04 ± 0.55	3.14	0.76	4.30 ± 1.13
	Mn	0.15 ± 0.04	<D.L	0.08	0.01	0.13 ± 0.06
	Al	7.83 ± 1.73	8.49 ± 3.37	6.99	0.99	18.6 ± 2.9
	Na	5.25 ± 1.11	<D.L	4.75	1.24	16.1 ± 5.0
	Ca	22.3 ± 12.8	39.0 ± 11.4	46.8	5.02	34.73 ± 12.6
	Fe	4.37 ± 2.22	3.52 ± 0.81	3.44	0.39	7.63 ± 2.41
	K	51.8 ± 36.8	2.16 ± 0.75	21.4	4.89	4.49 ± 1.15
	P	0.63 ± 0.28	0.78 ± 0.15	1.01	0.30	1.01 ± 0.14
	S	7.22 ± 2.25	11.0 ± 3.0	5.53	2.47	47.6 ± 22.4
	Ti	0.61 ± 0.32	0.71 ± 0.2	0.53	0.05	1.06 ± 0.38
	V	0.02 ± 0.01	0.03 ± 0.01	0.02	0.004	0.28 ± 0.23
	Zn	0.51 ± 0.27	1.5 ± 0.09	0.25	0.03	1.06 ± 0.28

Cu	0.03 ± 0.02	0.08 ± 0.02	0.03	0.01	0.10 ± 0.07
Ni	0.04 ± 0.02	0.14 ± 0.06	<D.L	<D.L	0.37 ± 0.20
Ba	<D.L	<D.L	<D.L	<D.L	<D.L
Cr	0.05 ± 0.02	<D.L	0.05	0.026	<D.L
Pb	0.41 ± 0.49	0.06 ± 0.01	0.05	<D.L	0.58 ± 0.14
Sr	0.04 ± 0.02	0.05 ± 0.01	0.17	0.035	0.10 ± 0.03
As	0.004 ± 0.001	0.0005 ± 0.0004	0.002	0.001	0.007 ± 0.001
Cd	0.013 ± 0.004	0.0005 ± 0.0003	0.031	0.001	0.003 ± 0.001
Co	0.002 ± 0.001	0.004 ± 0.001	0.004	0.000	0.009 ± 0.006
Rb	0.04 ± 0.02	<D.L	0.029	0.008	0.007 ± 0.003
Nb	0.004 ± 0.001	<D.L	0.021	0.002	0.009 ± 0.004
