

WHAT ARE WE BREATHING IN RAIL SUBWAY SYSTEMS, AND WHY?

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Implementing Methodologies and Practices to Reduce air pollution Of 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.



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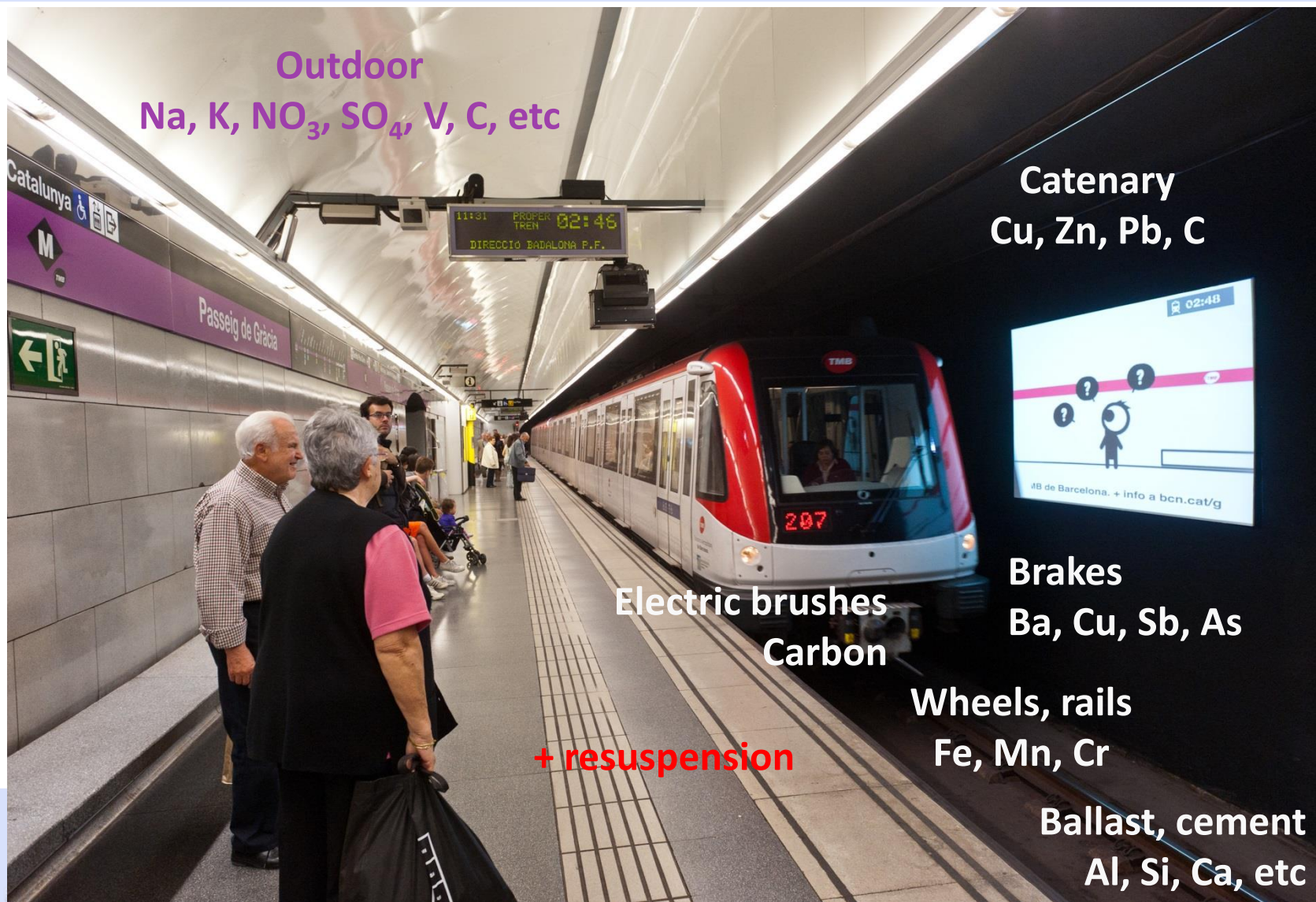
● On platforms	PM10 ($\mu\text{g}/\text{m}^3$)	PM2.5 ($\mu\text{g}/\text{m}^3$)	
Barcelona	87-325	13-186	<i>Querol et al. 2012; Moreno et al. 2014; Martins et al. 2015</i>
Budapest	155	51	<i>Salma et al. 2007</i>
London	1000-1500	270-480	<i>Seaton et al. 2005</i>
Los Angeles	78	57	<i>Kam et al. 2011</i>
Paris	200	61	<i>Raut et al. 2009</i>
Prague	215	94	<i>Cusack et al. 2015</i>
New York		68	<i>Wang and Gao 2011</i>
Seoul	359	129	<i>Kim et al. 2008</i>
Stockholm	357	199	<i>Johansson & Johansson 2003</i>
Taipei	51	35	<i>Cheng et al. 2008</i>
● Inside train	PM10	PM2.5	
Barcelona	36-100	11-75	<i>Querol et al. 2012; Martins et al. 2015</i>
Los Angeles	31	24	<i>Kam et al. 2011</i>
New York		40	<i>Wang and Gao 2011</i>
Taipei	41	32	<i>Cheng et al. 2008</i>



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PM SOURCES IN UNDERGROUND SYSTEMS



