Determination of airborne polycyclic aromatic compounds exhausted from buses

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Atmospheric particulate matter has been extensively studied to better understand its impact on human health, due to evidences of harmful effects in the respiratory and cardiovascular systems. Chronic respiratory effects related to particulate matter may include reduced lung function and increased symptoms of bronchitis in children and adults (Kelly, 2012). Polycyclic aromatic hydrocarbons (PAHs) are a group of environmental pollutants that might be present in both vapor and particulate phases. As products of incomplete combustion processes, PAHs and their derivatives are present not only in ambient particles but also in urban dust (Hasheminassab, 2013). PAHs and their nitrated and oxygenated derivatives deserve attention due to their well-known toxicities and harmful effects on health. Certain PAHs are carcinogenic and/or mutagenic, and nitro-PAHs and quinones have proved to be more potentially mutagenic and/or carcinogenic than the parent PAHs (Franco, 2010). The main goal of this study was determination of PAHs, nitro-PAHs and quinones associated to atmospheric aerosol.

Particulate matter samples were collected in the underground floor at the Lapa Bus Station (12°58′S, 38°30′W, 52 m altitude), in Salvador, State of Bahia, Northeastern Brazil during April 27th–May 18th, 2010. PM_{10} samples were collected using a high-volume (Hi-Vol) sampler equipped with particle separator for particles smaller than 10 µm aerodynamic diameter. Samples were collected on quartz fiber filters (22.8 cm × 17.7 cm) over 4 h, at 1.13 $m^3 min^{-1}$, each PM_{10} samples corresponding to 271 m^3. After collection, filters were folded in half face to face, placed in an aluminum foil envelope then in a zip lock plastic bag, transported cool to the laboratory and stored in a freezer (−4 °C) until analysis by GC-MS (Santos,2016).

Concentrations PAHs, nitro-PAHs and Quinones for all the urban samples PM10 (n = 30) collected in the bus station are summarized in Table 1. Some species indicated in Table 1 had concentrations below the quantitation limit and / or were not detected (n.d.). The average of the individual concentrations and the concentration ranges were (ng m^{-3}): 0.30 (coronene) - 4.90 (benzo(k)fluoranthene) tfor PAHs, 1.60 (4-nitrobiphenyl) to 34.5 (9-nitroanthracene) for nitro-PAHs and <LOQ (9,10-phenanthraquinone) to 21.7 $ng.m^{-3}$ (1,4-benzoquinone) to quinones.

The results presented in Table 1 are relevant because the quantification of such compounds as benzo[a]pyrene, 1-nitropyrene, 3-nitrofluoranthene and 9,10-anthraquinone at elevated concentrations indicates the impact of emission sources and incomplete combustion processes, primarily diesel engines and diesel exhaust gases.

Table 1. Absolute mass units (pg) and concentration ranges (ng m^{-3}) for PAHs, nitro-PAHs and quinones in particulate matter samples PM_{10} (n = 30).

