London Air Quality Network Seminar

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Results of intensive street cleaning tests on road dust mitigation in Spain

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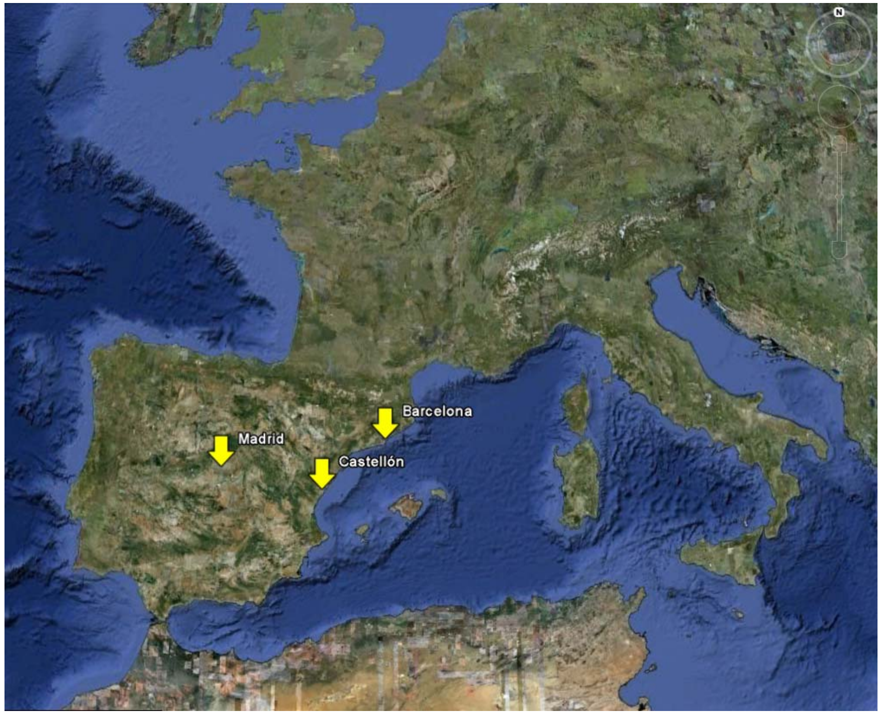
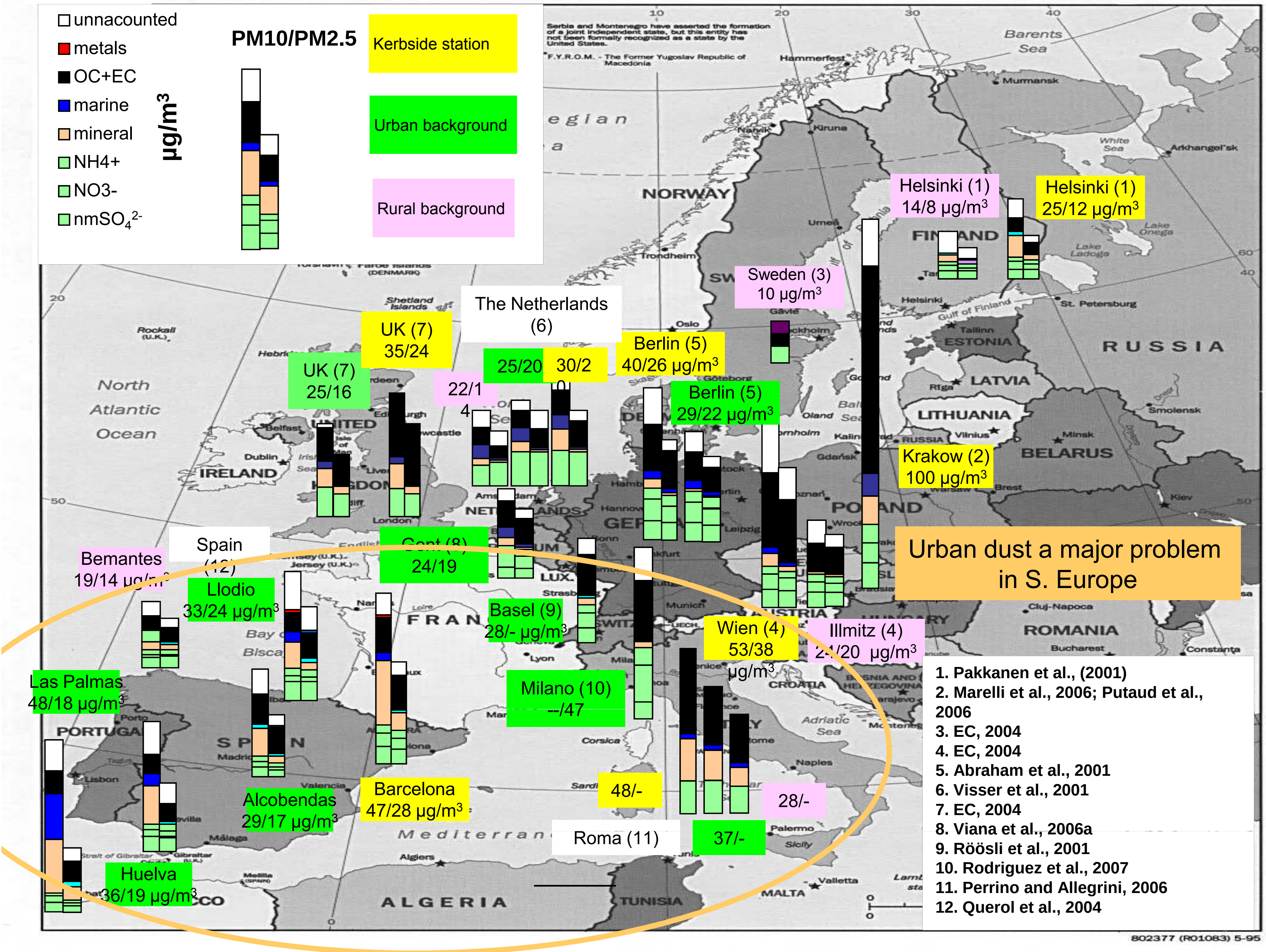
CSIC

