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Multi-site $PM_{2.5}$ and $PM_{2.5-10}$ Aerosol Source Apportionment in Rio de Janeiro, Brazil

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Table S1. Atmospheric conditions existing at each sampling day, measured at the Rio de Janeiro city center

Sampling day	Temperature maximum/(°C)	Temperature minimum/(°C)	Temperature at 3 pm/(°C)	Wind direction at 3 pm/(m s^{-1})	Wind velocity at 3 pm/(m s^{-1})	Relative Humidity % at 3 pm
09/17/2003	23.9	20.0	23.3	WSW	1.0	73
09/24/2003	35.2	21.7	29.3	SE	3.5	65
10/01/2003	25.7	19.9	24.6	SE	3.2	68
10/08/2003	23.8	22.0	23.4	ENE	0.6	92
10/15/2003	24.0	17.8	23.1	SE	4.4	54
10/22/2003	27.6	24.0	26.8	SSE	1.5	73
10/29/2003	31.2	23.3	30.9	SSE	3.4	56
11/05/2003	25.5	18.1	24.1	SSE	4.8	63
11/12/2003	40.0	23.2	39.1	ENE	0.8	39
11/18/2003	38.1	28.9	36.4	NNW	2.0	43
11/26/2003	35.7	24.3	32.0	SE	1.6	54
12/03/2003	33.4	24.5	29.8	SE	4.5	73
03/03/2004	37.5	23.9	36.8	S	4.3	45
03/10/2004	36.1	25.2	33.0	SE	1.8	58
03/17/2003	32.0	23.2	31.0	SW	3.1	43
03/24/2004	28.7	21.1	27.8	S	2.8	57
03/31/2004	30.4	Missing	29.0	SSW	3.1	61
04/06/2004	31.0	24.2	29.8	SSE	2.8	66
04/15/2004	33.7	25.3	33.1	ENE	0.8	61
04/28/2004	25.0	19.3	26.8	S	5.6	59
05/05/2004	29.9	23.9	28.2	SSE	2.2	68
05/12/2004	27.8	19.7	26.6	SSE	2.0	64
05/19/2004	26.2	20.0	24.4	S	1.9	72
05/26/2004	26.3	21.0	24.0	SW	1.1	60
06/02/2004	27.0	19.7	25.6	S	1.5	66
06/08/2004	26.2	18.5	26.2	ENE	1.3	58
06/16/2004	28.4	18.3	27.0	S	1.6	61
06/23/2004	27.0	19.4	26.1	SSE	1.3	61
06/30/2004	30.1	20.9	29.5	E	1.0	56
08/11/2004	24.9	14.9	23.9	SSE	1.6	50

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Table S2. Sampling points coordinates

Sampling point	City Quarter	Coordinates
1	Gávea	S 22º58´46.08² W43º13´56.00²
2	Maracanã	S 22º54´52.52² W43º13´25.32²
3	Ilha do Fundão	S 22º51´59.54² W43º13´32.16²
4	Recreio dos Bandeirantes	S 22º59´34.90² W43º25´13.40²
5	Jacarepaguá	S 22º57´10.30² W43º20´47.00²
6	Honório Gurgel	S 22º50´42.60² W43º21´21.00²
7	Guaratiba	S 23º00´03.88² W43º34´54.21²
8	Campo Grande	S 22º54´32.63² W43º33´32.65²
9	Realengo	S 22º53´05.53² W43º26´07.64²
10	Santa Cruz	S 22º56´18.48² W43º40´05.72²

Table S3. Dionex DX-120 ion chromatograph operation conditions

Parameter	Cations	Anions
Guard column	CG-12 (4mm)	AG-14 (4mm)
Analytic column	CS-12 (4mm)	AS-14 (4mm)
Loop volume/(μL)	450	450
Eluent	H_2SO_4 10 mmol L^{-1}	Na_2CO_3 10 mmol L^{-1}/$NaHCO_3$ 0.6 mmol L^{-1}
Flow rate/(mL min^{-1})	1.2	1.2
Detector	Electric conductivity	Electric conductivity
Temperature/(ºC)	25	25

Table S4. Achieved (LOD) for the determination of water soluble cations and anions and elemental concentration in aerosol samples

Species	LOD/(ng m^{-3})	
	$PM_{2.5}$	$PM_{2.5-10}$
Na^+	50	50
NH_4^+	10	10
K^+	50	20
Mg^{2+}	10	20
Ca^{2+}	100	300
Cl^-	20	50
NO_3^-	30	130
SO_4^{2-}	30	30
Na	6.4	5.8
Mg	8.5	11
Al	16	18
K	4.6	3.7
Ca	12	8.7
Ti	0.8	0.9
Fe	4.1	3.8

