INDOOR & OUTDOOR AIR QUALITY IN SCHOOLS FROM BARCELONA

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erc
European Research Council
Established by the European Commission

BREATHE STUDY (ERC Advanced Grant, PI Jordi SUNYER)

(Brain dEvelopment and Air polluTion ultrafine particles in scHool childrEn)

Objectives (only of the exposure side)

- Characterizing children exposure to **URBAN AIR POLLUTANTS** in schools
- Source contribution of main sources of indoor & outdoor
- Factors affecting PM levels and composition indoor & outdoor: road traffic, ventilation & type of playground

BREATHE Brain Air School investigation

- **Impact and application of results after BREATH**
- **Other school related subsequent studies on:**
- **Guidance documents for improving air quality**
- **Green paths to schools and efficiency masks**
- **Ventilation guideline to reduce risk for COVID19**

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ISGlobal Barcelona Institute for Global Health

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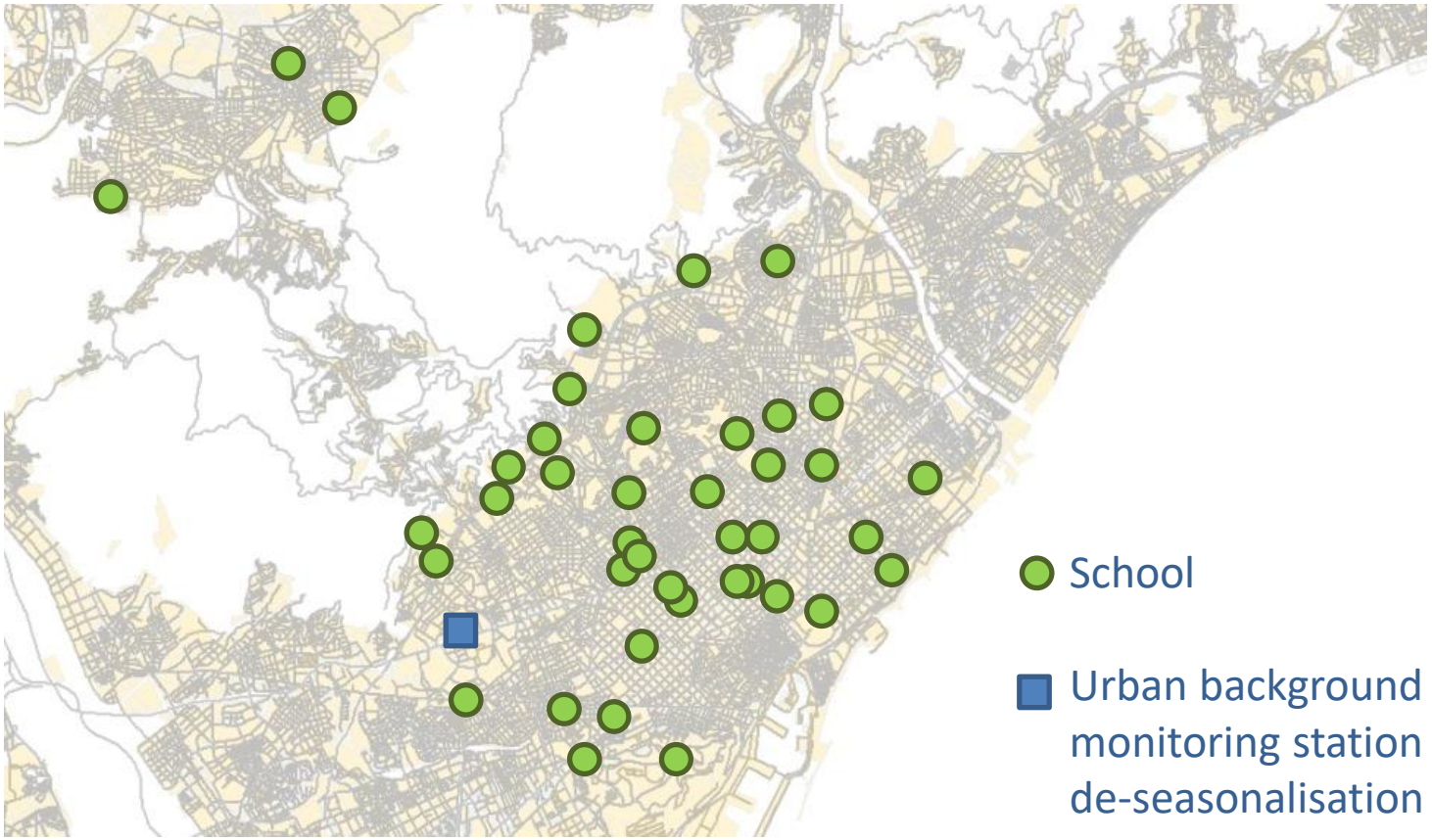
39 schools, 7-10 age children, 15 days (1 week cold 1 week warm seasons)



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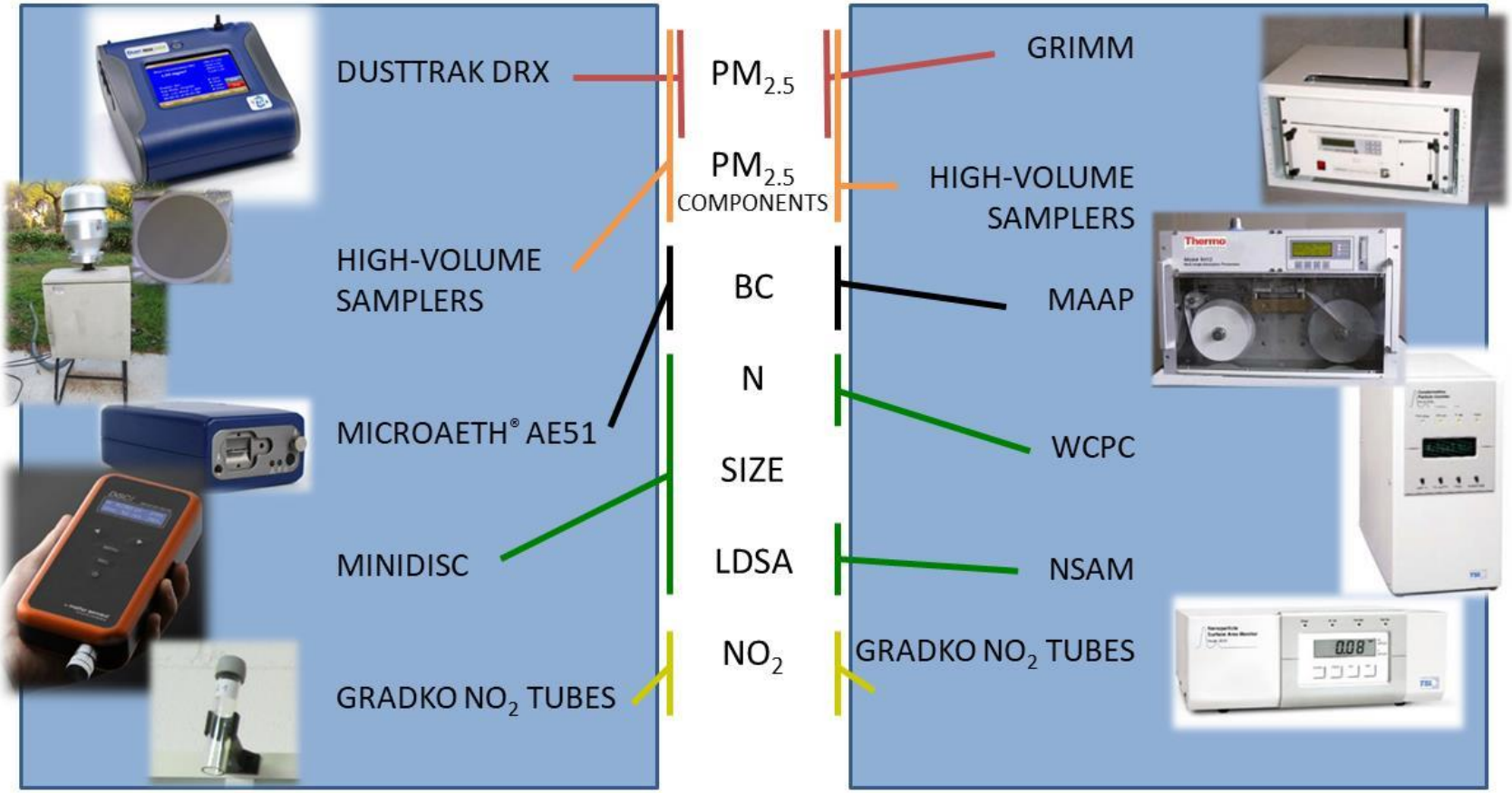
Measurements

1. February to June 2012
2. September 2012 to February 2013

- Two **simultaneous** schools & a **urban background reference station** of Palau Reial **(UB)**
- Simultaneously in **indoor** and **outdoor** school environments
- Sampling in **teaching hours** (9 to 17h), from Monday to Thursday
- **2 campaigns:**
  - 1 week/school in winter-spring
  - 1 week/school in fall-winter

SCHOOLS

UB REFERENCE SITE



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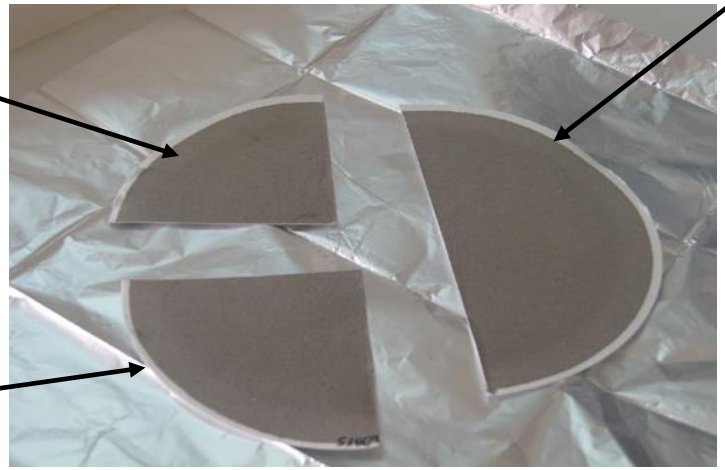
OC, EC
Organic speciation



Acidic digestion ($HF:HNO_3:HClO_4$)

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

H_2O leaching

Ion Chromat.:
NO_3^-, Cl^-, $SO_4^=$

Colorimetry FIA and ICP-AES:
NH_4^+, K^+, Ca^{2+}, Mg^{2+},…

Mass determined: 75-85% $PM_{2.5}$

BC Exposure

- **54 children** (7-10 years old) participate in personal monitoring of BC during 48h, **46 children valid**
- Children carried a belt bag with a MicroAeth AE51 (inlet tube in the breathing zone) and a GPS
- They filled in a time-activity diary reporting location and activity

Rivas I, et al., 2016. Spatio-temporally resolved BC concentration, schoolchildren's exposure and dose in Barcelona. Indoor Air

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Rivas I., et al ., 2014. Environment International 69, 200–212.

	INDOOR		OUTDOOR		UB REF. STATION	
	Mean	SD	Mean	SD	Mean	SD
NO_2 ($\mu g \cdot m^{-3}$)	30	13	47	19	41	20
$PM_{2.5}$ ($\mu g \cdot m^{-3}$)	37	16	29	24	17	8
N ($pt \cdot cm^{-3}$)	15625	6673	23614	9514	14665	6034
EBC ($\mu g \cdot m^{-3}$)	1.3	0.9	1.4	1.1	1.3	0.8

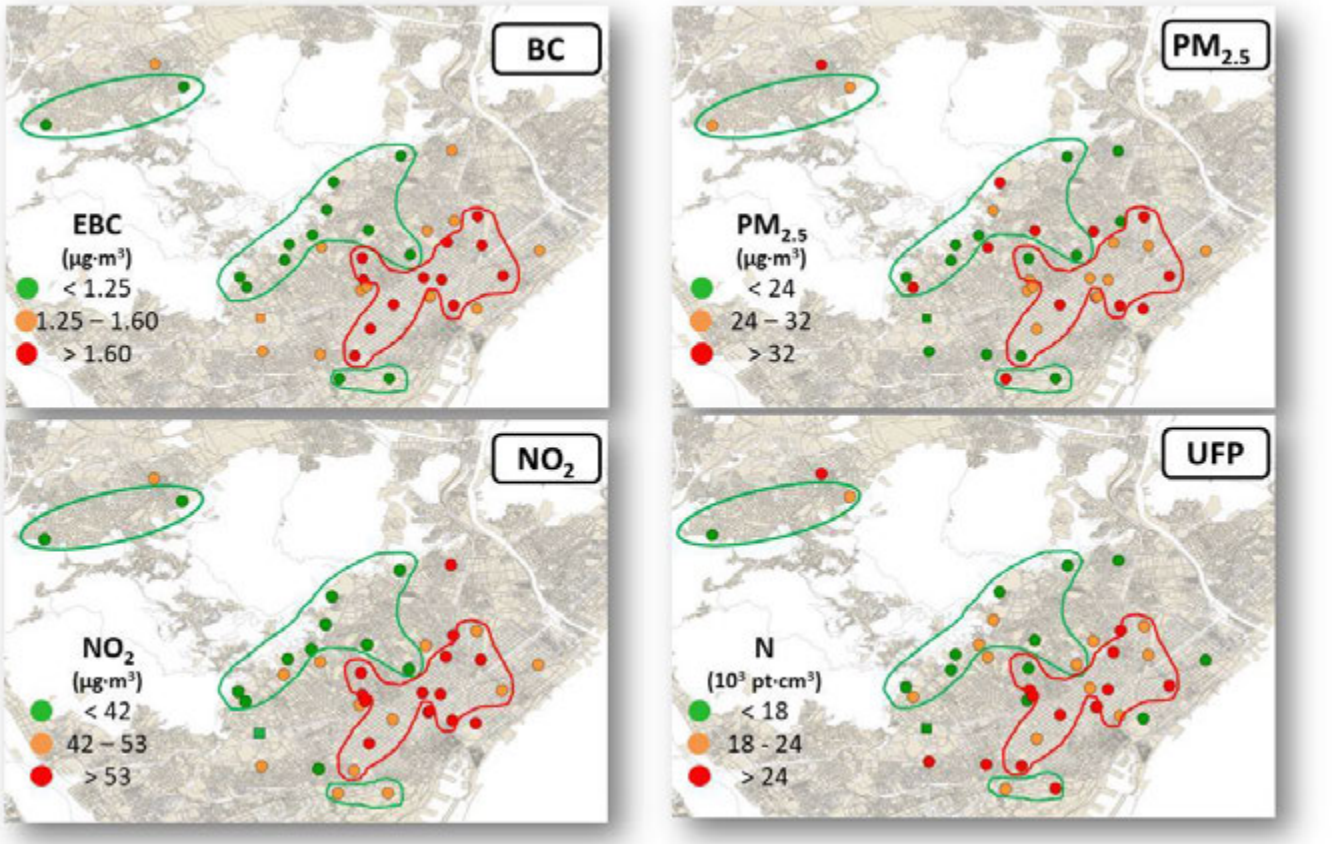
NO_2 outdoor levels for the rest of schools in Barcelona = 50 $\mu g \cdot m^{-3}$

- **High levels of $PM_{2.5}$ in schools → Local (school) emission of $PM_{2.5}$**
- **Mean levels of pollutants are intermediate between traffic and urban background sites**

Rivas I., et al ., 2014. Environment International 69, 200–212.

