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KEY FACTORS INFLUENCING AIR QUALITY IN RAIL SUBWAY SYSTEMS

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QUESTION 1:

WHY SHOULD WE STUDY AIR QUALITY IN THE SUBWAY ENVIRONMENT?

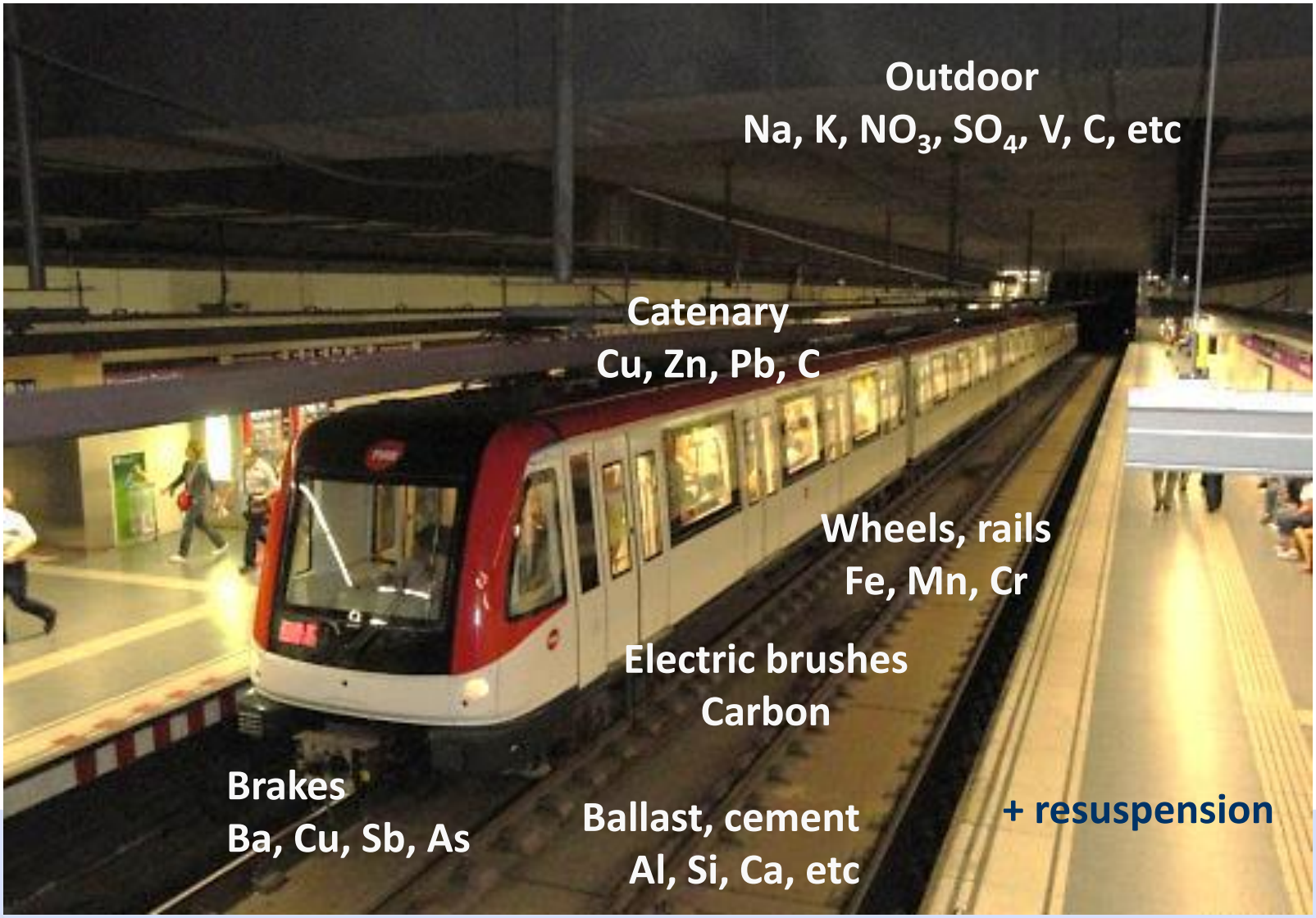
THE QUESTION OF AIR QUALITY IN UNDERGROUND SYSTEMS IS NOT TRIVIAL

- ✓ Underground subway systems worldwide transport > 100 million people daily
- ✓ Ambient PM10 concentrations on platforms can be >> 50 µg/m³.
- ✓ Subway PM is extremely metalliferous and very different in chemistry from outside ambient air.

On platforms	PM10 (µg/m³)	PM2.5 (µg/m³)	Reference
Barcelona	87-325	21-186	*Querol et al. 2012*
Barcelona	133	13-154	*Moreno et al. 2014; Martins et al. 2015*
Budapest	155	51	*Salma et al. 2007*
London	1000–1500	270–480	*Seaton et al. 2005*
Los Angeles	78	57	*Kam et al. 2011*
Paris	200	61	*Raut et al. 2009*
Seoul	359	129	*Kim et al. 2008*
Stockholm	357	199	*Johansson & Johansson 2003*
Taipei	51	35	*Cheng et al. 2008*

Inside train	PM10	PM2.5	Reference
Barcelona	36-100	11-32	*Querol et al. 2012*
Barcelona		*19-75*	*Martins et al. 2015*
Los Angeles	31	24	*Kam et al. 2011*
Taipei	41	32	*Cheng et al. 2008*