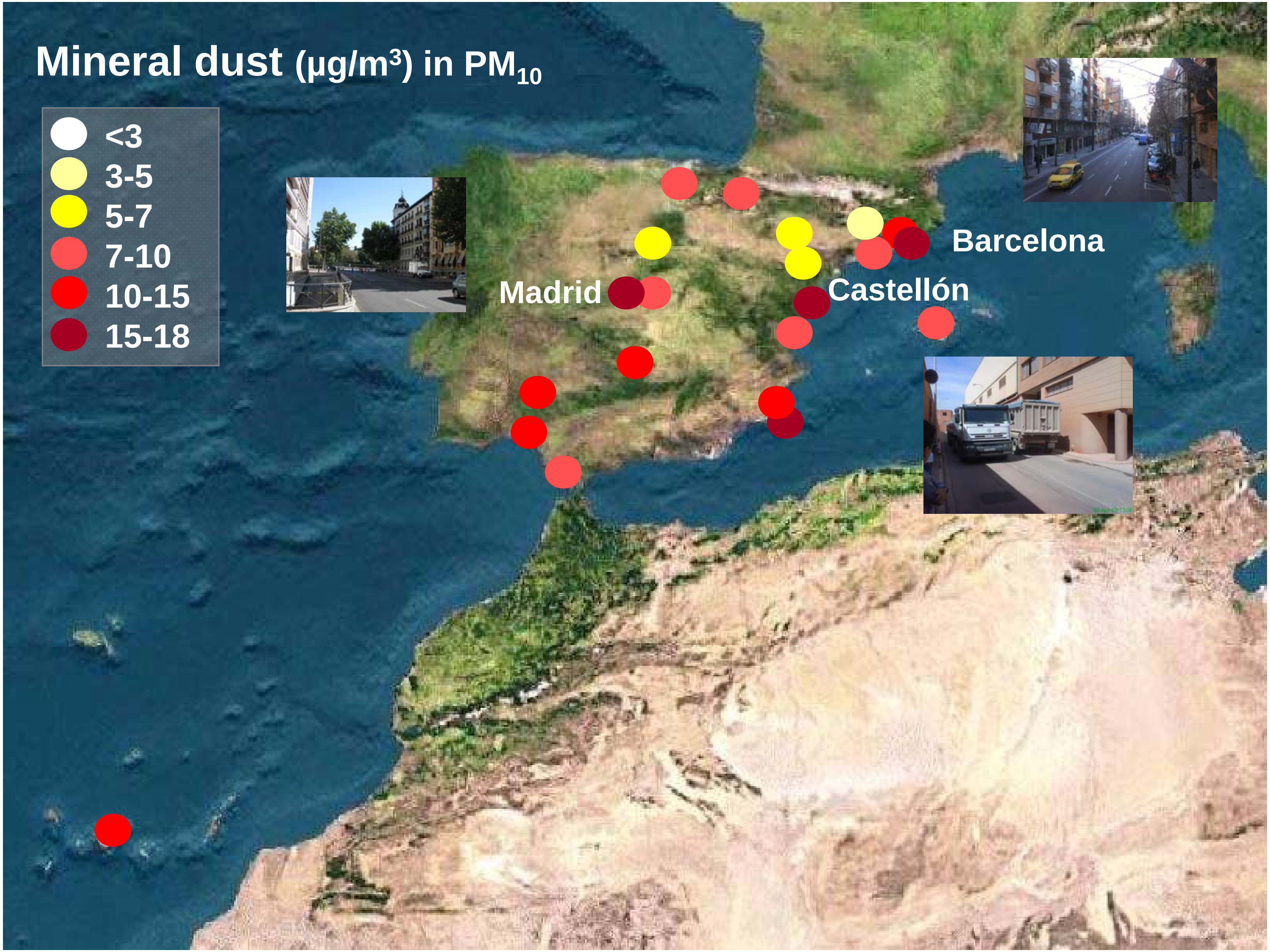
Outline

- Road dust resuspension in Spain: a barrier for PM_{10} standards attainment
- Objectives
- Areas of study
- Methods
- Results
  - Case 1: Barcelona
  - Case 2: Castellón
  - Case 3: Madrid
- Conclusions





unnacounted
metals
OC+EC
marine
mineral
NH4+
NO3-
nmSO4 2-
µg/m3
PM10/PM2.5
Kerbside station
Urban background
Rural background
Helsinki (1) 14/8 µg/m3
Helsinki (1) 25/12 µg/m3
Sweden (3) 10 µg/m3
The Netherlands (6)
25/20
30/20
22/14
UK (7) 35/24
UK (7) 25/16
Berlin (5) 40/26 µg/m3
Berlin (5) 29/22 µg/m3
Krakow (2) 100 µg/m3
Urban dust a major problem in S. Europe
Gent (8) 24/19
Spain (12)
Bemantes 19/14 µg/m3
Llodio 33/24 µg/m3
Basel (9) 28/- µg/m3
Wien (4) 53/38 µg/m3
Illmitz (4) 24/20 µg/m3
Las Palmas 48/18 µg/m3
Milano (10) --/47
Alcobendas 29/17 µg/m3
Barcelona 47/28 µg/m3
48/-
28/-
Roma (11)
37/-
Huelva 36/19 µg/m3
1. Pakkanen et al., (2001)
2. Marelli et al., 2006; Putaud et al., 2006
3. EC, 2004
4. EC, 2004
5. Abraham et al., 2001
6. Visser et al., 2001
7. EC, 2004
8. Viana et al., 2006a
9. Röösli et al., 2001
10. Rodriguez et al., 2007
11. Perrino and Allegrini, 2006
12. Querol et al., 2004



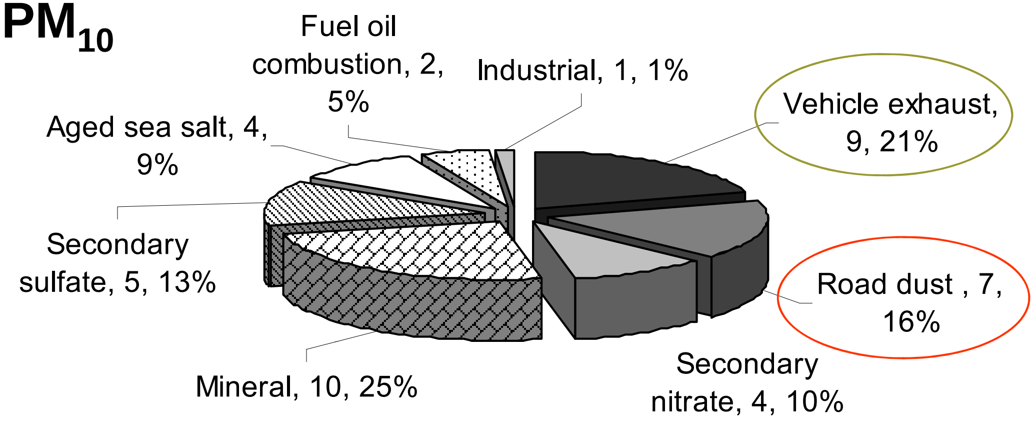
Mineral dust (µg/m3) in PM10
<3
3-5
5-7
7-10
10-15
15-18
Madrid
Barcelona
Castellón

Non-Exhaust vs Exhaust

Source contributions in Barcelona

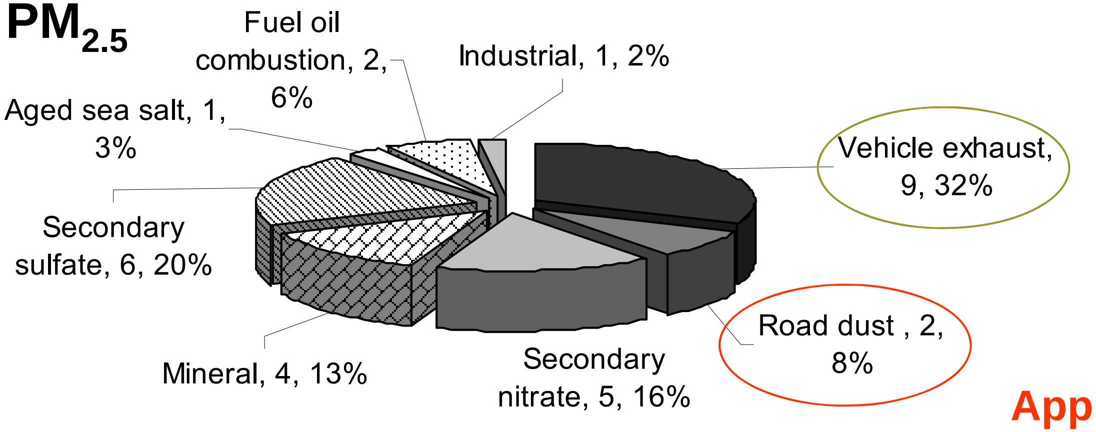
Amato et al., Atm. Env.(2009) 43 (17), 2770–2780