Outdoor
Na, K, NO₃, SO₄, V, C, etc

Catenary
Cu, Zn, Pb, C

Electric brushes
Carbon

Brakes
Ba, Cu, Sb, As

Wheels, rails
Fe, Mn, Cr

Ballast, cement
Al, Si, Ca, etc

+ resuspension



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BCN Metro



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

Open platform system



Closed platform system





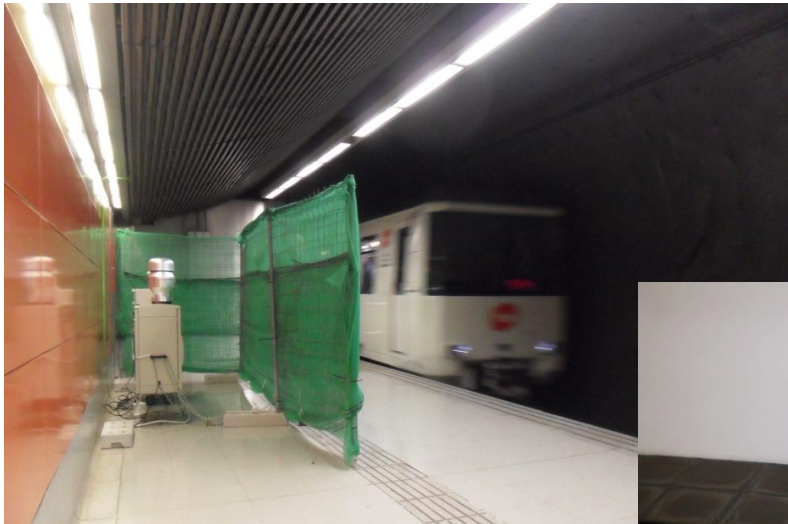
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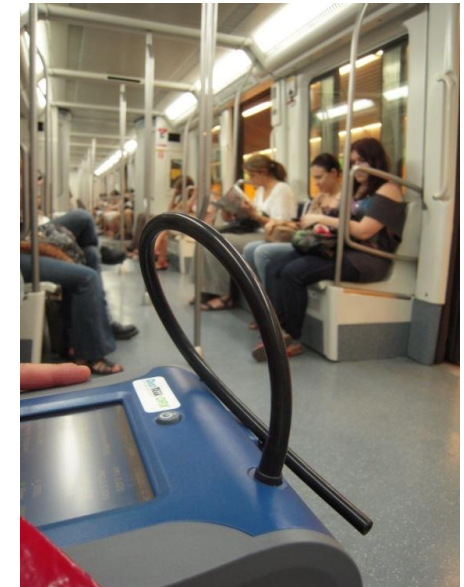
BARCELONA METRO AIR QUALITY PROJECT (2013-2015)

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)**



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METHODOLOGY AND WORK PLAN





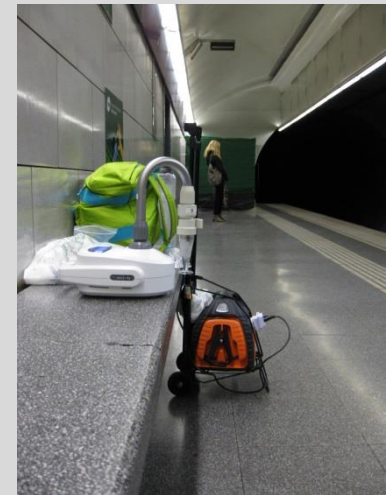
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METHODOLOGY AND WORK PLAN



- **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

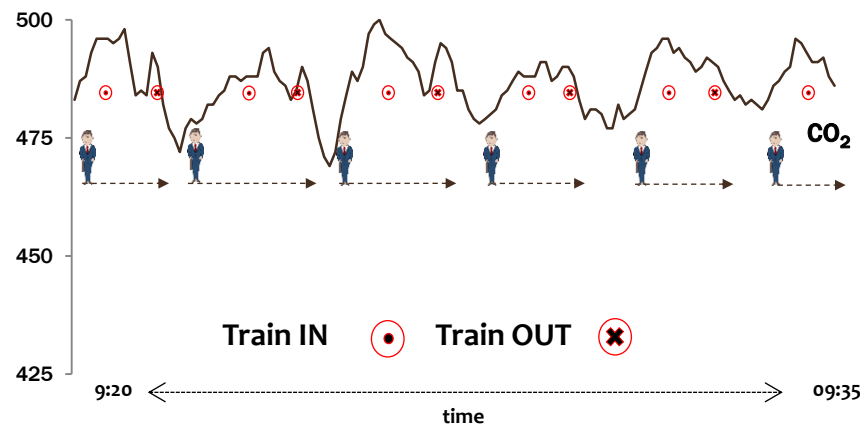
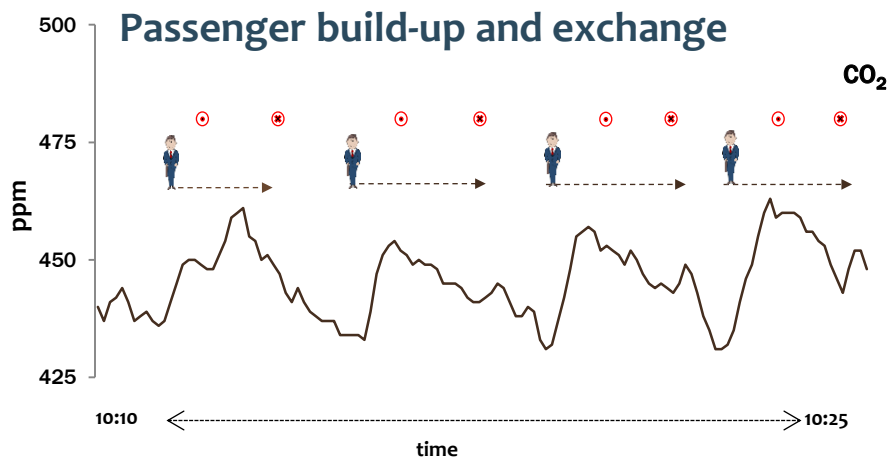
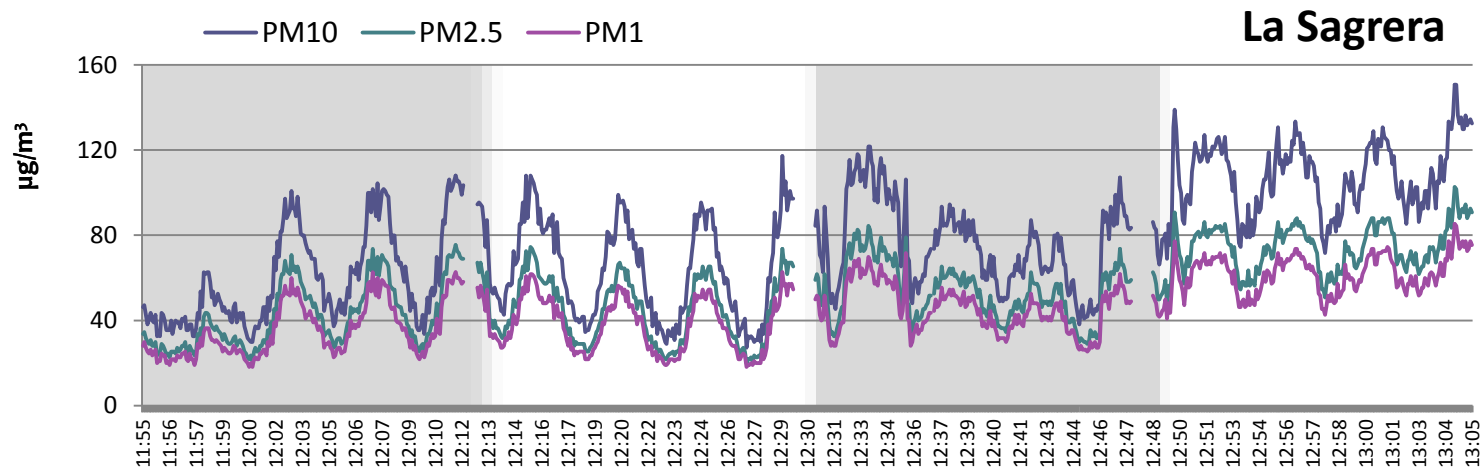
**CO, CO₂, T, HR
(levels) - 5 min**