OUTDOOR

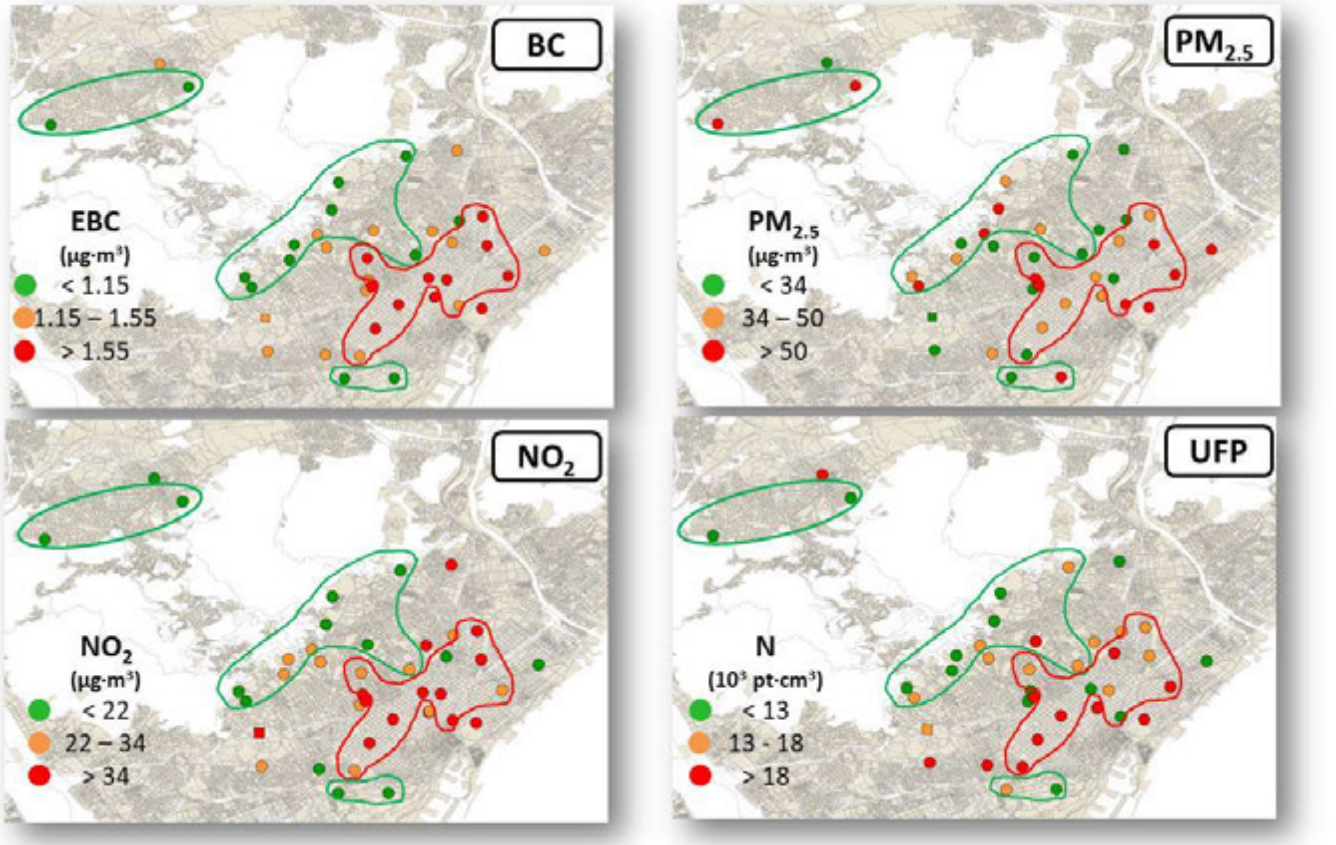
BREATHE Schools Reference Station Low High EC levels perimetre OUTDOOR



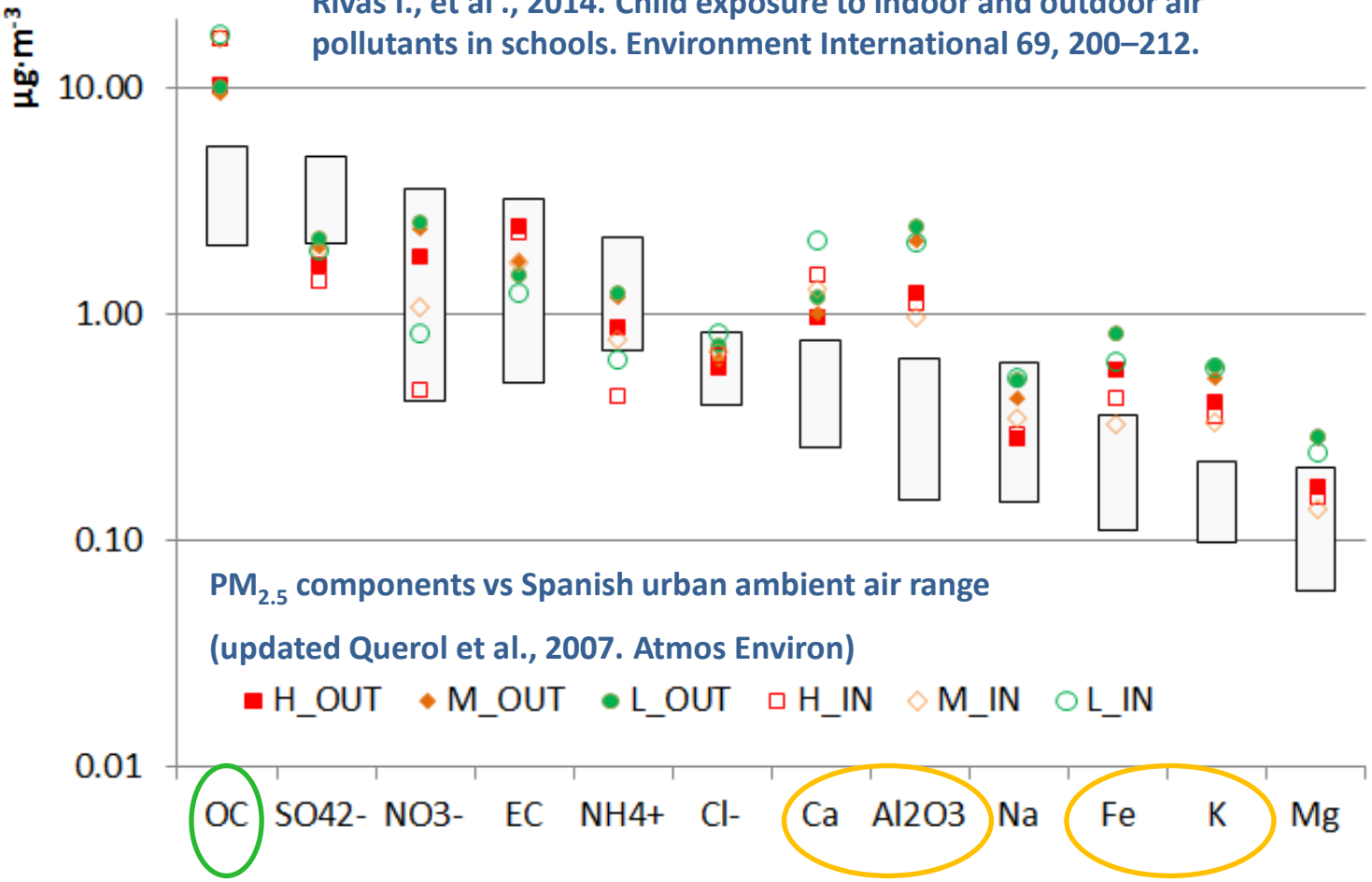
Rivas I., et al ., 2014. Environment International 69, 200–212.

INDOOR

BREATHE Schools Reference Station Low High EC levels perimetre OUTDOOR



Rivas I., et al ., 2014. Child exposure to indoor and outdoor air pollutants in schools. Environment International 69, 200–212.



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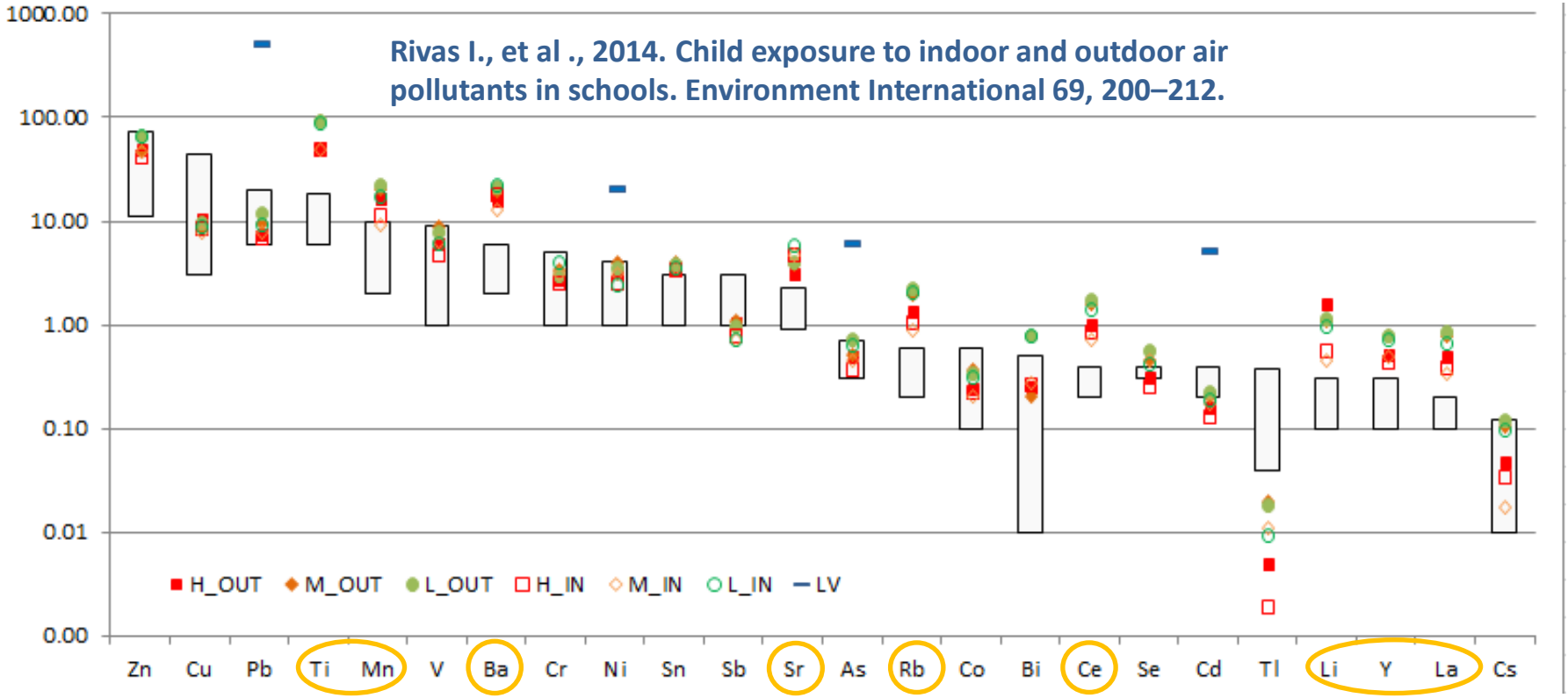

Rivas I., et al ., 2014. Child exposure to indoor and outdoor air pollutants in schools. Environment International 69, 200–212.

$PM_{2.5}$ components vs Spanish urban ambient air range

(updated Querol et al., 2007. Atmos Environ)

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Schools have been classified based on outdoor EC, Cu, Sb, Sn and outdoor NO_2 into 3 categories of road traffic influence

$$\left[\frac{C_{iNO_2}}{X_{NO_2}}\ x\ 0.2\right] + \left[\frac{C_{iEC}}{X_{EC}}\ x\ 0.2\right] + \left[\frac{C_{iCu}}{X_{Cu}}\ x\ 0.2\right] + \left[\frac{C_{iSb}}{X_{Sb}}\ x\ 0.2\right] + \left[\frac{C_{iSn}}{X_{Sn}}\ x\ 0.2\right]$$

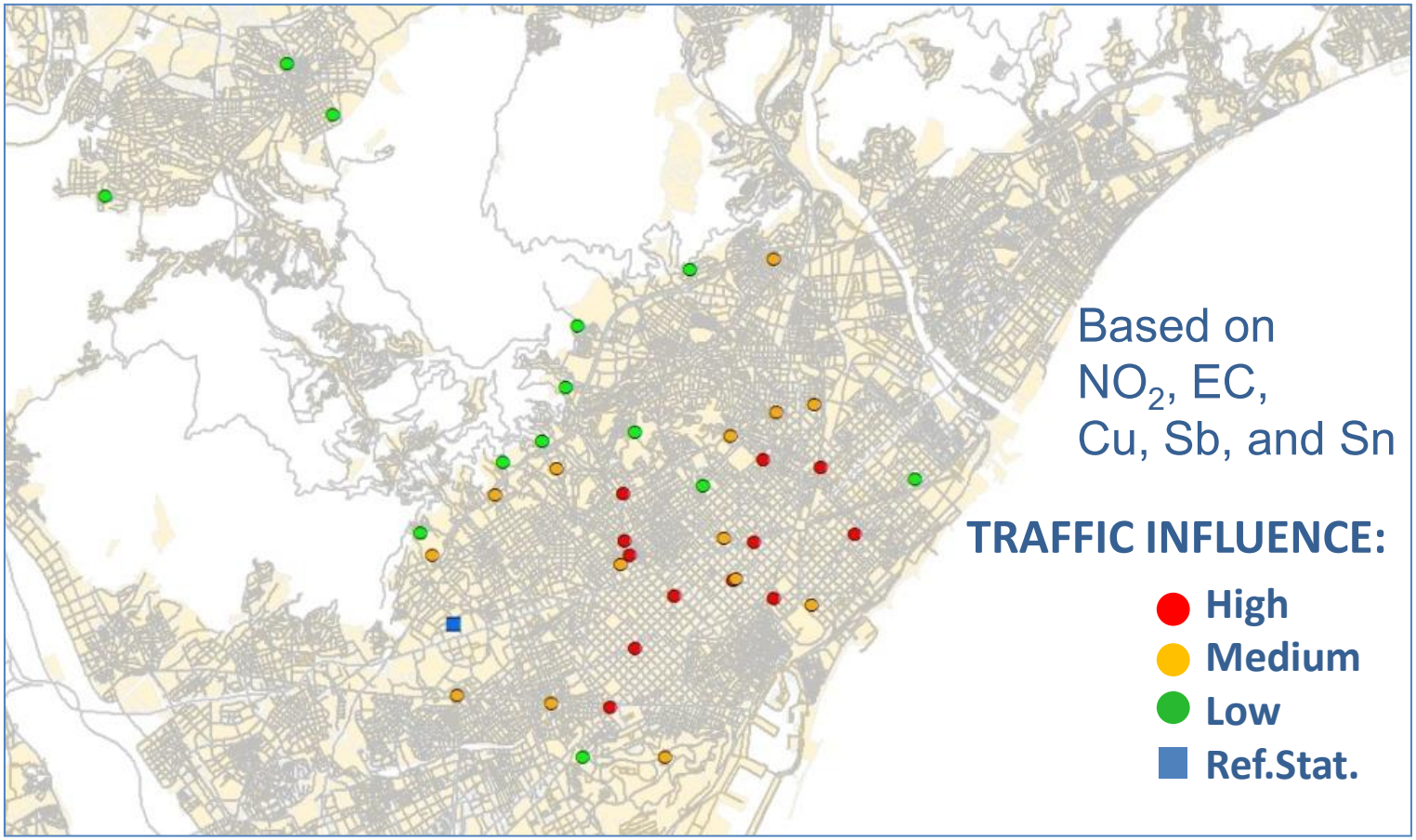
Cij: Mean concentration of the component in a given school
Xj: Mean concentration of the component for al school

