CHOICES IN COMMUTER EXPOSURE TO INHALABLE PARTICULATES

Teresa Moreno

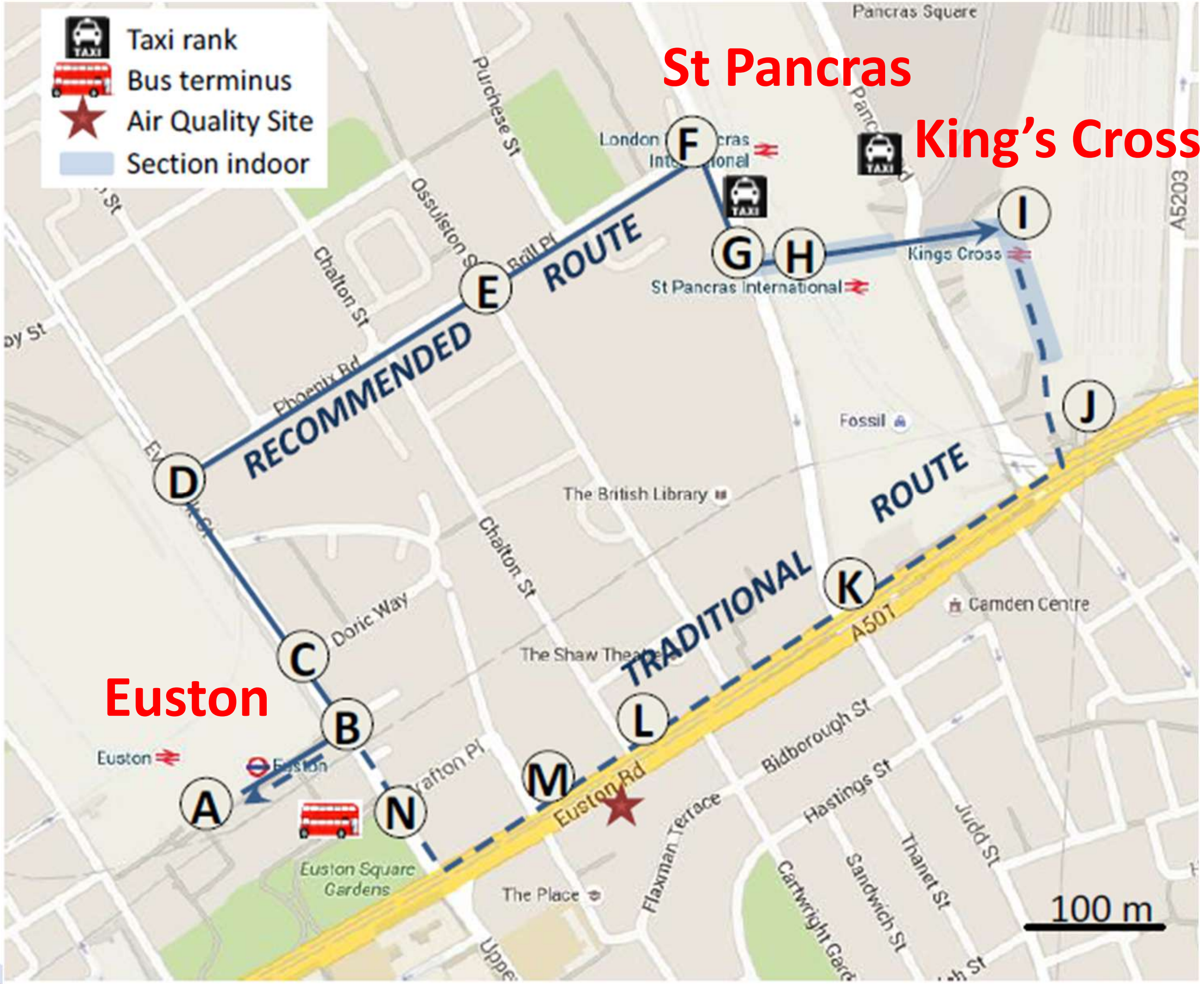
How much of your life do you spend commuting?

If your one-way commute takes around half an hour, then in one year you will spend around ten days respiring in your chosen commuting environment ..that is, around one year of your working lifetime.

The exposure is not trivial.

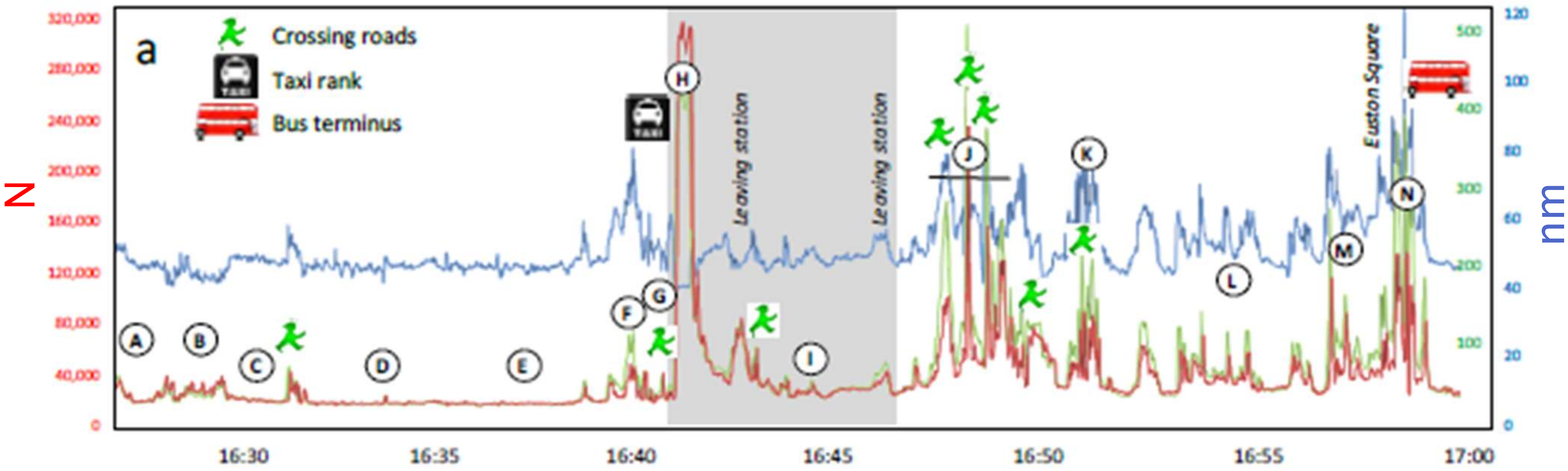
In terms of air quality and personal exposure our commuting choices matter

A simple example: The Euston-St Pancras-Kings Cross "Wellbeing Walk"



URBAN PARTNERS FOR KINGS CROSS EUSTON & ST PANCRAS

15 minutes one way (5 days/year)



Euston St Panc/Kings X Euston

N= 6 trips	Wellbeing backstreet walking route Average	SD	Median	Euston Road "traditional" route Average	SD	Median
N (pt/cm^3)	26301	3693	24003	42021	7702	43842
Mode (nm)	34	4	31	41	7	40
LDSA ($\mu m^2/cm^3$)	47	13	43	90	13	90

- Exposure of pedestrians to UFP is greatly reduced by choosing the Wellbeing Walk.
- Most UFP lie within the size range 25-50nm from vehicle exhaust emissions.
- N concentrations at road crossings are punctuated by extreme transient peaks <20nm.
- City initiatives such as Wellbeing Walk are to be encouraged.

Public awareness about commuter choice and air quality is enhanced by such initiatives

URBAN PARTNERS FOR KINGS CROSS EUSTON & ST PANCRAS

THE BARCELONA COMMUTING AIR QUALITY EXPERIMENT

A comparison of commuting routes by bus, subway, tram and walking

IDAEA-CSIC

CITY CENTRE

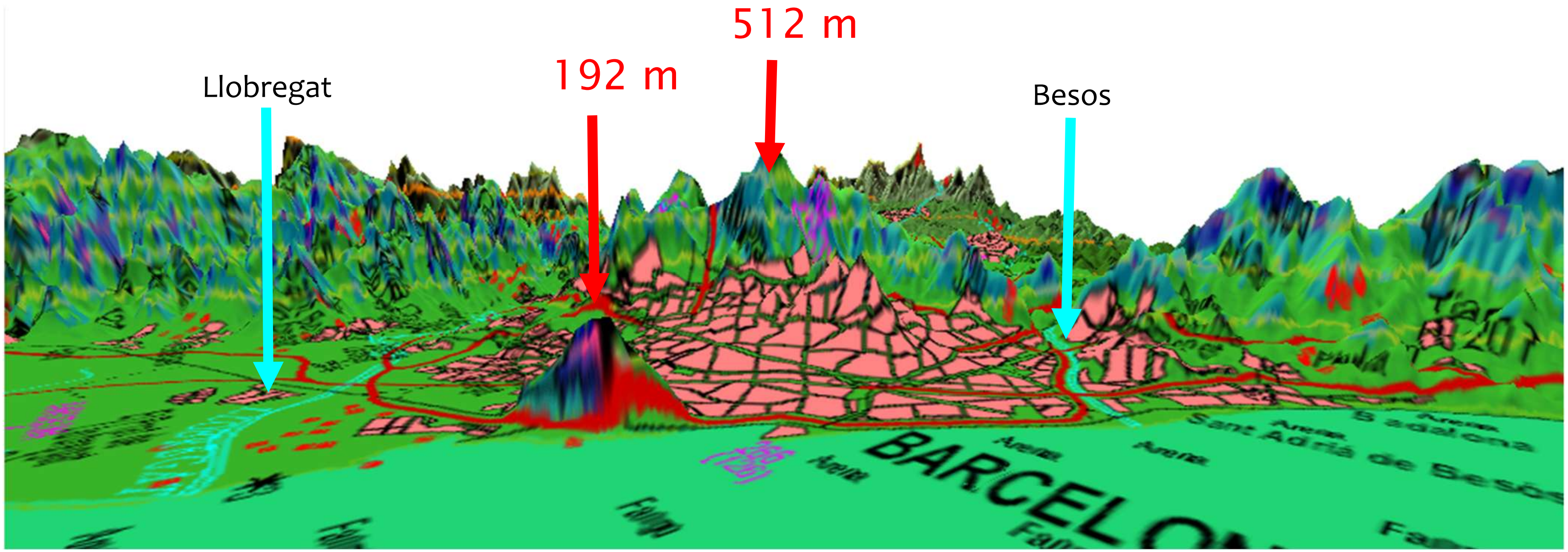
Moreno et al 2015, Environmental Research 142, 495–510

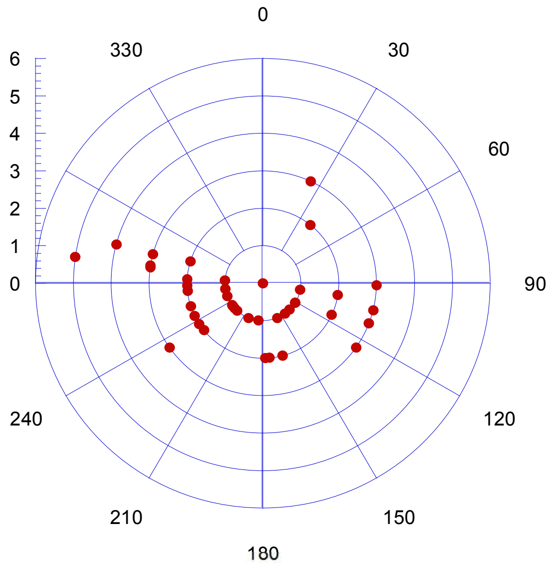
- We measured urban air quality experienced during travel on different forms of public transport and walking in the city.

- The study continuously tracks and compares not only PM mass and particle number during each journey, but also Black Carbon, Carbon Monoxide, Carbon Dioxide and chemical composition of the finer material inhaled ($PM_{2.5}$).

- We used continuously measuring portable equipments carried by two commuters making journeys through the city, with the same start and end point, and at the same time but using different transport modes (bus, subway, tram and walking).