Ag	0.07 ± 0.05	0.24 ± 0.16	0.088	0.022	0.25 ± 0.16
Sn	0.002 ± 0.001	<D.L	0.002	<D.L	<D.L
Sb	0.003 ± 0.002	0.006 ± 0.001	0.002	0.001	0.03 ± 0.02
La	0.005 ± 0.003	<D.L	0.006	0.001	0.021 ± 0.014
Ce	0.009 ± 0.001	0.005 ± 0.002	0.010	0.002	0.010 ± 0.005
Bi	0.0007 ± 0.0002	0.0010 ± 0.0003	0.0005	0.0001	0.002 ± 0.001
Total elements	104 ± 57	70.0 ± 19.8	94.4	16.3	139 ± 31

Table S2: Chemical mass fraction to OC of n-alkanes, PAHs, carboxylic acids, and levoglucosan in PM_{2.5} for the different sources (mg/g of OC)

Species		Wood burning	Diesel generator	Cooking			
		(WB)	(DG)	Beef grilling (BG)	Chicken grilling (CG)	General cooking activities (GCA)	
Alkanes	Tridecane	C13	<D.L	<D.L	0.02	0.01	<D.L
	Tetradecane	C14	<D.L	0.04 ± 0.01	0.03	0.01	<D.L
	Pentadecane	C15	<D.L	0.21 ± 0.18	0.04	0.03	<D.L
	Hexadecane	C16	<D.L	0.79 ± 0.60	0.04	0.02	0.07 ± 0.04
	Heptadecane	C17	<D.L	2.06 ± 1.23	0.05	0.04	0.06 ± 0.02
	Octadecane	C18	<D.L	6.16 ± 1.88	0.05	0.02	0.03 ± 0.01
	Nonadecane	C19	0.10 ± 0.08	14.2 ± 4.3	0.98	0.55	0.1 ± 0.04
	Eicosane	C20	0.07 ± 0.02	26.0 ± 5.8	0.40	0.38	0.14 ± 0.04
	Heneicosane	C21	0.13 ± 0.07	26.8 ± 6.9	0.19	0.16	0.25 ± 0.06