PM_{10}



Almost 1:1 to Exhaust

$PM_{2.5}$



Approx 1:4

Evidence on trace pollutants

Querol et al., Atm. Env. 2007

ng/m^3	Rural backg.		Urban backg.		Steel	Stainless steel	Copper metall.	Zinc metall.	Petrochem. estates		Ceramic estates		Former tech-brick manufacture
	min	max	min	max	mean	mean	mean	mean	min	max	min	max	mean
Li	0.1	0.2	0.2	0.7	0.4	0.8	0.4	0.4	0.4	1.1	0.6	1.2	**2.0**
Be	0.03	0.02	0.02	0.05	0.06	0.02	0.05	0.06	0.01	0.06	0.02	0.05	**0.07**
Sc	0.1	0.1	0.1	0.3	0.1	0.1	0.4	0.1	0.1	0.3	0.3	0.5	0.3
Ti	7	19	18	**83**	25	52	71	35	22	66	33	56	**99**
V	2	5	2	15	8	**25**	6	12	8	**21**	4	6	**138**
Cr	1	1	2	8	**25**	**35**	2	3	3	5	3	7	3
Mn	5	5	4	23	**87**	25	15	13	8	12	6	8	23
Co	0.1	0.1	0.2	0.5	0.5	0.7	0.3	0.4	0.2	**0.8**	0.4	0.7	0.6
Ni	2	3	2	7	**33**	**24**	4	7	4	**9**	3	4	**24**
Cu	2	8	7	**88**	33	15	**67**	17	20	28	4	11	66
Zn	12	26	14	**140**	**420**	103	41	**492**	31	56	45	**194**	21
Ga	0.1	0.2	0.1	0.3	0.4	0.3	**0.4**	0.2	0.1	0.4	0.2	0.4	**1.2**
Ge	0.1	0.3	0.04	0.3	0.2	0.2	0.3	0.0	0.14	0.22	0.05	0.2	0.1
As	0.3	0.4	0.3	1.6	1.8	1.2	**4.9**	1.0	0.5	2.1	1.7	**5.2**	1.6
Se	0.3	0.5	0.3	1.3	**2.8**	0.7	1.3	0.6	0.5	0.7	1.0	**2.4**	**2.2**
Rb	0.5	0.6	0.5	1.8	1.1	1.0	1.5	1.0	0.7	1.6	1.2	2.5	**5.6**
Sr	1	5	3	**10**	3	7	4	8	4.7	4.8	3	4	11
Y	0.1	0.2	0.1	0.4	0.1	0.3	0.3	0.1	0.1	0.2	0.2	0.3	0.4
Zr	3	4	2	**10**	2	5	2	2	2	7	10	**21**	4
Nb	0.05	0.1	0.05	0.4	0.1	0.23	0.2	0.14	0.1	0.3	0.2	0.3	0.36
Mo	3	4	2	5	**16**	**20**	4	2	2	8	2	5	4
Cd	0.2	0.2	0.1	0.7	**1.2**	0.3	0.6	**0.7**	0.1	0.3	0.6	1.6	0.3
Sn	1	1	1	6	**38**	2	2	2	1.7	2.3	1	1	NA
Sb	0.6	0.6	1	**11**	2	1.6	2	3.2	1	4	1	6	NA
Cs	0.04	0.04	0.03	0.13	0.10	0.07	0.09	0.07	0.03	**0.23**	0.14	**0.31**	**0.47**
Ba	5	8	4	**65**	14	17	18	16	8	13	12	16	16
La	0.1	0.2	0.2	0.6	0.3	0.7	0.5	0.4	0.3	**0.9**	0.3	0.6	**1.2**
Ce	0.2	0.4	0.4	1.3	0.4	0.9	0.9	0.7	0.5	1.2	0.7	1.9	**2.0**
Pr	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.3
Hf	0.2	0.2	0.1	0.5	0.2	0.2	0.1	0.3	0.1	0.2	0.2	0.4	NA
W	0.02	0.04	0.05	0.64	0.67	0.21	0.11	0.05	0.03	0.16	0.10	0.36	0.15
Tl	0.1	0.1	0.05	0.4	0.4	0.1	0.1	0.1	0.1	0.3	0.5	**2.7**	**2.2**
Pb	5	9	7	57	**103**	19	25	20	8	25	35	**106**	28
Bi	0.1	0.1	0.1	**1.0**	0.5	0.2	**1.0**	0.2	0.1	0.2	0.4	**1.4**	0.2
Th	0.1	0.2	0.1	0.3	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.3
U	0.1	0.2	0.1	0.3	0.3	0.1	0.2	0.1	0.1	0.3	0.0	0.1	0.1

Possible reduction strategies

- Sweeping
- Washing
- Combination Sweeping/Washing
- Chemical Suppressants
- Non-techonological measures
  - Reducing Traffic Volume
  - Ban of studded tires (Northern EU)

Objectives

- Is there any evidence of the effectiveness of sweeping+water flushing in reducing:
  - PM_{10} levels at kerbside?
  - Road dust loadings (source strength)?

Methodology

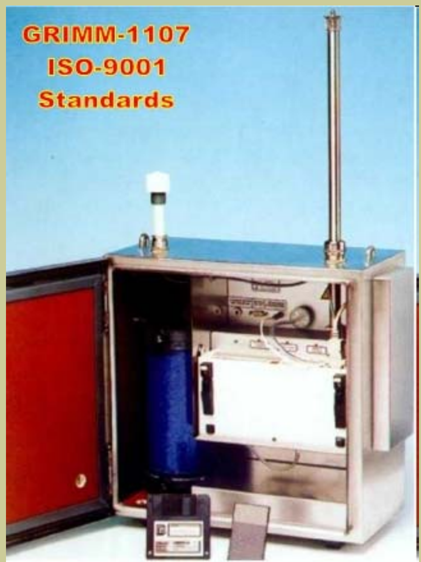
1. Ambient air PM measurements
2. Road dust (<10µm) measurements
3. Street cleaning

Methodology1:
Ambient air PM measurements





Hourly PMx levels

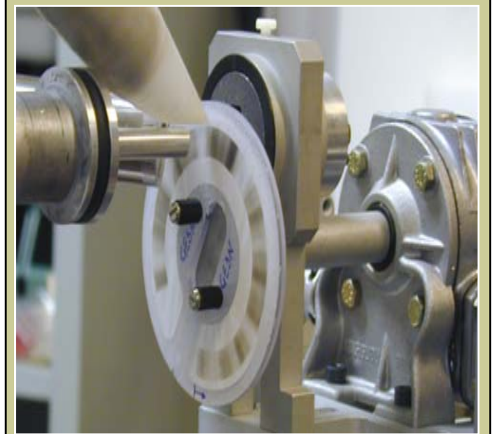


Optical counters and
β-gauge attenuation

Daily PM_{10} sampling and chemistry

HiVol samplers

Hourly PM chemistry



Two-stages sampler for
PM2.5
and PM2.5-10
↓
PIXE Analysis
at LABEC-INFN (Florence)

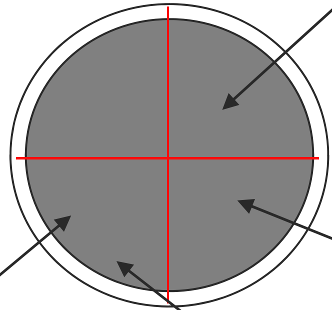
Chemical characterization of PM_{10} samples

Crustal-mineral

Al_2O_3	ICP-AES
Ca	ICP-AES
K	ICP-AES
Mg	ICP-AES
Fe	ICP-AES
Ti	ICP-AES
P	ICP-AES
CO_3^{2-}	ind. from Ca
SiO_2	ind. from Al_2O_3

Sea-salt

Na^+	ICP-AES
Cl^-	Ion Cromat.



Organic Carbon (OC)
Elemental carbon (EC)
thermal-optical (Sunset)

SIC

NH_4^+	specific electrode
SO_4^{2-}	Ion Cromat.
NO_3^-	Ion Cromat.

40 trace elements (ICP-MS)

As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

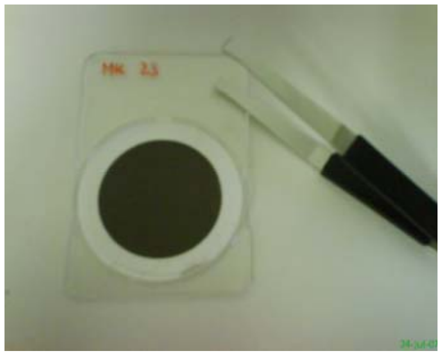
Determining:
80% of PM mass

Methodology 2:
Deposited Road dust measurements

Previous studies collect total road dust by sweeping.