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VARIABLES: TRAIN FREQUENCY & PASSENGER NUMBERS

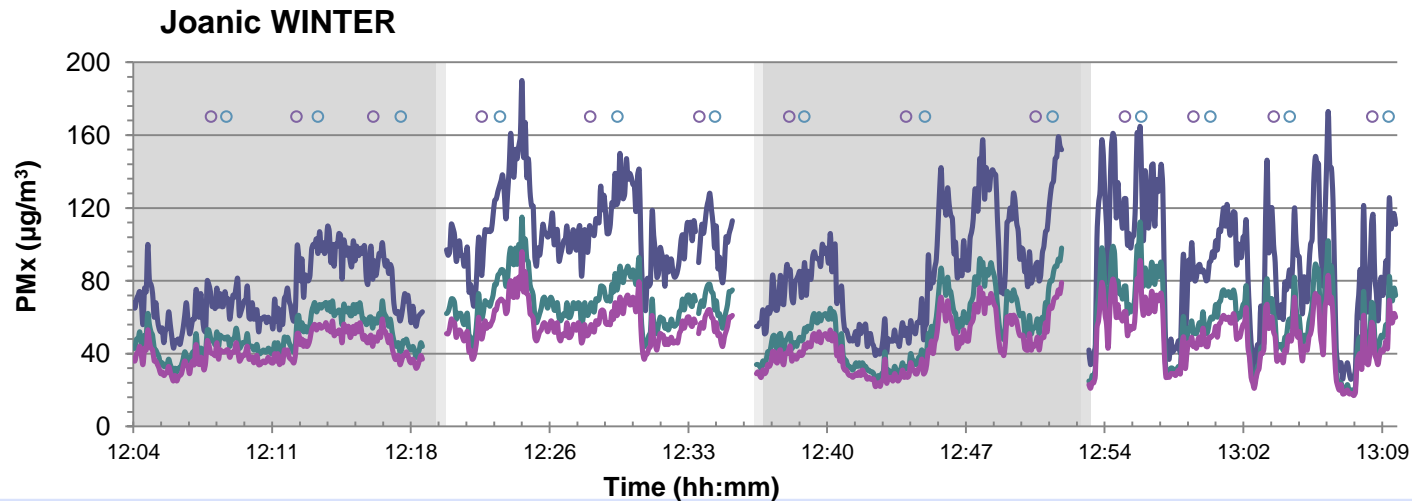
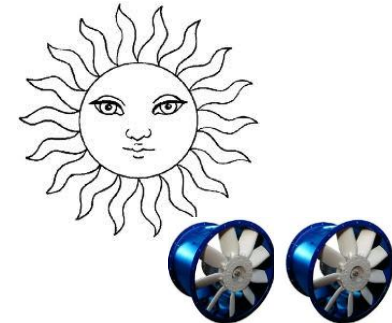
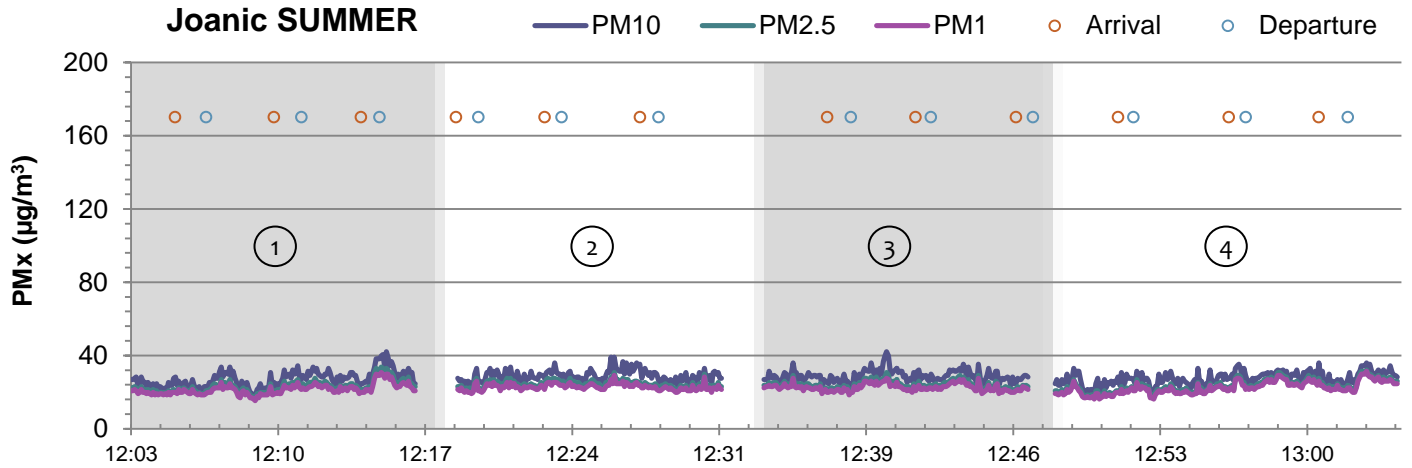




