Particulate matter concentrations and chemical composition in the European underground transport system

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The air quality in the subway system (the subway platform, subway cars, the station environment) may be worse than outdoor air. In major cities all over the world a large number of commuters use the subway to move every day and they are exposed for a variable percentage of time to the pollutants present in the air. Over the last 15 years a hundred papers on air quality in the subway systems has been published. One of the main interests of the scientific community is to know the characteristics of the PM in the subway because the assessment of exposure to air pollution in different microenvironments dedicated to the carriage of persons is of remarkable interest for the protection of human health.

Starting from a broader analysis of the current knowledge in the scientific literature, in this work we focused on particulate sources, levels, size distribution, and composition in European subway systems.

We found large difference among studies design. Most of the papers focuses on the mass concentration of various fractions of PM (PM_{10}, PM_5, $PM_{2.5}$, PM_1), their physical and chemical characterization, and the estimation of metals enrichment factors. Several papers report results on particle number concentration and size distribution. Moreover, since each subway system has unique features, it is particularly complex to compare the results of different studies. In Table 1 the main features of some European undergrounds are presented.

Table 1: characteristic of some European subway

City	System length (km)	Ridership (millions)	Stations (number)
Amsterdam (1977)	31,4	59,5	33
Athens (1904)	84,7	493,8	61
Barcelona (1924)	102,6	369,9	141
Budapest (1896)	38,2	302,4	52
Helsinki (1982)	21,1	62,1	17
London (1890)	402	1260	270
Madrid (1919)	294	557,9	301
Milan (1964)	100	419,8	110
Paris (1900)	214	1527	303
Prague (1974)	65,2	589,2	61
Rome (1955)	58,6	279	73
Stockholm (1950)	105,7	328	100

A detailed comparison of PM_{10} $PM_{2.5}$ levels and their metal contents, in platforms and inside trains in European subways was carried out, trying to link the differences founded to the study design and the metrosystem specificity. A synthesis of averages PM levels is provided in table 2.

Table 2: PM_{10} and $PM_{2.5}$ levels in European subways

	City	PM_{10} (average or range, µg/m^3)	$PM_{2.5}$ (average or range, µg/m^3)
Platform	London	1000-1500	270-480
	Stockholm	469	258
	Helsinki	-	47-60
	Prague	102.7	-
	Rome	409	-
	Budapest	155	51
	Paris	200-320	61-93
	Amsterdam	394	137
	Barcelona	-	20-91
	Milan	105-283	-
Inside trains	London	-	130-200
	Helsinki	-	21
	Prague	113.7	-
	Barcelona	-	20-99
	Athens	230-600	-

The observed concentrations levels suggest that inside urban microenvironments such as metro systems, intense particles and metals short-term exposures could arise, contributing significantly to the daily total exposure, allowing for suppose differential exposure pattern among commuters using or not the subway systems. However, little is known on such exposures and the role they could play, probably due to the challenges that the exposure assessment pone, since individuals move through multiple urban microenvironments and transport modes, with large differences among cities and within the same city as well. To this purpose, studies endeavoured to monitor the microenvironmental exposure of individuals (and not only concentration levels) based at least on the "time averaged approach"[1] including metro systems transport modes are needed.

[1] A time averaged approach estimates the microenvironmental exposure using average pollutant concentrations and the total time spent in each microenvironment