Table S5. Instrument and data acquisition settings for the ICP-MS and ultrasonic nebulizer with desolvator

Instrument settings	
RF power	1150 W
Nebulizer	Ultrasonic with membrane desolvator
Sample cone	Nickel, 1.1 mm orifice diameter
Skimmer cone	Nickel, 0.9 mm orifice diameter
Argon flow rates:	
Plasma gas	15 L min^{-1}
Auxiliary gas	1.2 L min^{-1}
Nebulizer gas	1.17 L min^{-1}
Ultrasonic Nebulizer settings	
Sample uptake rate	2.5 mL min^{-1}
Heating temp	140 °C
Cooling temp	3 °C
Membrane desolvator heating temp	160 °C
Sweep gas flow	2.0 L min^{-1}
Data acquisition settings	
Acquisition mode	Peak hopping
Lens scanning	Enabled
Read delay	40 s
Concentration measurements:	Totalquant mode
Internal standard	In and Tl
Sweeps/Replicate	6
Replicates	1
Dwell time	50 ms
Integration type	Average

Table S6. Obtained results with the ICP-MS for the analysis of the standard reference material NIST-1648 (urban dust), analysis in triplicate, values in mg kg^{-1}

Element	Certified value	Found value	RSD (%)	Bias (%)
Na	4250	5236	1	23
Mg	8000	7711	3.3	-3.6
Al	34200	32117	2.2	-6.1
K	10500	10586	2.4	0.8
Ca	Not reported	71376	0.5	
Ti	4000	3622	2.6	-9.5
Fe	39100	41114	2	5.2

Table S7. Obtained results with the ICP-MS for the analysis of the standard reference material NIST-2783 (air particulate on filter), values in ng/filter

Element	Certified value	Found value	Bias (%)
Na	1860	2131	15
Mg	8620	8172	-5.2
Al	23210	22666	-2.3
K	5280	5390	2.1
Ca	13200	16199	23
Ti	1490	1565	5
Fe	26500	29063	9.7

Table S8. Descriptive statistics of the aerosol mass concentration, as well as black carbon concentration, according to the different sampling points

Sampling Point	$PM_{2.5}$ /(μg m^{-3})		$PM_{2.5-10}$ /(μg m^{-3})		PM_{10} /(μg m^{-3})		BC /(μg m^{-3})	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	7.8	4.4	12	3.8	19.7	7.4	2.1	1.3
2	11	6	16.5	9.2	28	14	3.1	1.7
3	13	6.8	19.1	9.1	32	15	2.9	1.8
4	7.5	4.2	11.8	4.5	19.5	7.4	1.31	0.76
5	11	4.6	18.7	5.9	29.7	9.7	2.7	1.2
6	11	5	27	13	38	16	3.2	1.8
7	7.1	4.4	11.1	3.7	18.2	6.8	1.21	0.86
8	11.1	4.4	18.6	6.2	29.7	9	2.4	1.1
9	10.4	4.8	19.7	9.2	30	12	2.5	1.3
10	10.5	4.1	18.3	6.6	28.8	9.7	1.74	0.89

Table S9. Comparison between the obtained results in the present work and results obtained by other authors (values in μg m^{-3})