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VARIABLES: PLATFORM VENTILATION



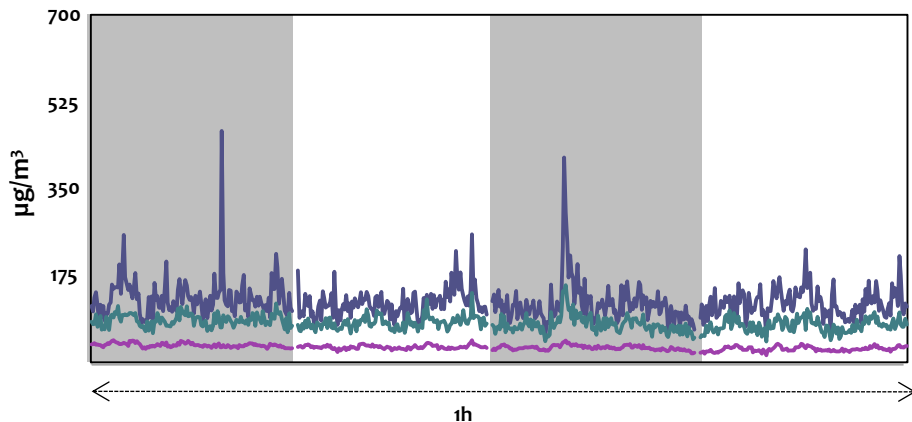


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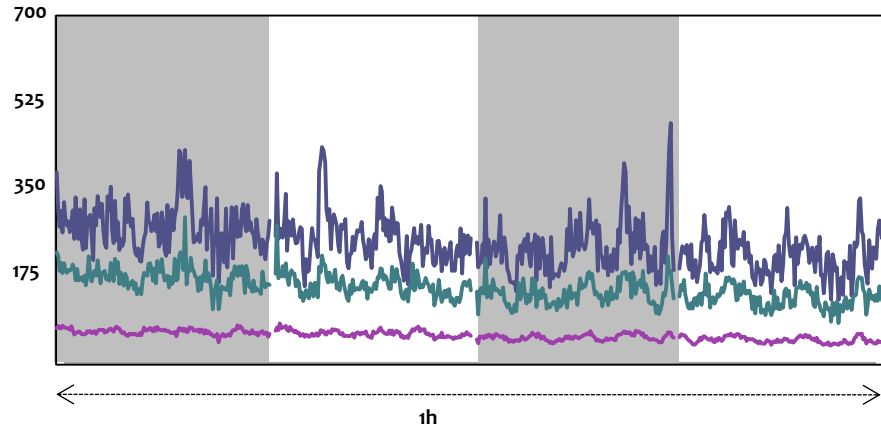