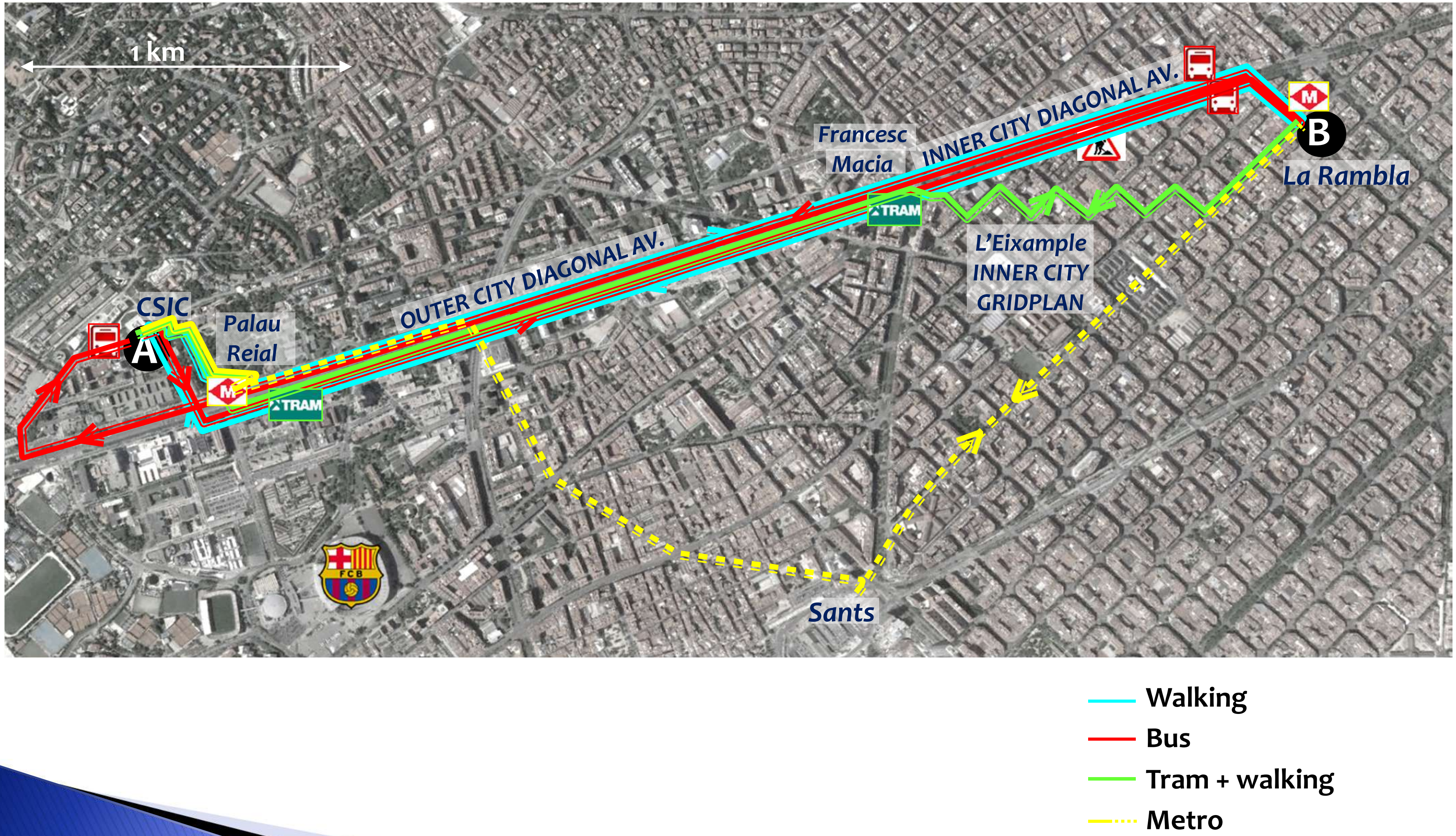
- The commuter pairs began their journey together but took different routes through the city. The commute chosen was 8.4 to 9 km long from the suburban area of the *IDAEA-CSIC Institute* to the metro stop on *Rambla de Catalunya* in the city centre.





October	T (°C)	Humidity (%)	Wind velocity (m/s)	Rain (mm)	Press. (hPa)
Average	23.9	64	1.8	0.0	1006
Max	26.8	80	3.3	0.0	1015
Min	19.9	31	0.5	0.0	998

November	T (°C)	Humidity (%)	Wind velocity (m/s)	Rain (mm)	Press. (hPa)
Average	17.6	71	2.1	0.6	1000
Max	21.5	96	5.2	12.6	1011
Min	13.7	49	0.5	0.0	985

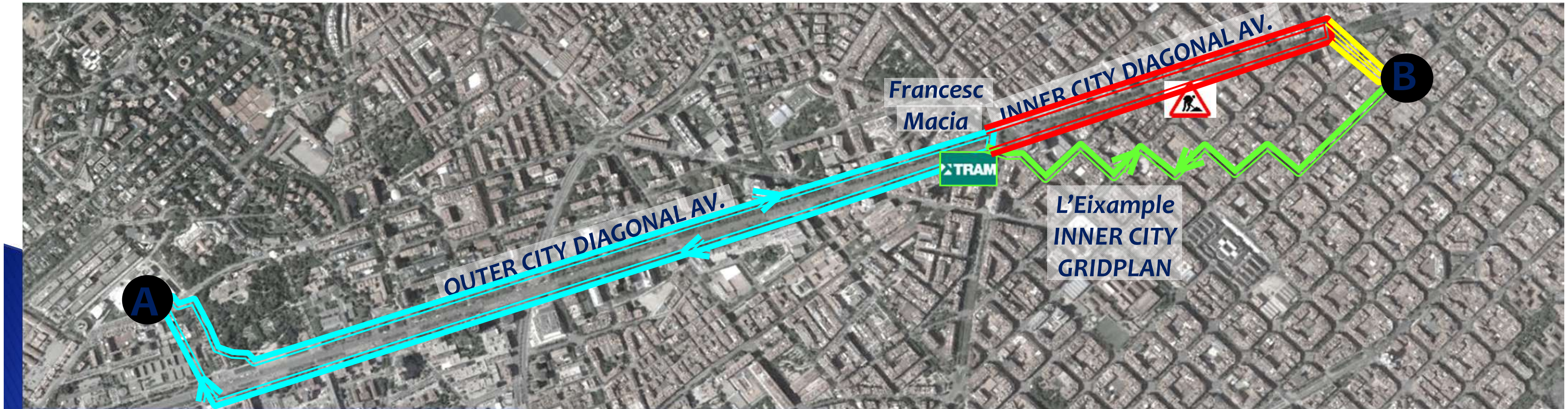

1 km
INNER CITY DIAGONAL AV.
Francesc
Macia
B
La Rambla
TRAM
L'Eixample
INNER CITY
GRIDPLAN
OUTER CITY DIAGONAL AV.
CSIC
Palau
Reial
A
M
TRAM
Sants
Walking
Bus
Tram + walking
Metro

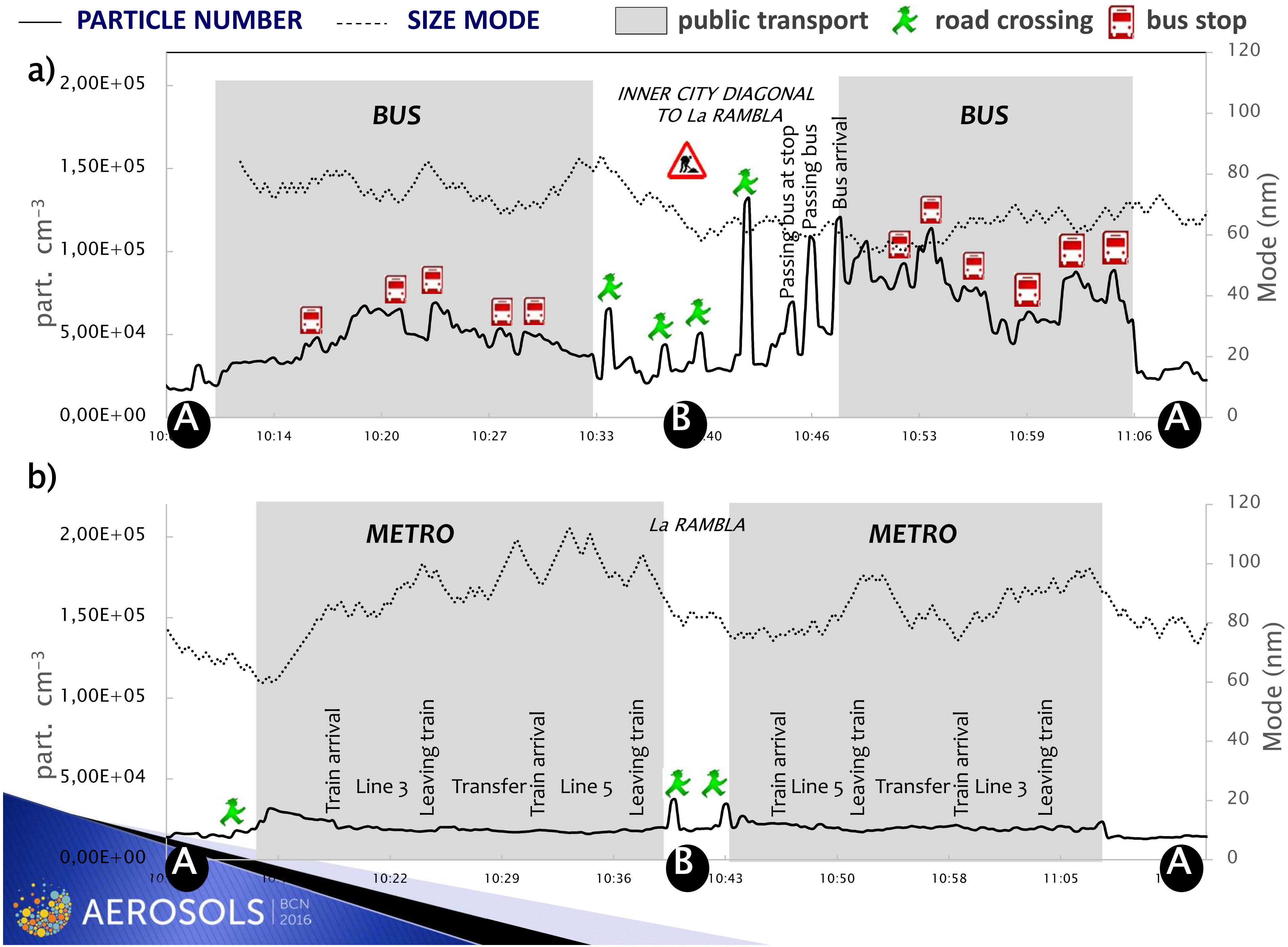

5. $PM_{2,5}$ sampler chemistry
SKC
10.00
L/min
1. PM concentrations
3. Black carbon
4. CO, CO_2, Temp, RH.
2. Nanoparticles number
7471
53
6. GPS
LOGGER
GPS