	Docosane	C22	0.16 ± 0.07	23.5 ± 6.6	0.34	0.19	0.54 ± 0.2
	Tricosane	C23	0.40 ± 0.13	17.5 ± 4.9	1.24	0.49	1.07 ± 0.6
	Tetracosane	C24	0.23 ± 0.10	13.0 ± 3.7	0.83	0.42	1.13 ± 0.2
	Pentacosane	C25	0.61 ± 0.36	7.27 ± 2.46	5.02	1.43	0.93 ± 0.39
	Hexacosane	C26	0.31 ± 0.10	4.20 ± 1.51	0.06	0.04	0.64 ± 0.1
	Heptacosane	C27	1.61 ± 1.15	1.73 ± 0.73	0.05	0.03	0.82 ± 0.19
	Octacosane	C28	0.32 ± 0.15	0.68 ± 0.38	0.04	0.05	0.61 ± 0.1
	Nonacosane	C29	3.39 ± 2.76	0.50 ± 0.28	0.40	0.11	1.44 ± 0.58
	Triacontane	C30	0.45 ± 0.30	0.24 ± 0.01	0.04	0.02	0.43 ± 0.12
	Hentriacontane	C31	1.68 ± 1.30	0.12 ± 0.08	0.16	0.10	0.94 ± 0.43
	Dotriacontane	C32	0.29 ± 0.19	0.08 ± 0.04	0.06	0.03	0.72 ± 0.4
Total	ΣA	9.75 ± 6.50	145 ± 39	10.0	4.14	9.92 ± 2.25	
Acenaphthylene	Acy	0.02 ± 0.01	<D.L	0.002	0.05	<D.L	
Acenaphthene	Ace	0.007 ± 0.004	0.005 ± 0.002	0.001	0.001	0.008 ± 0.006	

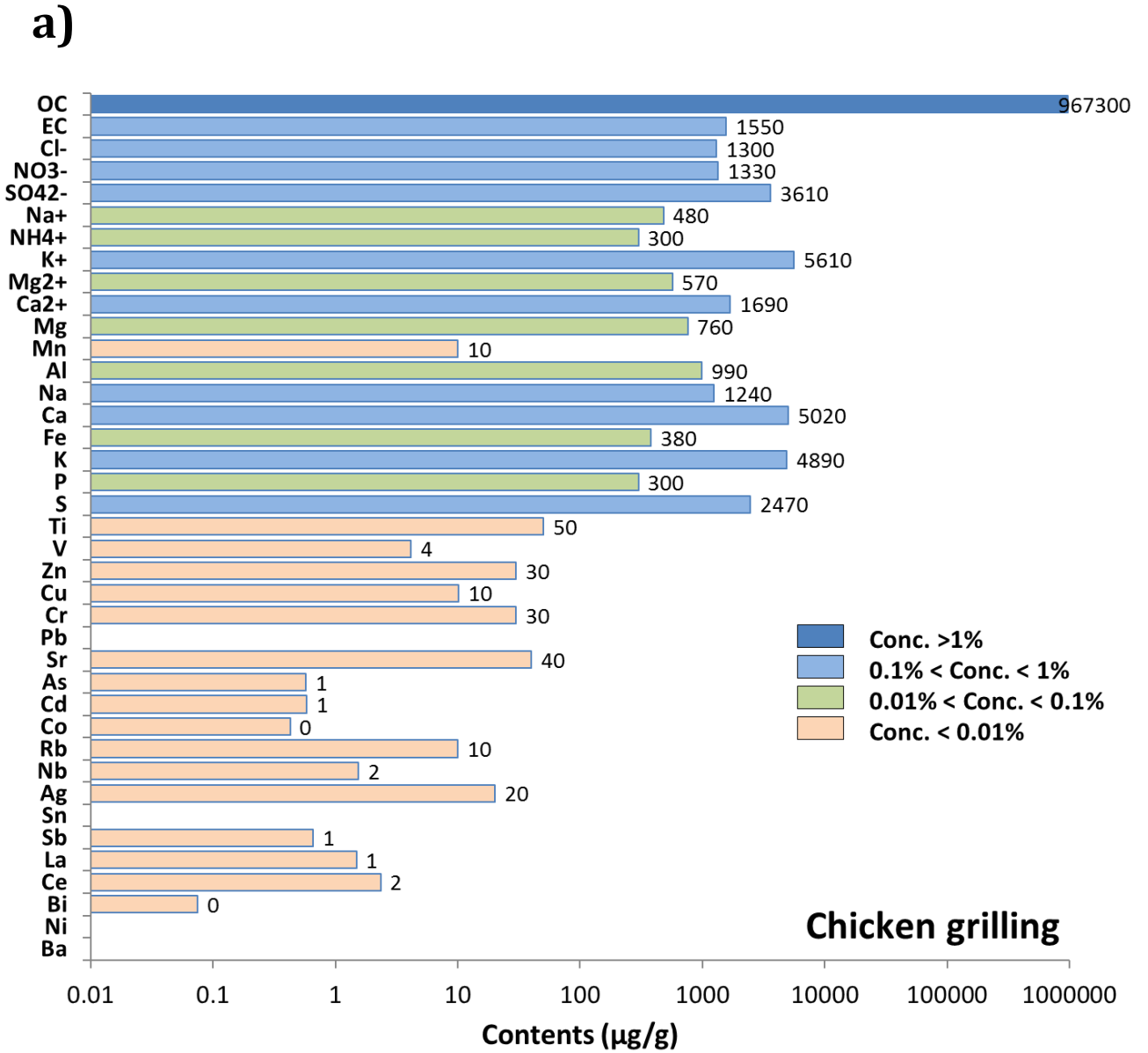
Polycyclic Aromatic Hydrocarbons (PAHs)	Fluorene	Flu	0.019 ± 0.005	0.005 ± 0.002	0.001	0.001	<D.L
	Anthracene	Anth	0.08 ± 0.06	0.04 ± 0.02	0.04	0.02	<D.L