VARIABLES: TUNNEL AND TRAIN VENTILATION

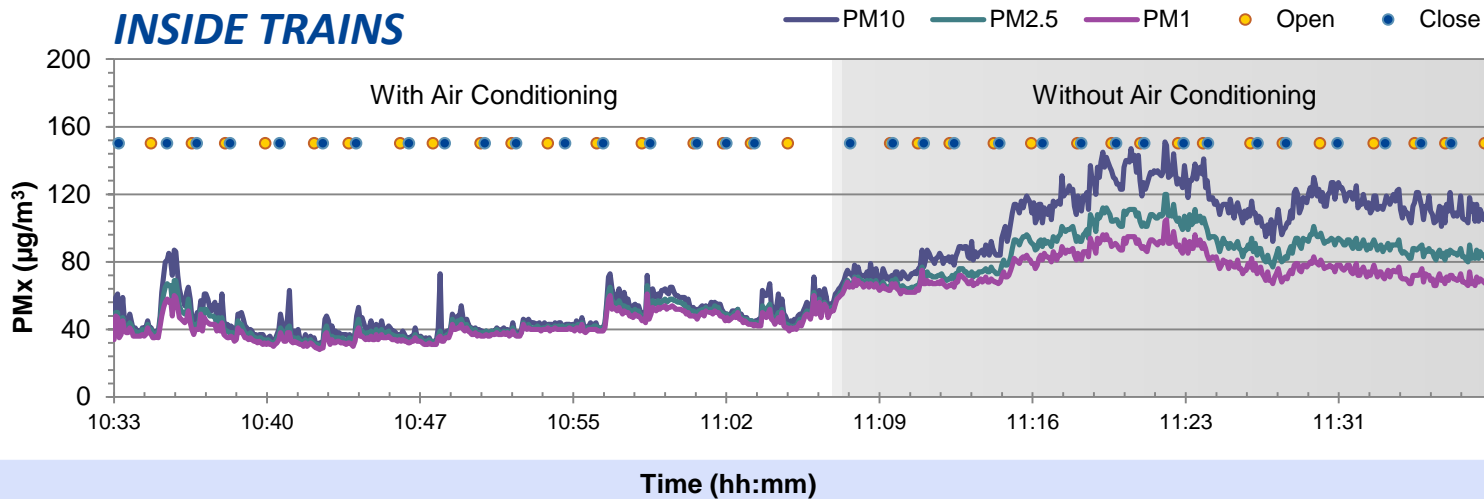
WITH FORCED TUNNEL VENTILATION



WITHOUT FORCED TUNNEL VENTILATION



INSIDE TRAINS

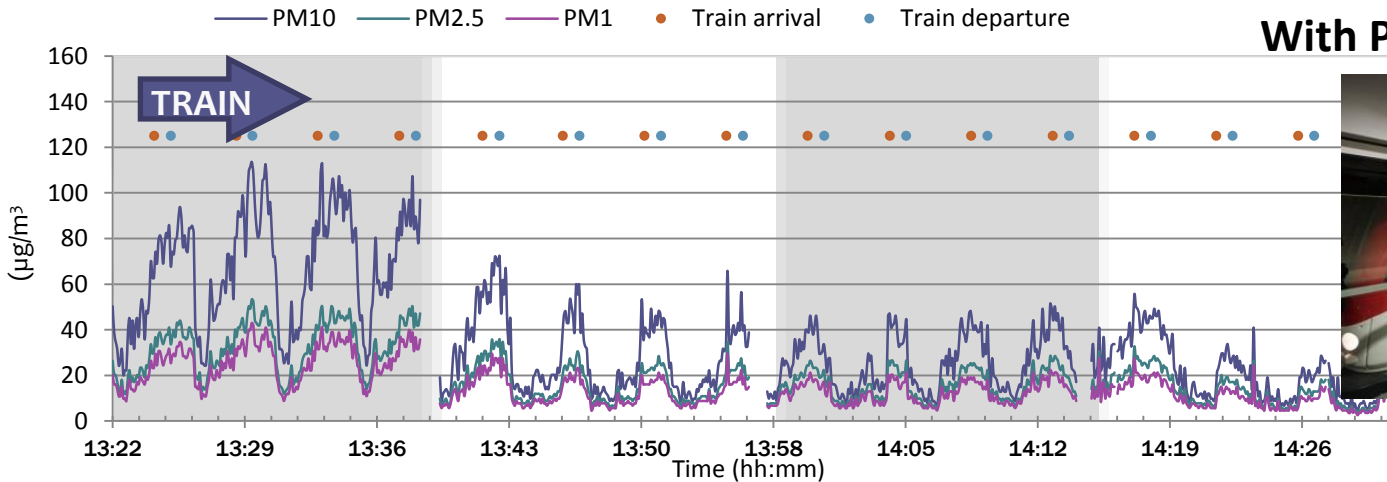
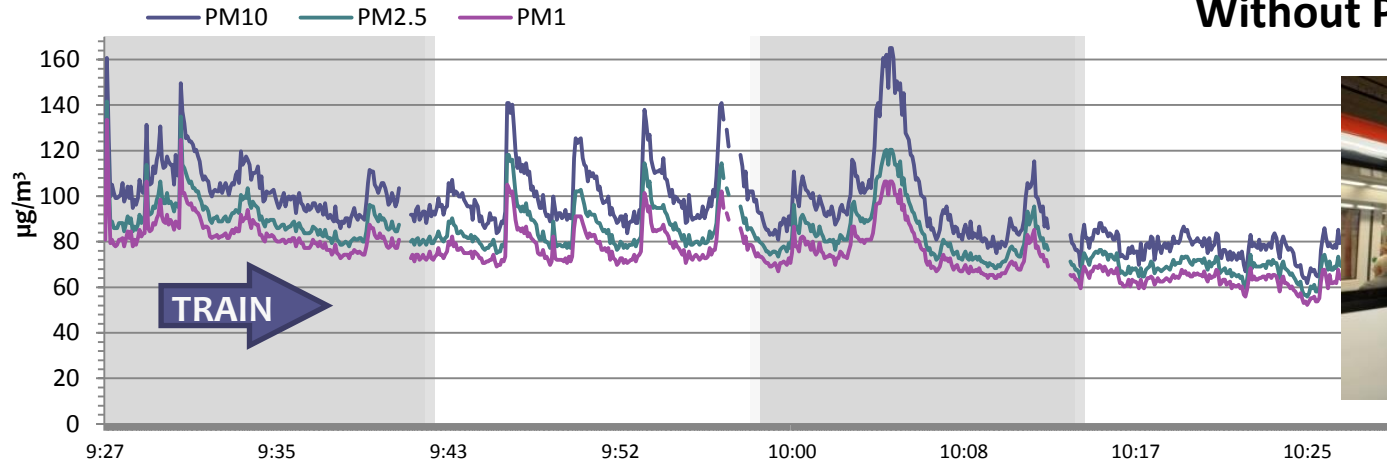