But there's no point to measure total load since:
- coarser particles dominate the mass
- toxic components are in the finer fraction

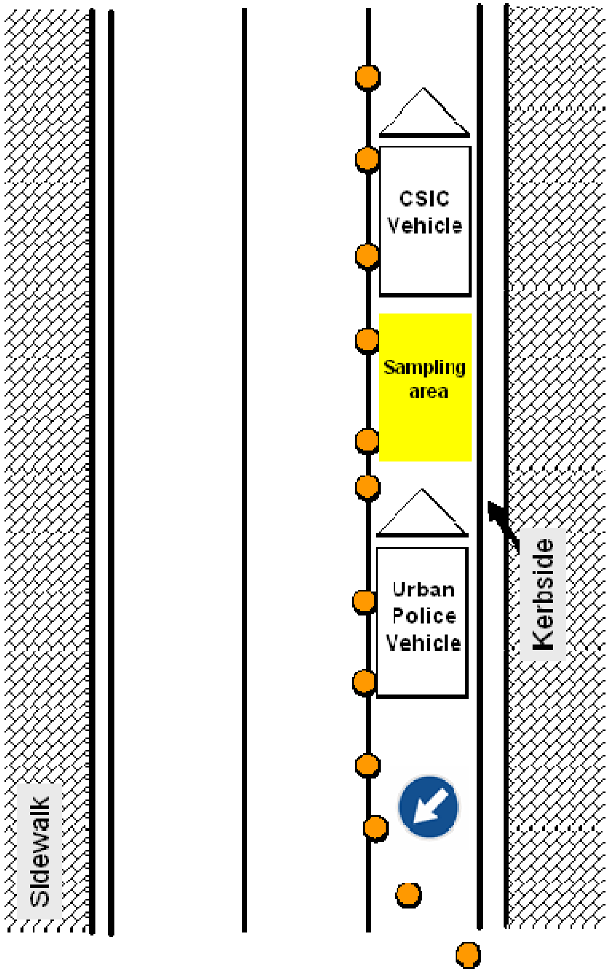
Development of new sampling device allowing to:
- collect only the fraction <10µm
- quantifying the load per m^2
- monitoring the time evolution



Method: <u>Amato et al., Atm. Env. 2009</u>

Methodology 2: Deposited Road dust measurements

Method: Amato et al., Atm. Env. 2009



From active traffic lanes

Filters are weighted and chemically characterised

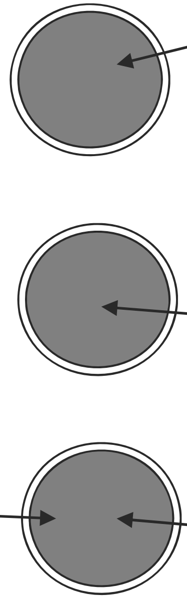
Chemical characterization: Road dust samples

Crustal-mineral

Al_2O_3	ICP-AES
Ca	ICP-AES
K	ICP-AES
Mg	ICP-AES
Fe	ICP-AES
Ti	ICP-AES
P	ICP-AES
CO_3^{2-}	ind. from Ca
SiO_2	ind. from Al_2O_3

Sea-salt

Na^+	ICP-AES
Cl^-	Ion Cromat.



Organic Carbon (OC)
Elemental carbon (EC)
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40 trace elements (ICP-MS)

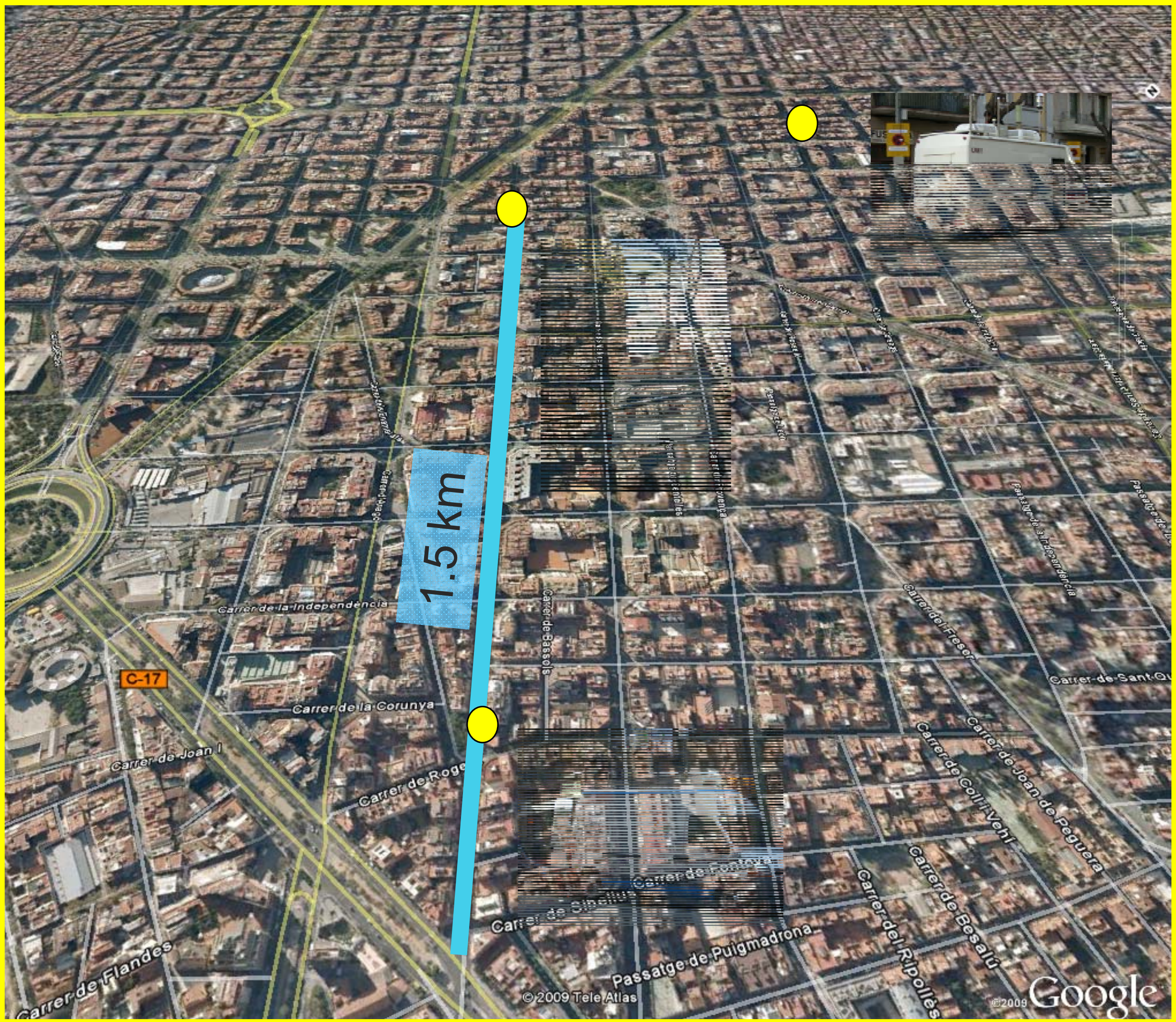
As, Ba, Bi, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Ga, Gd, Ge, Hf, La, Li, Mn, Mo, Nd, Ni, Pb, Pr, Rb, Sb, Sc, Se, Sm, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Yb, Zn, Zr