	Phenanthrene	Phe	0.03 ± 0.01	0.008 ± 0.006	0.01	0.01	0.004 ± 0.001
	Fluoranthene	Fla	0.58 ± 0.31	0.09 ± 0.02	0.13	0.13	0.03 ± 0.01
	Pyrene	Pyr	0.58 ± 0.29	0.27 ± 0.07	0.12	0.10	0.03 ± 0.02
	Benzo[a]anthracene	B[a]An	0.60 ± 0.08	0.02 ± 0.01	0.08	0.04	0.03 ± 0.02
	Chrysene	Chr	0.46 ± 0.07	0.02 ± 0.01	0.09	0.05	0.03 ± 0.01
	Benzo[b]fluoranthene	B[b]Fl	0.32 ± 0.14	0.02 ± 0.01	0.06	0.03	0.04 ± 0.03
	Benzo[k]fluoranthene	B[k]Fl	0.39 ± 0.04	0.013 ± 0.005	0.04	0.01	0.03 ± 0.02
	Benzo[a]pyrene	B[a]P	0.40 ± 0.13	0.006 ± 0.003	0.03	0.01	0.014 ± 0.008
	Dibenzo[a,h]anthracene	DiB[a,h]An	0.57 ± 0.26	<D.L	0.06	0.02	<D.L
Benzo[g,h,i]perylene	B[ghi]Pe	0.26 ± 0.07	0.019 ± 0.002	0.03	0.01	<D.L	
Indeno[1,2,3-c,d]pyrene	InPy	0.22 ± 0.09	0.004 ± 0.002	0.04	0.01	<D.L	
	Total	∑PAHs	4.55 ± 1.05	0.53 ± 0.14	0.72	0.47	0.21 ± 0.15
Carboxylic Acids	Dodecanoic acid	DDA	0.74 ± 0.26	8.85 ± 3.11	0.69	0.40	4.35 ± 2.16
	Tetradecanoic acid	TDA	1.34 ± 0.2	8.50 ± 3.02	13.2	2.62	6.04 ± 2.48
	Hexadecanoic acid	HDA	30.5 ± 14.5	23.7 ± 7.4	133	85.6	139 ± 52
	Octadecanoic acid	ODA	16.0 ± 7.0	35.9 ± 11.1	87.3	36.1	162 ± 87