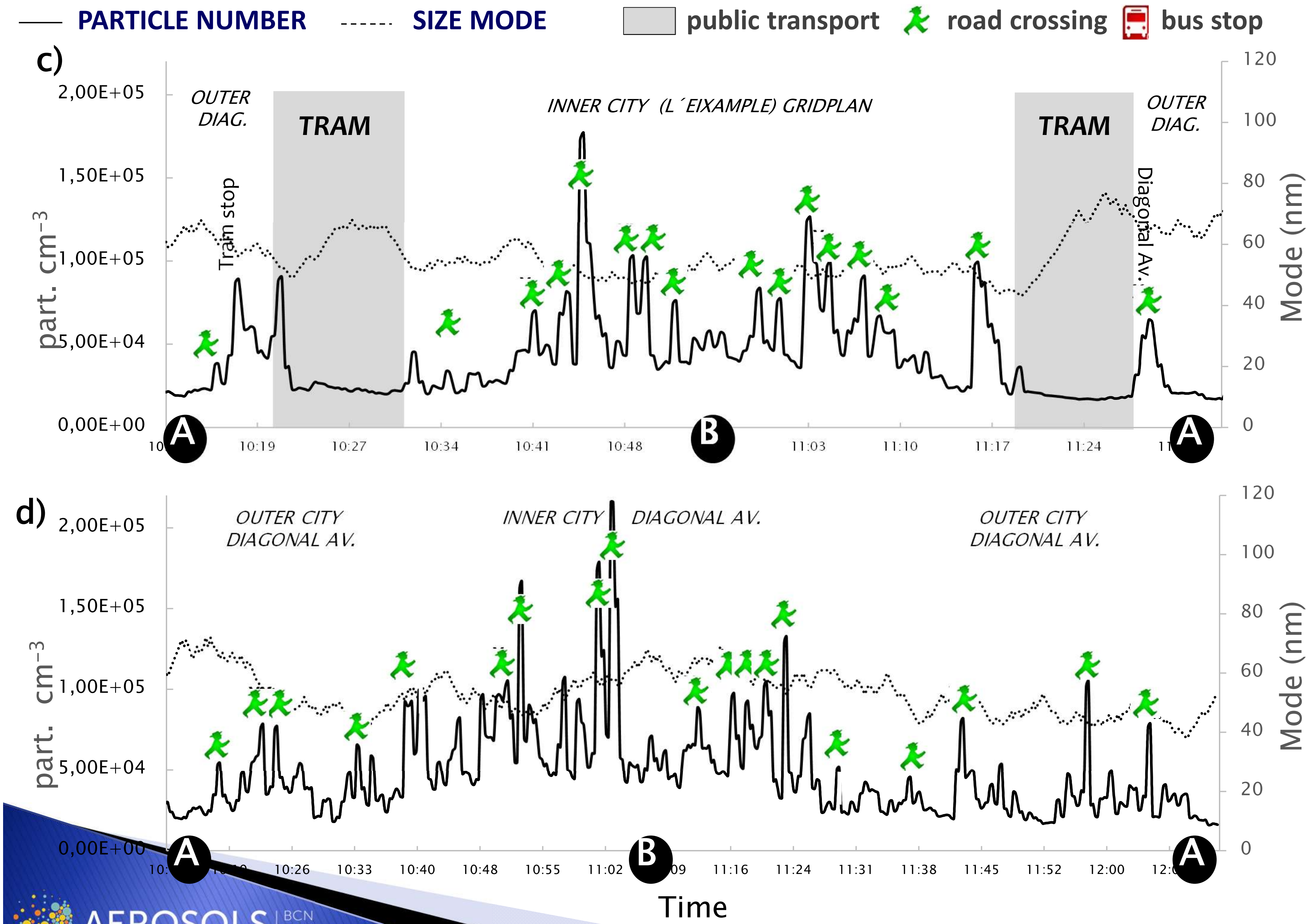
VALUES FOR EACH TYPE OF TRANSPORT

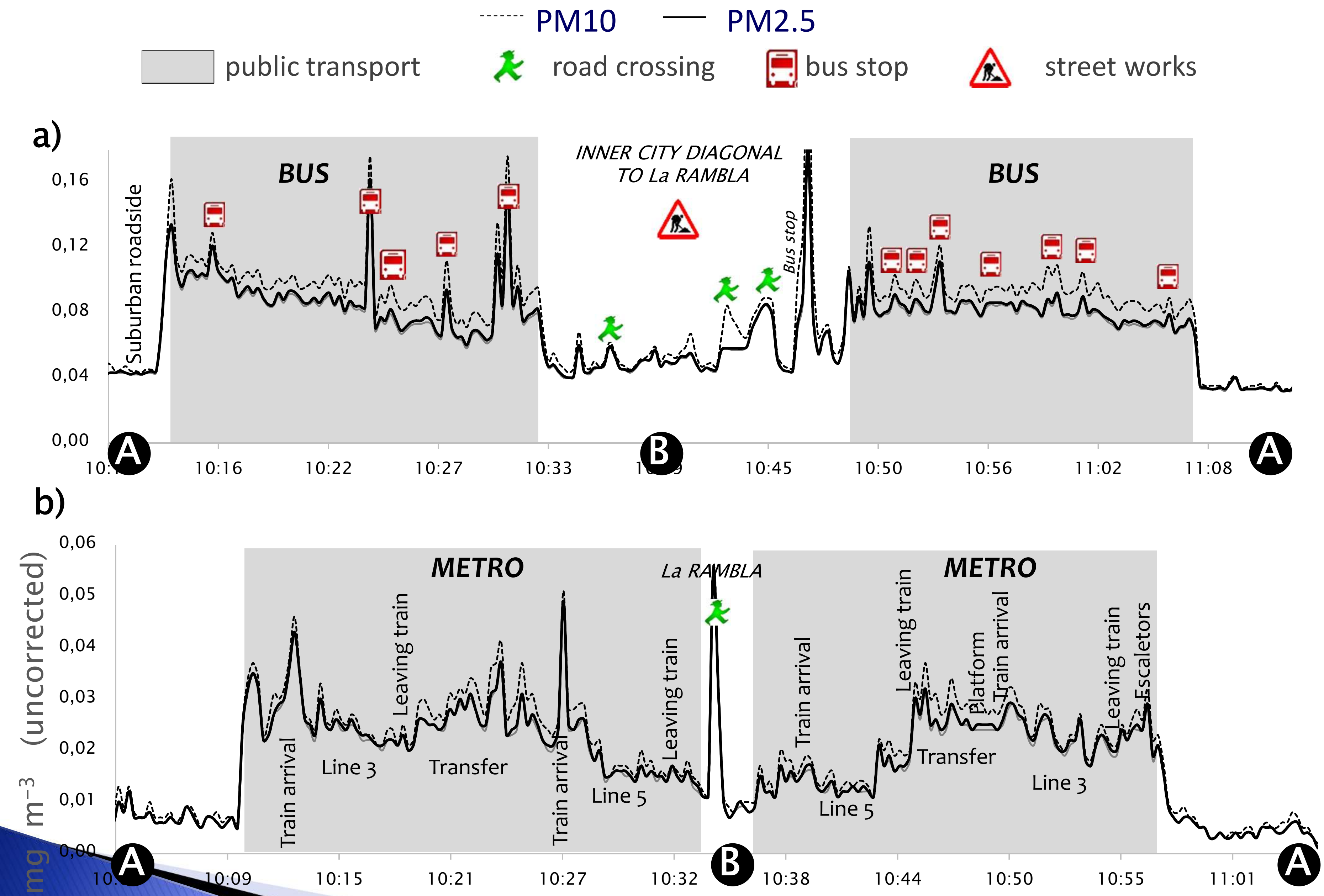
	METRO			TRAM			BUS		
	Mean	St. dev	Median	Mean	St. dev	Median	Mean	St. dev	Median
N (part. cm^{-3})	2.3×10^4	0.4×10^4	2.1×10^4	3×10^4	1×10^4	2.8×10^4	**5.4×10^4**	1.6×10^4	4.6×10^4

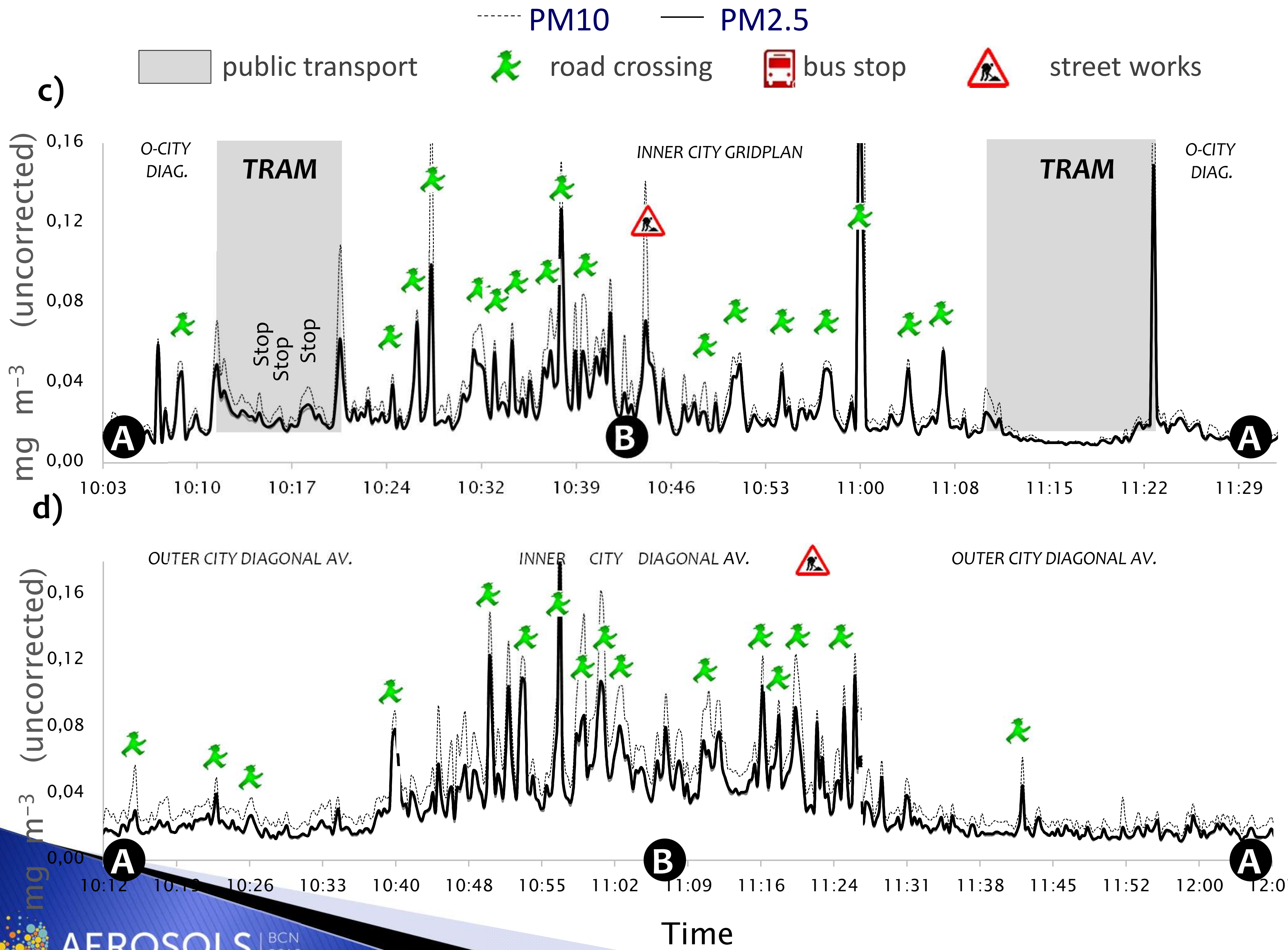
	WALKING											
	OUTER DIAGONAL			INNER DIAGONAL			CENTRAL GRIDPLAN			DIAGONAL TO LA RAMBLA		
	Mean	St. dev	Median	Mean	St. dev	Median	Mean	St. dev	Median	Mean	St. dev	Median
N	3.7×10^4	0.6×10^4	3×10^4	**5.9×10^4**	1.3×10^4	4.8×10^4	**5.4×10^4**	1.8×10^4	4.4×10^4	**5.4×10^4**	2×10^4	4.2×10^4