Outdoor

Factor 1 Crustal		Factor 2 Traffic		Factor 3 comb+ sec		Factor 4 Industrial	
Mg	1.0	**Cu**	0.8	**SO42-**	0.8	**Cr**	0.7
Al2O3	1.0	**Sb**	0.8	**Se**	0.8	**Ni**	0.5
Cs	1.0	**EC**	0.8	**V**	0.7	Cd	0.4
Rb	1.0	**OC**	0.7	**Ni**	0.6	Ba	0.4
Ti	1.0	**NO3-**	0.7	**NH4+**	0.6	Th	0.3
Ga	1.0	**Sn**	0.7	Sn	0.3	Pb	0.2
Fe	1.0	**Pb**	0.7	As	0.3	NO3-	0.2
Ce	1.0	**As**	0.7	PM2.5	0.2	Co	0.2
La	1.0	**NH4+**	0.6	Na	0.2	Zn	0.2
Mn	1.0	**Zn**	0.6	Pb	0.2	As	0.2
K	0.9	**Cd**	0.6	OC	0.2	Sr	0.2
Sr	0.9	**PM2.5**	0.5	NO3-	0.2	Cu	0.2
Sc	0.9	Cr	0.4	Nb	0.2	La	0.2
Co	0.9	Ba	0.3	Cd	0.2	Ce	0.2
Nb	0.9	SO42-	0.3	Th	0.2	Ca	0.1
Ca	0.9	K	0.2	Co	0.2	V	0.1
Th	0.8	Co	0.2	Sc	0.1	Mn	0.1
Na	0.8	Mn	0.2	EC	0.1	Sc	0.1
PM2.5	0.8	Se	0.2	Ga	0.1	NH4+	0.1
Ba	0.8	V	0.2	Al2O3	0.1	Ga	0.1
Li	0.7	Ca	0.2	Ce	0.1	Al2O3	0.1
As	0.5	La	0.2	La	0.1	Rb	0.1
V	0.5	Th	0.2	Mg	0.1	PM2.5	0.1

Rivas I., et al ., 2014. Child exposure to indoor and outdoor air pollutants in schools. Environment International 69, 200–212.

Classification of the schools based on traffic-related pollutants levels



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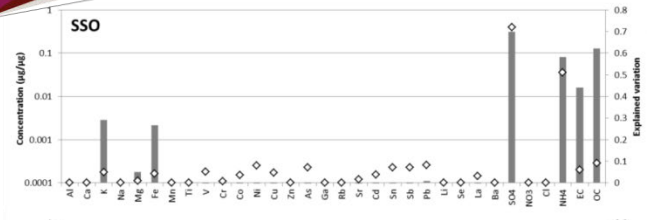
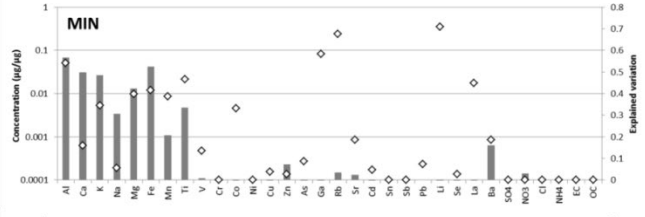
PMF source apportionment PM2.5

Amato A., et al., 2014. Sources of indoor and outdoor PM2.5 concentrations in primary schools. The Science of Total Environment, 490, 757–765

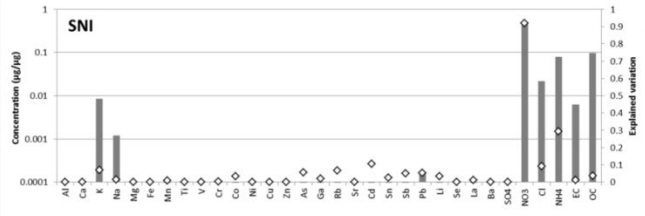
Secondary Sulfate



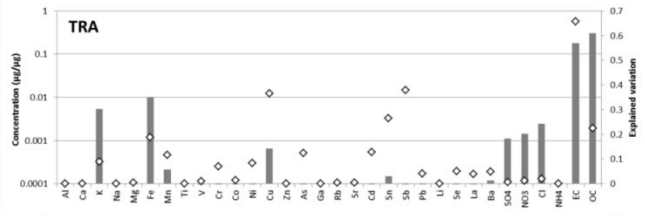
Mineral



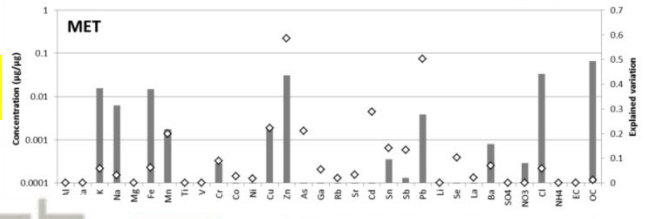
Secondary Nitrate



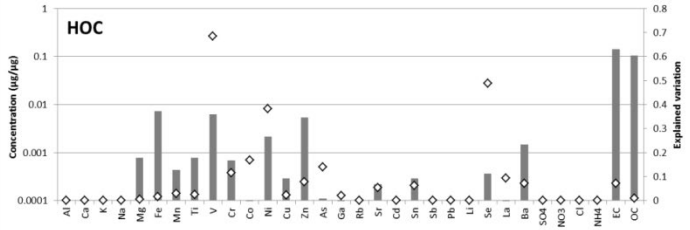
Traffic



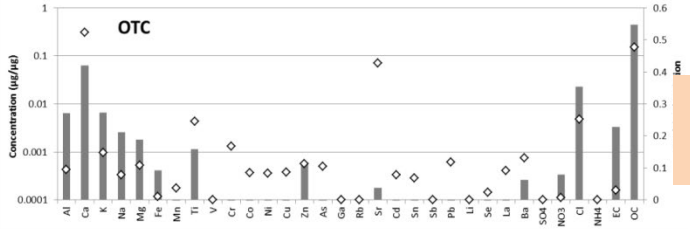
Metallurgy



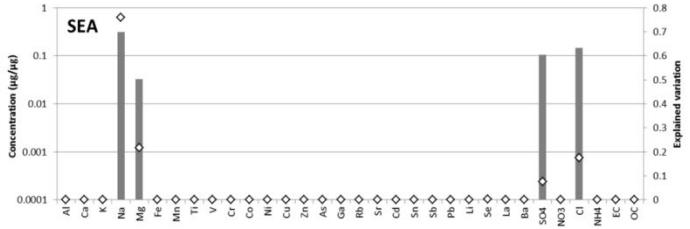
Heavy oil combustion



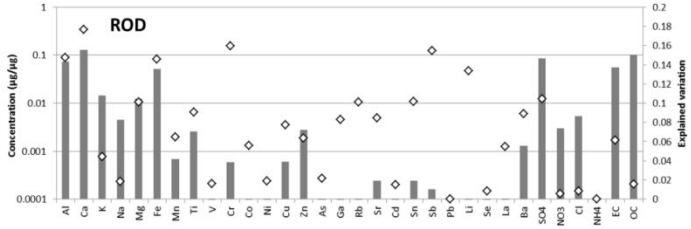
Organics/Textile/Chalk



Sea salt



Road dust



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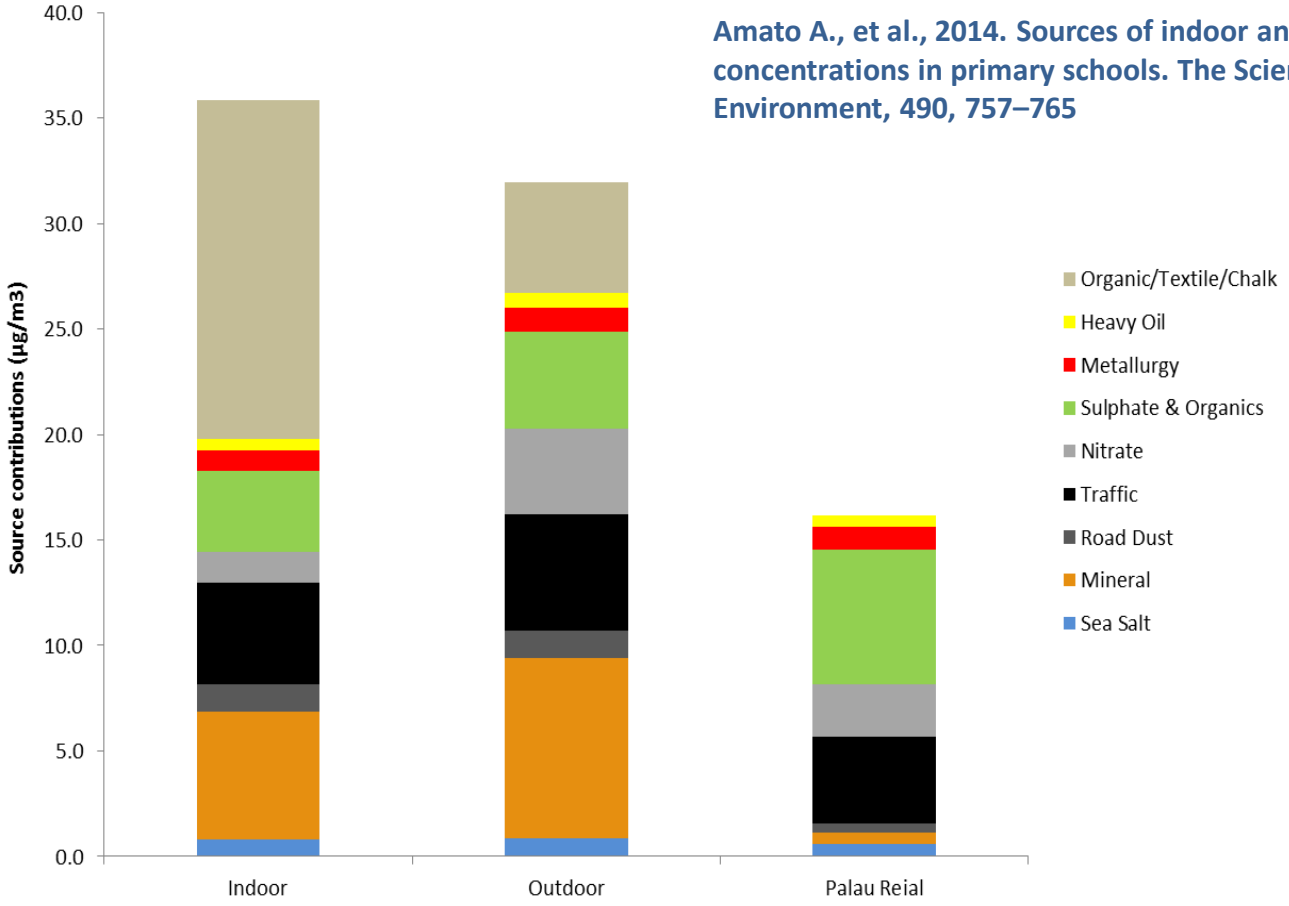
PM2.5 SOURCE APPORTIONMENT (POSITIVE MATRIX FACTORIZATION)

Amato A., et al., 2014. Sources of indoor and outdoor PM2.5 concentrations in primary schools. The Science of Total Environment, 490, 757–765



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Every 2 years sands are replaced and mineralogy taken into account

Mineral sources

PM2.5 (µg/m³)	Paved playground	Unpaved playground
Reference site	0.6	
Schools (outdoor)	2.5	16.0
Schools (indoor)	3.6	9.1

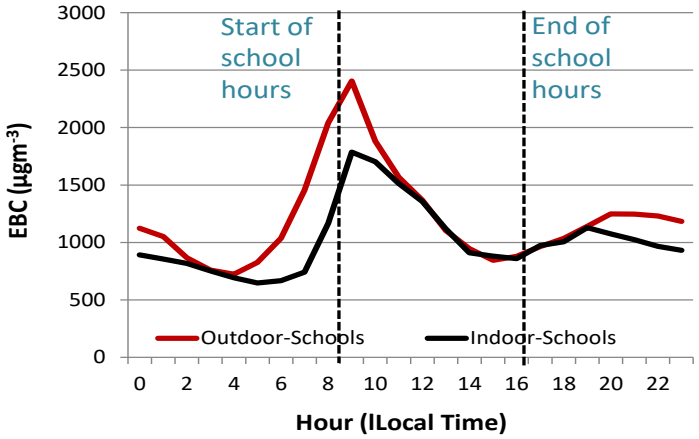
Indoor resuspension

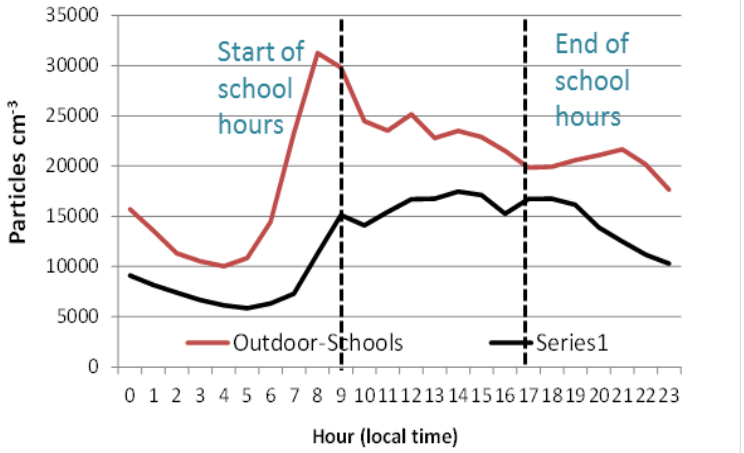
Increases indoors PM2.5 by 5-6 µg/m³

Moreno et al., 2014. *Atmospheric Environment 91, 162-171*

Amato A., et al., 2014. The Science of Total Environment, 490, 757–765

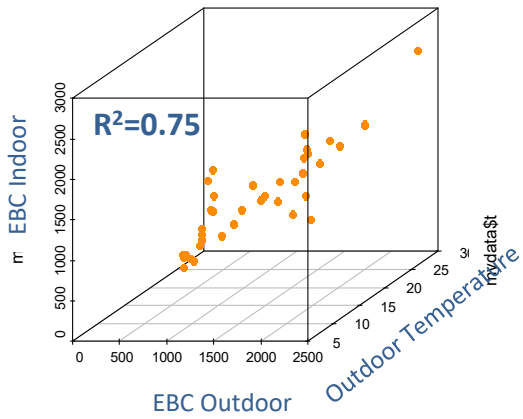
Reche C. et al., 2014. Science of the Total Environment 493, 943-953.
Reche C., et al.., 2015. Atmospheric Environment 120, 417-426.