	Eicosanoic acid	EA	6.16 ± 3.2	14.8 ± 5.5	3.23	3.50	11.2 ± 4.3
	Docosanoic acid	DA	26.7 ± 10.2	5.74 ± 2.75	5.87	12.8	35.8 ± 17.1
	Tetracosanoic acid	TA	8.57 ± 5.85	0.2 ± 0.1	0.54	1.26	6.07 ± 3.9
	Total	∑FA	90.1 ± 31.8	97.3 ± 32.3	244	142	363 ± 138
Sugars	Levogluconan	Lev	302 ± 103	1.30 ± 0.49	2.43	0.53	24.5 ± 31.7

Table S3: PCDD/F and DL-PCBs contribution to OC (pg/g of OC) for the different sources

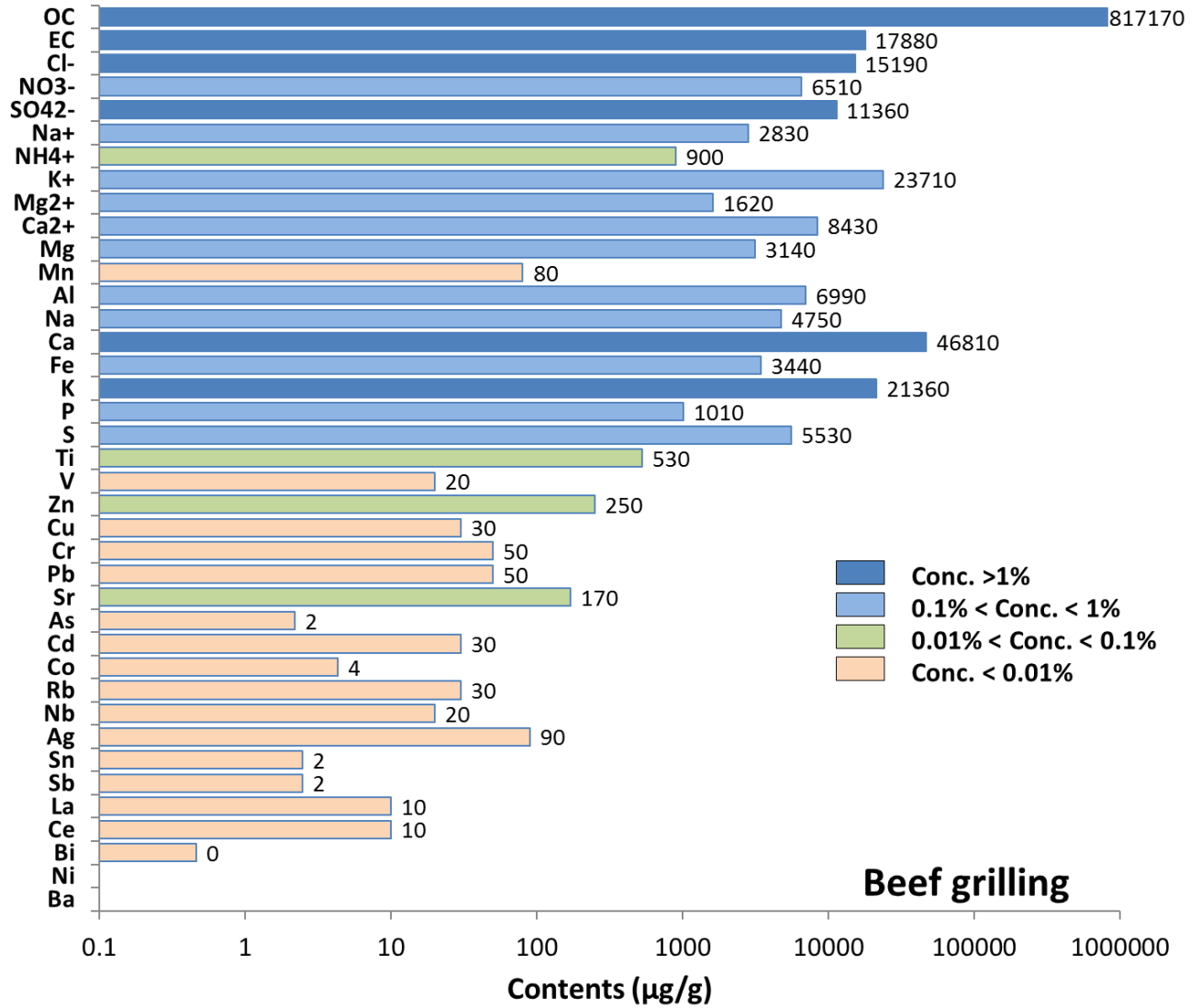
Compounds		TEF	Wood burning	Diesel generator	Cooking	
					Beef and chicken charcoal grilling	General cooking activities
PCDD						
2,3,7,8-tetrachlorinated dibenzo-p-dioxin	2,3,7,8 TCDD	1	<D.L	<D.L	< D.L	< D.L
1,2,3,7,8-pentachlorinated dibenzo-p-dioxin	1,2,3,7,8 PeCDD	1	<D.L	<D.L	60	< D.L
1,2,3,4,7,8-hexachlorinated dibenzo-p-dioxin	1,2,3,4,7,8 HxCDD	0.1	<D.L	<D.L	< D.L	< D.L
1,2,3,6,7,8-hexachlorinated dibenzo-p-dioxin	1,2,3,6,7,8 HxCDD	0.1	<D.L	<D.L	110	< D.L
1,2,3,7,8,9-hexachlorinated dibenzo-p-dioxin	1,2,3,7,8,9 HxCDD	0.1	<D.L	<D.L	< D.L	< D.L
1,2,3,4,6,7,8-heptachlorinated dibenzo-p-dioxin	1,2,3,4,6,7,8 HpCDD	0.01	1880	2370	800	2600