Determining:
80% of PM mass

Case 1:
Barcelona city center

2 campaigns in 2008 and 2009

- high car density: 6100 cars/km^2
- widespread construction emissions



Valencia Avenue
19,000 veh day^{-1}

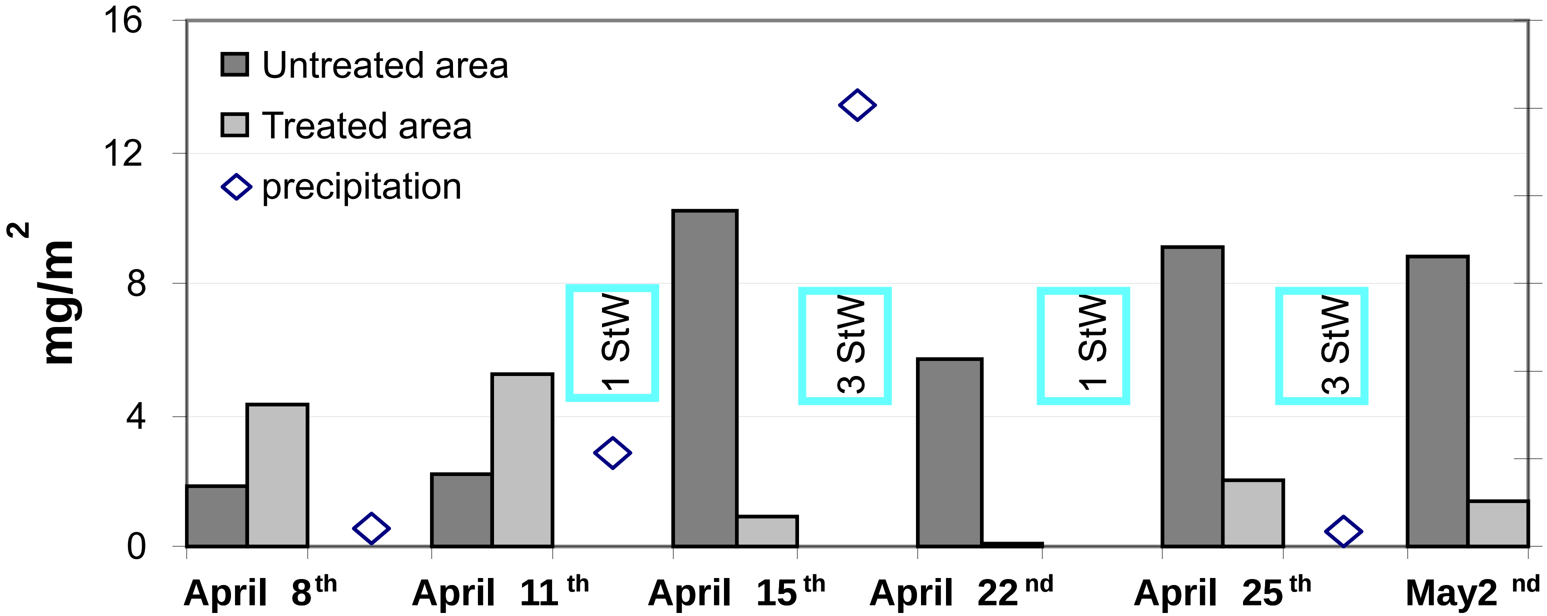
Case 1: Barcelona
Street Cleaning methods

During several nights:

A) Vacuum-assisted Sweepers

B) Water-jet flushing in all lanes

Results 1: Barcelona
Monitoring of deposited road dust



Case 1: Barcelona
Effect on ambient air PM_{10}

Kerbside concentrations

test 2008

Amato et al., Atm. Env. 2009

Code	City area	Type of station	Measurement site	PM_{10} (μg/m^3)	
				Days with StW	Days without StW
1	NE	Traffic	DO-W	44.4	53.2
2	NE	Traffic	UP-W	50.3	54.0
3	NE	Urban background	Poble Nou	38.9	43.8
4	NE	Urban background	St. Adriá	38.6	42.3
5	SW	Urban background	Eixample	42.2	44.3
6	SW	Urban background	Grácia	38.1	38.2

Daily mean reductions

At the cleaned site: - 8-9 μg/m^3

At the reference sites: - 3-5 μg/m^3

Cleaning-induced reduction: - 3-5 μg/m^3 (7-10%)