Compounds	Mass	Concentration ranges	Mean ± SD	Compounds	Mass	Concentration ranges	Mean ± SD
1,4-benzoquinone	255	3.15 - 96.23	21.7±23.6	9,10-phenanthraquinone	LOD>9.40	nd - 4.5	0.6±1.1
naphthalene	20.6	0.43 - 5.40	1.9±1.3	1-nitrophenanthrene	176	4.9 - 41.8	16.4±9.1
1,4-naphthoquinone	126	1.24 - 51	11.311.4	9-nitrophenanthrene	78.0	1.5 - 28.3	7.5±6.3
acenaphthylene	4.60	0.13 - 1.08	0.4±0.3	2-nitroanthracene	90.4	1.0 - 38.5	8.8±8.5
acenaphthene	9.30	0.20 - 2.06	0.9±0.6	9-nitroanthracene	401	7.0 - 101.3	34.5±29.2
fluorene d10*	-	-	-	Benzo[a]anthracene	22.8	0.06 - 15.0	2.1±3.7
fluorene	12.4	0.23 - 3.37	1.2±0.8	chrysene	15.7	0.02 - 11.1	1.4±2.8
1-nitronaphthalene	73.0	2.47 - 19.50	6.9±4.2	2-nitrofluoranthene	202	nd - 69.39	7.0±17.0
1,2 - naphthoquinone	LOD>9.60	nd - 3.04	0.8±0.7	3-nitrofluoranthene	173	nd - 49.8	11.5±11.2
1-methyl-4-nitronaphthalene	nd	nd	-	1-nitropyrene	104	nd - 21.8	6.7±5.5
2-nitronaphthalene	70.2	1.68 - 26.46	6.5±5.5	2-nitropyrene	57	nd - 19.48	2.3±4.9
2-nitrobiphenyl	41.3	1.53 - 6.29	3.4±1.4	4-nitropyrene	133	nd - 24.11	2.4±6.2
1-methyl-5-nitronaphthalene	nd	nd	-	Benzo[b]fluoranthene	36	0.14 - 23.3	2.5±4.8
1-methyl-6-nitronaphthalene	nd	nd	-	Benzo[k]fluoranthene	53.3	1.03 - 12.2	4.9±3.4
2-methyl-4-nitronaphthalene	nd	nd	-	7-nitrobenz[a]anthracene	54.9	1.00 - 28.6	5.5±6.6
phenanthrene	75.0	nd - 15.98	7.1±4.2	Benzo[a]pyrene	24.8	nd - 20.5	1.3±3.8
anthracene	11.2	0.4 - 2.84	1.1±0.7	perylene	7.1	nd - 3.43	0.5±0.9
3-nitrobiphenyl	27.0	0.25 - 9.22	2.6±2.5	6-nitrochrysene	45	nd - 17.8	4.1±3.9
4-nitrobiphenyl	17.0	0.29 - 5.05	1.6±1.3	Indeno[1,2,3 c,d]pyrene	13.5	nd - 10.6	0.6±1.9
9,10-anthraquinone	194	2.09 - 115.32	19.0±26.7	Dibenzo[a,h]anthracene	5.3	nd - 2.53	0.3±0.6
5-nitroacenaphthene	65.0	0.40 - 36.85	5.1±6.9	6-nitrobenzo[a]pyrene	159	nd 30.9	11.6±10.0
fluoranthene	16.0	0.19 - 3.88	1.5±1.0	1-nitrobenzo[e]pyrene	74.1	nd - 26.5	6.4±7.0
pyrene d10*	-	-	-	Benzo[ghi]perylene	17	nd - 15.1	0.8±2.7
2-nitrofluorene	61.0	0.62 - 16.33	5.4±3.5	3-nitrobenzo[e]pyrene	29.3	0.85 - 7.2	2.8±1.6
pyrene	26.2	0.25 - 6.97	2.5±1.6	coronene	4.80	nd - 3.76	0.3±0.67
2-nitrophenanthrene	47.3	0.05 - 30.28	4.6±6.9				

In the present study concentrations were compared between PAHs precursors (naphthalene, phenanthrene, anthracene), nitro-PAHs (1 nitronaphthalene, 2-nitronaphthalene, 2-nitrophenanthrene, 3-nitrophenanthrene, 9-nitrophenanthrene, 2-nitroanthracene, 9-nitroanthracene) and quinones (1,4-naphthoquinone, 9,10-anthraquinone, 9,10-phenanthraquinone) which can be derived from these PAHs were quantified and the samples collected at Lapa station.

Correlations between PAHs, nitro-PAHs and quinones show strong correlations, r=0.96 (among NAPH, 1-NNAPH, and 1,4-NQ), r=0,93 (for NAPH, 2-NNAPH, and 1,4-NQ), r=0.9369 (for PHE, 2-NPHE, 9,10-PQ), 0.9836 (for ANT, 2-NANT, 9,10-AQ), r= 0.95 (for PHE, 3-NPHE, 9,10-PQ), 0.95 (for PHE, 9-NPHE, and 9,10-PQ) and 0.99 (for ANT, 9-NANT, 9.10-AQ).

The strong correlations between the precursor to HPA and its derivatives in the samples collected at Lapa station suggests that these compounds may have the same origin, such as diesel and /or biodiesel/ diesel combustion.

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