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VARIABLES: STATION DESIGN AND PISTON EFFECT

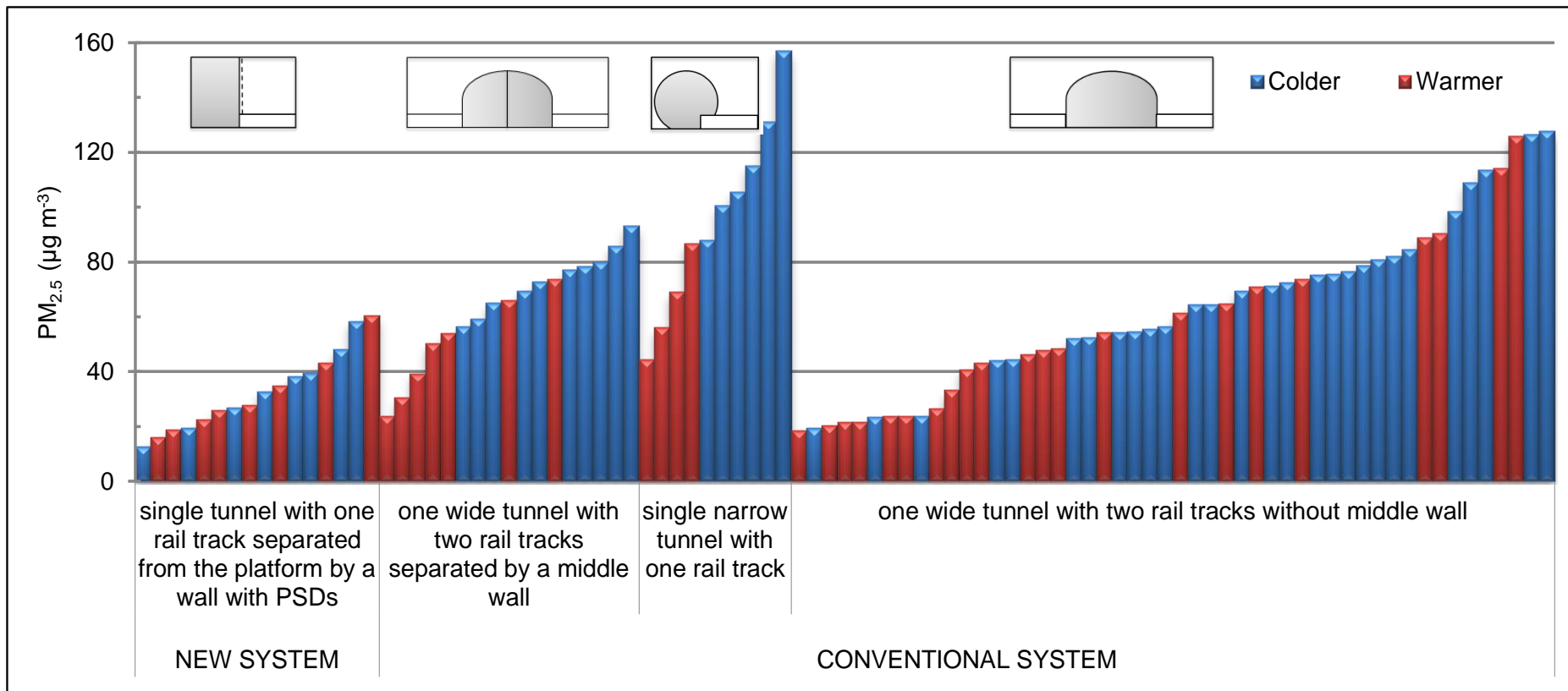




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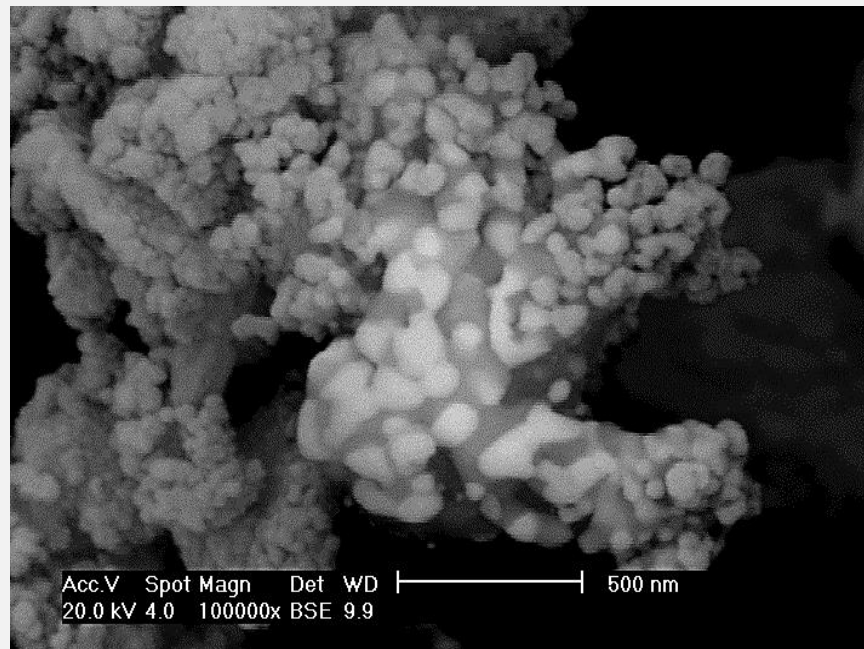
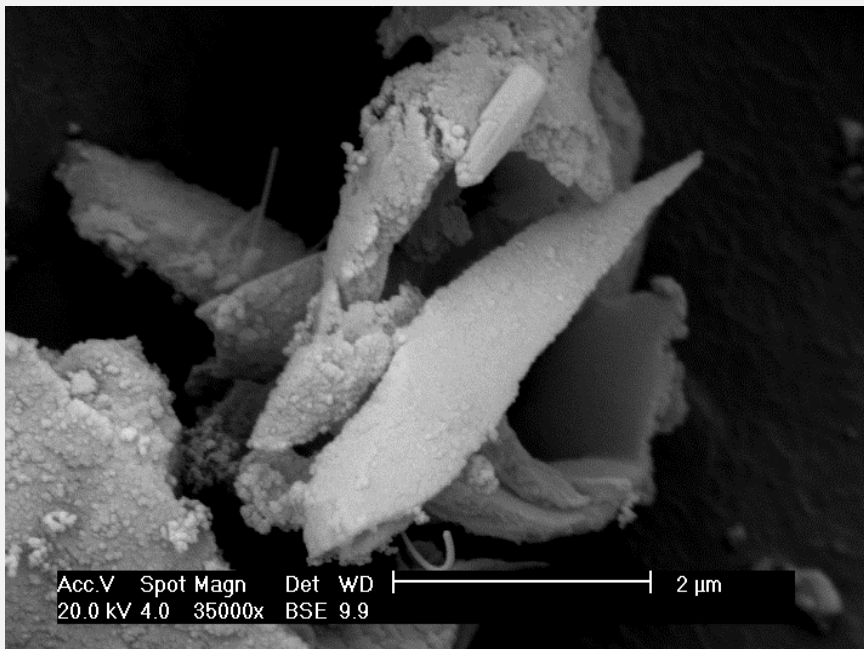