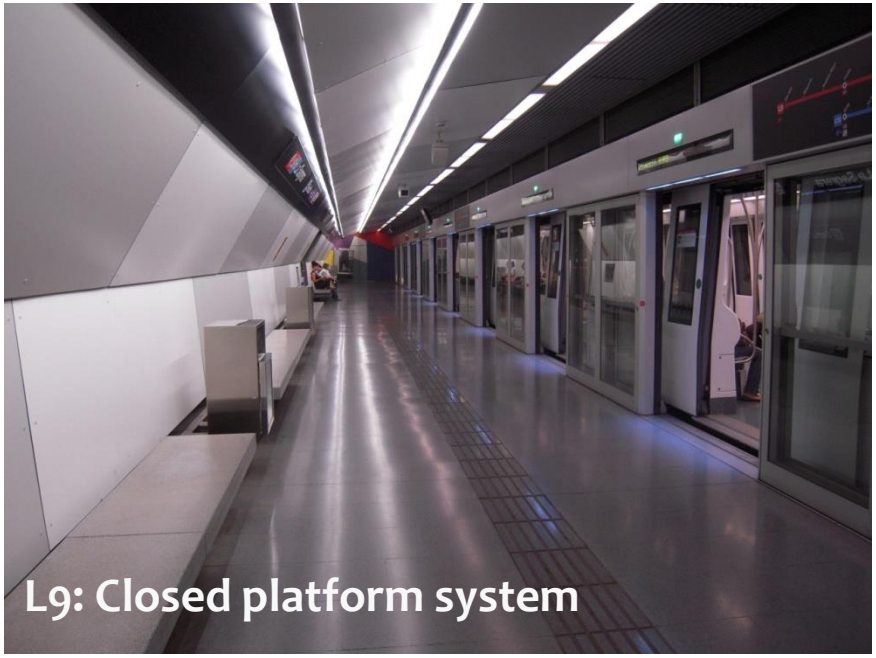
PM SOURCES IN UNDERGROUND SYSTEMS



BCN Metro

1.25 million passengers per weekday
50% of public transport loading
Average journey time (inside train) 12 minutes

L3: Open platform system

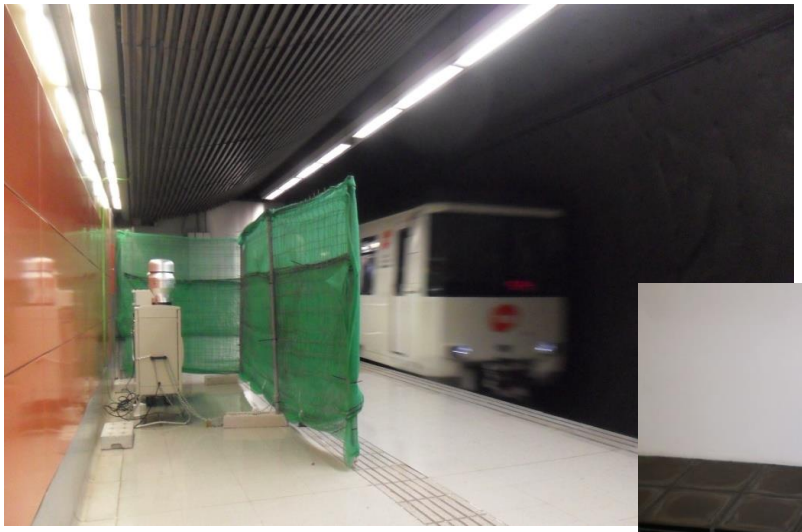


L9: Closed platform system

BARCELONA METRO AIR QUALITY PROJECT (2013-2015)

METHODOLOGY AND WORK PLAN

Continuous aerosol monitoring at 4 platforms during one whole month (twice a year).



24 platforms (6 lines)

Inside trains (6 lines)

METHODOLOGY AND WORK PLAN

Total Carbon

Organic

Acidic digestion

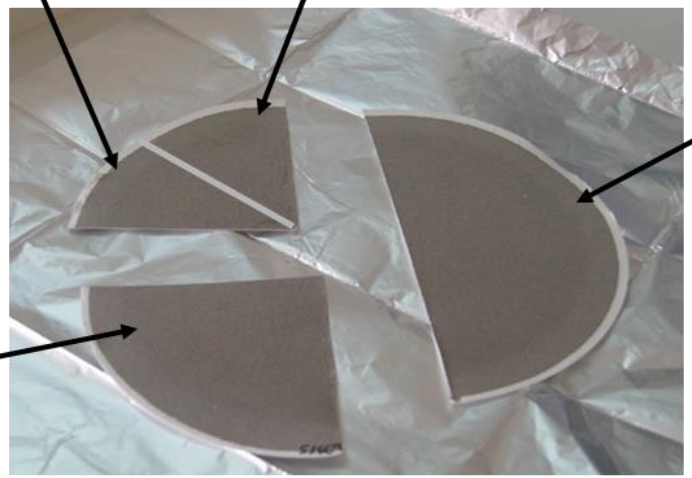
Leaching

Ion Chromat.:

NO_3^-, Cl^-, $SO_4^=$

Colorimetry FIA and ICP-AES:

NH_4^+, K^+, Mg^{2+},...



ICP-AES:

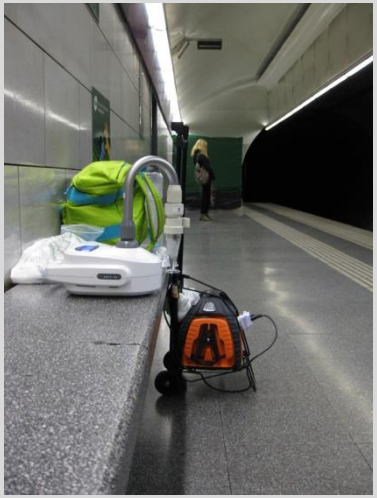
Al, Ca, K, Na, Mg, Fe, Ti, P

ICP-MS:

Li, Ti, V, Cr, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, Cd, Sn, Cs, Ba, La, Ce, Pr, Nd, Hf, Tl, Pb, Bi, Th, U

METHODOLOGY AND WORK PLAN

- ASAP: PM10 samples for microscopy (Cardiff Univ.-UK)
- Coriolis: Bacteria (DNA, RNA) in trains and at platforms – 10 min (CEAB/CSIC, Univ. Laval-Canada & Queensland Univ. of Technology-Australia)



OPS 3330

particle number 0.3–10 µm (16 channels) - 5 min.

Dusttrak

PM10, PM2.5, PM1 mass concentrations - 5 min.