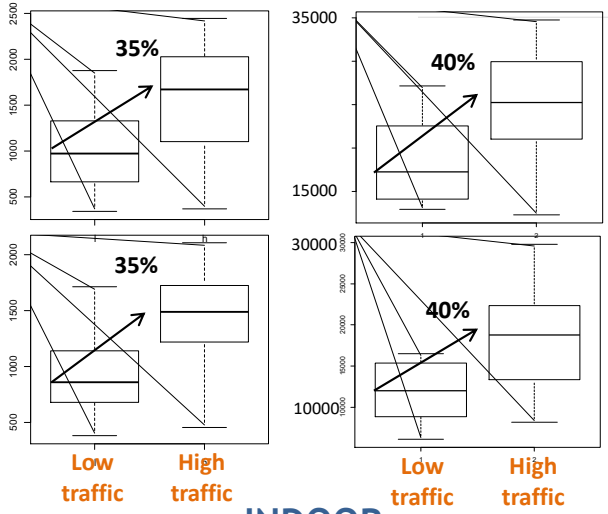




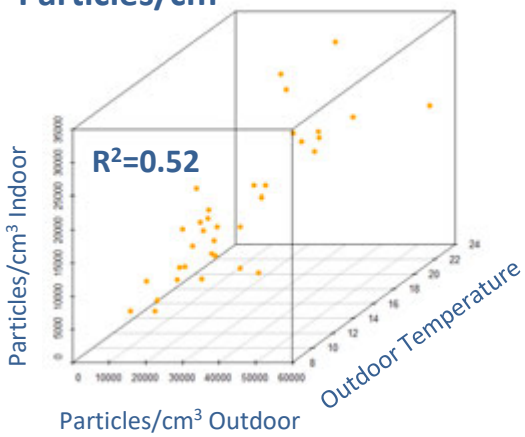
OUTDOOR

EBC (µg/m³)





Particles/cm³



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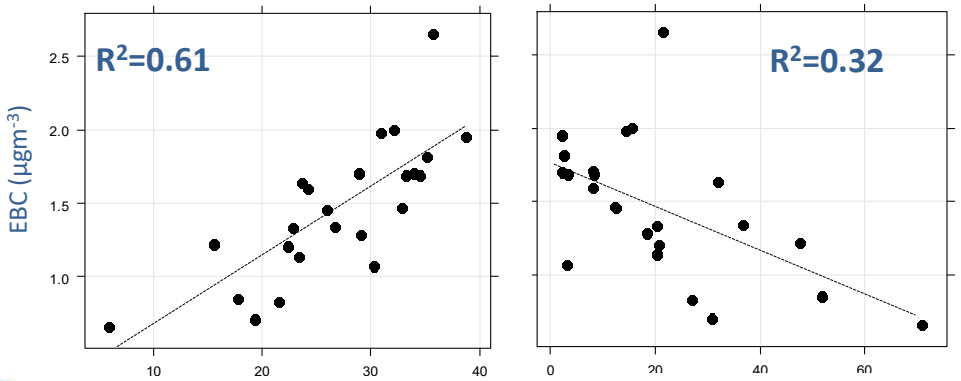
Reche C. et al., 2014. Science of the Total Environment 493, 943-953.
Reche C., et al.., 2015. Atmospheric Environment 120, 417-426.
Dadvand P. et al., 2015. PNAS, 112, 26, 7937–7942.

Correlation between average **EBC levels and ultrafine particle concentrations** at different districts of the city of Barcelona and the percentage of surface area used for the **road network and for parks**



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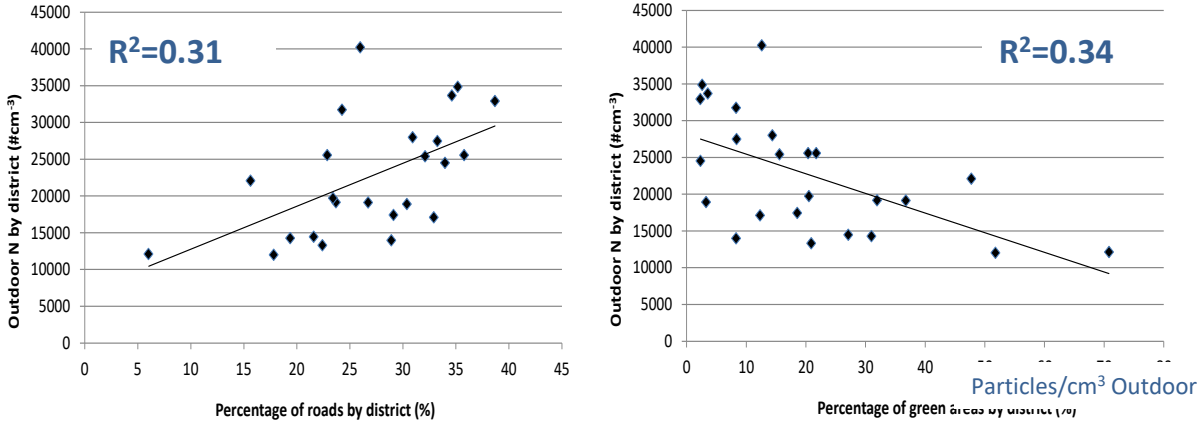

The 100 most traffic polluted schools identified & measures applied: reducing traffic & greening

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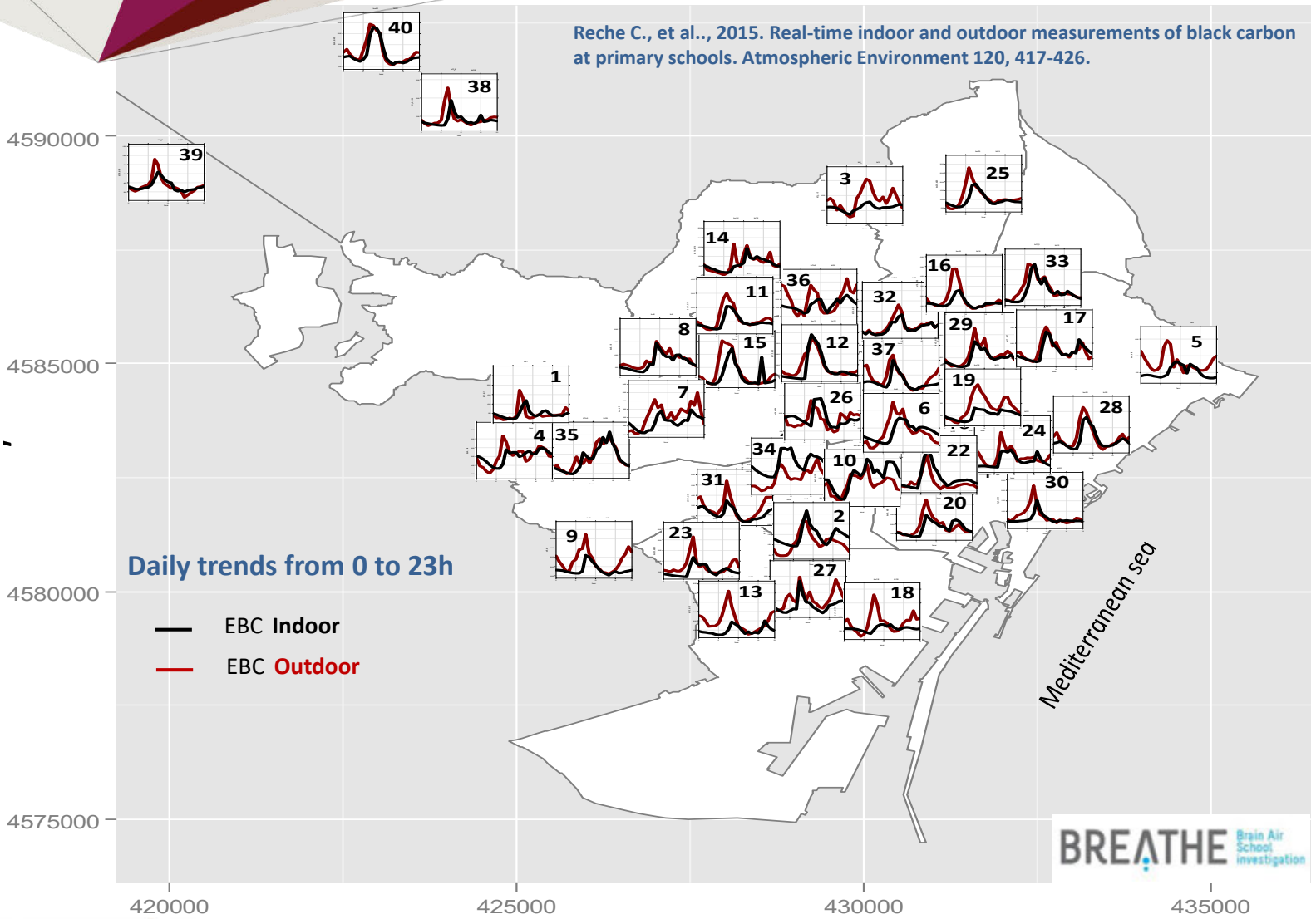
Black carbon in schools

Reche C., et al.., 2015. Real-time indoor and outdoor measurements of black carbon at primary schools. Atmospheric Environment 120, 417-426.



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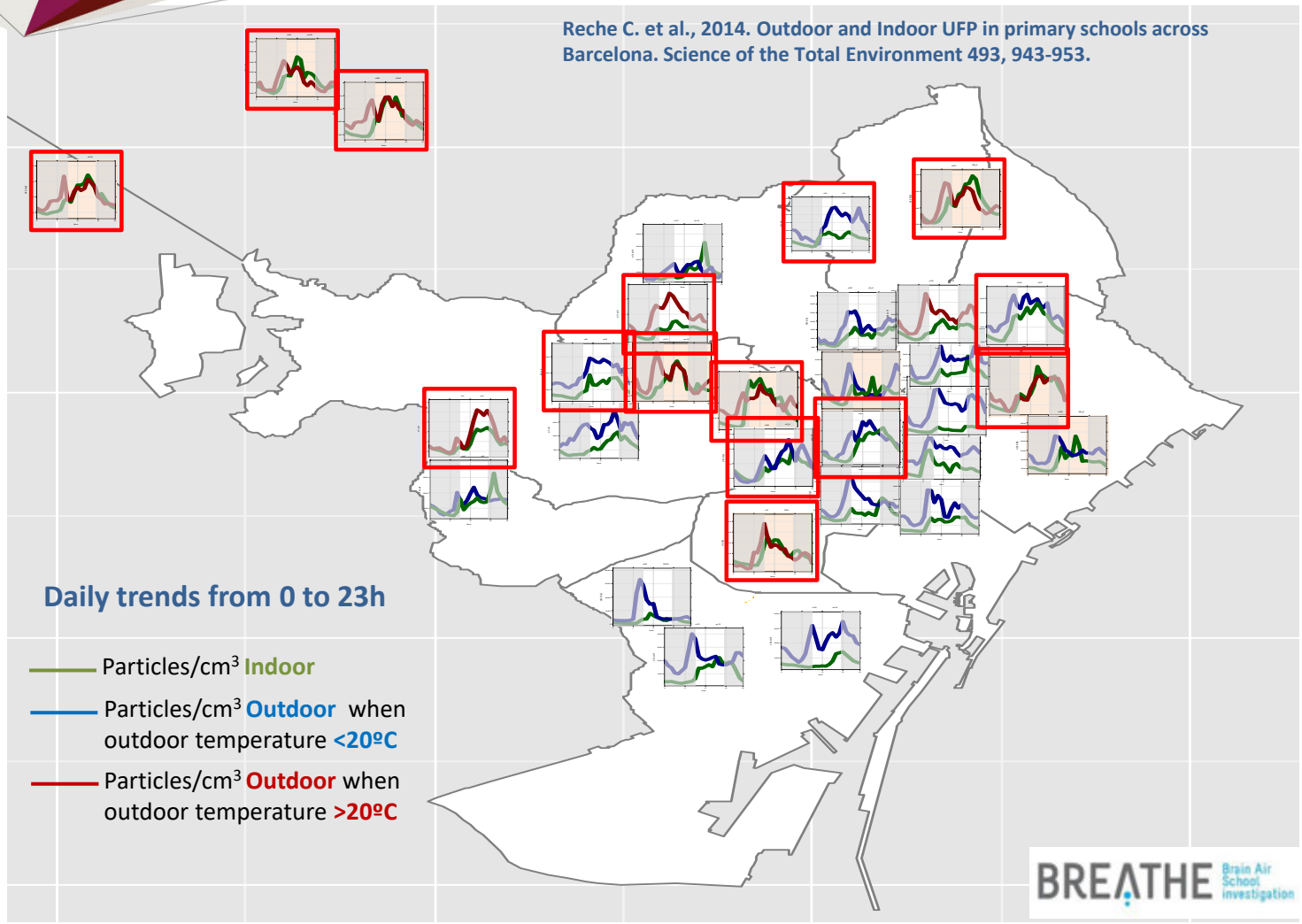
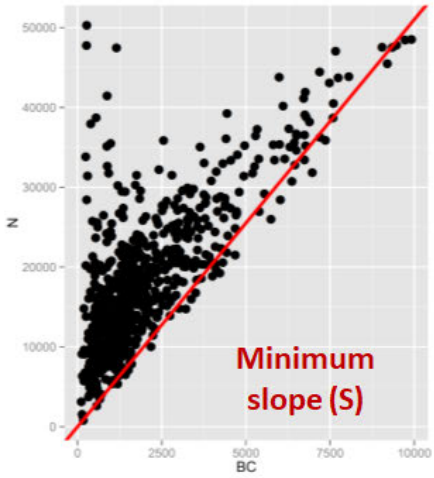
UFP in schools

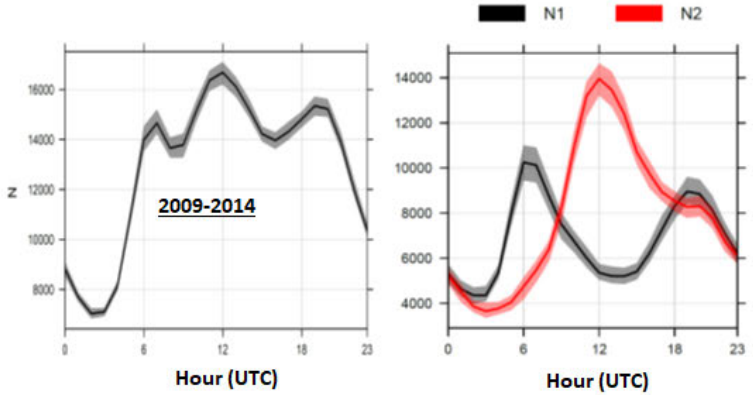
Reche C. et al., 2014. Outdoor and Indoor UFP in primary schools across Barcelona. Science of the Total Environment 493, 943-953.