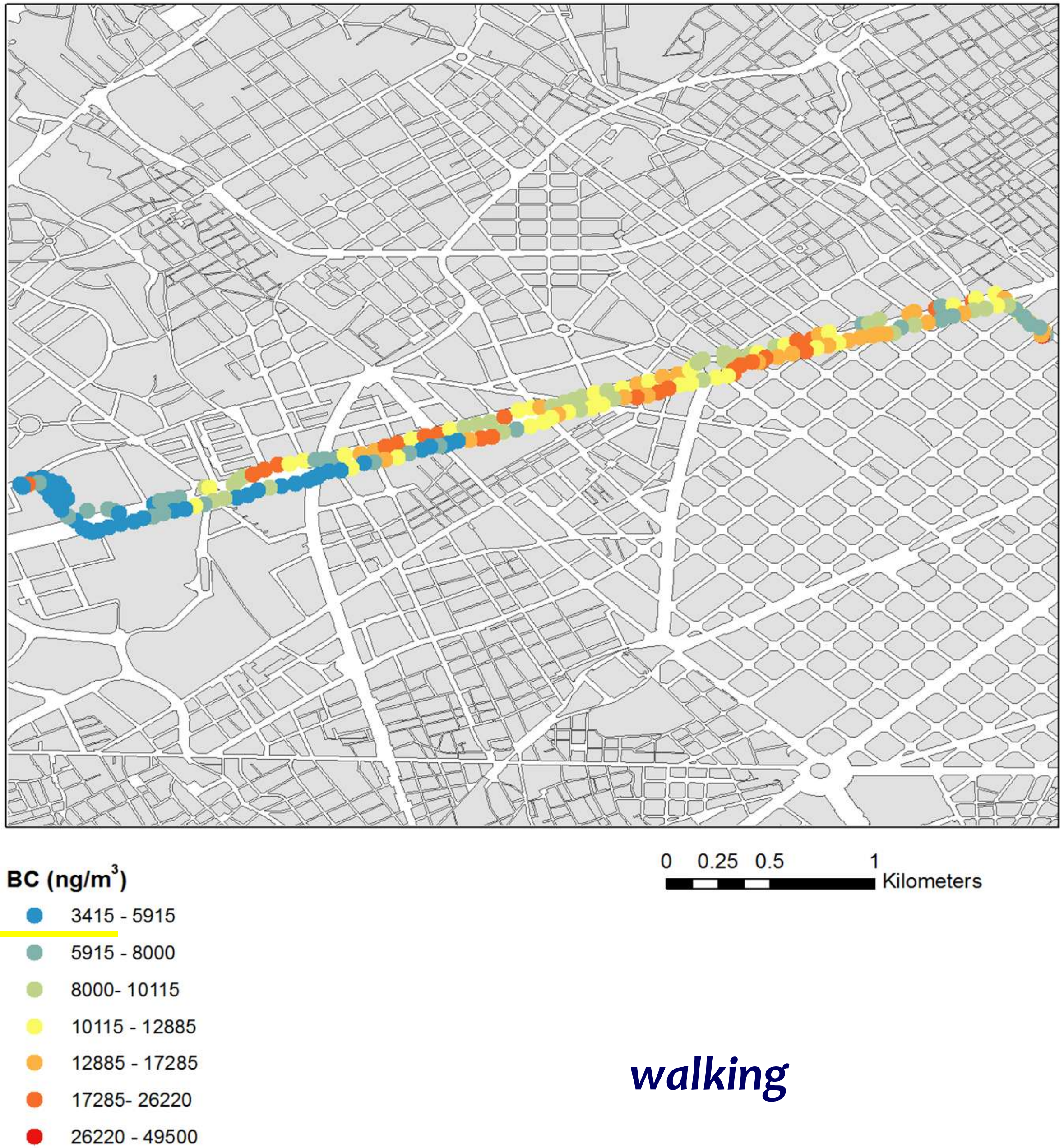



PARTICLE NUMBER
SIZE MODE
public transport
road crossing
bus stop
a)
part. cm-3
Mode (nm)
BUS
INNER CITY DIAGONAL
TO La RAMBLA
Passing bus at stop
Passing bus
Bus arrival
BUS
10:14
10:20
10:27
10:33
10:46
10:53
10:59
11:06
A
B
A
b)
METRO
La RAMBLA
METRO
Train arrival
Line 3
Leaving train
Transfer
Train arrival
Line 5
Leaving train
Train arrival
Line 5
Leaving train
Transfer
Train arrival
Line 3
Leaving train
10:22
10:29
10:36
10:43
10:50
10:58
11:05
AEROSOLS BCN 2016

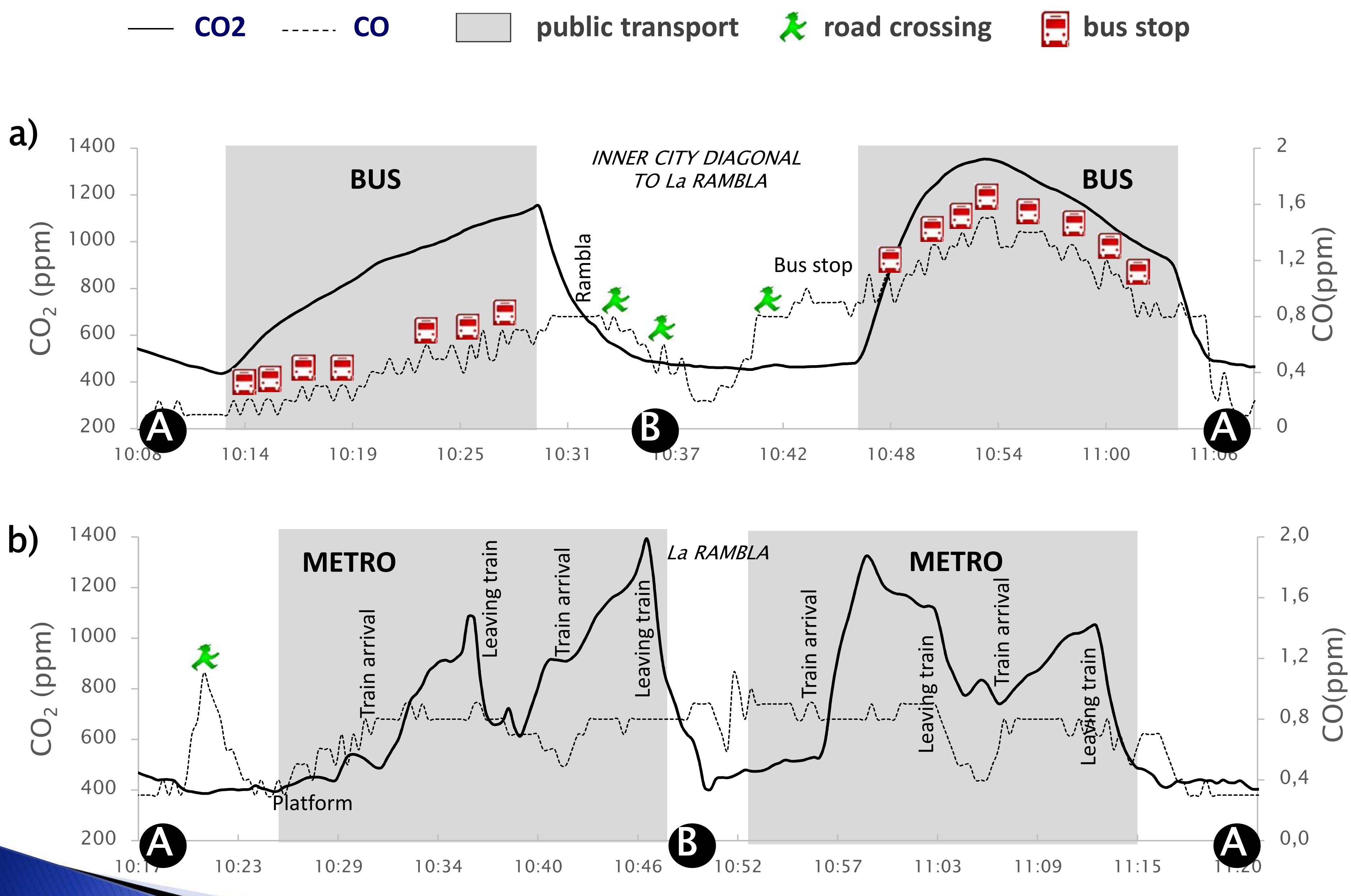

PARTICLE NUMBER
SIZE MODE
public transport
road crossing
bus stop
c)
OUTER DIAG.
TRAM
INNER CITY (L´EIXAMPLE) GRIDPLAN
TRAM
OUTER DIAG.
Train stop
Diagonal Av.
part. cm-3
Mode (nm)
2,00E+05
1,50E+05
1,00E+05
5,00E+04
0,00E+00
120
100
80
60
40
20
0
10:19
10:27
10:34
10:41
10:48
11:03
11:10
11:17
11:24
A
B
A
d)
OUTER CITY DIAGONAL AV.
INNER CITY
DIAGONAL AV.
OUTER CITY DIAGONAL AV.
part. cm-3
Mode (nm)
2,00E+05
1,50E+05
1,00E+05
5,00E+04
0,00E+00
120
100
80
60
40
20
0
10:26
10:33
10:40
10:48
10:55
11:02
11:16
11:24
11:31
11:38
11:45
11:52
12:00
A
B
A
Time


PM10
PM2.5
public transport
road crossing
bus stop
street works
a)
BUS
INNER CITY DIAGONAL
TO La RAMBLA
Bus stop
BUS
Suburban roadside
0,16
0,12
0,08
0,04
0,00
10:16
10:22
10:27
10:33
10:45
10:50
10:56
11:02
11:08
A
B
A
b)
mg m⁻³ (uncorrected)
METRO
La RAMBLA
METRO
0,06
0,05
0,04
0,03
0,02
0,01
0,00
Train arrival
Line 3
Leaving train
Transfer
Train arrival
Line 5
Leaving train
Train arrival
Line 5
Leaving train
Transfer
Platform
Train arrival
Line 3
Leaving train
Escaletors
10:09
10:15
10:21
10:27
10:32
10:38
10:44
10:50
10:55
11:01
A
B
A

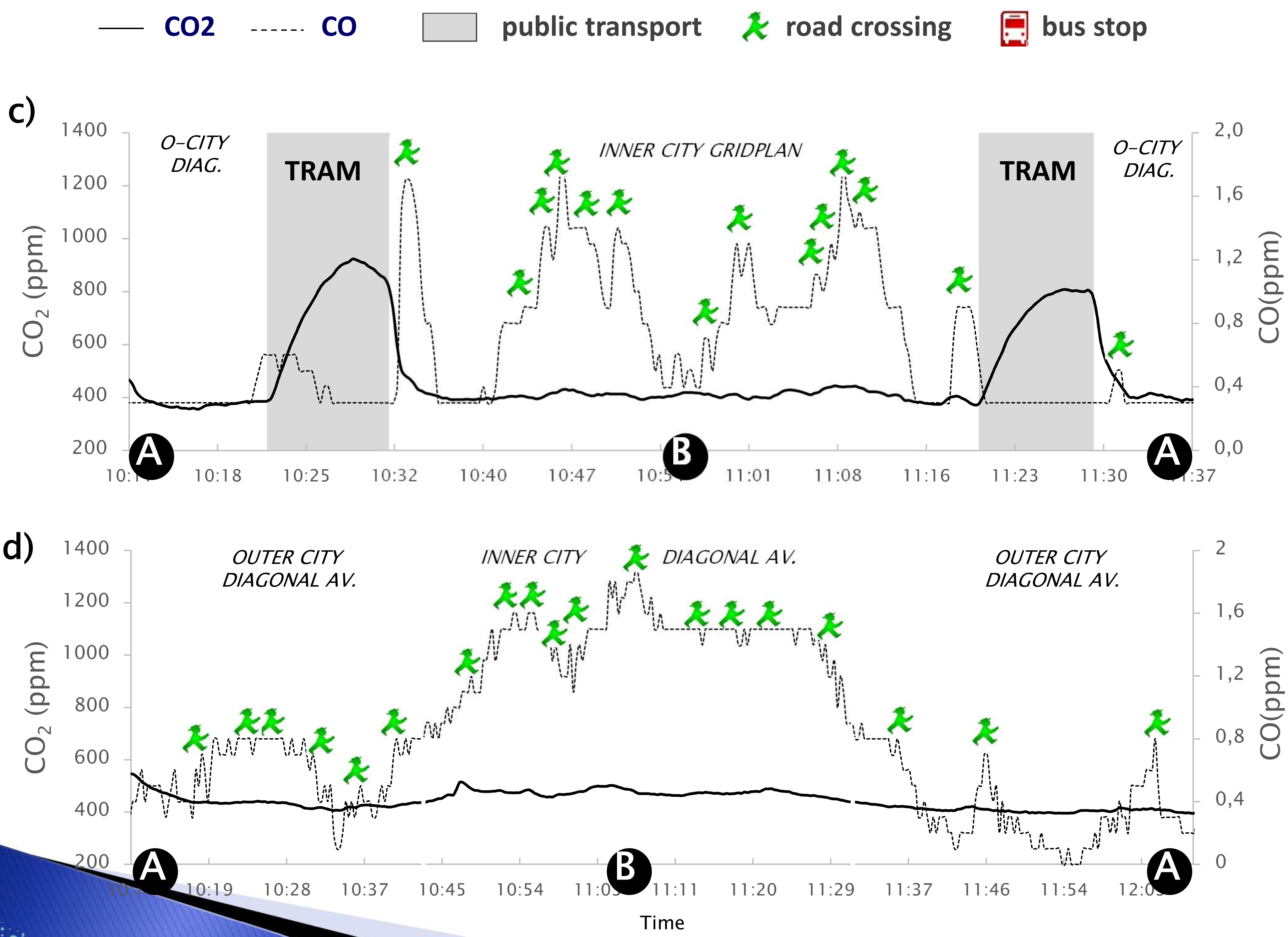

PM10
PM2.5
public transport
road crossing
bus stop
street works
c)
mg m⁻³ (uncorrected)
0,16
0,12
0,08
0,04
0,00
O-CITY DIAG.
TRAM
Stop
Stop
Stop
INNER CITY GRIDPLAN
TRAM
O-CITY DIAG.
A
B
A
10:03
10:10
10:17
10:24
10:32
10:39
10:46
10:53
11:00
11:08
11:15
11:22
11:29
d)
mg m⁻³ (uncorrected)
0,16
0,12
0,08
0,04
0,00
OUTER CITY DIAGONAL AV.
INNER CITY DIAGONAL AV.
OUTER CITY DIAGONAL AV.
A
B
A
10:12
10:19
10:26
10:33
10:40
10:48
10:55
11:02
11:09
11:16
11:24
11:31
11:38
11:45
11:52
12:00
12:07
Time