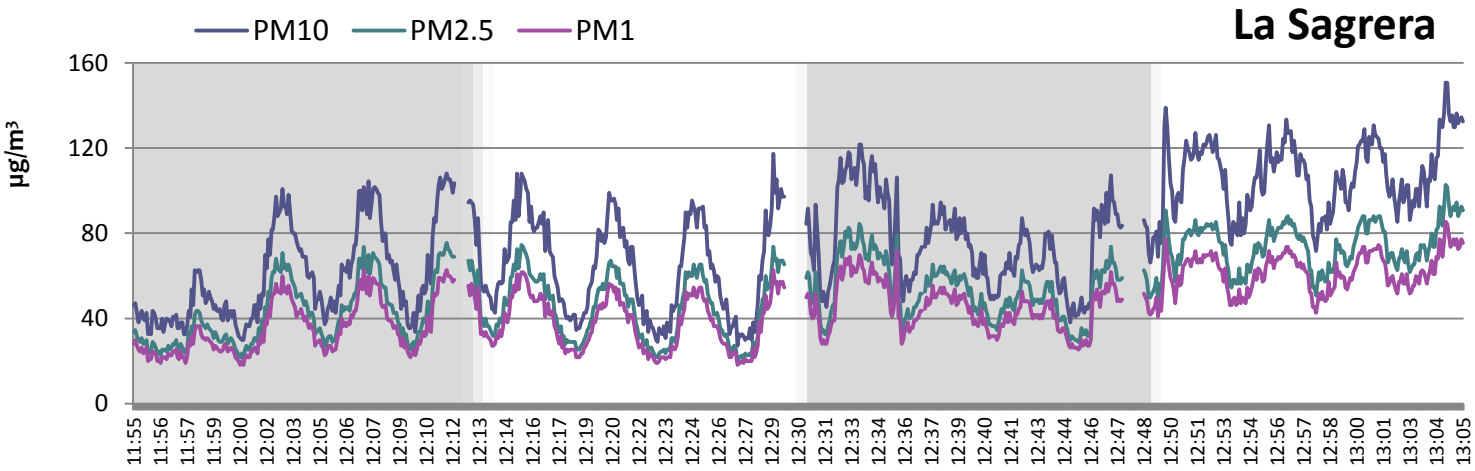
IAQ

CO, CO2, T, HR (levels) - 5 min

QUESTION 2:

WHAT ARE THE FACTORS INFLUENCING AIR QUALITY IN THE SUBWAY ENVIRONMENT?

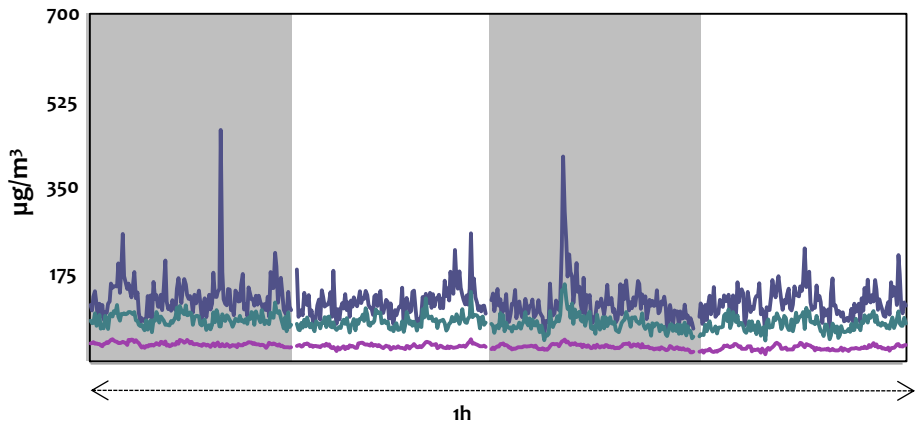
VARIABLES: TRAFFIC VOLUME



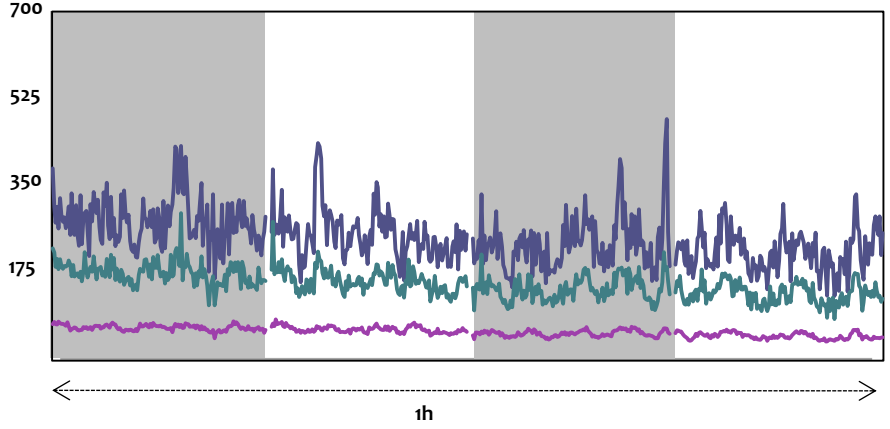
Moreno et al 2014, Atmos Environ 92, 461-68