octachlorinated dibenzo-p-dioxin	OCDD	0.0003	5160	7750	2240	< D.L
	Total PCDD		7040	10120	3210	2600
	TEQ for PCDD		20	26	78	26
PCDF						
2,3,7,8 tetrachlorinated dibenzofuran	2,3,7,8 TCDF	0.1	< D.L	< D.L	< D.L	< D.L
1,2,3,7,8 pentachlorinated dibenzofuran	1,2,3,7,8 PeCDF	0.03	< D.L	< D.L	< D.L	< D.L
2,3,4,7,8 pentachlorinated dibenzofuran	2,3,4,7,8 PeCDF	0.3	< D.L	< D.L	170	< D.L
1,2,3,4,7,8 hexachlorinated dibenzofuran	1,2,3,4,7,8 HxCDF	0.1	< D.L	< D.L	110	< D.L
1,2,3,6,7,8 hexachlorinated dibenzofuran	1,2,3,6,7,8 HxCDF	0.1	< D.L	< D.L	100	< D.L
2,3,4,6,7,8 hexachlorinated dibenzofuran	2,3,4,6,7,8 HxCDF	0.1	< D.L	1195	180	< D.L
1,2,3,7,8,9 hexachlorinated dibenzofuran	1,2,3,7,8,9 HxCDF	0.1	< D.L	< D.L	< D.L	< D.L
1,2,3,4,6,7,8-heptachlorinated dibenzofuran	1,2,3,4,6,7,8 HpCDF	0.01	725	3307	450	1070
1,2,3,4,7,8,9-heptachlorinated dibenzofuran	1,2,3,4,7,8,9 HpCDF	0.01	< D.L	< D.L	< D.L	< D.L
octachlorinated dibenzofuran	OCDF	0.0003	1430	4195	640	< D.L
	Total PCDF		2156	8698	1650	1070
	TEQ for PCDF		8	154	93	11
PCB						
3,4,4',5'-Tetrachlorobiphenyl	PCB 81	0.0003	< D.L	< D.L	< D.L	< D.L