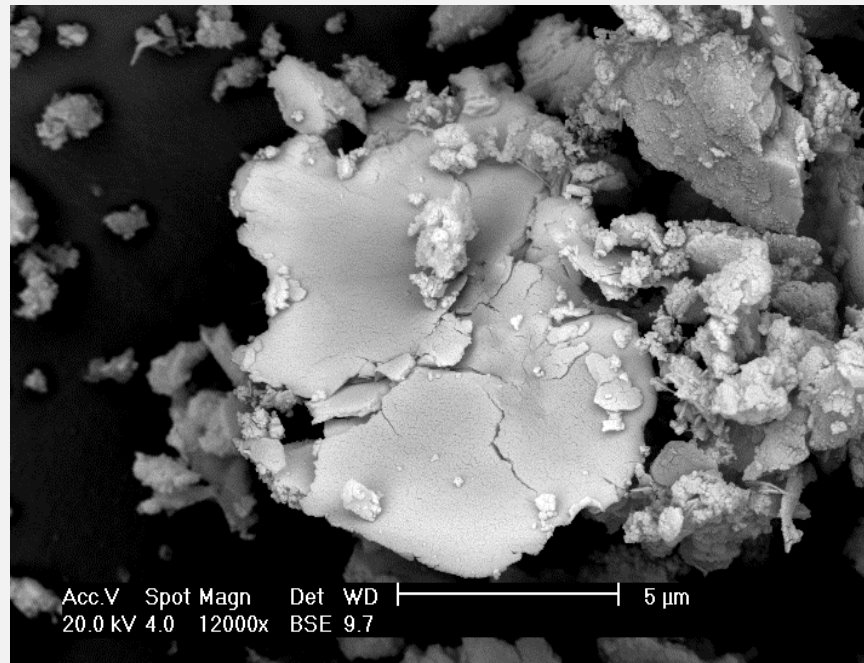
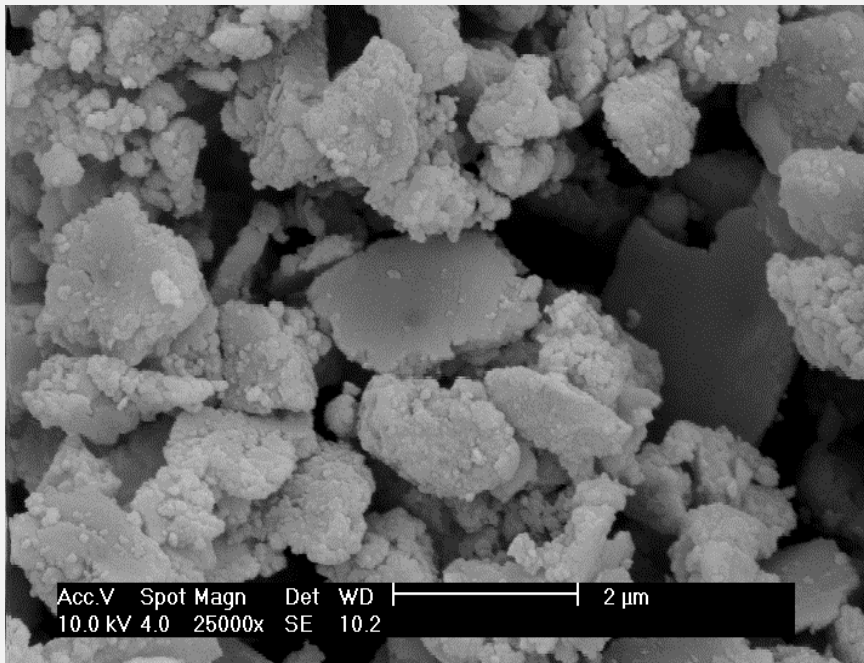


VARIABLES CONTROLLING PLATFORM AIR QUALITY



PM sources in underground systems





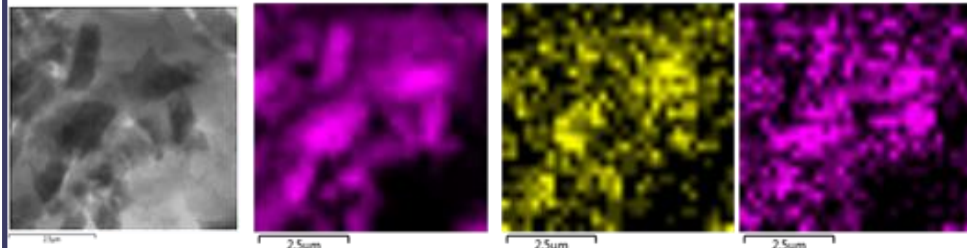


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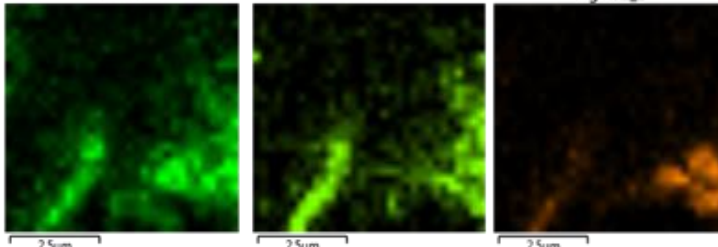


