



Personal exposure to PM during commuting in a subway system

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Open Day on "Air quality in rail subway systems"
7th May 2015, Barcelona.

Aim of the work

Characterization of **personal exposure** to PM while commuting in the **Barcelona subway system**

Waiting on the platforms

Travelling inside the trains



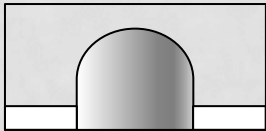
Air Quality Measurements

Platforms

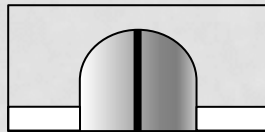
- During two seasonal periods: **Warmer** (2nd April 2013 – 30th July 2013)
Colder (28th October 2013 – 10th March 2014)
- 4 stations with different designs:



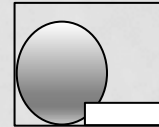
one wide tunnel with two rail tracks without middle wall



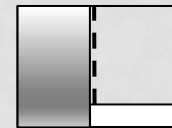
one wide tunnel with two rail tracks separated by a middle wall



a single narrow tunnel with one rail track



a single tunnel with one rail track separated from the platform by a wall with mechanical doors (platform screen door systems)



- **Daily measurements** performed at each station for **a month**

New station

Air Quality Measurements

Platforms

- **Instrumentation:**

- High volume sampler with a $PM_{2.5}$ inlet;

Daily sampling: 05:00 – 24:00h
(metro operating time)



- DustTrak (PM_{10} , $PM_{2.5}$ and PM_1);



- Indoor Air Quality analyser (CO_2 , CO, T, RH);



Continuous measurements
(24h/day)

Air Quality Measurements

Platforms

- **Instruments were placed:**
 - at the end of the platform (train entry point);
 - far from the passengers' access-to-platform point;
 - behind a light fence for safety;



Air Quality Measurements

Platforms

- **Additional platform measurements in:**
 - 24 stations with wide variety of designs, from 6 subway lines



Measurements were performed at each station for **1 hour**

divided into periods of **15 minutes in 4 positions** approximately equidistant along the platform

To observe possible spatial variations



Air Quality Measurements Inside the trains

- 6 subway lines
- During **a return trip** along the whole subway line
- In the **middle** of the central car of the train

L2

L1

L3

L4



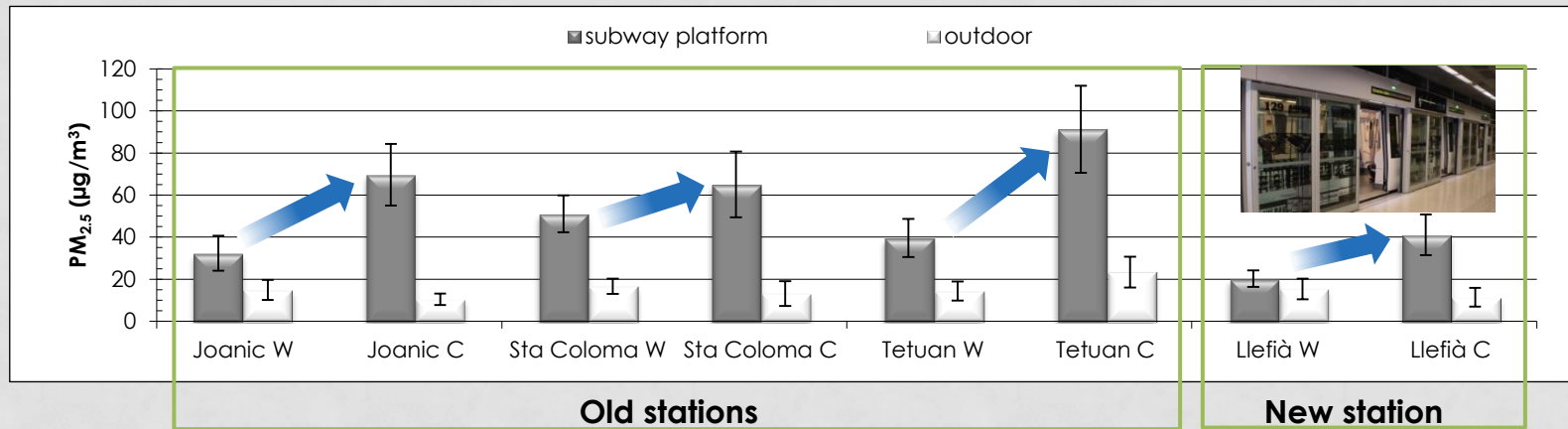
L10

L5

- Effect of **air conditioning** into the trains



PM concentrations on platforms



- **PM_{2.5} concentrations:**

- Higher on the platforms than outdoors;



Abrasion and wear of rail tracks, catenaries, pantographs, wheels and brakes.