VARIABLES: TUNNEL AND TRAIN VENTILATION

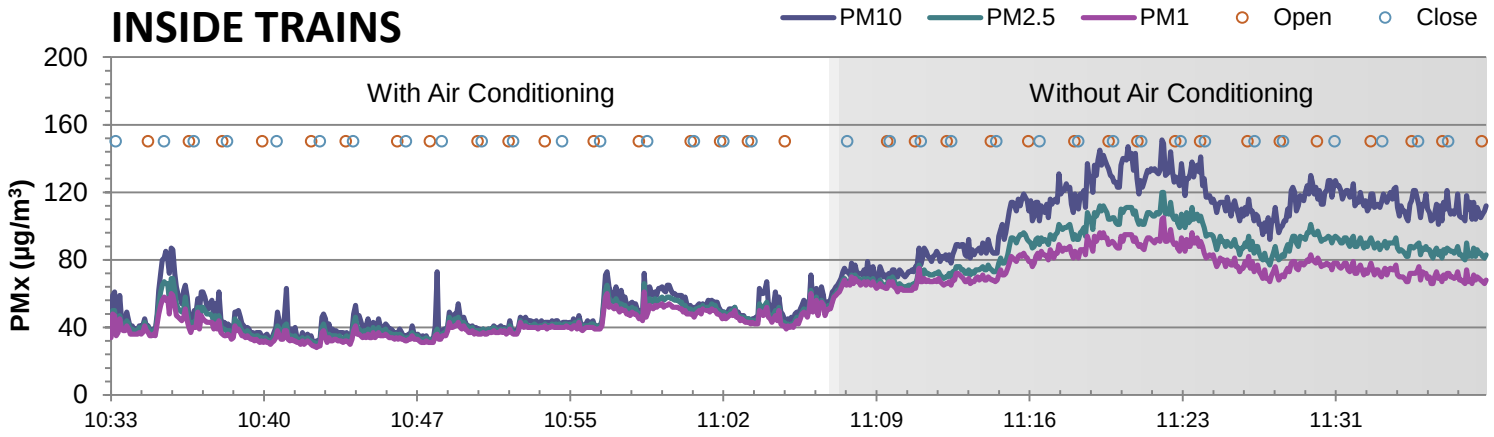
WITH FORCED TUNNEL VENTILATION



WITHOUT FORCED TUNNEL VENTILATION

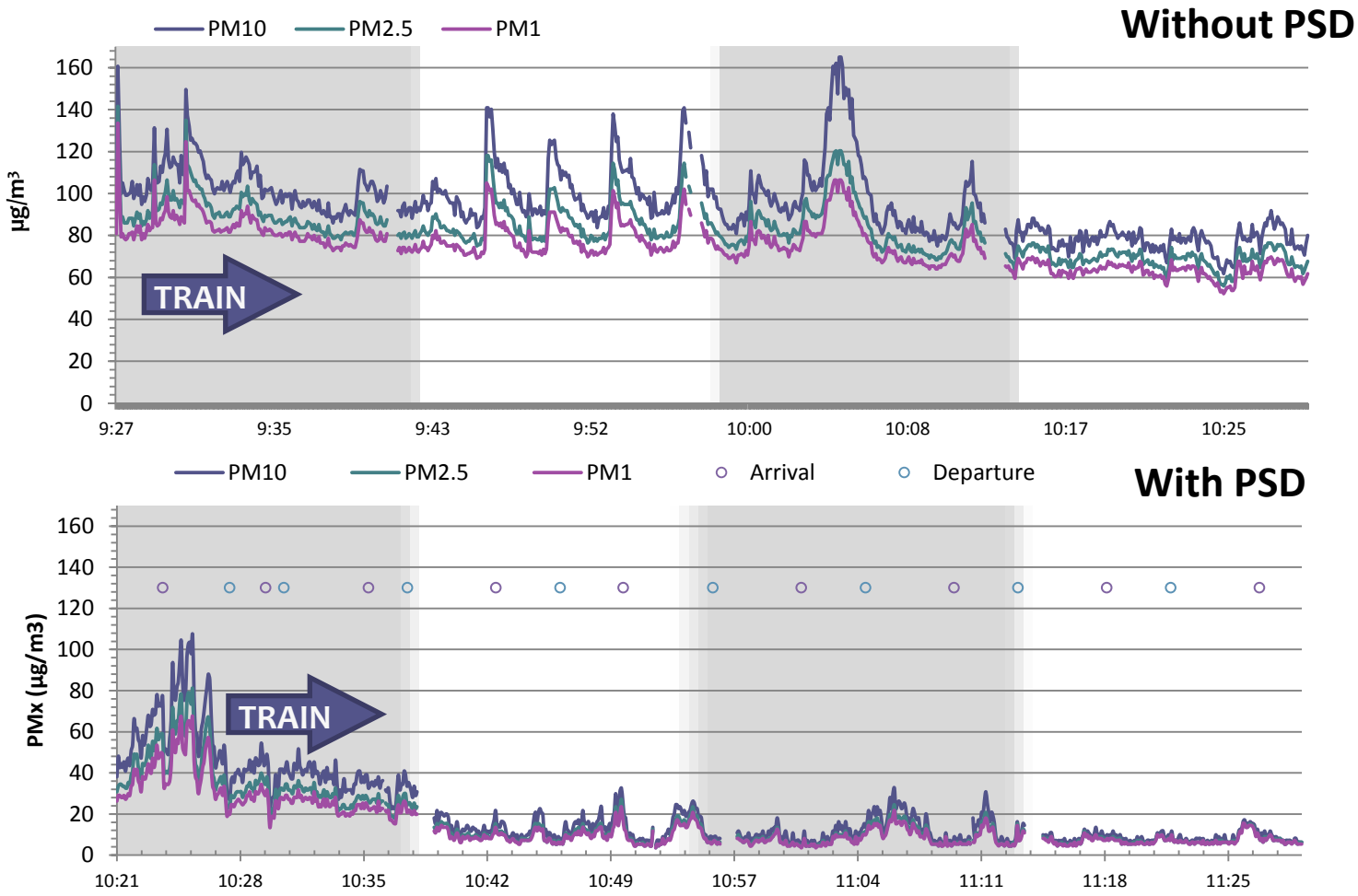


INSIDE TRAINS

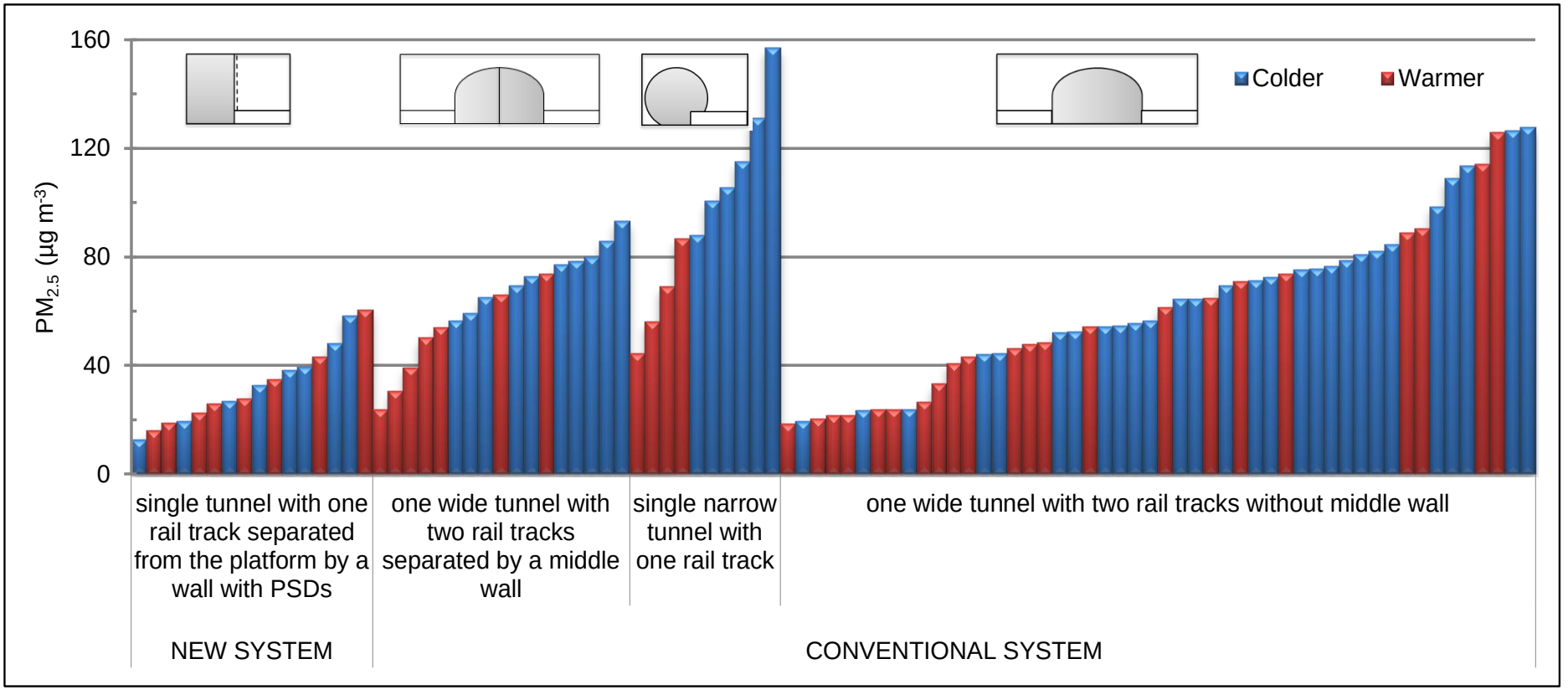


Martins et al 2015, Sci. Total Env. 511, 711-722