3,3',4,4'-Tetrachlorobiphenyl	PCB 77	0.0001	< D.L	< D.L	< D.L	< D.L
2,3',4,4',5'-Pentachlorobiphenyl	PCB 123	0.00003	8930	5580	3510	< D.L
2,3',4,4',5-Pentachlorobiphenyl	PCB 118	0.00003	52130	90630	18010	192700
2,3,4,4',5-Pentachlorobiphenyl	PCB 114	0.00003	3330	< D.L	< D.L	9700

2,3,3',4,4'-Pentachlorobiphenyl	PCB 105	0.00003	27710	59940	10120	118670
3,3',4,4',5-Pentachlorobiphenyl	PCB 126	0.1	< D.L	< D.L	< D.L	< D.L
2,3',4,4',5,5'-Hexachlorobiphenyl	PCB 167	0.00003	< D.L	< D.L	< D.L	12830
2,3,3',4,4',5-Hexachlorobiphenyl	PCB 156	0.00003	< D.L	< D.L	2310	35330
2,3,3',4,4',5'-Hexachlorobiphenyl	PCB 157	0.00003	< D.L	< D.L	< D.L	< D.L
3,3',4,4',5,5'-Hexachlorobiphenyl	PCB 169	0.03	< D.L	< D.L	< D.L	< D.L
2,3,3',4,4',5,5'-Heptachlorobiphenyl	PCB 189	0.00003	< D.L	< D.L	< D.L	< D.L
	Total PCB		92100	156150	33950	369230
	TEQ for PCB		3	5	1	11
	Total TEQ		31	185	172	48

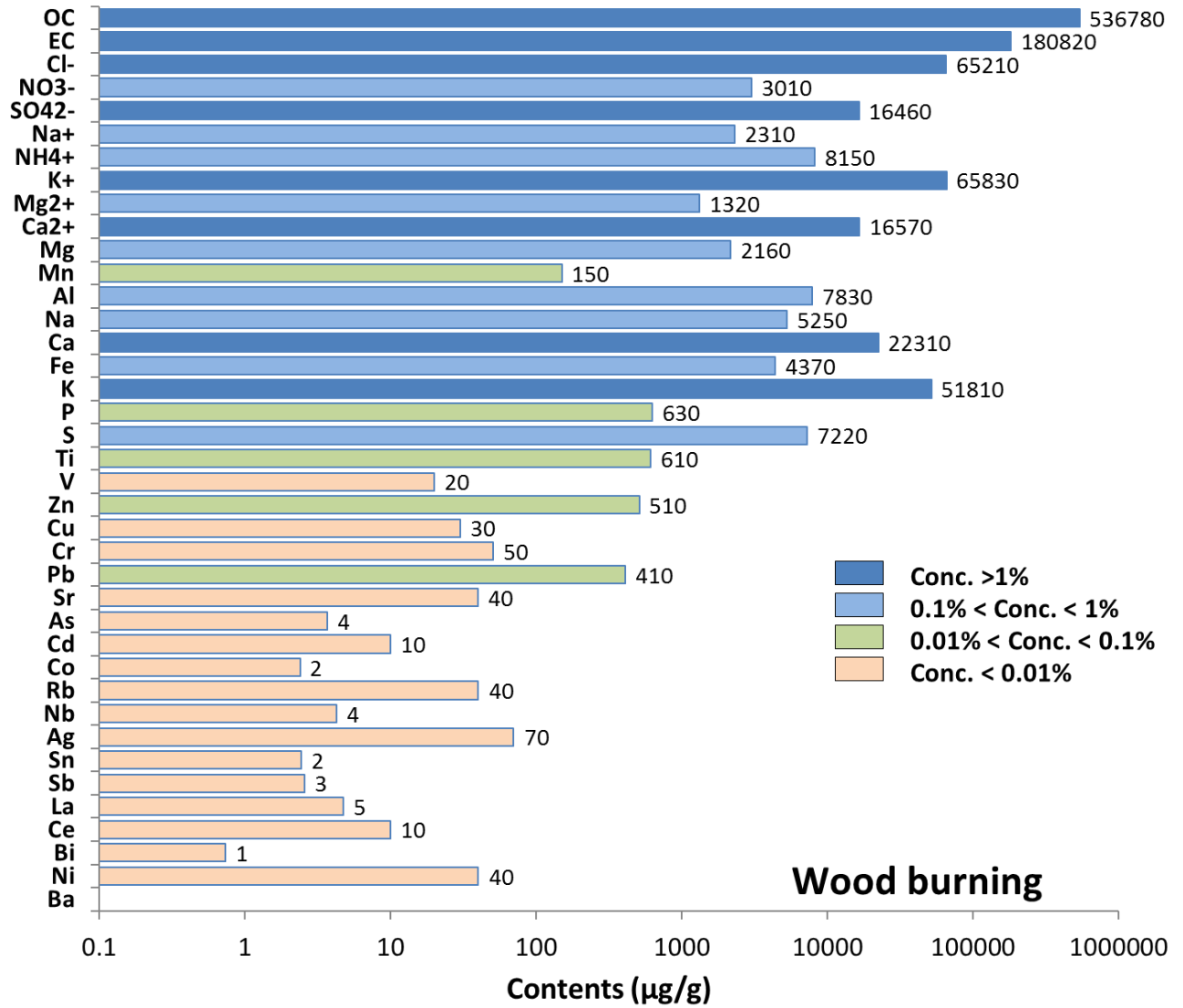
Figure S1: Contents (in $\mu\text{g/g}$) of the different species in the carbonaceous, ionic, and elemental fractions for the different sources



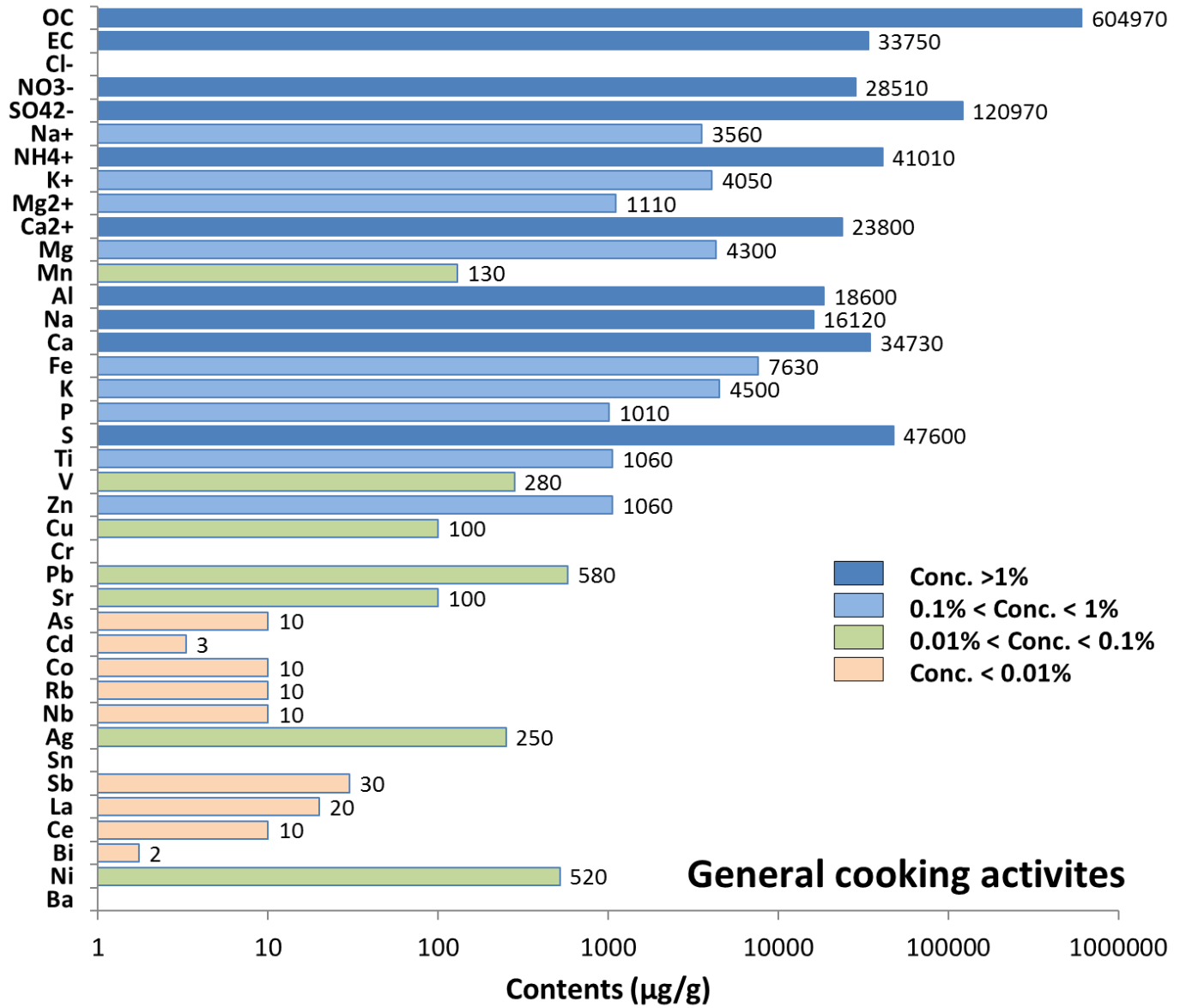
b)



c)



d)



e)