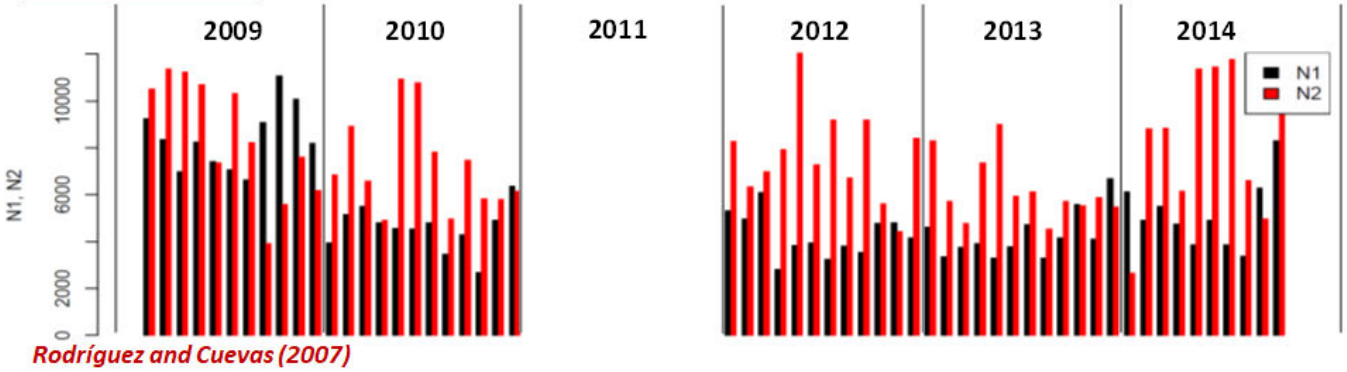
Primary vs secondary ultrafine particles



Contribution of minimum primary emissions (N1) and new particle formation enhancements (N2) in Barcelona urban environment



MONTHLY AVERAGES



Rodríguez and Cuevas (2007)

Methods: BC/UFP ratios, PMF, Clustering (Rodriguez & Cuevas, 2007; Harrison et al., 2011; Beddows et al., 2014)

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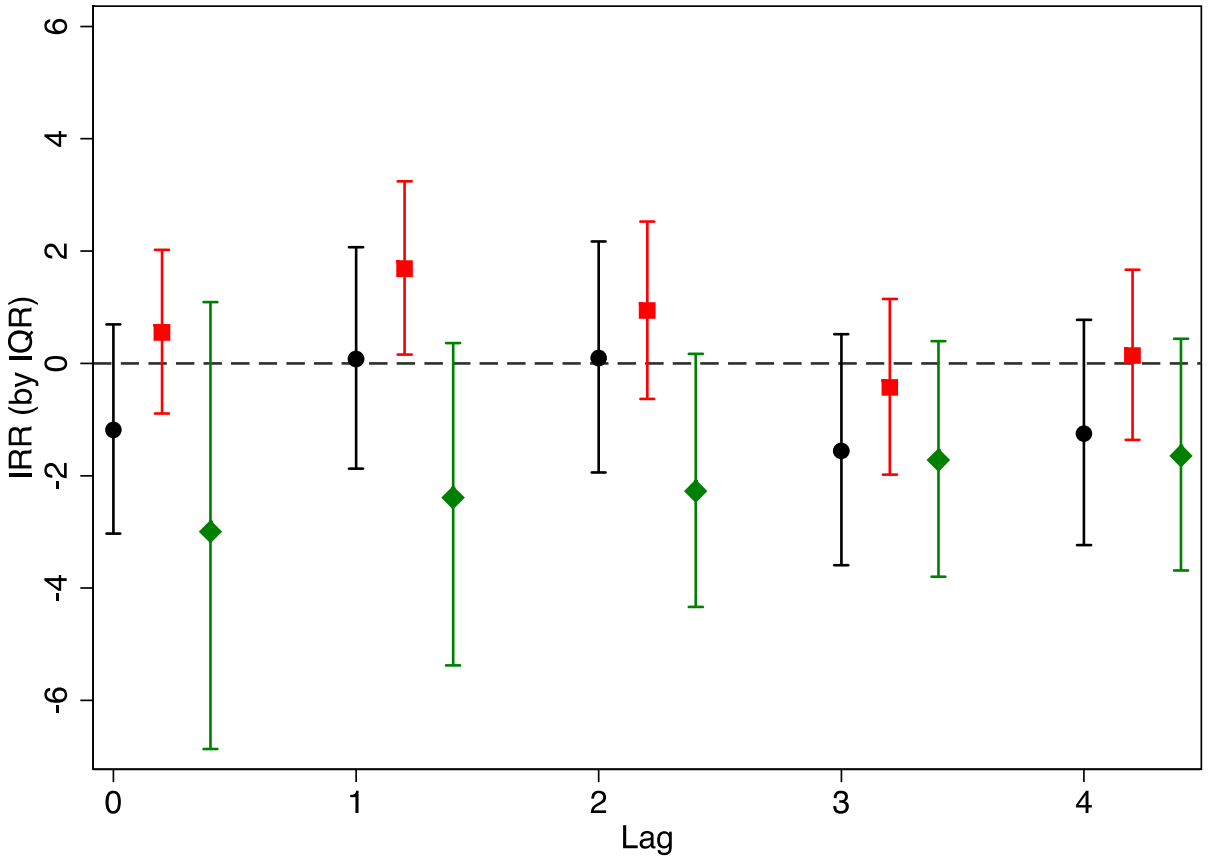
Short-term health effects of total, primary and secondary UFP in Barcelona 2009-2011 series total mortality



- **N total**
  IQR = 7313 ng/cm^3
- **N primary TRAFFIC**
  IQR = 3953 ng/cm^3
- **N secondary**
  IQR = 5749 ng/cm^3

Tobías A. et a., 2018. Environment International 111, 144-151

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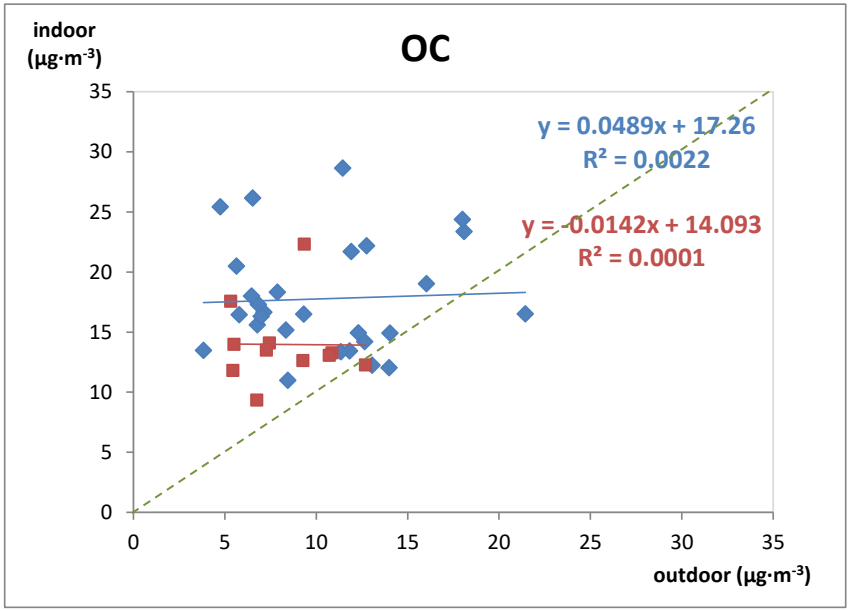
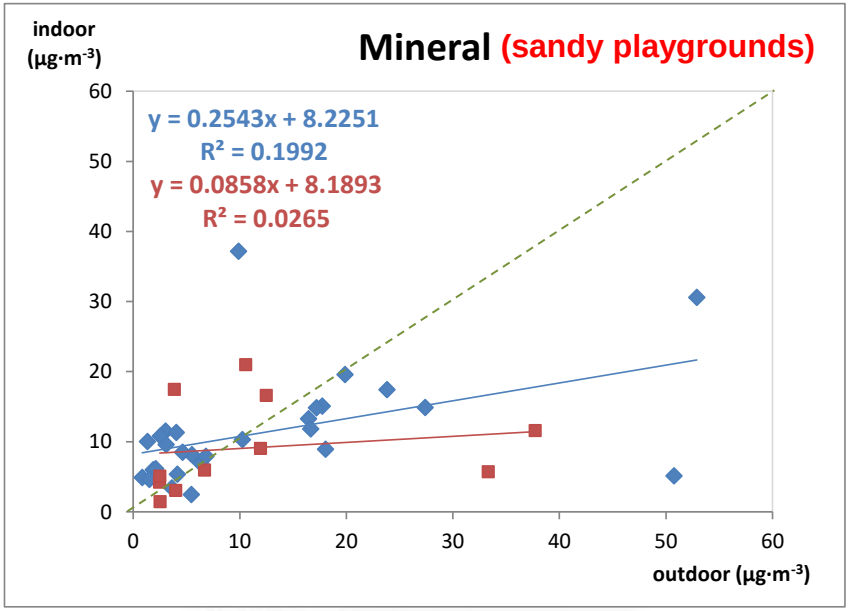
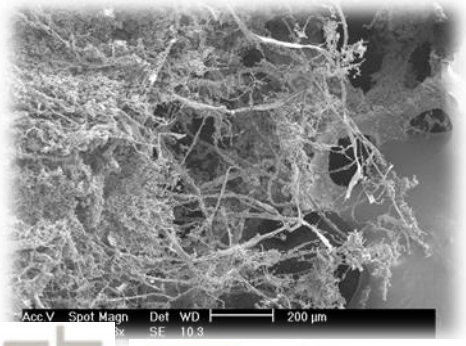
Rivas I., et al., 2015. Atmospheric Environment 106, 129-138.

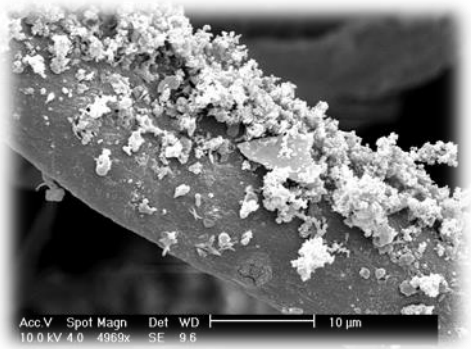
◆ Closed windows

■ Opened windows









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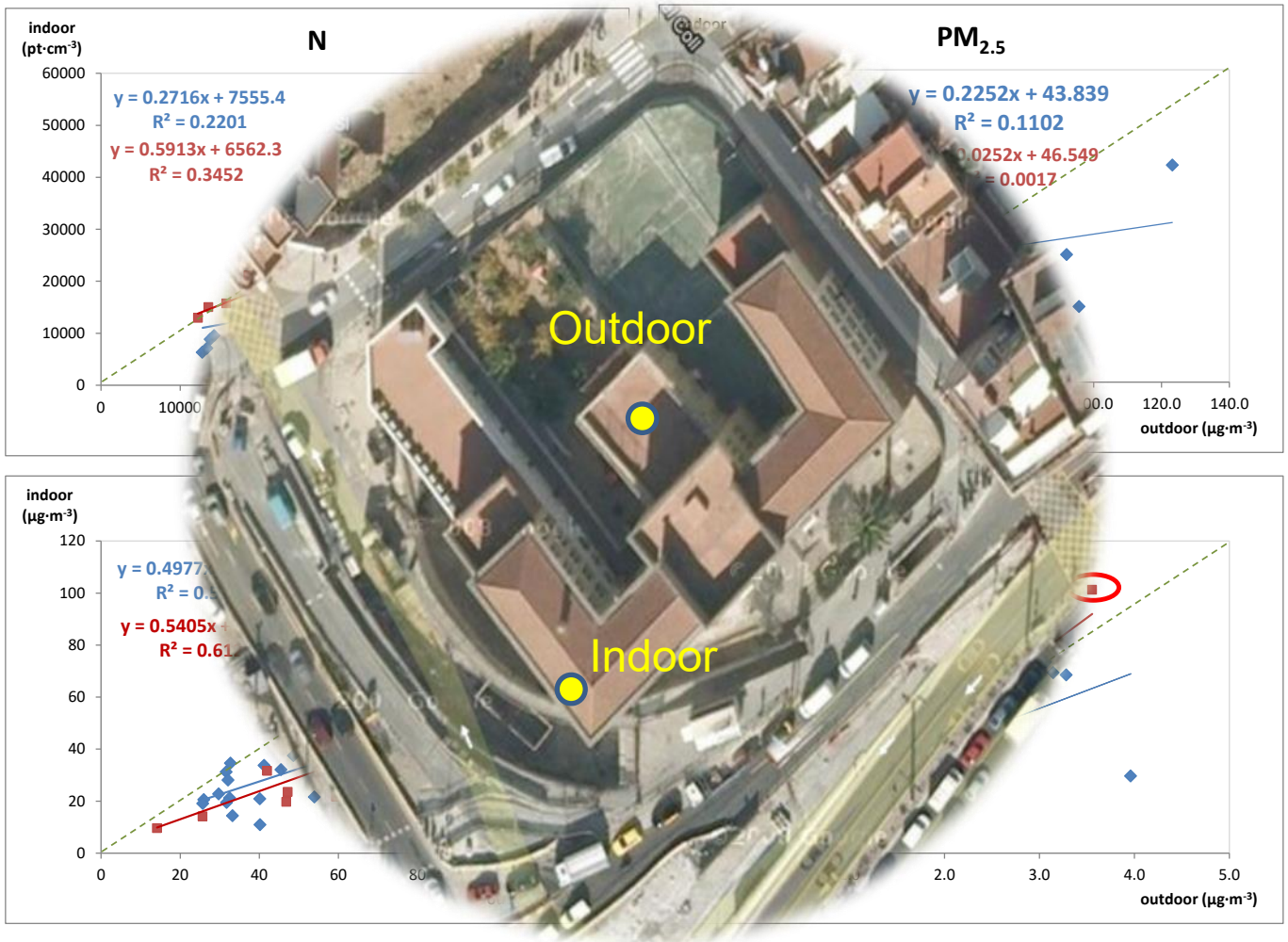
Rivas I., et al., 2015. Atmospheric Environment 106, 129-138.