VARIABLES: STATION DESIGN AND PISTON EFFECT



VARIABLES CONTROLLING PLATFORM AIR QUALITY



Martins et al 2015, Sci. Total Env. 511, 711-722

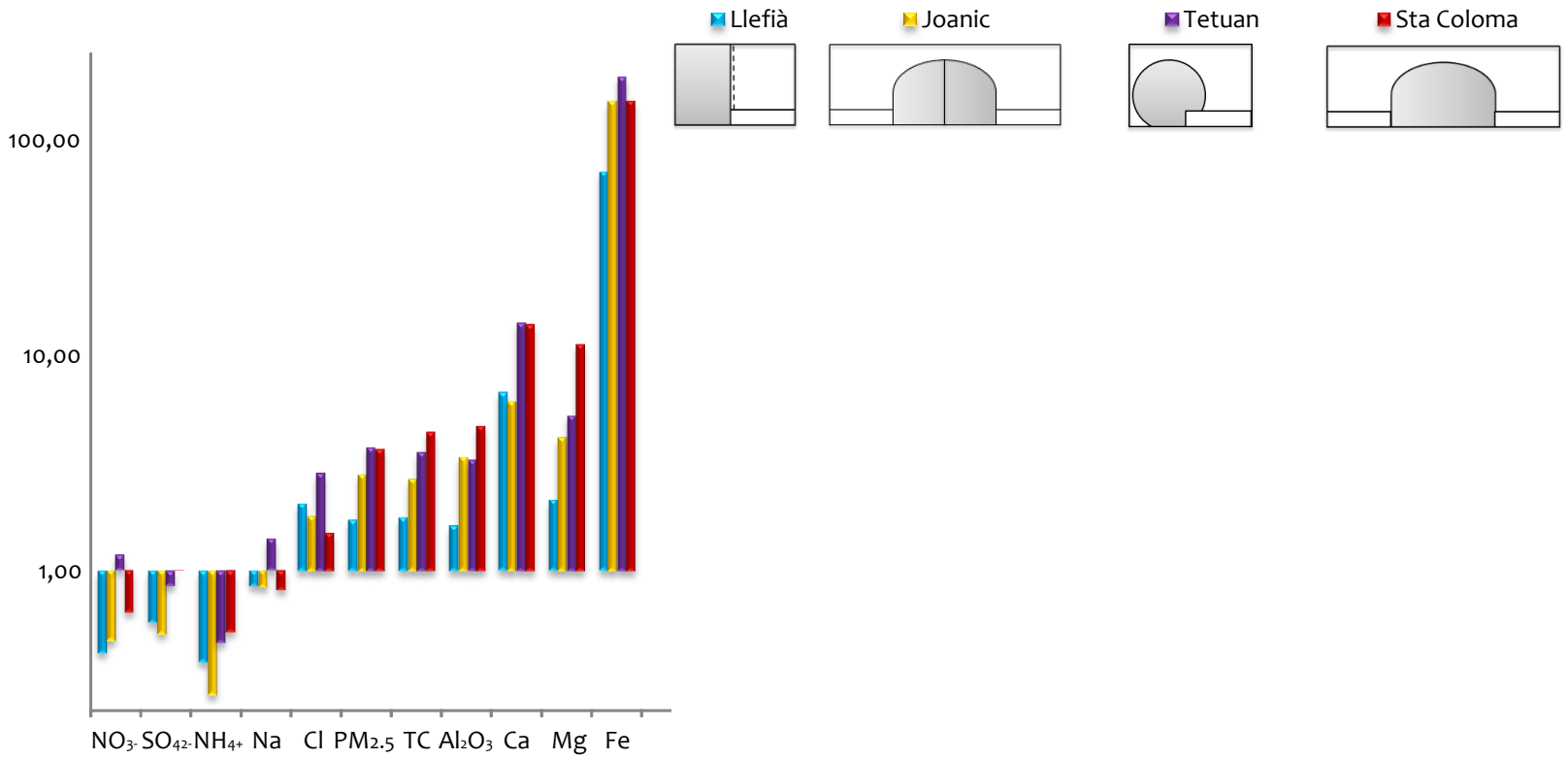
QUESTION 3:

WHAT IS THE COMPOSITION OF THE AIR WE BREATHE IN THE SUBWAY?