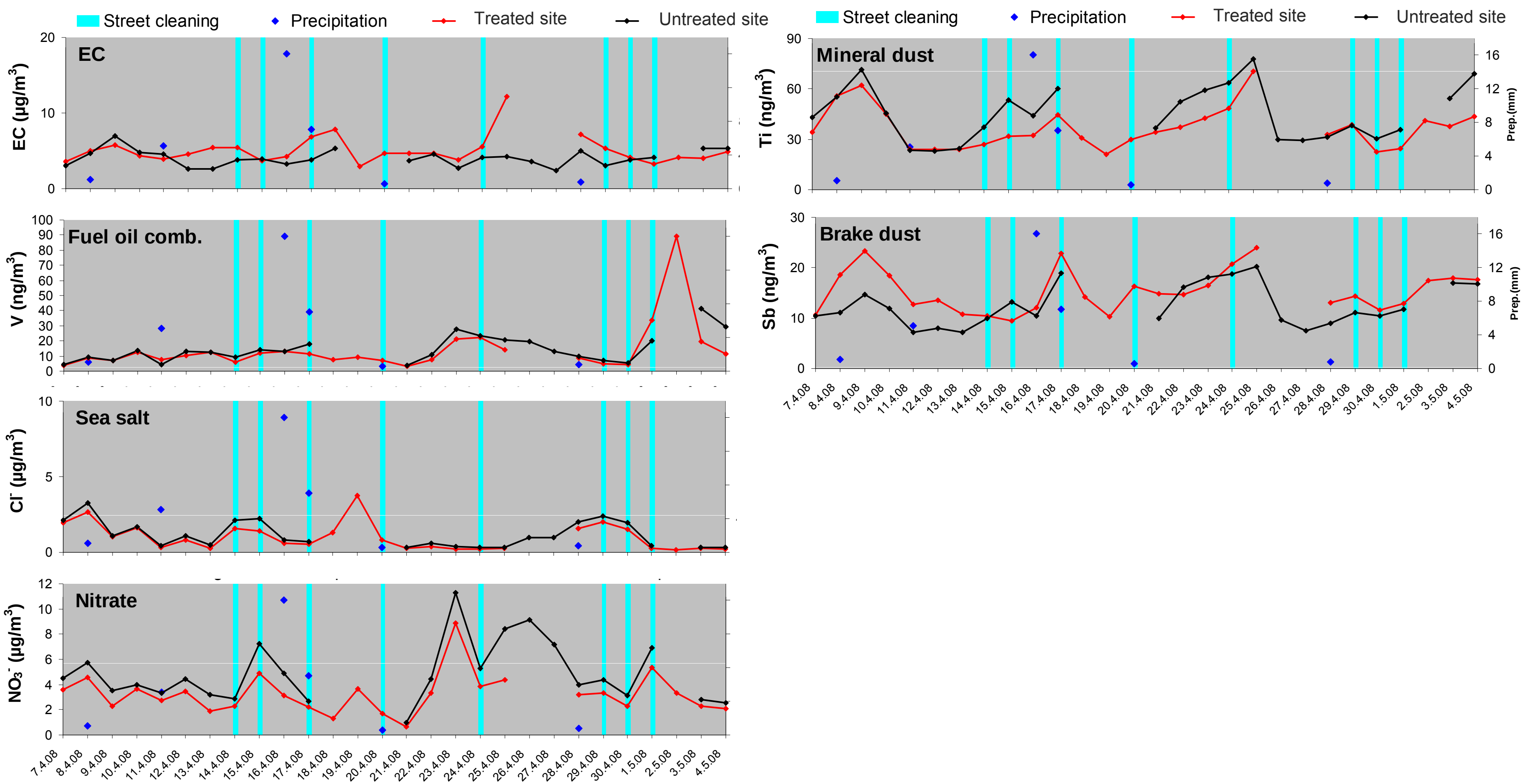
Case 1: Barcelona

Effect on atmospheric PM_{10}

Different aerosol types

test 2008

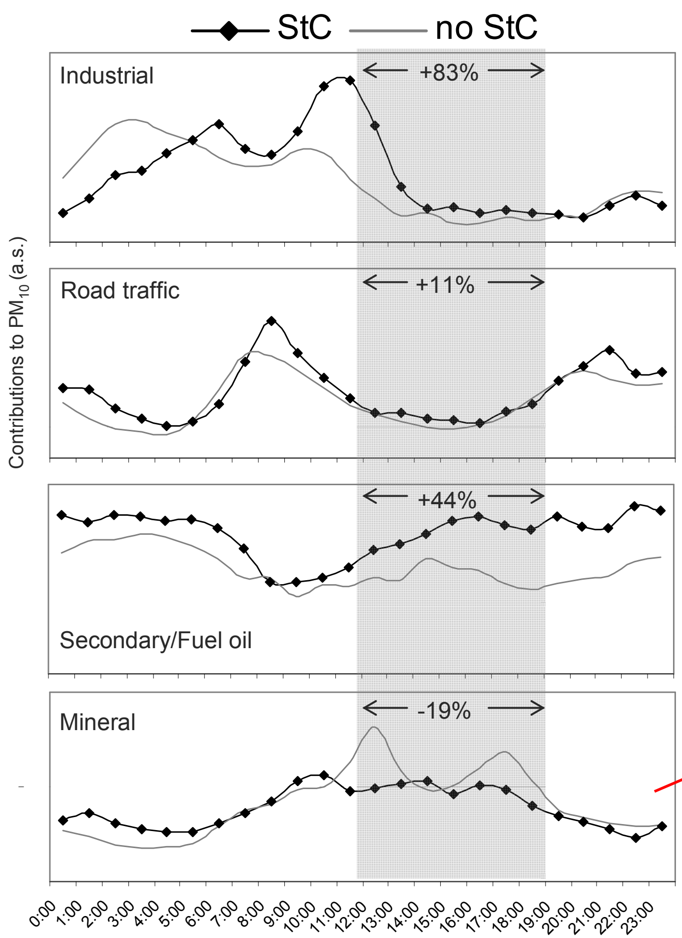
Amato et al., Atm. Env. 2009



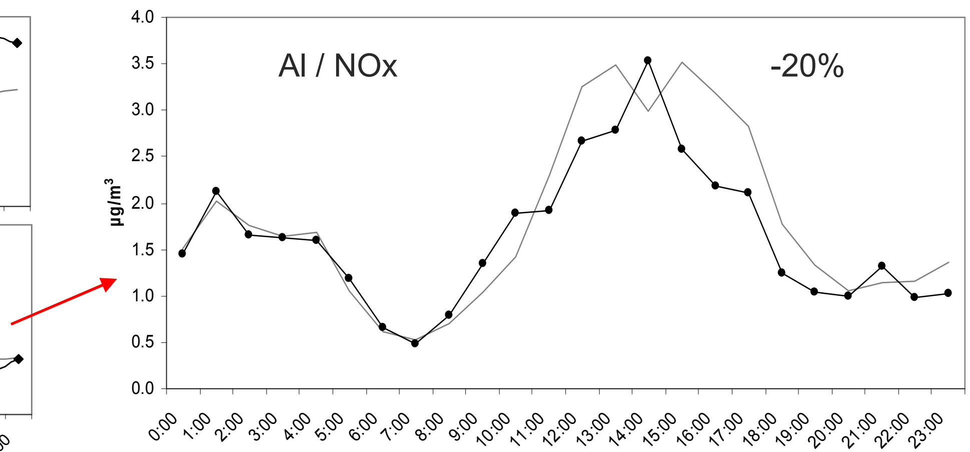
Case 1: Barcelona
Effect on atmospheric PM_{10}

Hourly elemental evolution test 2009

Amato et al., STOTEN 2010

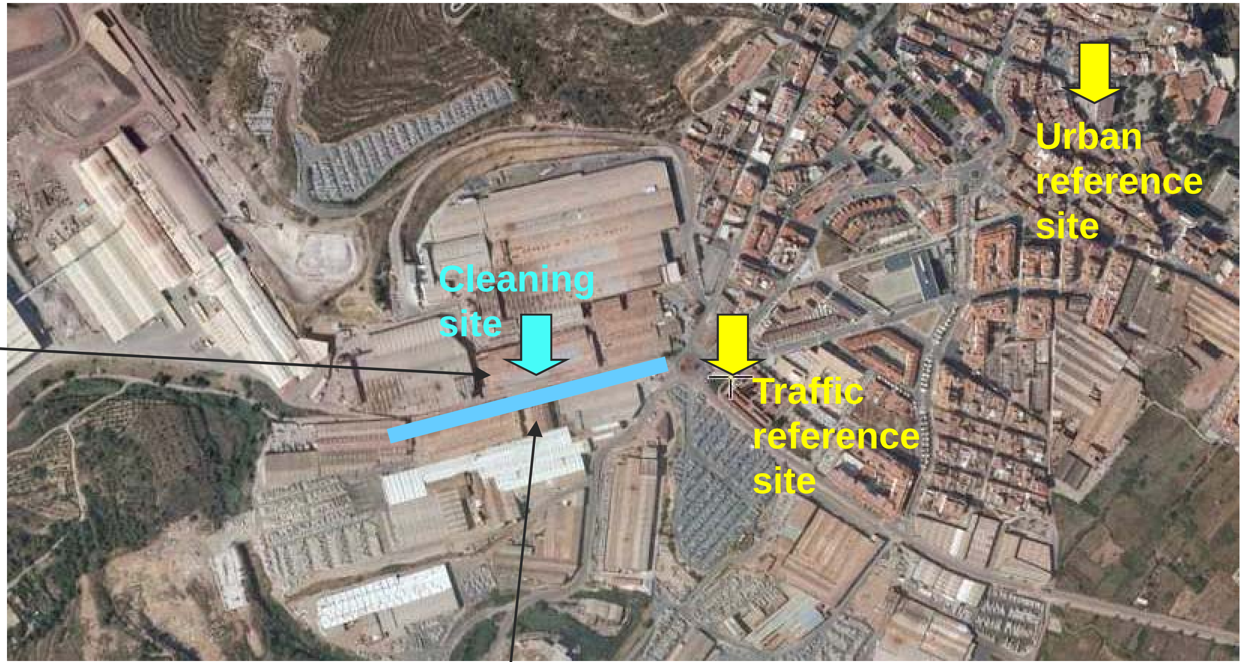


Cleaning days coincided with adverse meteo conditions and more congestion



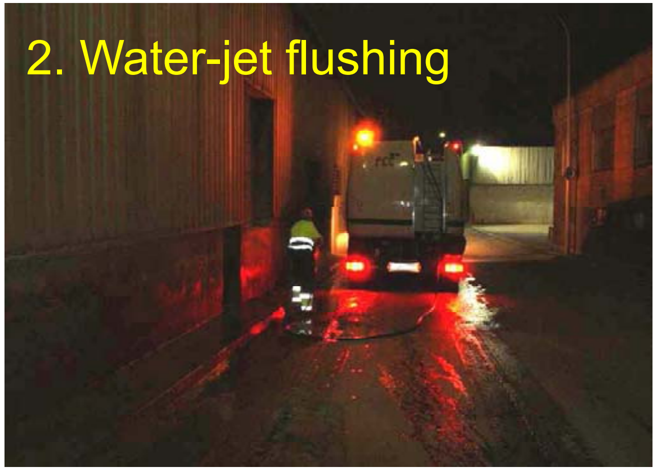
Case 2:
Castellón: Industrial ceramic production

- 250 companies (tiles, spray-dried granules, pigments..)
- 17% of the worldwide supply
- consumes 12 Mt/year of clay