◆ Closed windows ■ Opened windows



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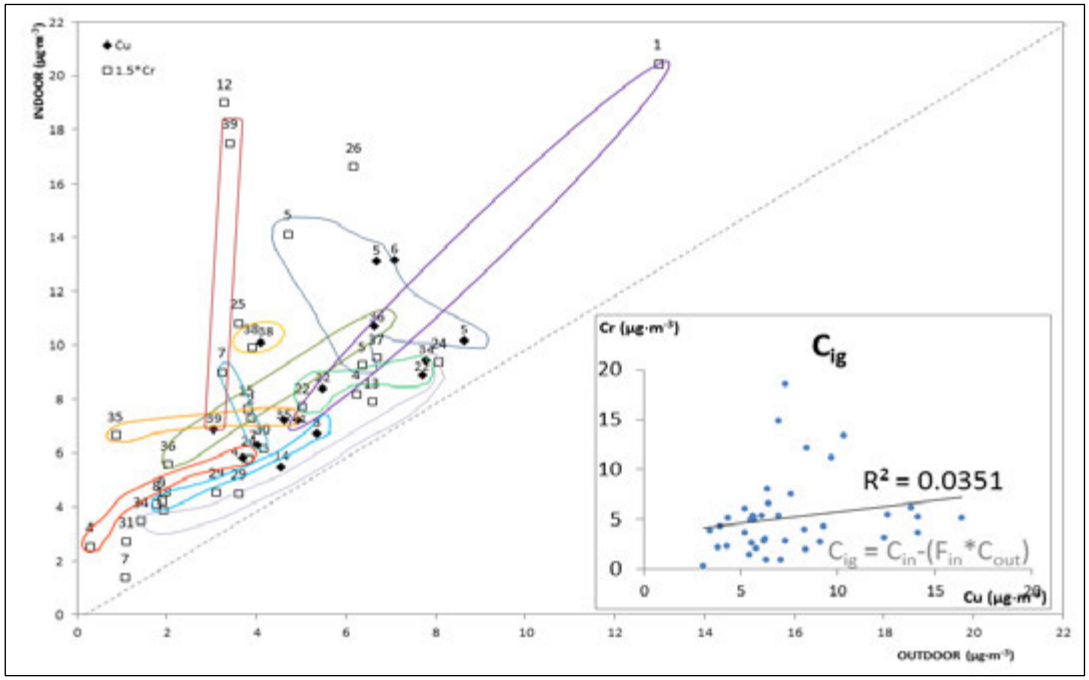
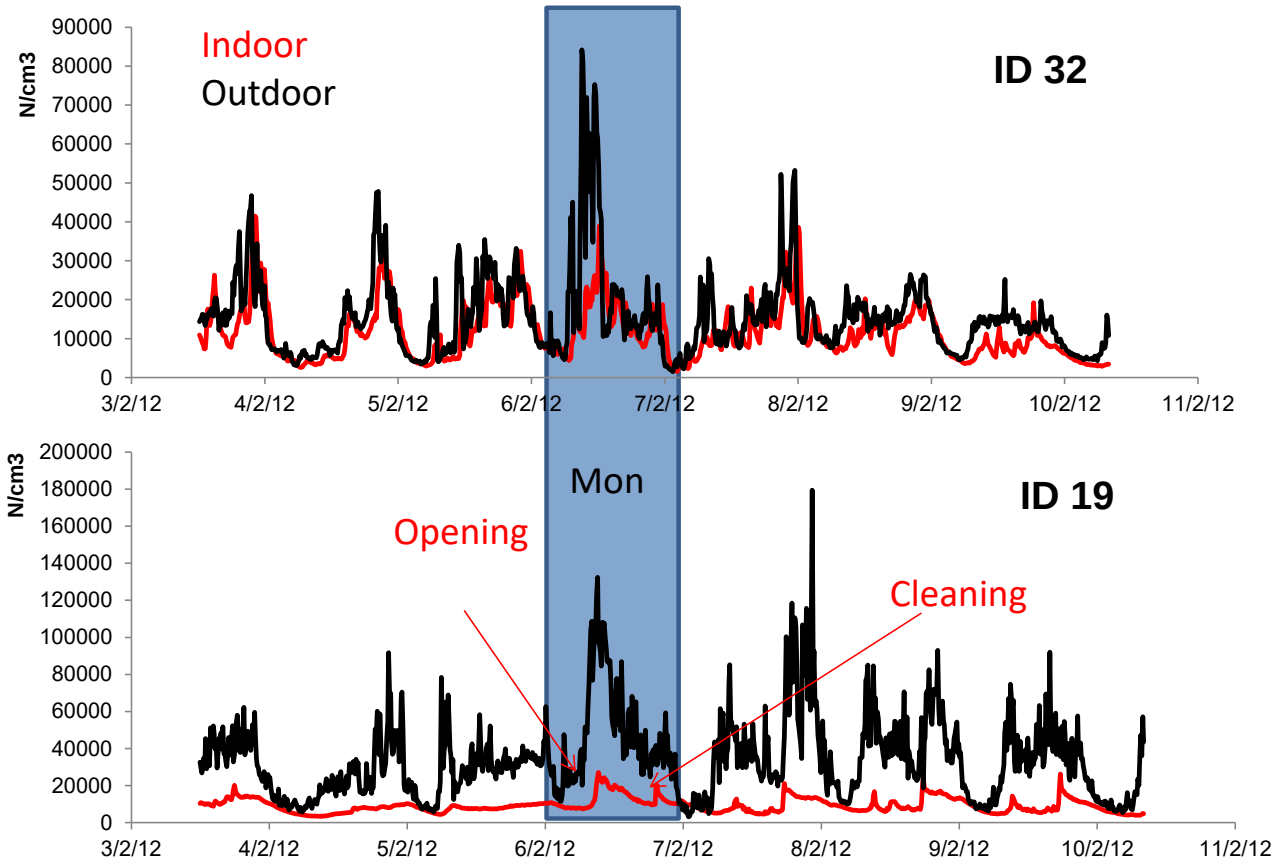
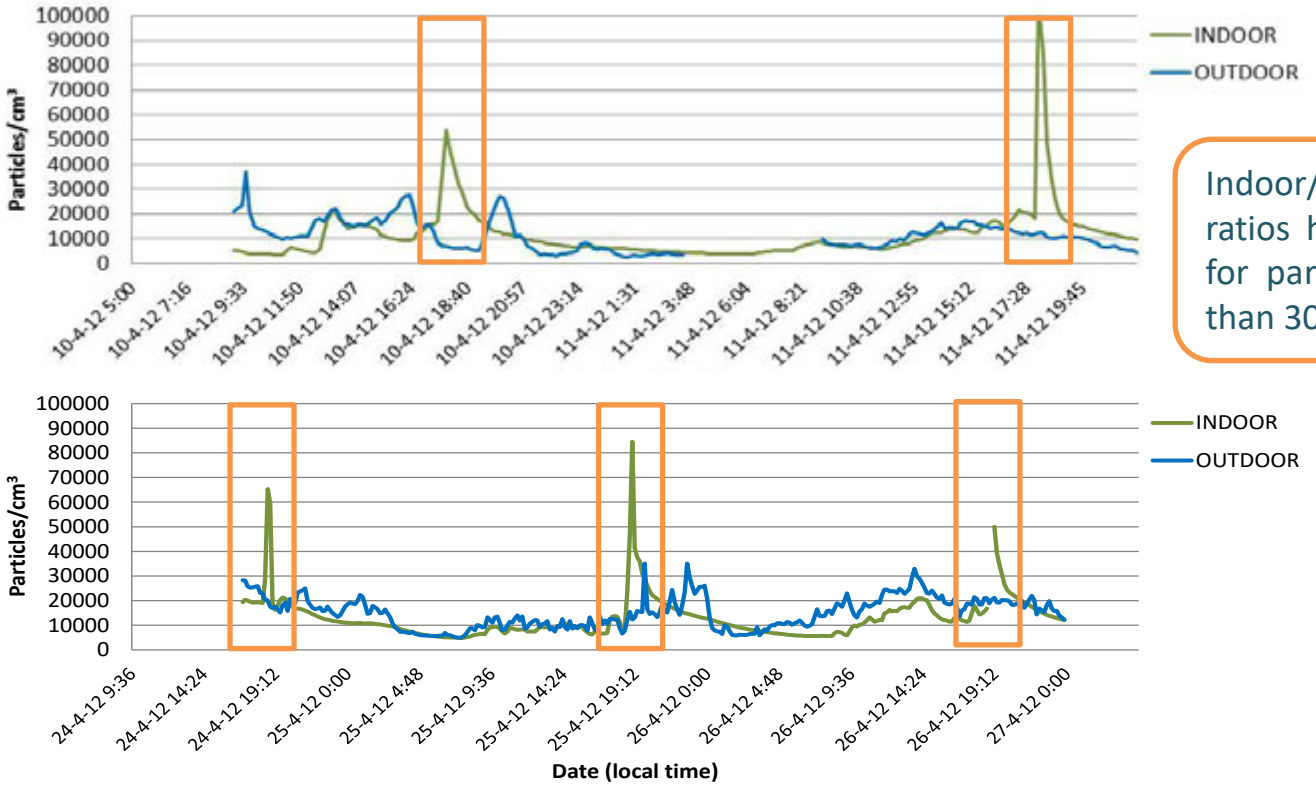


- Higher indoor vs outdoor concentration Cr, Cu and As have been observed simoultaneously in schools
- Wood treatment for forniture and metalic wear
- Further research needed on this topic

Rivas I., et al., 2015. Outdoor infiltration and indoor contribution of UFP and BC, OC, secondary inorganic ions and metals in PM2.5 in schools. Atmospheric Environment 106 (2015) 129-138.

Pollutants infiltration: 2 opposite cases

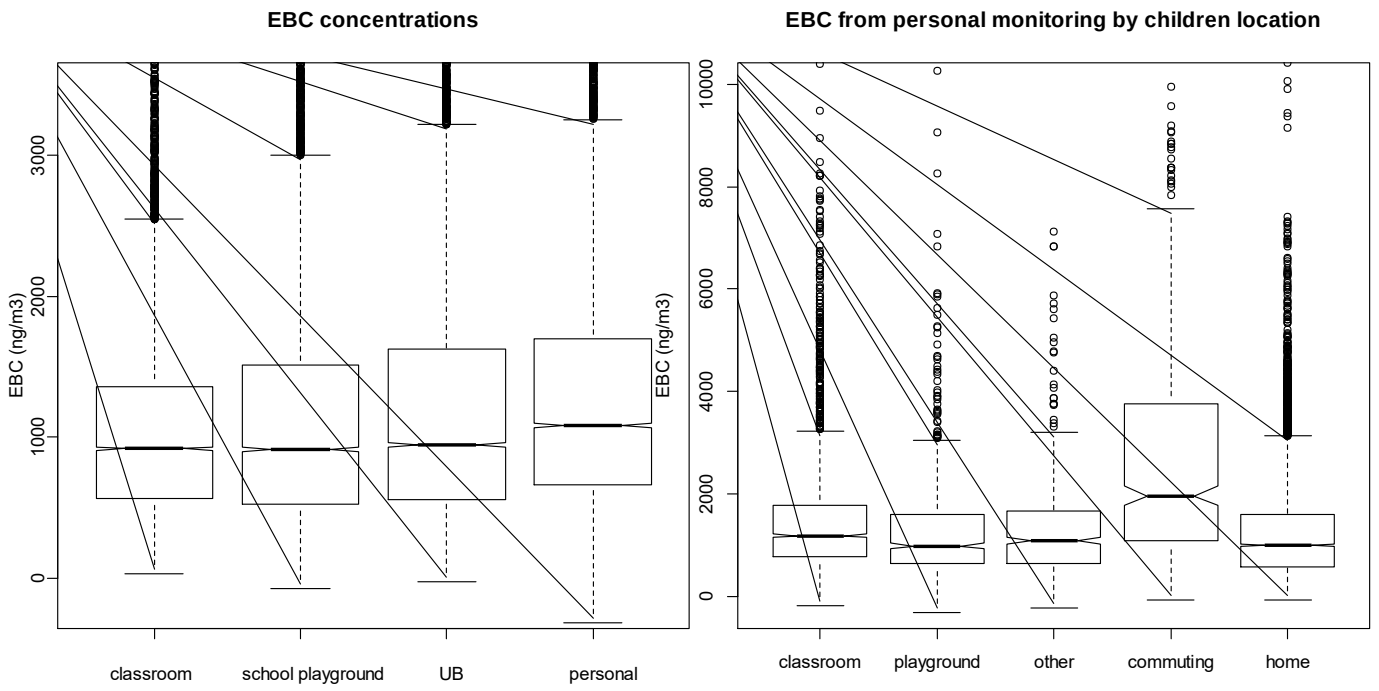




Indoor/Outdoor ratios higher than 3 for particles smaller than 30nm

Significant indoor UFP increases after schools hours in a few instances probably associated with cleaning activities (O_3+LIMONENE/α-PINENE)

Children's exposure to BC



- Personal EBC measurements in 46 schoolchildren during 48h
- Commuting periods are clearly those with the highest EBC concentrations

Rivas I, et al., 2016. Spatio-temporally resolved black carbon concentration, schoolchildren's exposure and dose in Barcelona. Indoor Air, 26(3):391-402.

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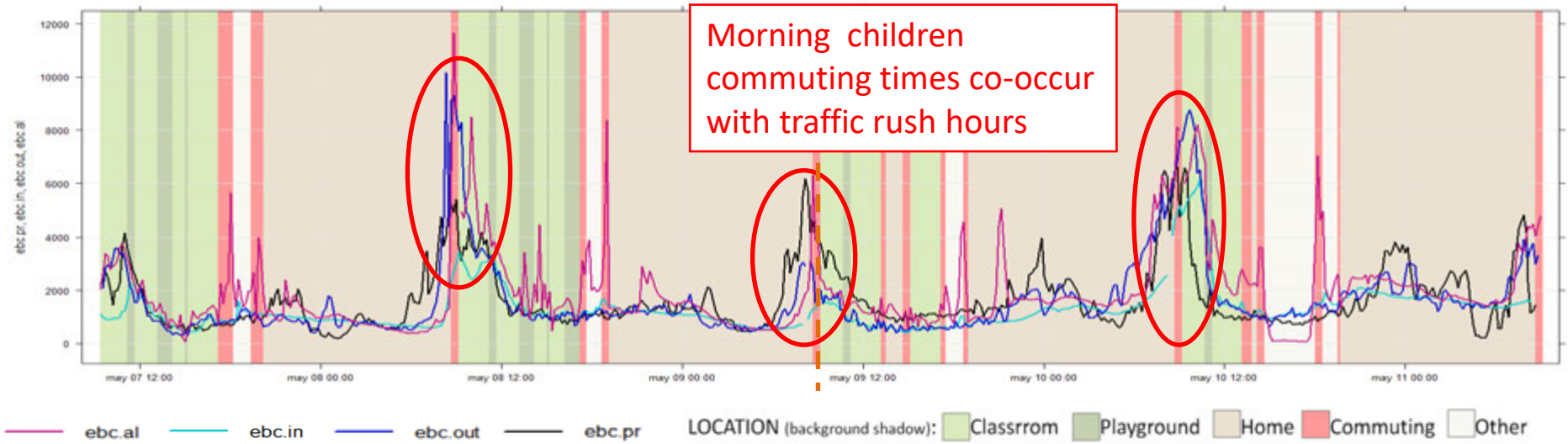
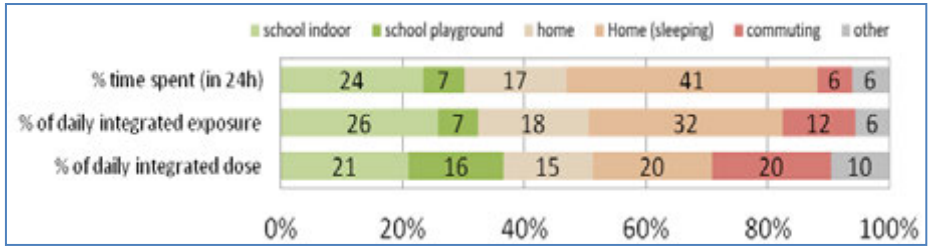
Children's exposure to BC





Commuting contributes to **20 %** of the integrated daily **DOSE** although it corresponds to the **5.6%** of the **time** of a day

School contributes with **37%** total **DOSE**, **home 35%**

Rivas I, et al., 2016. Spatio-temporally resolved black carbon concentration, schoolchildren's exposure and dose in Barcelona. Indoor Air, 26(3):391-402.