	Rio de Janeiro (a)	Niterói (10)	Rio de Janeiro (10)	São Paulo (17, b)	Porto Alegre (14)	Santiago (5)	Edinburgh (12)	Brisbane (15)	Auckland (13)	Zurich (11)	Bern (11)	Ho Chi Minh (16)
Fine Mode ($PM_{2.5}$)												
$PM_{2.5}$	7.0-13	24	31	15-30	15	36-54	7.1	7.3	8.2	20	24.6	16
BC	1.2-3.2			4.1-7.6		3.5-10.4	5.7	1.8	1.2	1.8	4.2	
NH_4^+	0.44-0.74	0.98	0.90						0.08	2.1	1.6	
Na^+	0.17-0.30	0.40	0.45					0.28	0.45	0.094	0.094	
K^+	0.12-0.23	0.36	0.45					0.055	0.049	0.18	0.18	
Mg^{2+}	0.020-0.030	0.086	0.10					0.037	0.046	0.011	0.009	
Cl^-	0.13-0.32	0.24	0.29					0.15	0.49	0.072	0.10	
NO_3^-	0.26-0.50	0.70	2.4					0.18	0.23	3.5	3.0	
SO_4^{2-}	1.5-2.2	0.71	2.7					0.79	0.50	3.5	2.8	
Na	0.16-0.28									0.096	0.084	0.20
K	0.091-0.17			0.12-0.41	0.25			0.056		0.22	0.19	0.83
Mg	0.015-0.030									0.017	0.013	0.27
Ca	0.049-0.11			0.068-0.15	0.064			0.03		0.054	0.11	0.21
Al	0.067-0.15			0-0.44				0.033	0.011	0.048	0.026	0.55
Fe	0.069-0.14			0.18-0.53	0.13		0.028	0.05	0.02	0.124	0.20	0.26
Ti	0.017-0.025			0.015-0.031			0.0037	0.006	0			0.10
Coarse Mode ($PM_{2.5-10}$)												
$PM_{2.5-10}$	11-27	34	31	19-46	12	41-94	6.3	10.4	9.9	6.3	19.6	31.8
NH_4^+		0.20	0.20						0	0	0.2	
Na^+	0.73-1.19	0.32	1.14					0.90	1.24	0.11	0.75	
K^+	0.14-0.18	0.32	0.23					0.043	0.059	0.028	0.048	
Mg^{2+}	0.09-0.19	0.079	0.38					0.13	0.16	0.021	0.037	
Cl^-	0.82-1.26	3.7	1.6					1.31	2.14	0.042	1.0	
NO_3^-	0.92-1.44	1.6	1.6					0.45	0.19	0.6	1.1	
SO_4^{2-}	0.51-1.05	1.7	1.1					0.31	0.38	0.2	0.7	
Na	1.02-1.53									0.14	0.85	0.86
K	0.16-0.49			0.20-0.49	0.43			0.078		0.037	0.10	1.76
Mg	0.14-0.22									0.043	0.076	0.64
Ca	0.31-1.21			0.52-1.20	0.40			0.24		0.18	1.14	1.20
Al	0.31-1.17			0.51-1.52				0.19	0.10	0.037	0.13	2.13
Fe	0.28-0.66			0.67-1.98	0.66		0.15	0.20	0.13	0.41	2.0	1.22
Ti	0.04-0.10			0.079-0.22			0.003	0.033	0.016			0.37

[a]Maximum and minimum mean annual value among the 10 sampling sites; [b]Summer and winter mean values, respectively; (#): Reference source.

Table S10. Fine, coarse, total inhalable and black carbon mass concentration ratios according to the different sampling points

Sampling Point	$PM_{2.5}/PM_{10}$	$PM_{2.5-10}/PM_{10}$	$PM_{2.5}/PM_{2.5-10}$	$BC/PM_{2.5}$
1	0.39	0.60	0.65	0.27
2	0.41	0.59	0.69	0.28
3	0.41	0.59	0.68	0.22
4	0.39	0.63	0.62	0.18
5	0.37	0.63	0.58	0.25
6	0.29	0.71	0.41	0.29
7	0.39	0.61	0.64	0.17
8	0.37	0.63	0.58	0.22
9	0.33	0.67	0.50	0.25
10	0.36	0.64	0.56	0.17

Table S11. Descriptive statistics of the water soluble cations and anions concentration in the fine mode particles (values in μg m^{-3})

Sampling point	Sodium		Ammonium		Potassium		Chloride		Nitrate		Sulfate	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.24	0.16	0.56	0.37	0.136	0.090	0.22	0.36	0.26	0.27	1.5	1.1
2	0.22	0.16	0.67	0.44	0.18	0.16	0.14	0.11	0.39	0.46	1.9	1.2
3	0.30	0.52	0.74	0.47	0.21	0.14	0.28	0.55	0.47	0.46	2.2	1.1
4	0.23	0.16	0.44	0.31	0.16	0.12	0.15	0.12	0.30	0.29	1.43	0.94
5	0.23	0.19	0.54	0.35	0.22	0.19	0.13	0.10	0.50	0.44	1.75	0.92
6	0.24	0.20	0.53	0.38	0.23	0.24	0.32	0.60	0.35	0.31	1.52	0.98
7	0.18	0.12	0.45	0.28	0.120	0.046	0.28	0.64	0.35	0.35	1.5	1.0
8	0.20	0.10	0.59	0.35	0.18	0.11	0.15	0.15	0.39	0.37	1.7	1.0
9	0.17	0.11	0.55	0.39	0.169	0.088	0.21	0.29	0.35	0.31	1.7	1.1
10	0.26	0.22	0.50	0.33	0.21	0.19	0.31	0.56	0.33	0.32	1.7	1.0

Table S12. Descriptive statistics of the water soluble cations and anions concentration in the coarse mode particles (values in μg m^{-3})