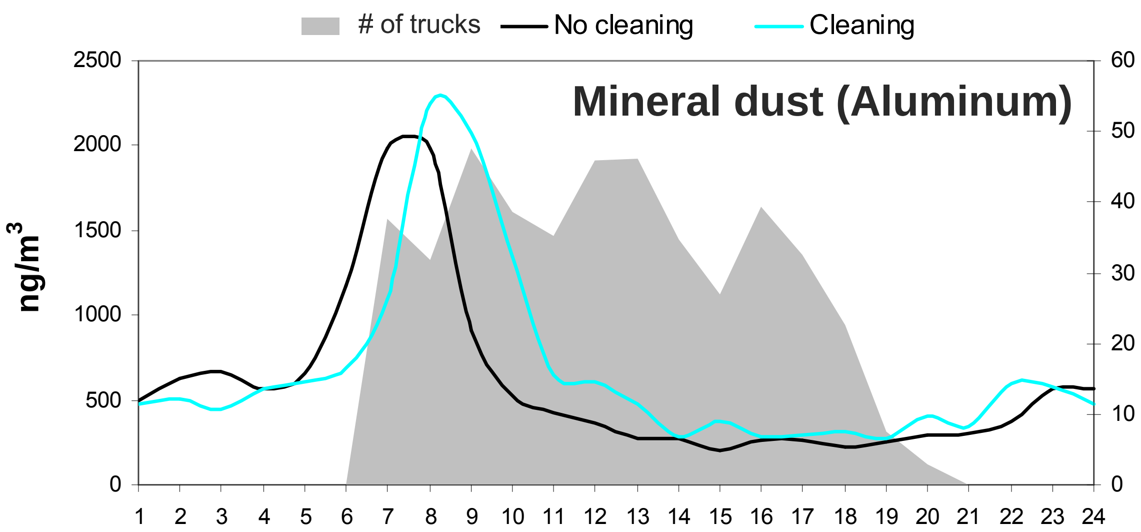
Measurements 30 m away from the road

Case 2: Castellón
Street Cleaning method



Case 2: Castellón
Effect on atmospheric PM_{10}

	Cleaning days	No cleaning	Reduction
Cleaned Canyon	43	50	-7
Reference 1	45	53	-8
Reference 2	31	34	-3

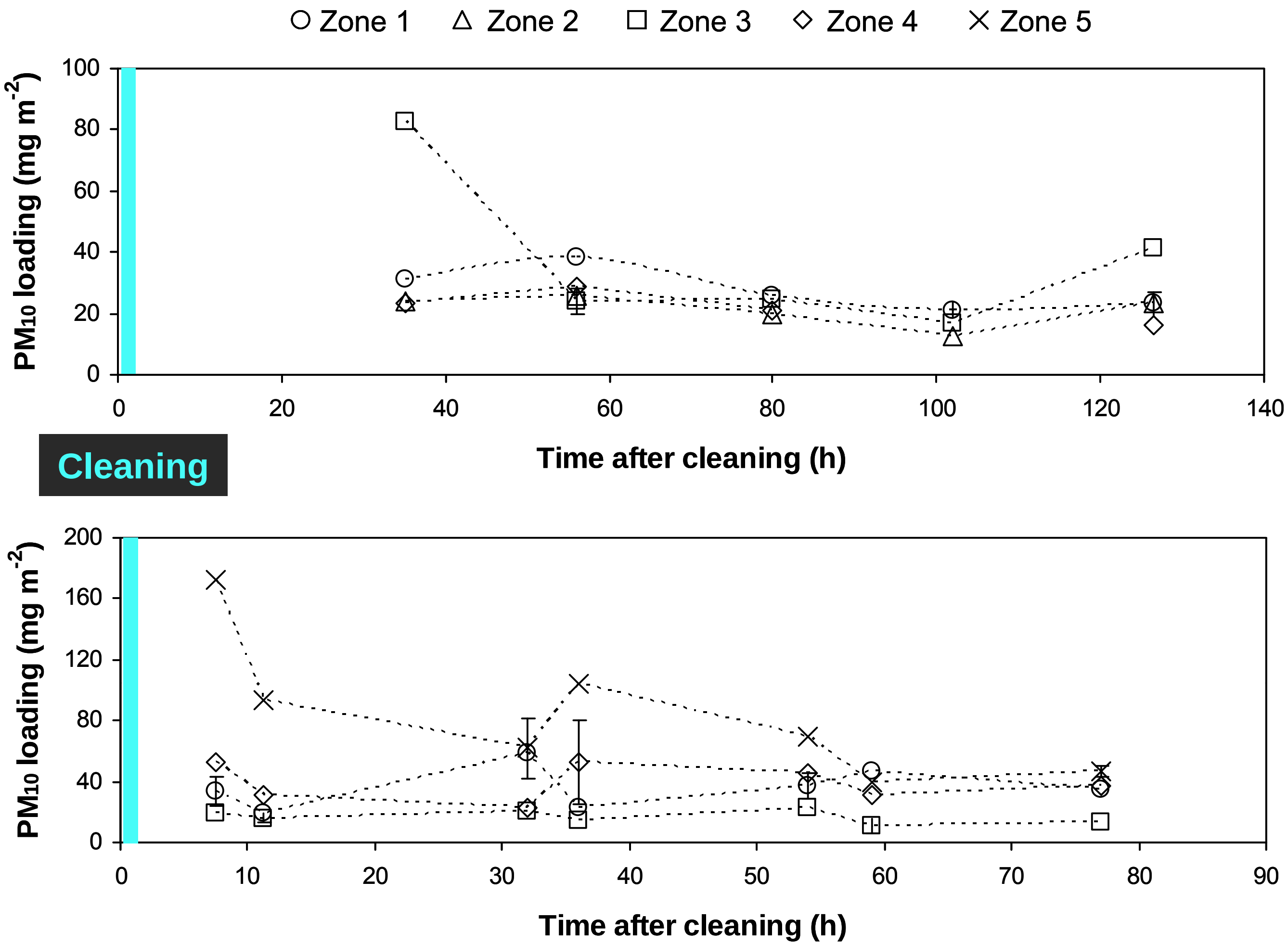


Why no reduction was observed?

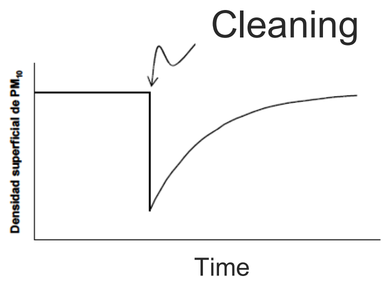
- measurements too distant from the road?
- huge deposition rate (46-85 mg m^{-2} h^{-1})?