0 0.25 0.5 1 Kilometers
BC (ng/m3)
3415 - 5915
5915 - 8000
8000- 10115
10115 - 12885
12885 - 17285
17285- 26220
26220 - 49500

walking

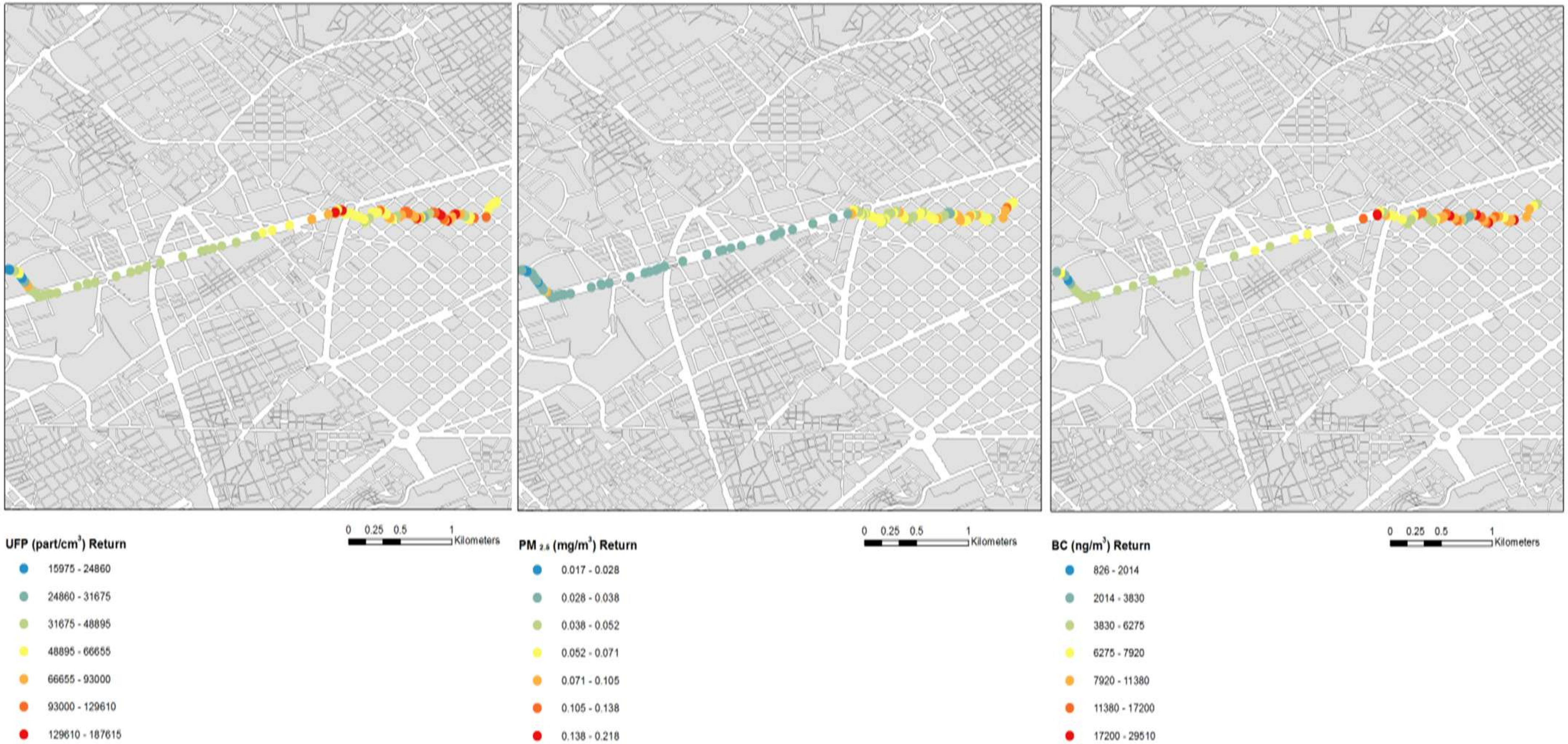


CO2
CO
public transport
road crossing
bus stop
a)
BUS
INNER CITY DIAGONAL TO La RAMBLA
BUS
Rambla
Bus stop
CO2 (ppm)
CO(ppm)
1400
1200
1000
800
600
400
200
2
1,6
1,2
0,8
0,4
0
A
B
A
10:08
10:14
10:19
10:25
10:31
10:37
10:42
10:48
10:54
11:00
11:06
b)
METRO
La RAMBLA
METRO
Platform
Train arrival
Leaving train
Train arrival
Leaving train
Train arrival
Leaving train
Train arrival
Leaving train
CO2 (ppm)
CO(ppm)
1400
1200
1000
800
600
400
200
2,0
1,6
1,2
0,8
0,4
0,0
A
B
A
10:17
10:23
10:29
10:34
10:40
10:46
10:52
10:57
11:03
11:09
11:15
11:20



AEROSOLS BCN 2016

TRAFFIC-RELATED POLLUTANTS

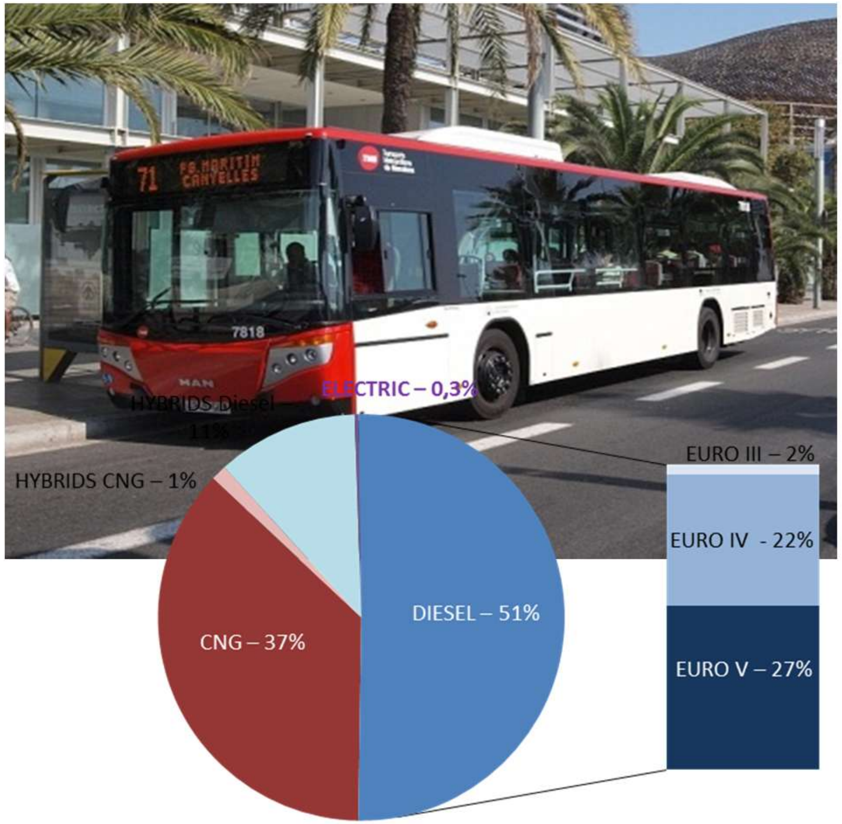


tram + walking

FILTER SAMPLES COLLECTED IN PARALLEL USING FOUR COMMUTING MODES

Time period	Transport mode	$PM_{2.5}$	Transport mode	$PM_{2.5}$	UB $PM_{2.5}$
06-14/10	Walking	23	Metro	37	12
15-23/10	Walking	29	Bus	48	12
24-31/10	Walking	32	Tram+Walking	35	17
13-21/11	Tram+Walking	27	Metro	49	12
24/11-2/12	Metro	42	Bus	49	11
05-12/11	Tram+Walking	29	Bus	39	10

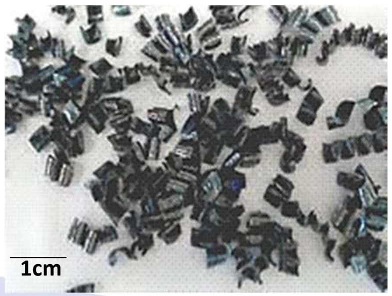
UB: Urban Background Site



Cu catenary

2cm

Wheels



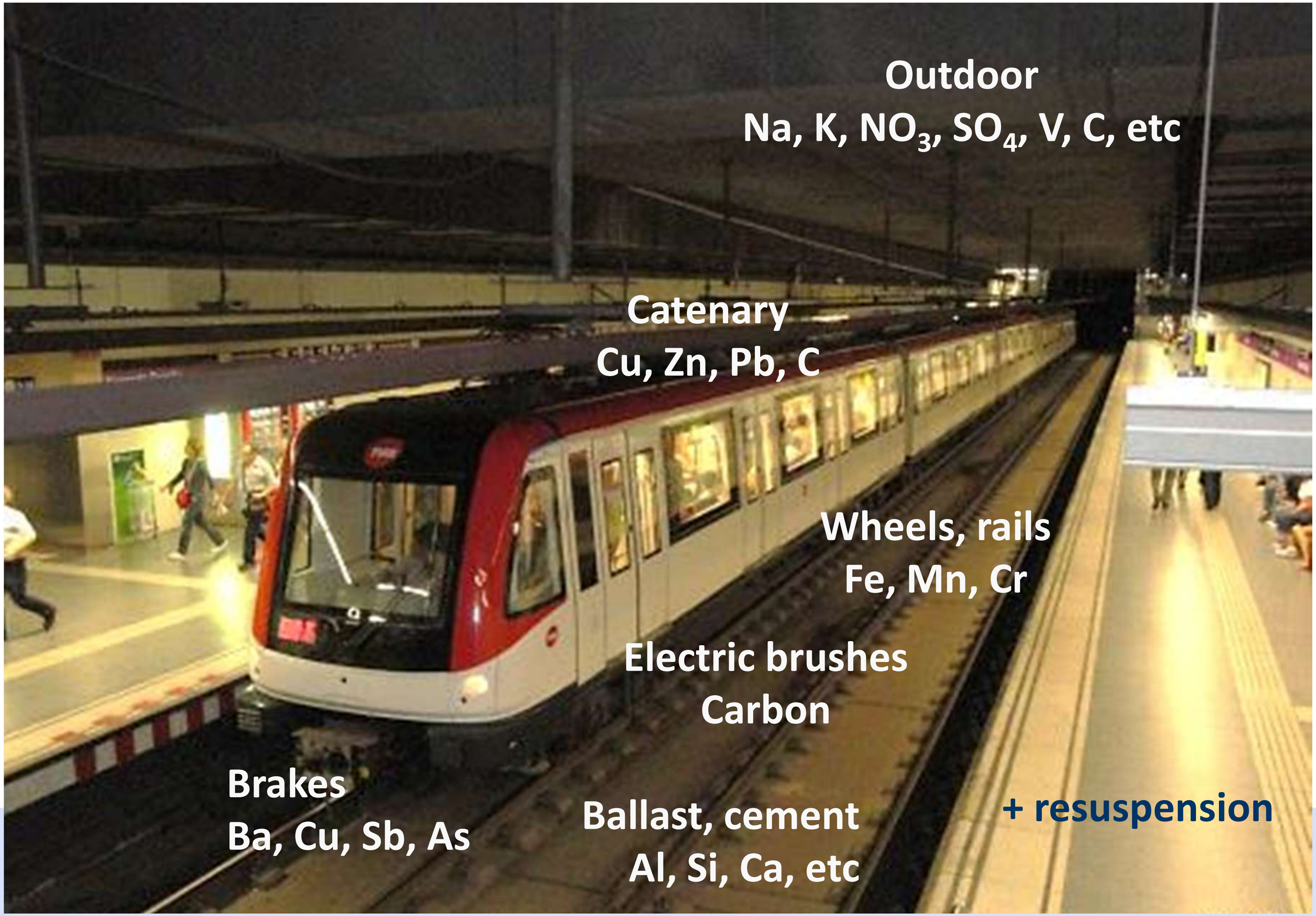
LIFE13 ENV/ES/000263

Implementing Methodologies and Practices to Reduce air pollution Of the subway enVironmEnt

01/10/2014 - 31/03/2018

The **objective** of the project is to provide to the local and national transport authorities of European countries the appropriate measures and strategies to reduce concentrations of inhalable particulate matter (PM1, PM2.5 and PM10) and identify main chemical components in underground rail air.