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Exposure to BC vs distance to road traffic

Amato et al., 2019 STOTEN

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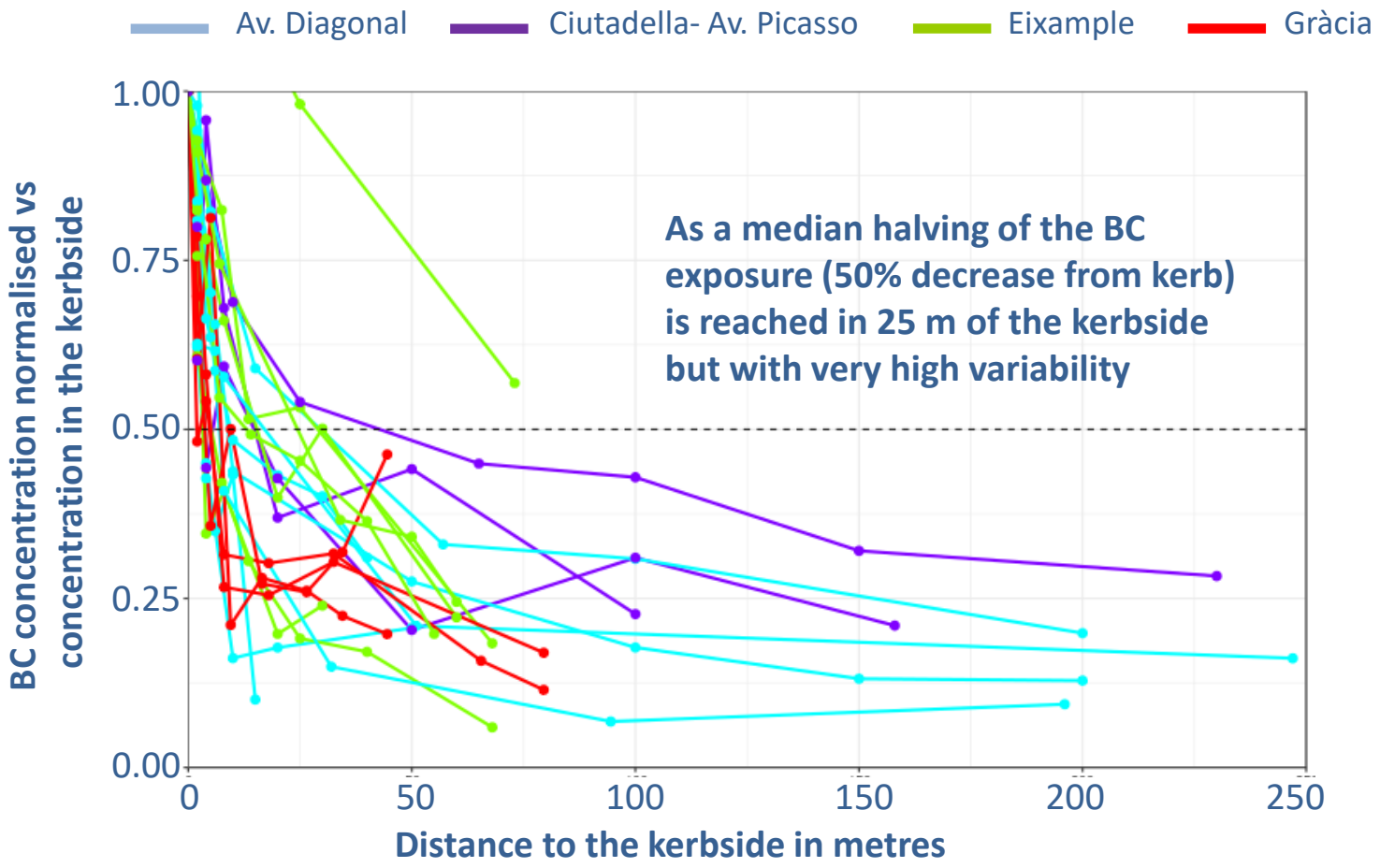
Exposure to BC vs distance to road traffic



Amato et al., 2019 STOTEN

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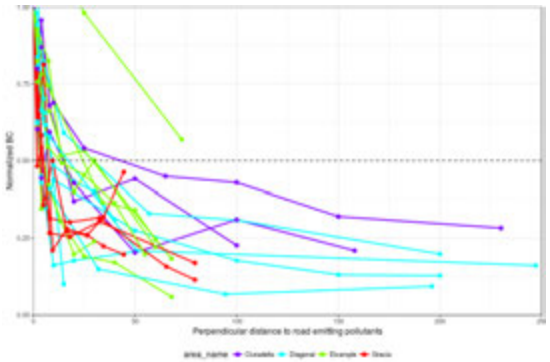
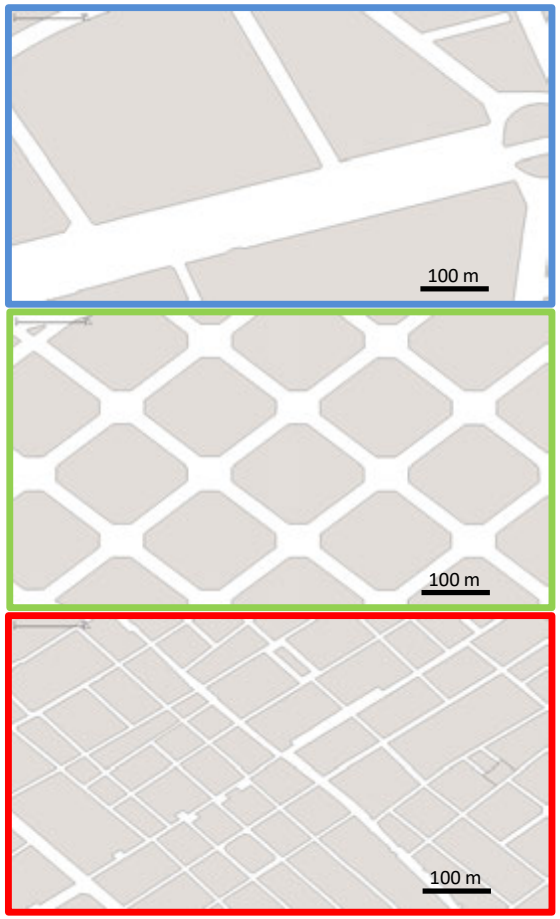
Exposure to BC vs distance to road traffic





Open busy roads (*Diagonal*)

50% reduction at: 32 m
Background conc. at: 80 m

Street canyon (*Eixample*)

50% Reduction at: 26 m
Background conc. at: 49 m

Historical center (*Gracia*)

50% Reduction at: 22 m
Background conc. at: 56 m

Amato et al., 2019 STOTEN

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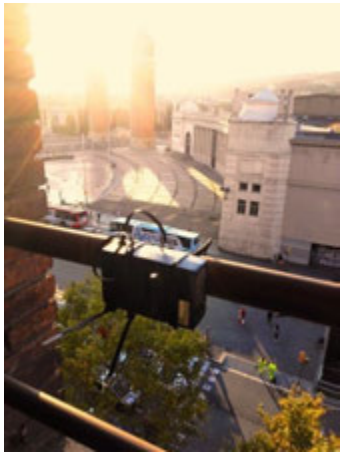
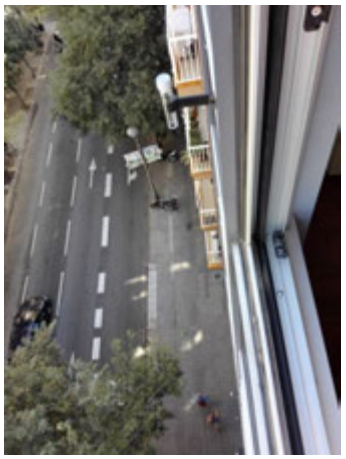
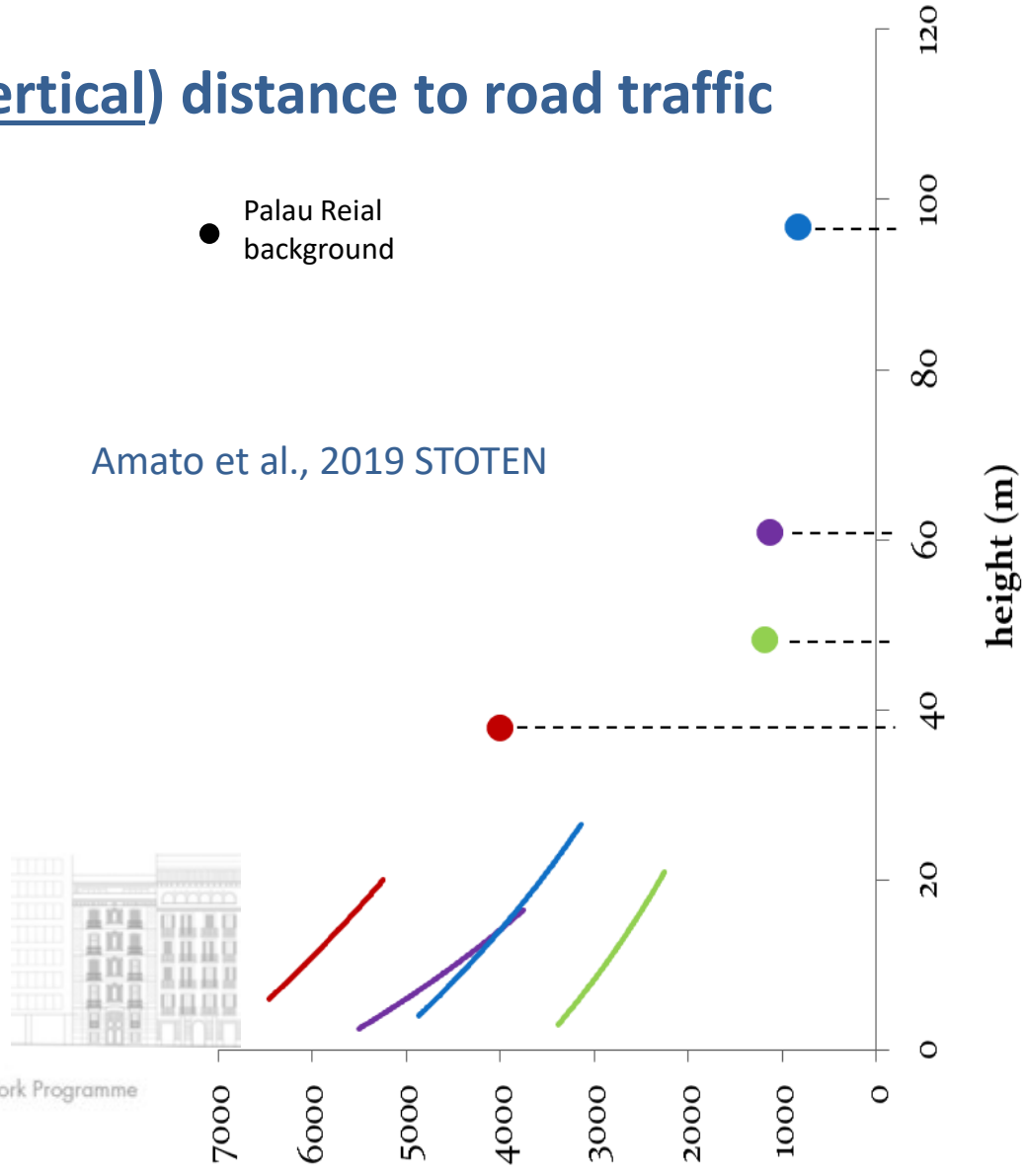
Exposure to BC vs (vertical) distance to road traffic





Amato et al., 2019 STOTEN



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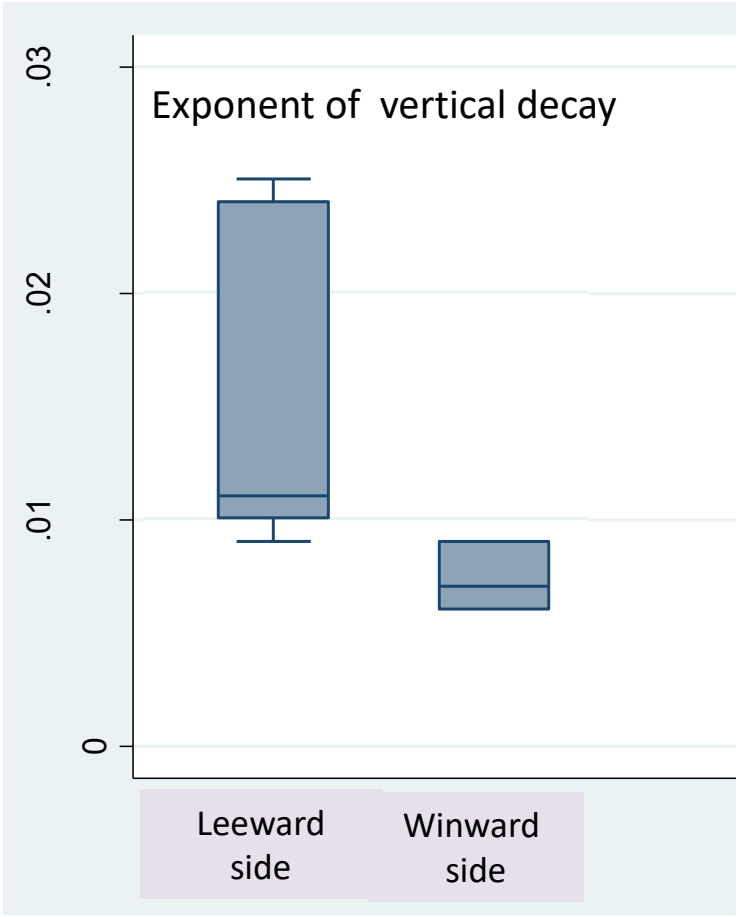
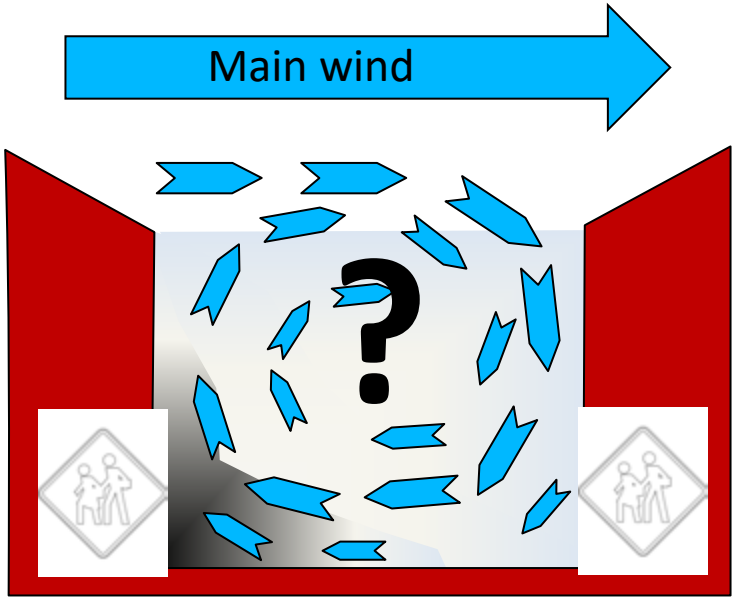
Amato et al., 2019 STOTEN