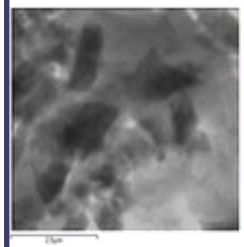
PM sources in underground systems

SUBWAY PM CHEMISTRY

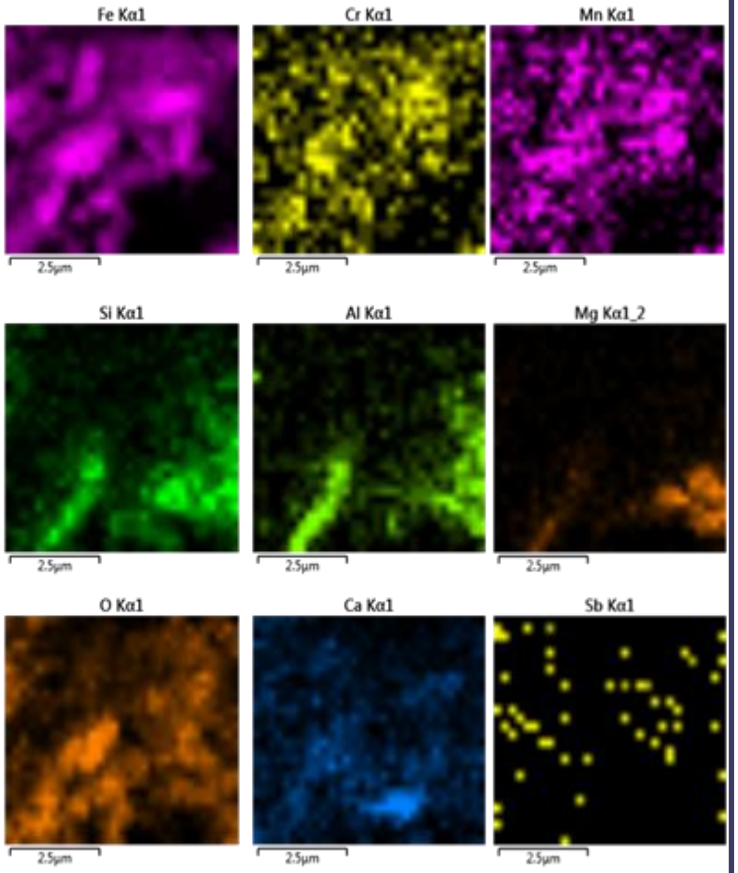
Subway/Barcelona outdoor



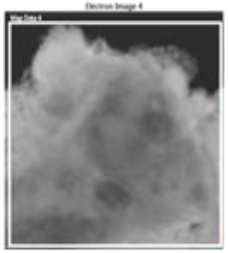
RAIL/WHEEL



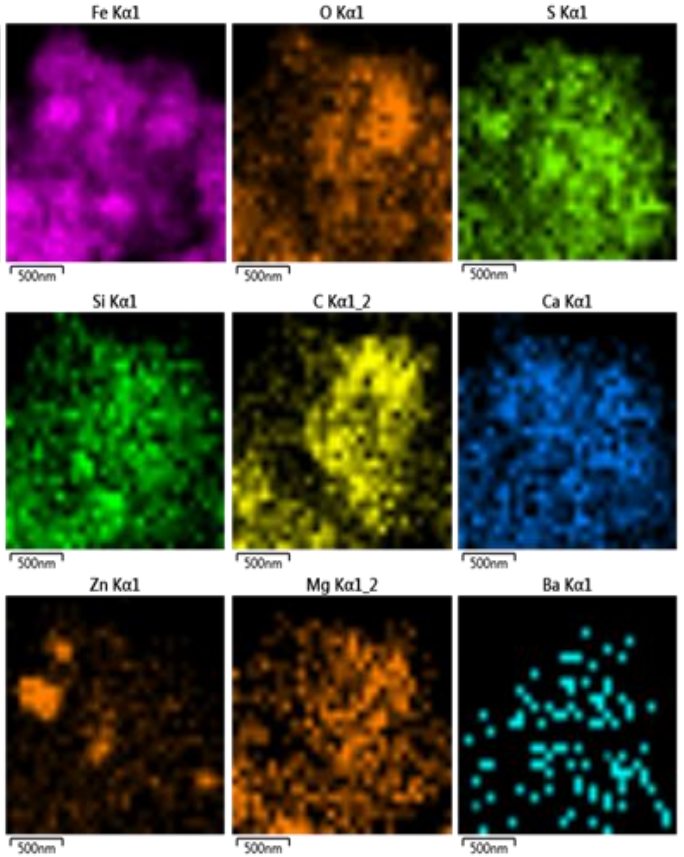
Element	Wt%
C	1.96
O	22.23
Na	0.86
Mg	0.92
Al	0.93
Si	2.54
S	0.56
Cl	0.59
K	0.86
Ca	2.35
Cr	0.35
Mn	0.65
Fe	64.69
Zn	0.05
As	0.08
Sb	0.39
Total:	100.00