Case 2: Castellón

Deposit build-up after cleaning



Escrig et al., under review



Deposition rate= 46-85 mg m^{-2} h^{-1}

Case 3:
Madrid city center

- Scarce industrial emissions, no shipping

Velazquez Avenue
32,000 veh day^{-1}

Case 3: Madrid

Street Cleaning methods

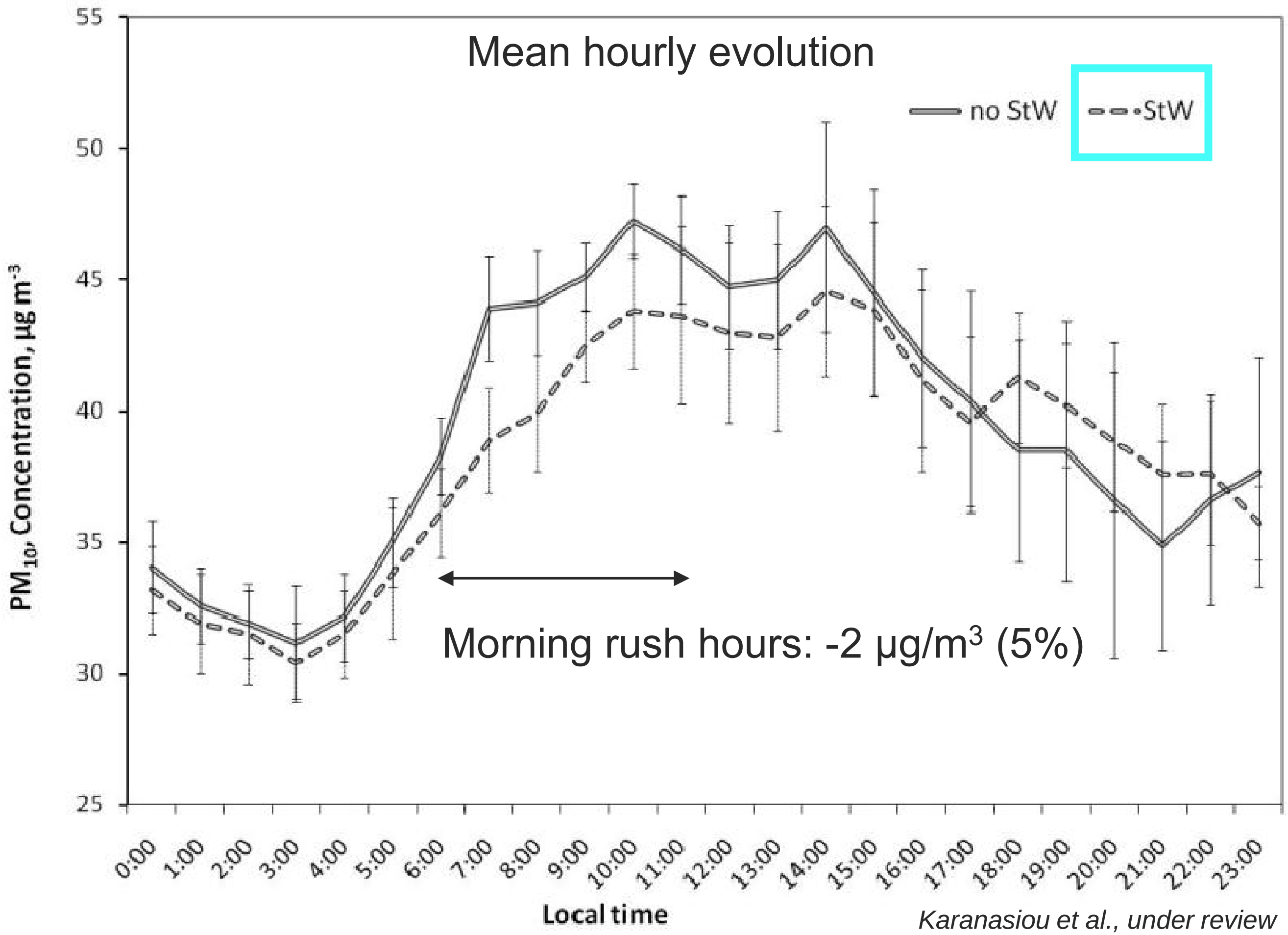
During several nights:

A) Vacuum-assisted sweeping

B) Water-jet flushing in all lanes

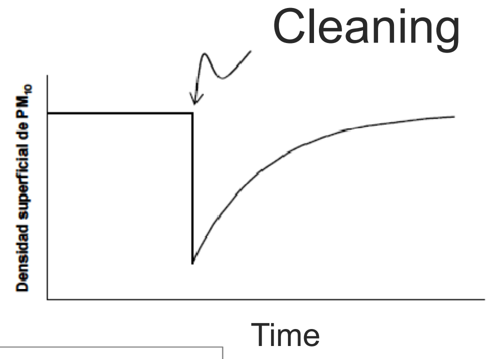
Case 3: Madrid
Effect on atmospheric PM_{10}

Kerbside concentrations

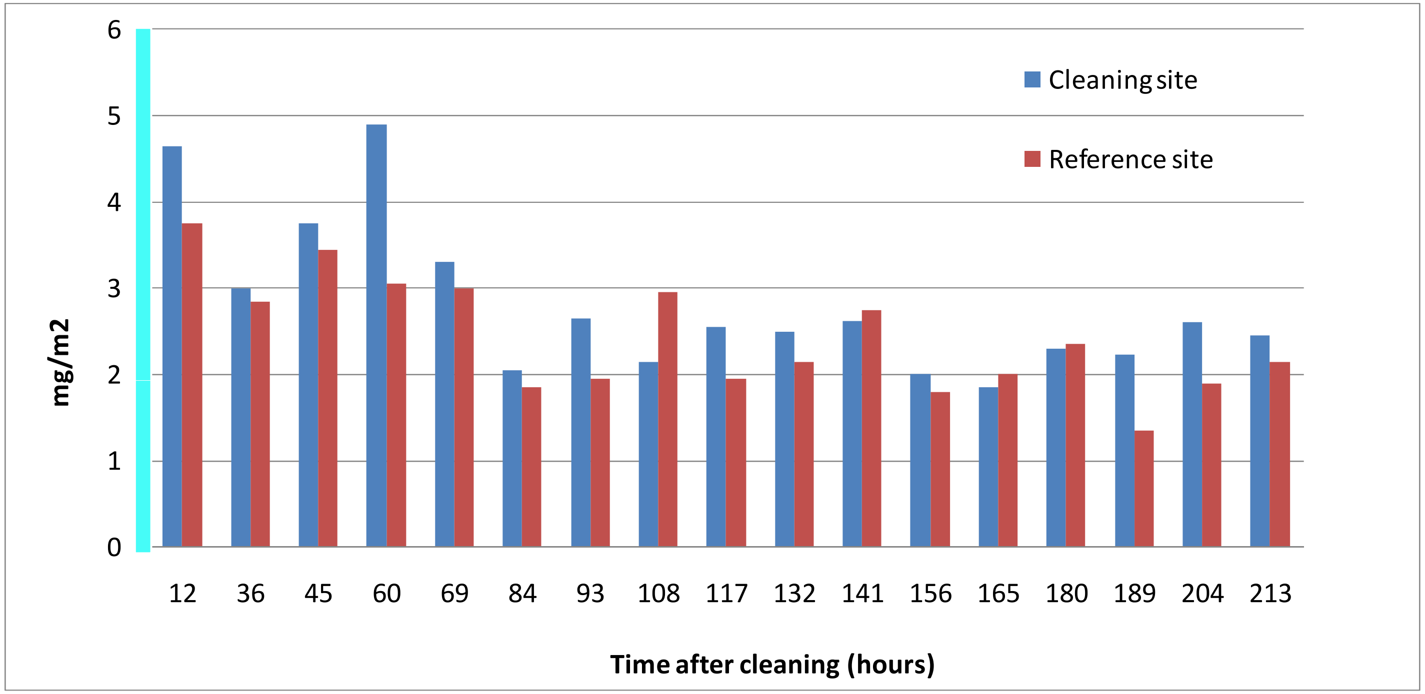


Karanasiou et al., under review

Case 3: Madrid
Deposit build-up after cleaning



The equilibrium value was reached in few hours



Conclusions

- **In general there is evidence of effectiveness of Street Cleaning (3 out of 4 cases)**

- **In some cases there is a difficulty in identifying the emission reduction.**

- Barcelona (urban site):
  - Ambient air PM_{10} **decrease at urban kerbside 7-10% on a daily mean**, identified with mineral and brake dust.
- Madrid (urban site):
  - Ambient air PM_{10} **decrease but short-lived** (5% during morning hours).
- Castellón (industrial site):
  - Huge deposition rate, **no reduction could be observed**, maybe also due to technical reasons.

- Tests on wider areas are needed in order to:
  - Increase the abatement of emissions
  - See effect on UB

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- Spanish Ministry of Science and Innovation
- Council of Alcora
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Thanks for your attention!

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