RAIL/WHEEL

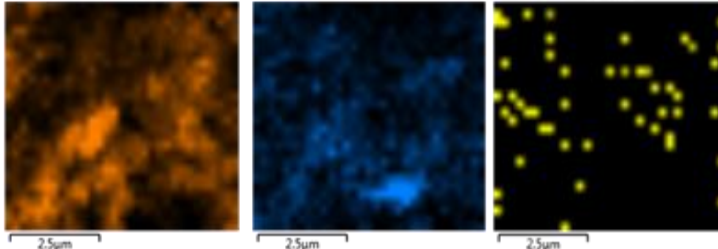
Fe Ka1 Cr Ka1 Mn Ka1



Si Ka1 Al Ka1 Mg Ka1_2



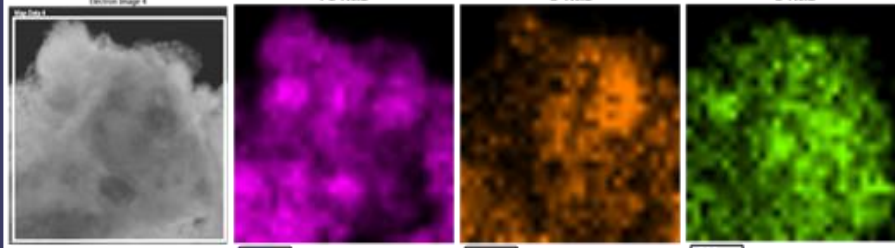
O Ka1 Ca Ka1 Sb Ka1



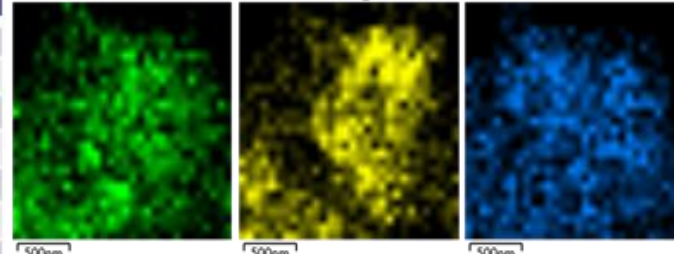
Element	Wt%
C	1.96
O	22.23
Na	0.86
Mg	0.92
Al	0.93
Si	2.54
S	0.56
Cl	0.59
K	0.86
Ca	2.35
Cr	0.35
Mn	0.65
Fe	64.69
Zn	0.05
As	0.08
Sb	0.39
Total:	100.00

BRAKE PADS

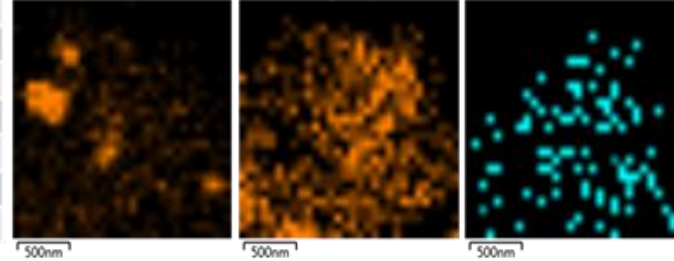
Fe Ka1 O Ka1 S Ka1



Si Ka1 C Ka1_2 Ca Ka1



Zn Ka1 Mg Ka1_2 Ba Ka1



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



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IMPROVE OBJECTIVES (20014-2018)

1. To determine the emission sources and **their contribution** to air quality in platforms and trains,
2. To develop and propose to local/national authorities effective air mitigation measures for subway systems



Testing and Development of mitigation strategies:

- ✓ Tunnel activities,
- ✓ Practicability/effect of applying dry suppressant compounds to ballast,
- ✓ Mitigation strategies for emissions from specific rail sources (brake pads, rails & electrical catenaries).





CONCLUSIONS

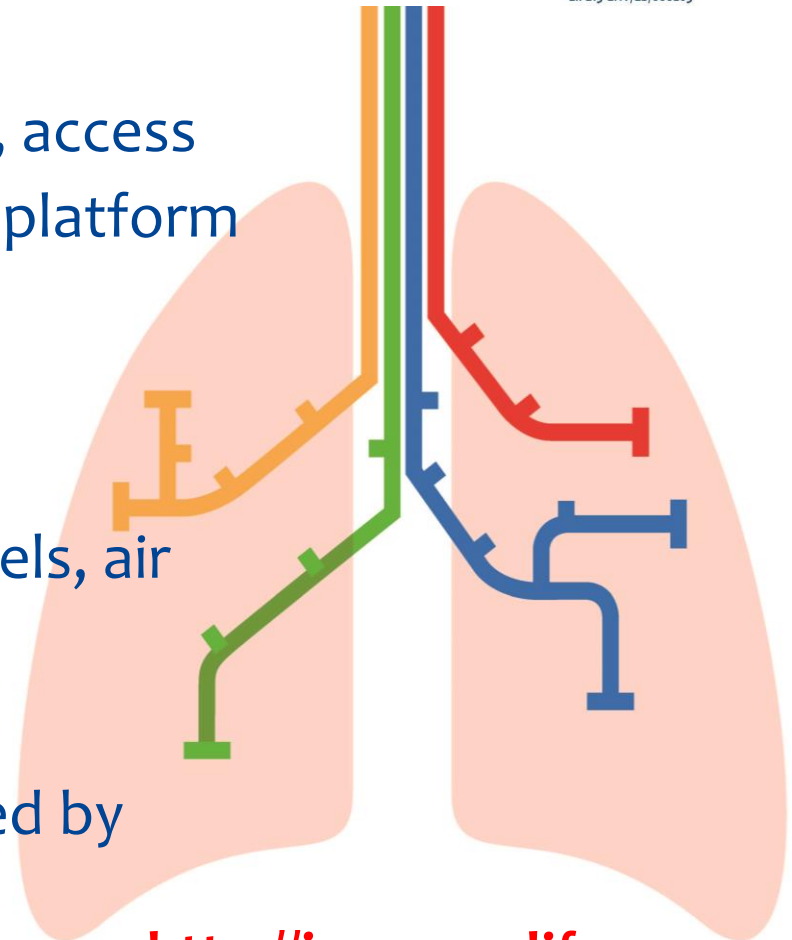
- ✓ Station design: single/double track, access points, depth, ventilation systems, platform door systems
- ✓ Train frequency and piston effect
- ✓ Passenger numbers
- ✓ Train design: braking systems, wheels, air conditioning, etc.
- ✓ Contamination by outside city air
- ✓ Ferruginous environment influenced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



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SUBWAY PM CHEMISTRY

Subway/Barcelona outdoor