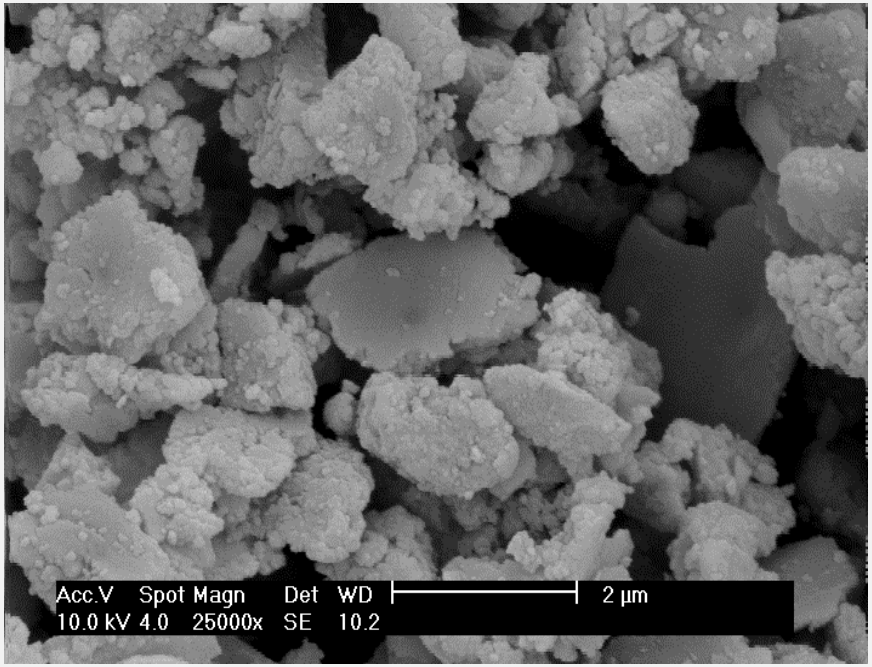


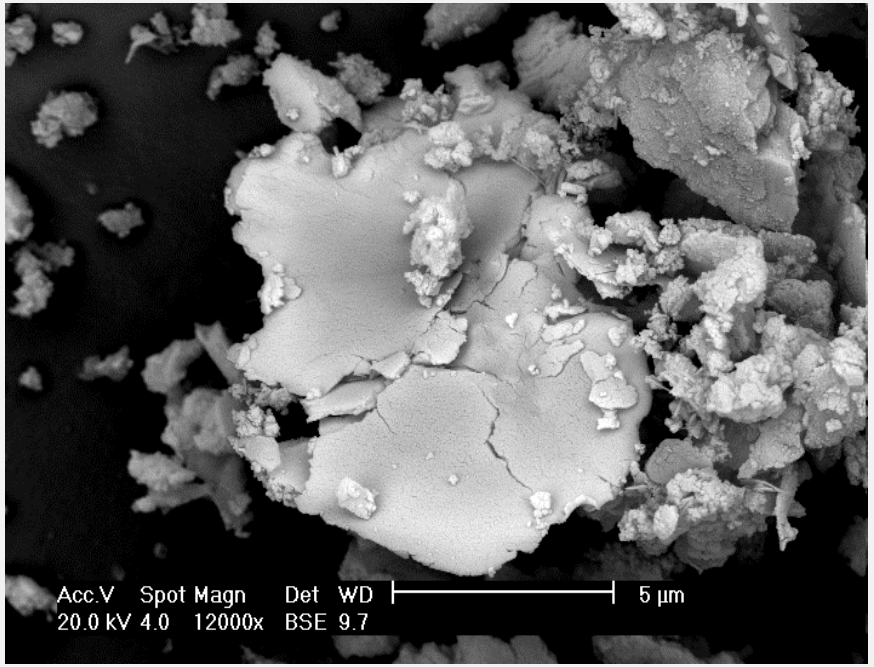
BRAKE PADS

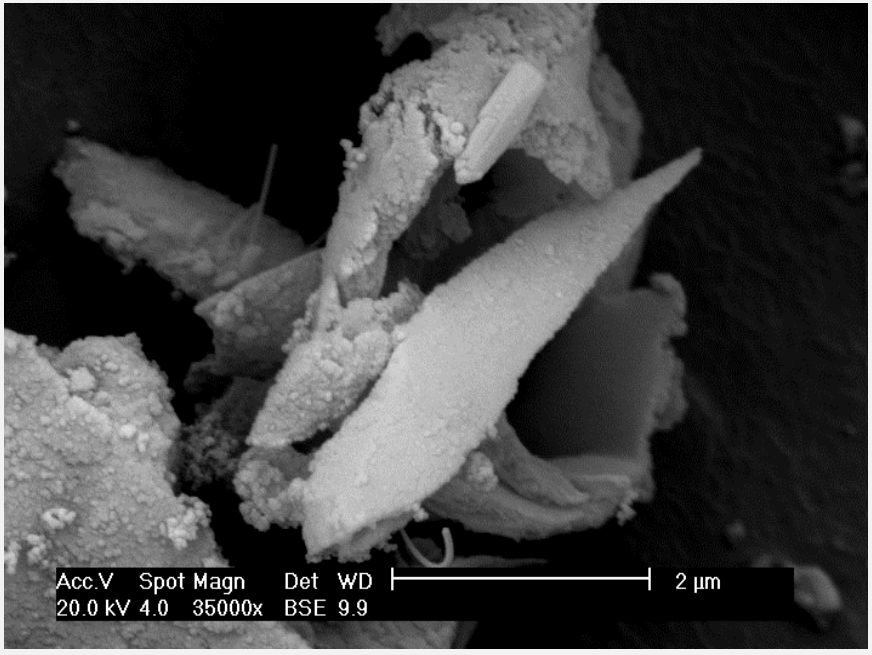


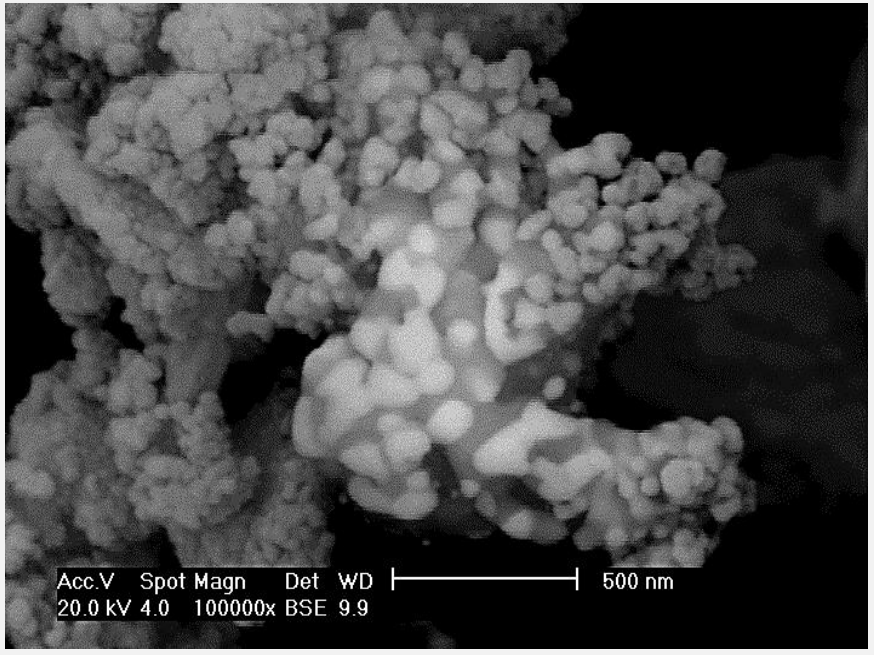
Element	Wt%
C	11.06
O	15.12
Mg	1.41
Al	0.53
Si	2.31
S	4.34
Cl	0.76
K	0.39
Ca	2.14
Fe	42.11
Zn	0.99
Sb	0.28
Ba	18.56
Total:	100.00