PM SOURCES IN UNDERGROUND SYSTEMS



Frontal brake pad

Lateral brake pad

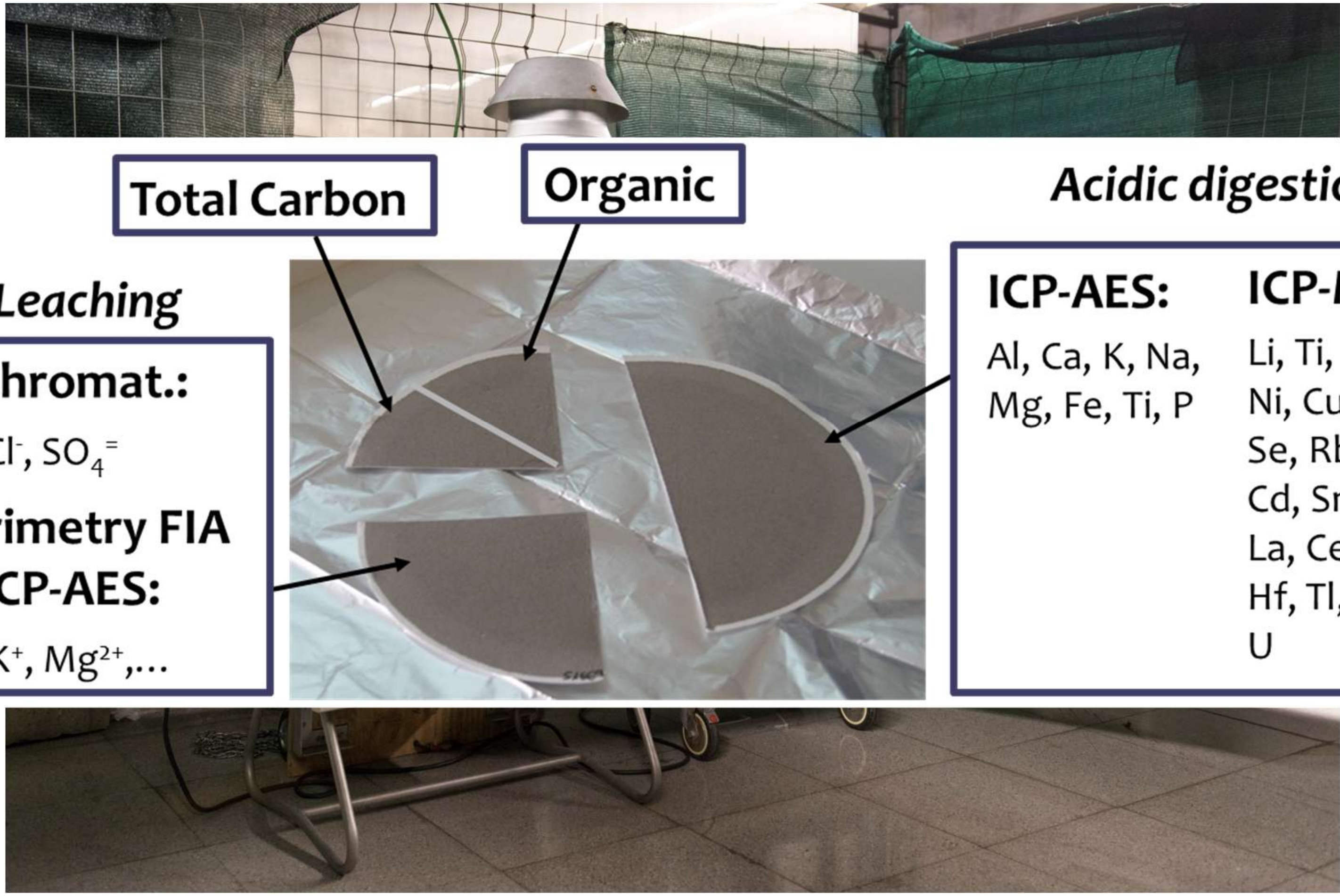
Cu catenary

2cm

Wheels

	BALLAST	CATENARY	BRUSHES	PANTOG.	BRAKES		RAIL	WHEEL
wt %					*lateral*	*frontal*		
C	<0,1	<0,1	95,4	78,7	24	40,4	0,8	0,50
ppm								
Al	83008	<0,1	0,03	719	529	22603	15	<0,1
Ba	591	10	28	85	14331	40002		0,1
Ca	23491	<0,1	0,1	1207	27857	35516		<0,1
Cu	35	950000	1000	197104	35436	193	160	1000
Fe	29705	9000	3000	1353	329000	17239	979595	980000
K	29221	<0,1	<0,1		83	2609		<0,1
Mg	9783	<0,1	<0,1	272	25800	43558		<0,1
Na	21952			1064	<0.01	3715		
S	163	<0,1	<0,1	3178	30800	17813	110	<0,1
Li	28				<0,01	7,5		
Ti	2716	53	28	43	60	1473	30	9,8
V	61	17	1	18	2,2	34	15	15
Cr	76	131	22	18	132	69	300	1173
Mn	646	40	1	16	3099	569	11300	7000
Co	5,2	1,4	<0,1	1,3	14,5	8,1		80
Ni	39	54	9,1	20	104	18	210	782
Zn	61	102	115	122	52220	10682		6
As	2,1	2,9	<0,1	2,9	22	4,9		51
Rb	112				0,8	8,0		
Sr	160	3,9	1,7	4,7	295	1905		<0,1
Cd					1,7			
Sn	2,9	0,9	15	2,9	15,3	3,1	20	95
Sb		12	4,9	30	3059	43	25	24
La	20				1,2	7,7		
Ce	43				0,9	16		
W	39	1,8	1,6		<0,01	1,8		91
Pb	17	2,4	4,2	8,6	1260	7,8		<0,1
Bi					1,6			

METHODOLOGY AND WORK PLAN



Total Carbon

Organic

Leaching

Ion Chromat.:

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

Colorimetry FIA and ICP-AES:

NH_4^+, K^+, Mg^{2+},…

Acidic digestion

ICP-AES:

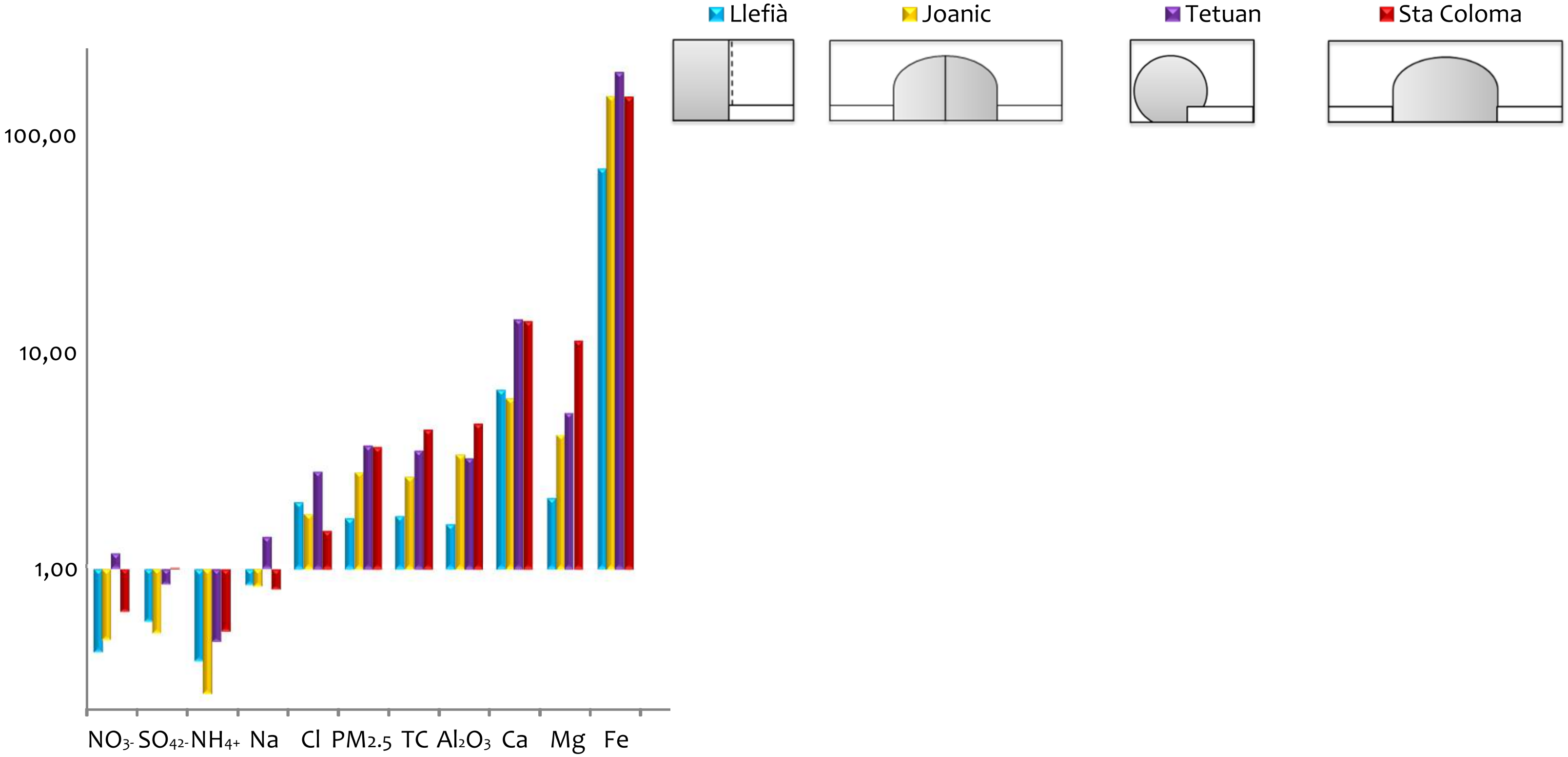
Al, Ca, K, Na, Mg, Fe, Ti, P

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

SUBWAY PM CHEMISTRY

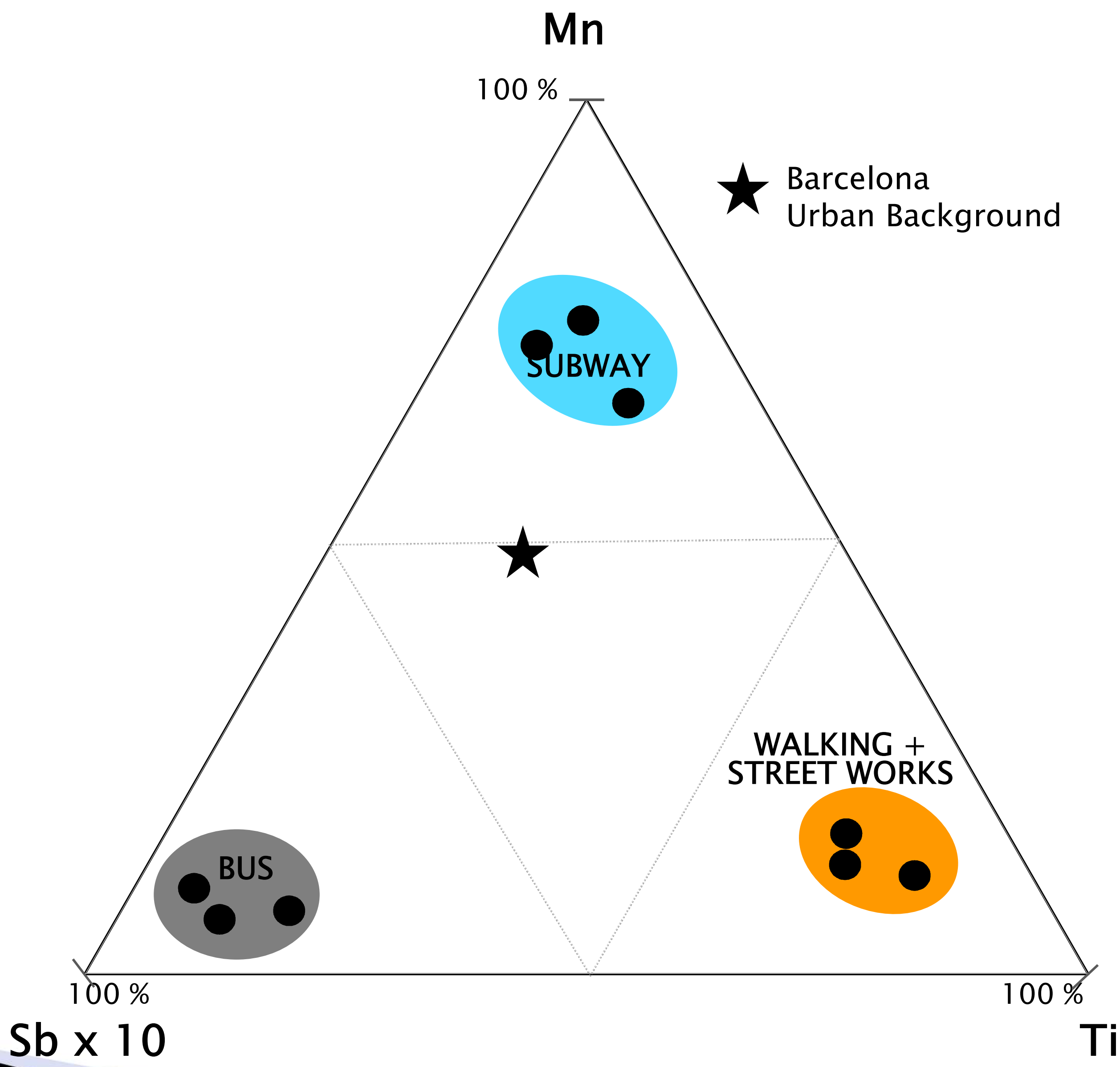
Subway/Barcelona outdoor



PM2.5 CHEMISTRY

	AVERAGE (3 filters)			
Date	Walking	Metro	Tram + walking	Bus
$\mu g\ m^{-3}$				
$PM_{2.5}$	27.8	42.6	30.6	45.2
Al_2O_3	1.2	0.2	0.01	0.2
Ca	1.8	1.1	0.6	1.2
Fe	1.1	13.3	0.7	2.2
K	0.5	0.7	0.9	0.6
Na	0.4	0.3	0.2	0.3
Mg	0.3	0.3	0.1	0.2
P	0.04	0.03	0.03	0.06
S	1.1	0.7	0.6	0.6

	AVERAGE			
Date	Walking	Metro	Tram + walking	Bus
$ng\ m^{-3}$				
Ti	106.5	27.1	14.3	34.6
V	8.9	4.7	3.5	7.7
Mn	18.4	120.3	14.2	23.7
Co	0.7	1.5	0.3	< dl
Cu	36.2	112.0	24.9	170.6
Zn	101.6	179.8	53.0	130.2
As	2.0	1.0	0.5	1.9
Rb	0.9	1.1	< dl	1.1
Sr	5.2	14.3	2.9	4.2
Zr	7.7	13.3	< dl	32.4
Cd	0.2	0.1	0.3	< dl
Sn	5.8	5.4	3.9	5.7
Sb	2.0	2.5	0.7	24.1
Ba	23.1	494.6	19.8	59.9
La	0.5	0.4	0.5	0.5
Ce	1.2	0.9	0.6	1.1
Nd	0.3	0.2	< dl	0.2
Sm	0.7	1.1	0.9	1.0
Pb	8.8	7.5	6.6	7.1
U	0.9	1.0	1.2	1.4


Mn
100 %
Barcelona
Urban Background
SUBWAY
WALKING +
STREET WORKS
BUS
100 %
Sb x 10
100 %
Ti

SCIENTIFIC SUMMARY

- The average N were lowest in subway trains (< **2.5×10^4**) and highest in diesel bus or walking in the city centre trafficked streets (> **5.0×10^4**). Pedestrians at busy traffic crossings are exposed to transient peaks reaching > **10^6**.
- Subway particles display a size mode larger (90 nm) than in outdoor commuting environments (<70 nm).
- Regarding $PM_{2.5}$ & BC, commuting using the tram appears to be consistently the cleanest form of city public transport when compared to bus and subway.
- CO concentrations (like BC) are good proxies for traffic contamination, whereas CO_2 concentrations are an indicator of the number of indoor passengers on public transport.
- Urban roadside pedestrians can inhale more siliceous dust, whereas subway passengers inhale a more obviously anthropogenic PM mix enhanced in Fe, Mn, Zn, Sr and Ba. Bus air registered unusually high levels of Sb and Cu, probably contaminated mainly from the bus itself.

Moreno et al 2015, Environmental Research 142, 495–510

TAKE HOME MESSAGE

- When we commute through the city the air pollutants we breathe vary greatly in concentration, number, size and chemical composition, depending on the route and transport chosen.
- The kinds of data presented here offer the urban traveller better informed choices to help understand differences in air quality to which they are exposed during the daily commute.

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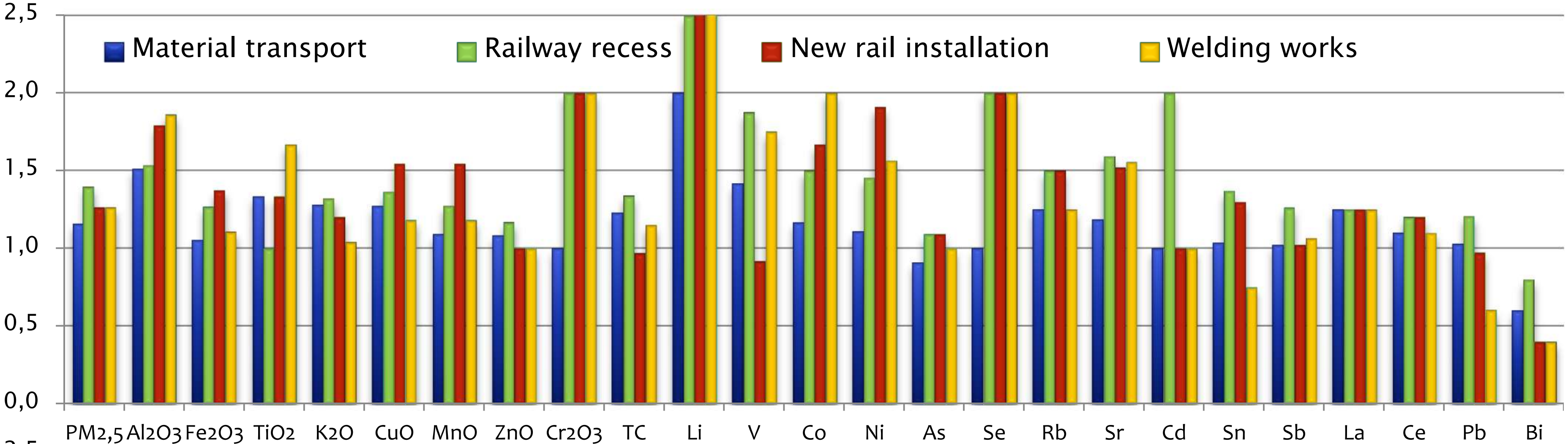
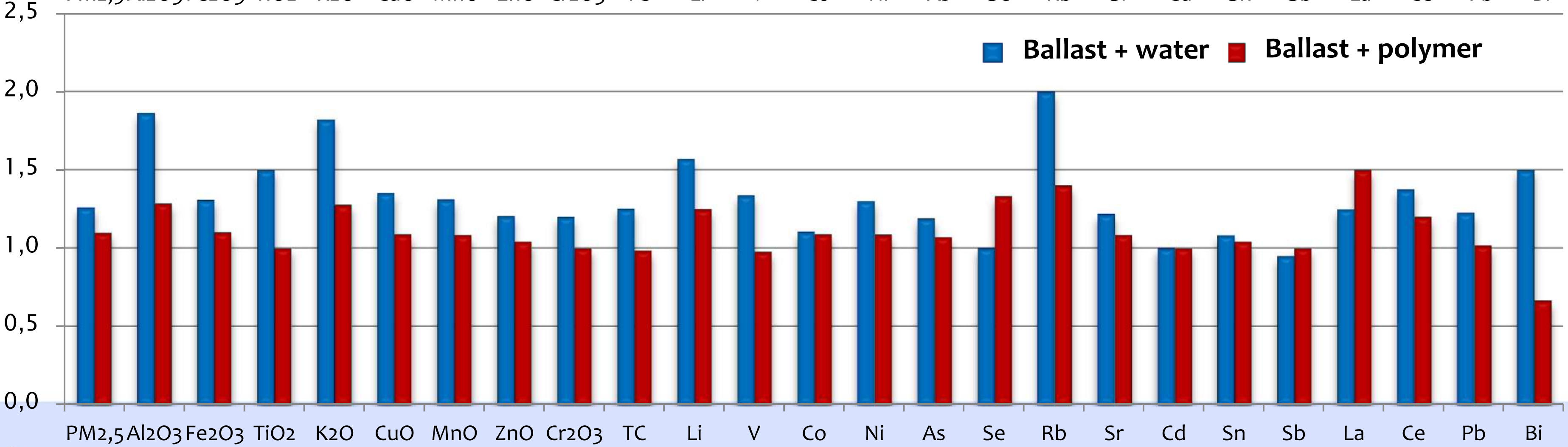
MAINTENANCE NIGHT WORKS