Sampling point	Sodium		Magnesium		Potassium		Chloride		Nitrate		Sulfate	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.19	0.60	0.18	0.07	0.09	0.05	1.26	0.95	1.25	0.78	0.79	0.67
2	0.76	0.40	0.15	0.08	0.11	0.09	0.82	0.71	1.3	1.0	0.68	0.65
3	0.92	0.49	0.17	0.07	0.14	0.13	0.97	0.67	1.5	1.1	0.67	0.62
4	0.94	0.45	0.14	0.05	0.09	0.05	1.06	0.70	1.07	0.57	0.54	0.38
5	0.93	0.47	0.16	0.07	0.10	0.06	0.98	0.67	1.44	0.87	0.74	0.53
6	0.91	0.49	0.17	0.10	0.19	0.11	0.97	0.70	1.7	1.0	1.05	0.89
7	0.86	0.49	0.14	0.06	0.14	0.17	0.94	0.68	0.92	0.59	0.51	0.39
8	0.73	0.48	0.15	0.08	0.11	0.07	0.91	0.69	1.26	0.89	0.60	0.36
9	0.73	0.38	0.14	0.07	0.10	0.08	0.92	0.70	1.24	0.87	0.76	0.63
10	0.90	0.38	0.15	0.07	0.10	0.07	0.98	0.68	1.22	0.81	0.56	0.40

Table S13. Descriptive statistics of the elemental mass concentration in the fine mode particles according to the different sampling points (values in μg m^{-3})

Sampling point	Sodium		Magnesium		Calcium		Potassium		Aluminium		Titanium		Iron	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.26	0.17	0.026	0.069	0.122	0.082	0.091	0.018	0.13	0.33	0.018	0.006	0.088	0.039
2	0.18	0.095	0.015	0.05	0.057	0.062	0.107	0.011	0.119	0.03	0.02	0.055	0.136	0.007
3	0.2	0.11	0.017	0.096	0.084	0.09	0.137	0.012	0.126	0.048	0.025	0.066	0.13	0.007
4	0.21	0.11	0.021	0.072	0.052	0.05	0.094	0.014	0.112	0.043	0.017	0.04	0.088	0.006
5	0.21	0.12	0.02	0.067	0.074	0.085	0.122	0.013	0.145	0.03	0.023	0.04	0.11	0.005
6	0.165	0.097	0.017	0.06	0.108	0.094	0.128	0.014	0.15	0.06	0.021	0.073	0.14	0.005
7	0.2	0.13	0.03	0.068	0.049	0.052	0.093	0.041	0.067	0.035	0.018	0.046	0.069	0.005
8	0.18	0.12	0.019	0.065	0.088	0.074	0.169	0.014	0.154	0.038	0.022	0.042	0.145	0.005
9	0.16	0.11	0.017	0.072	0.087	0.078	0.119	0.014	0.135	0.035	0.021	0.039	0.1	0.004
10	0.28	0.16	0.028	0.075	0.115	0.079	0.155	0.021	0.125	0.041	0.022	0.036	0.092	0.008

Table S14. Descriptive statistics of the elemental mass concentration in the coarse mode particles according to the different sampling points (values in μg m^{-3})

Sampling point	Sodium		Magnesium		Calcium		Potassium		Aluminium		Titanium		Iron	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.53	0.72	0.187	0.057	0.31	0.19	0.158	0.07	0.37	0.2	0.04	0.17	0.298	0.019
2	1.06	0.52	0.18	0.066	0.6	0.28	0.269	0.066	0.67	0.42	0.06	0.31	0.624	0.035
3	1.15	0.47	0.205	0.073	0.82	0.27	0.345	0.073	0.57	0.49	0.08	0.29	0.66	0.042
4	1.16	0.53	0.155	0.055	0.43	0.19	0.197	0.055	0.31	0.23	0.04	0.15	0.283	0.02
5	1.36	0.63	0.222	0.065	0.8	0.81	0.365	0.065	0.82	0.34	0.08	0.26	0.608	0.035
6	1.22	0.54	0.225	0.063	1.21	0.41	0.492	0.063	1.17	0.53	0.1	0.53	0.892	0.053
7	1.05	0.61	0.139	0.054	0.49	0.24	0.205	0.054	0.29	0.31	0.05	0.19	0.319	0.029
8	1.11	0.64	0.203	0.068	0.86	0.35	0.351	0.068	0.77	0.45	0.08	0.29	0.57	0.042
9	1.02	0.45	0.191	0.057	0.91	0.3	0.38	0.057	1.01	0.48	0.09	0.31	0.611	0.044
10	1.25	0.66	0.181	0.076	0.98	0.19	0.296	0.076	0.58	0.46	0.09	0.25	0.54	0.04