Canyon street





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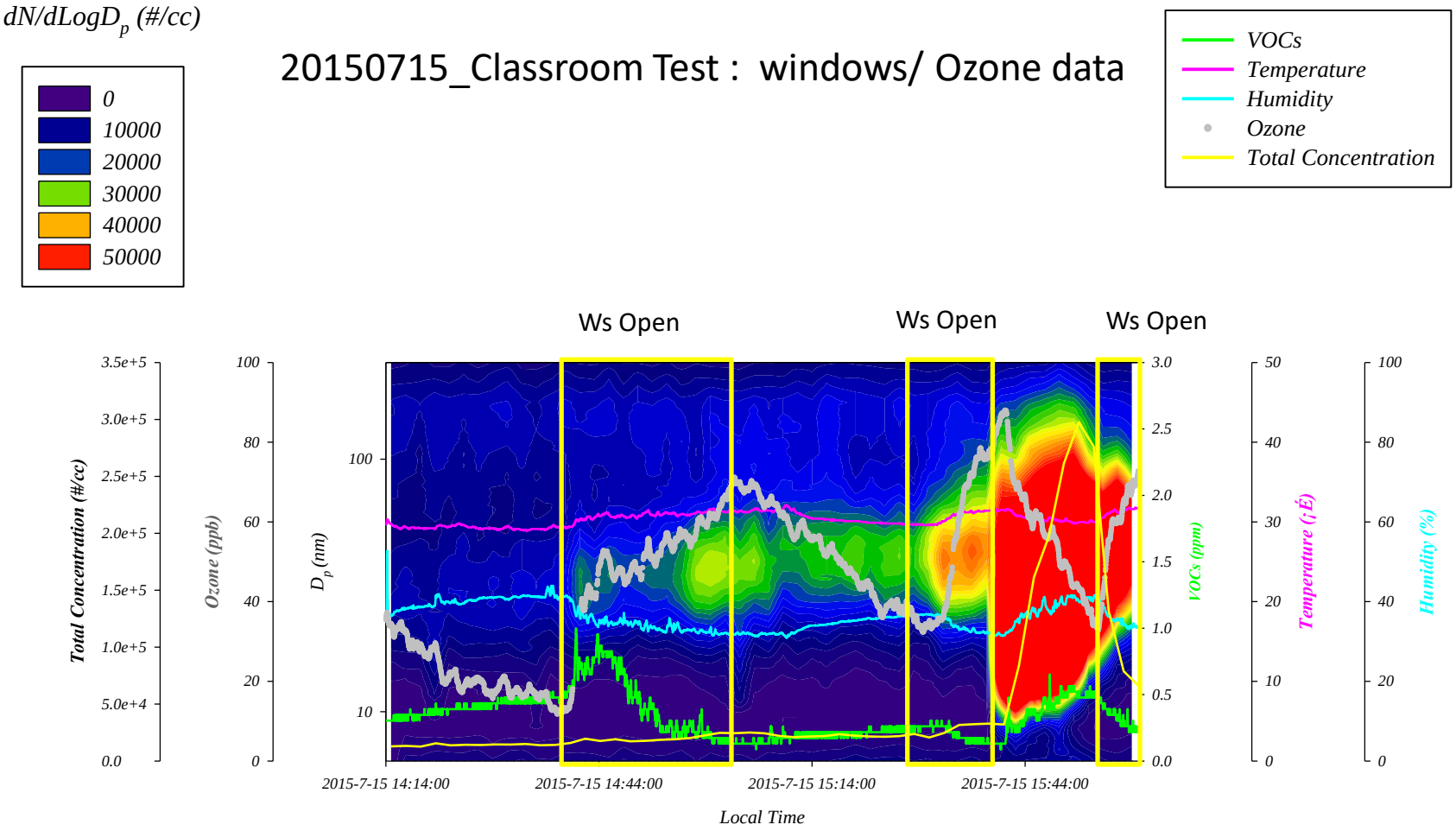
20150715_Classroom Test : windows/ Ozone data



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Science of the Total Environment 650 (2019) 1582–1590

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Effectiveness of commercial face masks to reduce personal PM exposure

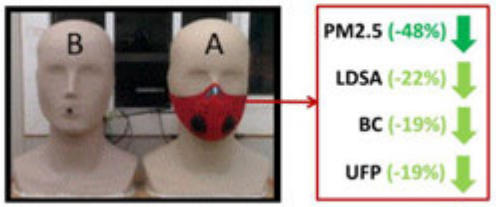
A. Pacitto [a,b], F. Amato [a,*], A. Salmatonidis [a], T. Moreno [a], A. Alastuey [a], C. Reche [a], G. Buonanno [c,d,b], C. Benito [e], X. Querol [a]

[a] Institute of Environmental Assessment and Water Research (IDAEA), Spanish National Research Council (CSIC), Barcelona, Spain
[b] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino (FR), Italy
[c] International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, Australia
[d] Department of Engineering, University "Parthenope", Naples, Italy
[e] BACC, Bicicleta Club de Catalunya, Barcelona, Spain

HIGHLIGHTS

- Evaluation of low cost face masks effectiveness to reduce personal exposure
- High personal exposure reduction in term of PM2.5
- Evaluation of Cyclist exposure reduction by means of personal respirators
- Evaluation of face masks effectiveness under different breathing rate
- Evaluation of personal protective equipment under a typically traffic-affected urban background environment

GRAPHICAL ABSTRACT



PM2.5 (-48%)
LDSA (-22%)
BC (-19%)
UFP (-19%)

Science of the Total Environment 712 (2020) 135673

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Effect of ventilation strategies and air purifiers on the children's exposure to airborne particles and gaseous pollutants in school gyms

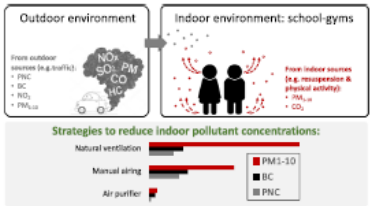
A. Pacitto [a,b], F. Amato [a,*], T. Moreno [a], M. Pandolfi [a], A. Fonseca [a], M. Mazaheri [a,c], L. Stabile [b], G. Buonanno [b,c], X. Querol [a]

[a] Institute of Environmental Assessment and Water Research (IDAEA), Spanish National Research Council (CSIC), Barcelona, Spain
[b] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, FR, Italy
[c] International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, Australia

HIGHLIGHTS

- Different ventilation methods and air purifiers on indoor pollutants were evaluated.
- In school gyms air purifier lead to significant reductions.
- The effect is larger with closed windows.

GRAPHICAL ABSTRACT



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RECULL DE RECOMANACIONS PER REDUIR L'EXPOSICIÓ A LA CONTAMINACIÓ DE L'AIRE EXTERIOR A LES ESCOLES DE BARCELONA

2 Agost 2019

Elaborat per l'Agència de Salut Pública de Barcelona

Consorci Sanitari de Barcelona

Agència de Salut Pública

Amb la col·laboració de
IDAEA-CSIC
Aiguasol
ICTA-UAB
ISGlobal
Consorci d'Educació de Barcelona
Mobilitat i Infraestructures - Ecologia Urbana - Ajuntament de Barcelona.
Departament de Qualitat Ambiental. Medi Ambient i Serveis Urbans - Ecologia Urbana - Ajuntament de Barcelona.

Environment International 121 (2018) 199–206

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

How to protect school children from the neurodevelopmental harms of air pollution by interventions in the school environment in the urban context

Ioar Rivas[a,b,c,*], Xavier Querol[b], John Wright[d], Jordi Sunyer[a,e]

[a] ISGlobal, Centre for Research in Environmental Epidemiology (CREAL), C/Dr. Aiguader 88, 08003 Barcelona, Catalonia, Spain
[b] Institute of Environmental Assessment and Water Research, IDAEA-CSIC, C/Jordi Girona 18-26, 08034 Barcelona, Spain
[c] MRC-PHE Centre for Environment and Health, Environmental Research Group, King's College London, 150 Stamford Street, London SE1 9NH, UK
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Keywords:
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Air quality
Neurodevelopment
School children
Exposure

ABSTRACT

Recently, there has been a flurry of publications assessing the effect of air pollution on neurodevelopment. Here we present a summary of the results obtained within the BRain dEvelopment and Air polluTion ultrafine particles in scHool childrEn (BREATHE) Project, which aimed to evaluate the effects of the exposure to traffic related air pollutants in schoolchildren in Barcelona. To this end, we comprehensively characterised air quality in 39 urban schools from Barcelona and identified the main determinants of children's increased exposure. We propose a series of measures to be implemented to improve air quality in schools within the urban context and, consequently, minimise the negative effects on children's neurodevelopment that we found to be associated with the exposure to air pollution. We also aimed to list some of the actions pushed by governments and the society (including school managers, parents, and children) that have been taking place around Europe for promoting better high quality in the school and its surroundings.

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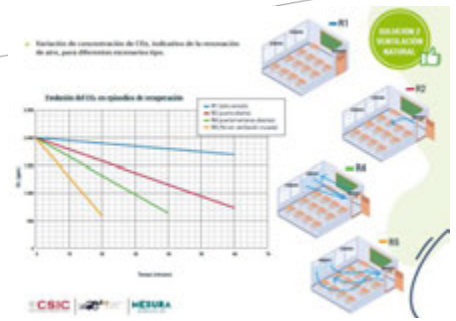

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Conclusions

- Schools have high levels of pollutants because proximity to traffic
- Outdoor levels in the schools are intermediate traffic and urban background levels
- PM2.5 is an exception, the influence of sand playgrounds as well as indoor organic emissions from clothes and skin of children accounts for higher PM2.5 levels than in traffic sites
- Indoor levels for many pollutants are similar to those found outdoors
- Infiltration yields differ a lot for specific schools and pollutants.
- An article is published on measures to abate influence of outdoor pollution and a official guideline is being issued now
- BC levels are governed by traffic, with 35% higher levels in high traffic schools
- UFP increase also by 40% as a mean in high traffic schools, but in most of the schools photochemically generated secondary UFPs highly contribute at midday when BC is at the lowest.
- In spite of this secondary generation of UFP, both UFP and BC show and inverse correlation with green areas and a direct correlation with 5 of area used by traffic
- **Ventilation required to decrease CIVID19 risk might increase air pollution.**
- **Both risk of transmission and air pollution have to be taken into account**

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ERC-Advanced Grant, PI: Jordi Sunyer, CREAL

Exposure to air pollution at school

Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A Prospective Cohort Study

Jordi Sunyer*[1,2,3,4], Mikel Esnaola[1,2,3], Mar Alvarez-Pedrerol[1,2,3], Joan Forns[1,2,3], Ioar Rivas[1,2,3,5], Mònica López-Vicente[1,2,3], Elisabet Suades-González[1,2,3,6], Maria Foraster[1,2,3], Raquel Garcia-Esteban[1,2,3], Xavier Basagaña[1,2,3], Mar Viana[5], Marta Cirach[1,2,3], Teresa Moreno[5], Andrés Alastuey[5], Núria Sebastian-Galles[2], Mark Nieuwenhuijsen[1,2,3], Xavier Querol[5]

PLoS Med. 2015;12(3):e1001792

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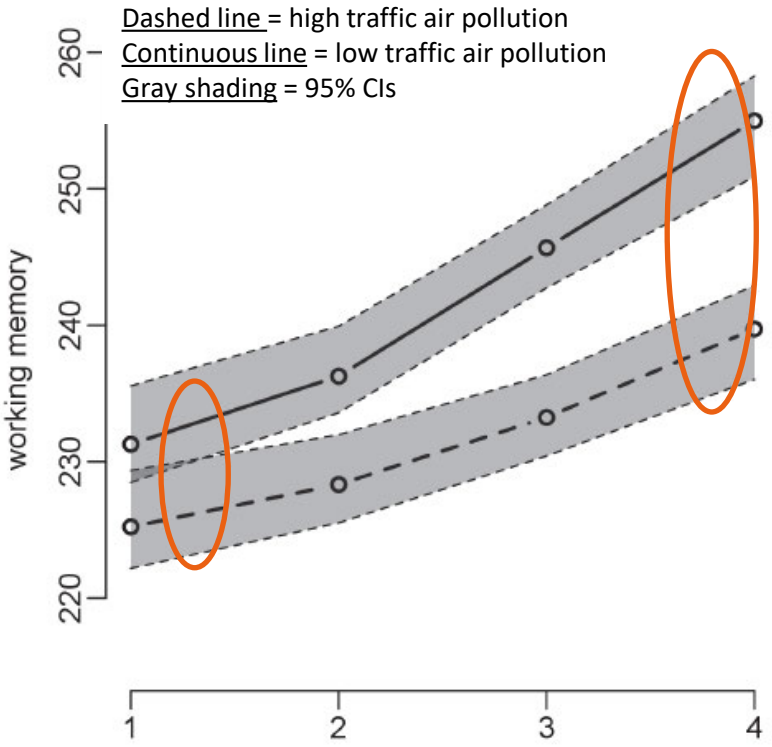

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Levels of road traffic related pollution and green space in school and brain development and imaging

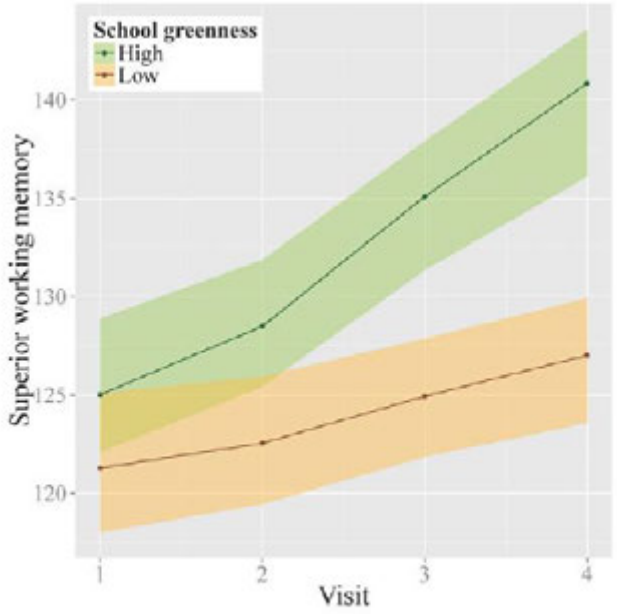
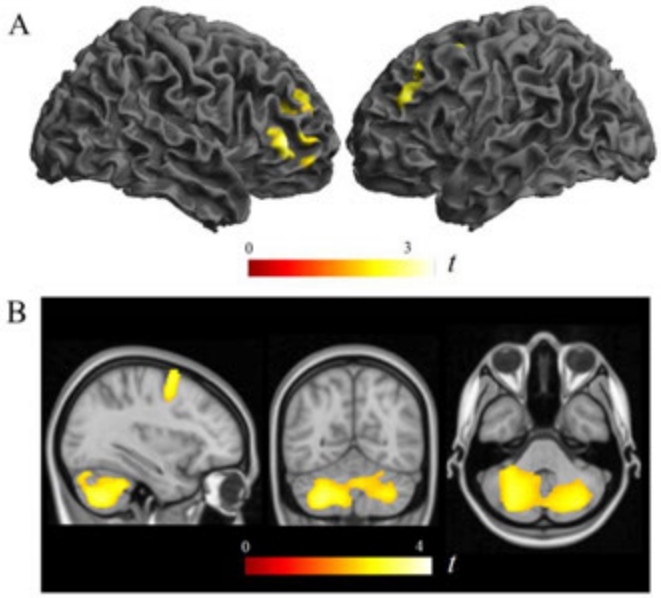


Fig. 1. Twelve-month progress (with 95% confidence bands) in superior working memory for participants with the first (low greenness) and third (high greenness) tertiles of greenness within the school boundaries.

N=2,593 children, 7-10 yrs

Dadvand et al 2015. PNAS, 112, 26, 7937–7942



Pujol, et al., 2016. Neuroimage

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Thank you very much for you attention!

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National Plan for R+D+i ERC-AG-BREATHE

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