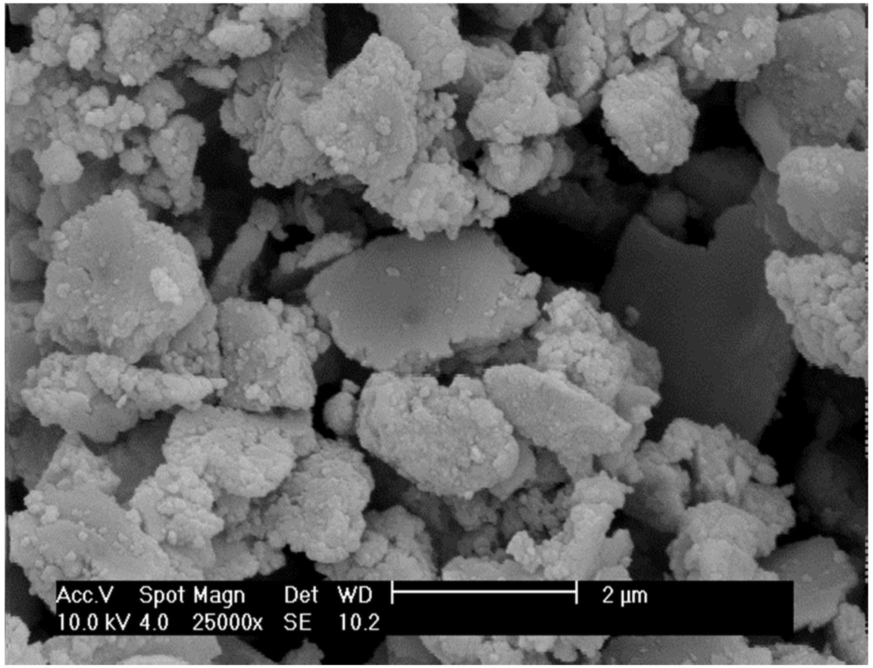
CHEMICAL COMPOSITION OF SUBWAY PIECES

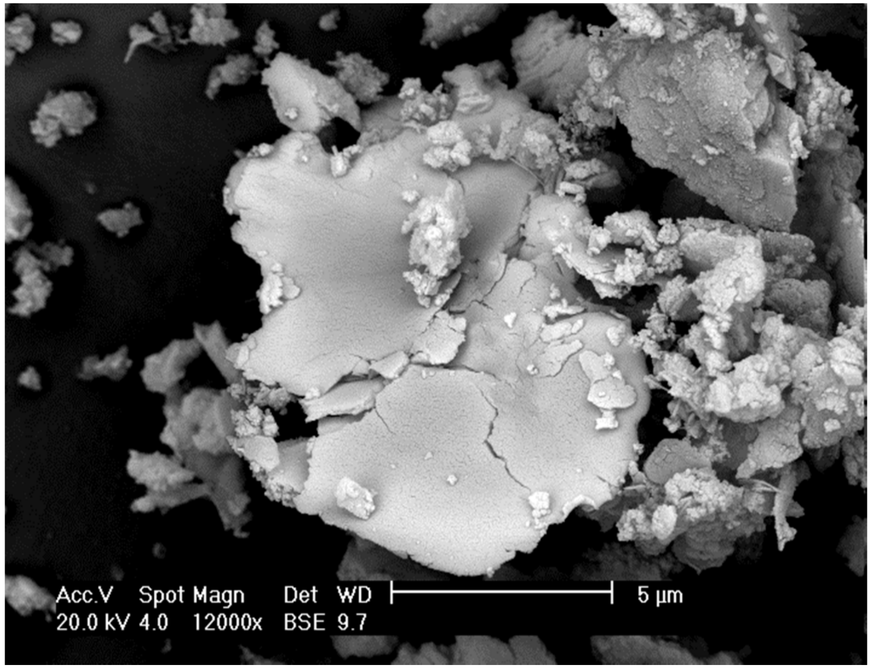
Ballast (1),
Catenary (1),
Brushes (1),
Pantograph (3),
Brakes (4),
Rail (2),
Wheel (5)

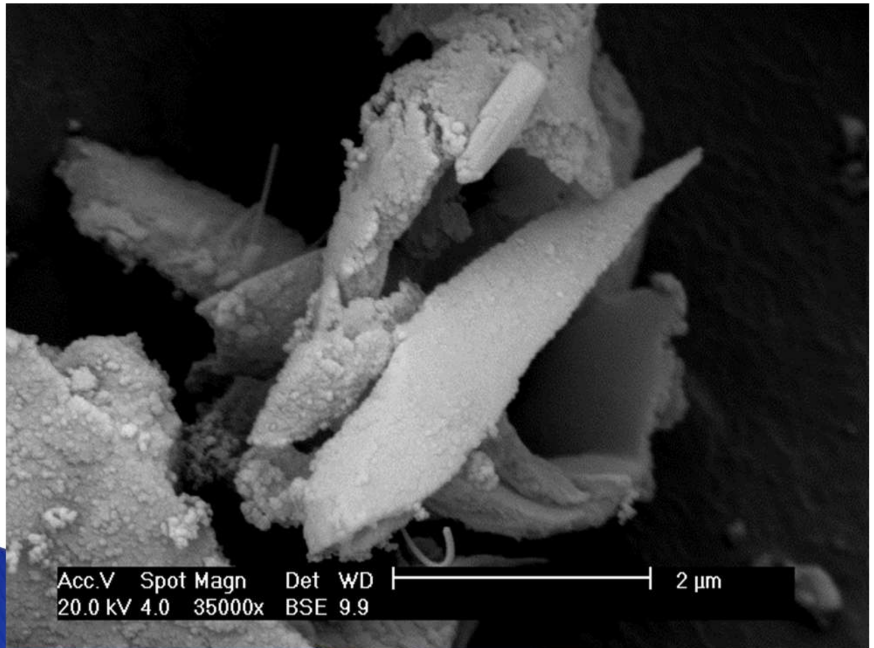
	Balasto	Catenaria	Escobilla	Pantógrafo	Freno		Carril	Rueda
					Lat	Frn		
C			X	X	X	X		
Al	X			(X)		X		
Ba	(X)				X	X		
Ca	X			(X)	X	X		
Cu		X	(X)	X	X			(X)
Fe	X	X	X	(X)	X	X	X	X
K	X					X		
Mg	X				X	X		
Na	X							
P	X				X	X		
S				X	X	X		
Li						(X)		
Ti	X					X		
V				(X)				
Cr		(X)						X
Mn					X	X	X	X
Ni				(X)				X
Zn					X			
As								(X)
Rb						(X)		
Sr						X		
Zr						(X)		
Mo						X		X
Sb					X			
Pb					X			

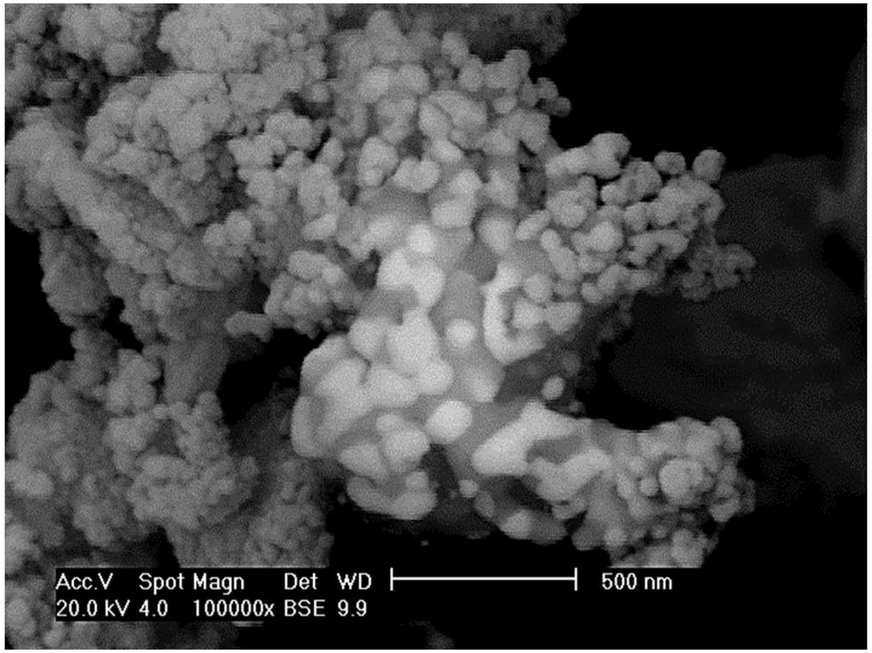
THE QUESTION OF AIR QUALITY IN UNDERGROUND SYSTEMS IS NOT TRIVIAL

- ✓ Underground subway systems worldwide transport > 100 million people daily
- ✓ Ambient PM_{10} concentrations on platforms can be >> 50 µg/m³.
- ✓ Subway PM is extremely metalliferous and very different in chemistry from outside ambient air.

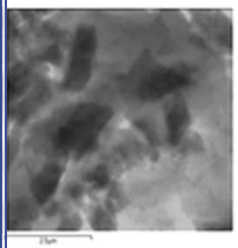

Acc.V Spot Magn Det WD
10.0 kV 4.0 25000x SE 10.2
2 µm

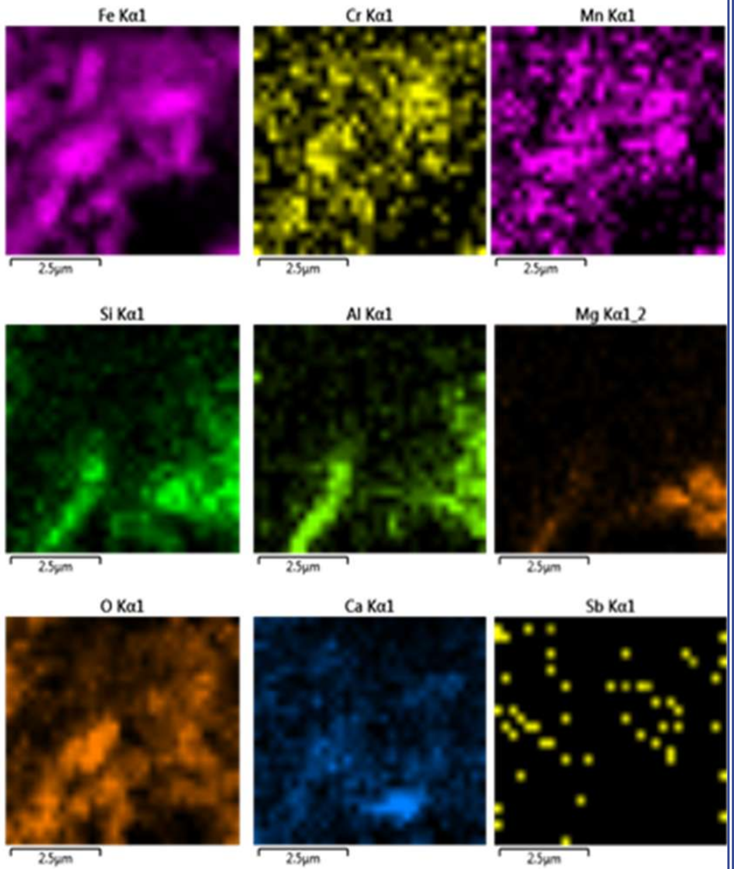

Acc.V Spot Magn Det WD
20.0 kV 4.0 12000x BSE 9.7
5 µm


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


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

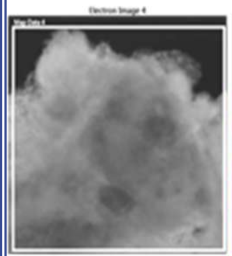
RAIL/WHEEL

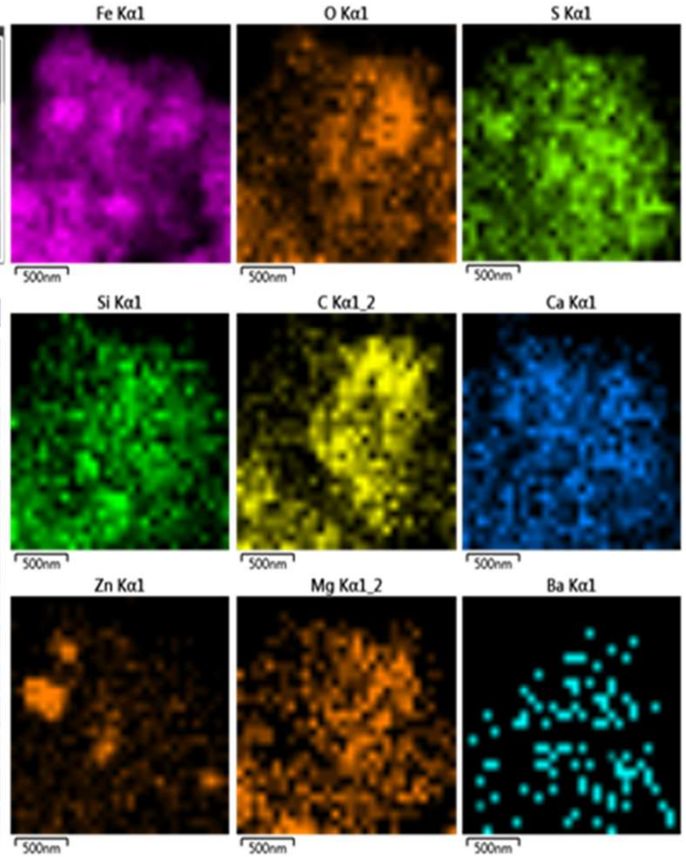




Element	Wt%
C	1.96
O	22.23
Na	0.86
Mg	0.92
Al	0.93
Si	2.54
S	0.56
Cl	0.59
K	0.86
Ca	2.35
Cr	0.35
Mn	0.65
Fe	64.69
Zn	0.05
As	0.08
Sb	0.39
Total:	100.00

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