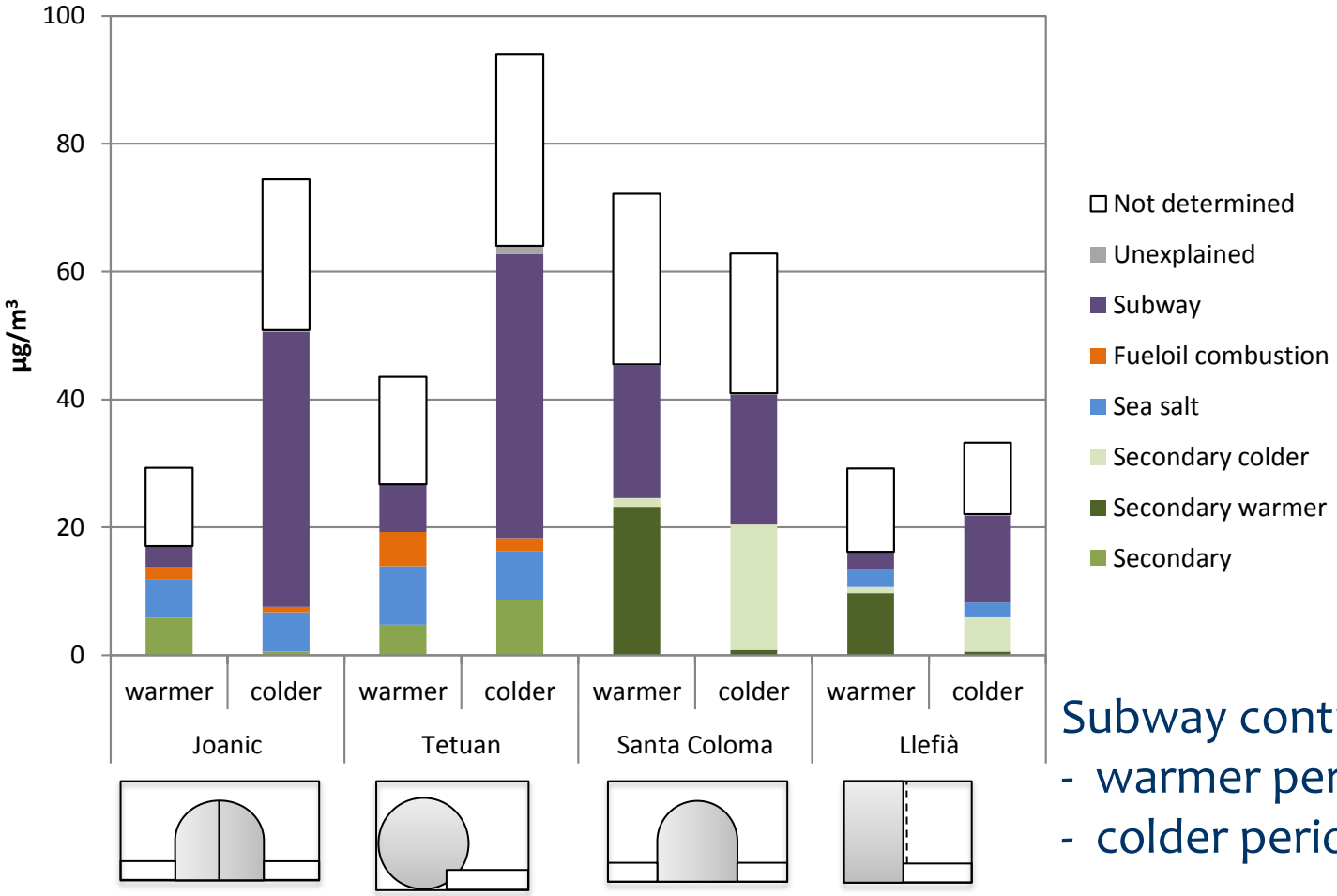

Acc.V Spot Magn Det WD 2 µm
10.0 kV 4.0 25000x SE 10.2


Acc.V Spot Magn Det WD 5 µm
20.0 kV 4.0 12000x BSE 9.7


Acc.V Spot Magn Det WD 2 µm
20.0 kV 4.0 35000x BSE 9.9


Acc.V Spot Magn Det WD 500 nm
20.0 kV 4.0 100000x BSE 9.9

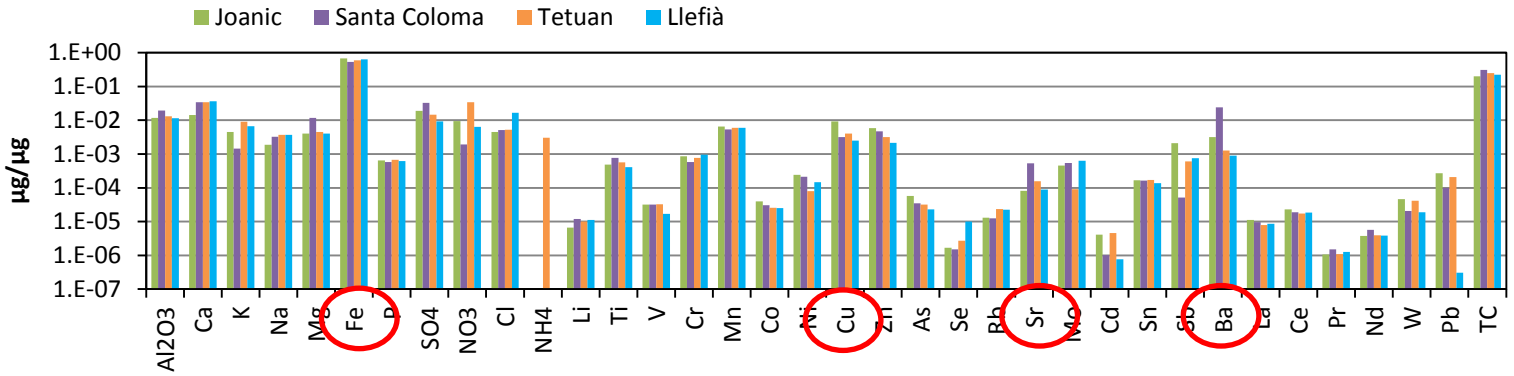
SOURCE APPORTIONMENT



Subway contribution:

- warmer period: 9 to 17% of $PM_{2.5}$
- colder period: 32 to 58% of $PM_{2.5}$

SOURCE APPORTIONMENT



- Fe dominates the composition of this source at all stations (53%-68%)

- Cu/Fe ratio varies from 0.004 – 0.007 in Llefià, Santa Coloma, and Tetuan to 0.013 in Joanic
  - ➢ Catenary- pantographs emissions

- Ba/Sr ratio varies from 8 – 10 in Tetuan and Llefià to 39 – 45 in Joanic and Santa Coloma
  - ➢ Brakes composition

CONCLUSIONS

- ✓ Station design: single/double track, access points, depth, ventilation systems, platform door systems
- ✓ Train frequency and piston effect
- ✓ Passenger numbers
- ✓ Train design: braking systems, wheels, air conditioning, etc.
- ✓ Contamination by outside city air
- ✓ Ferruginous environment influenced by brake pad chemistry

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