- Lower in the **warmer period** than in the **colder period**;

(strong ventilation)

(weak ventilation)

- Lower in the **new station** than in the **old stations**;

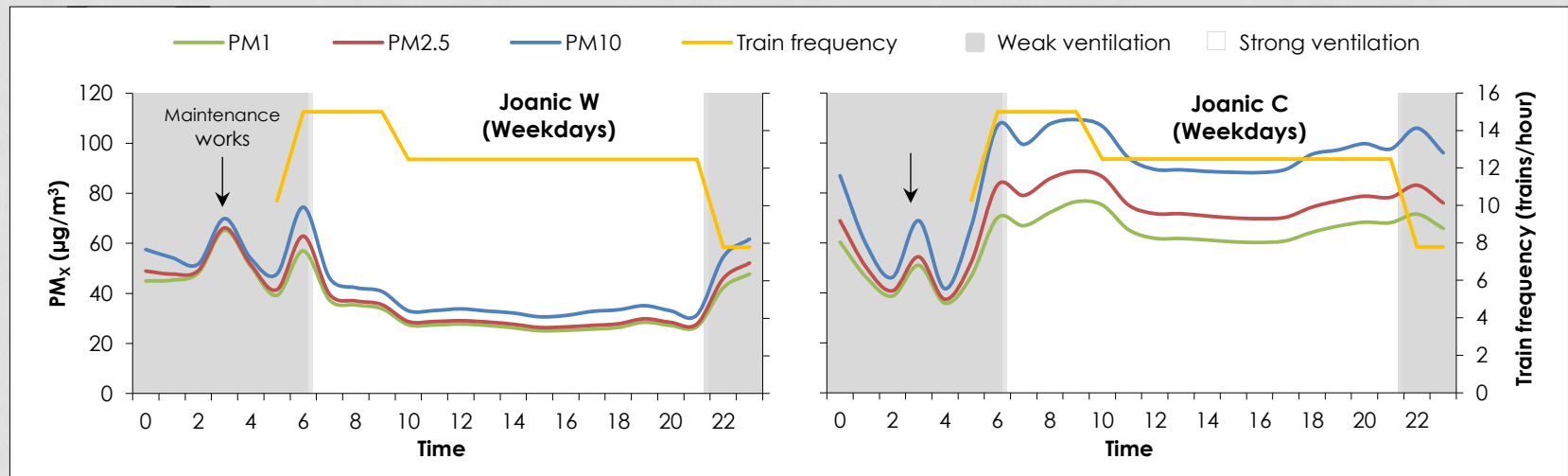
(around 50%)



Station design (PSDs), lower train frequency and more advanced ventilation setup.

PM concentrations on platforms

Daily patterns



- **PM_x concentrations:**

- displayed a typical daily pattern;

- lower during the **weekends**
(about 33% lower)



Lower frequency of trains

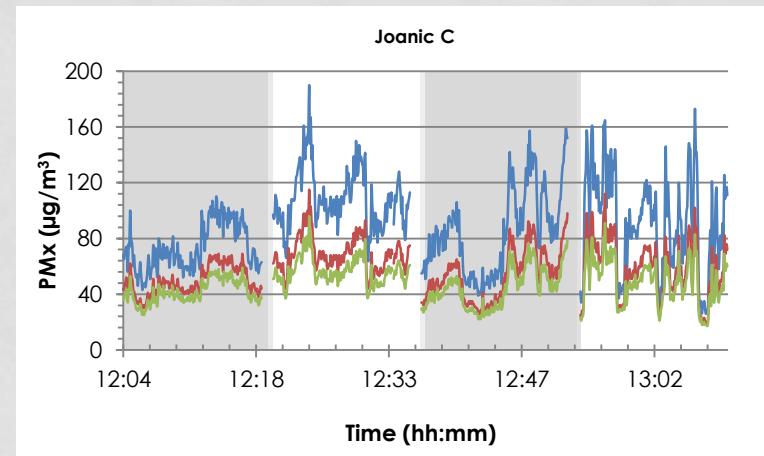
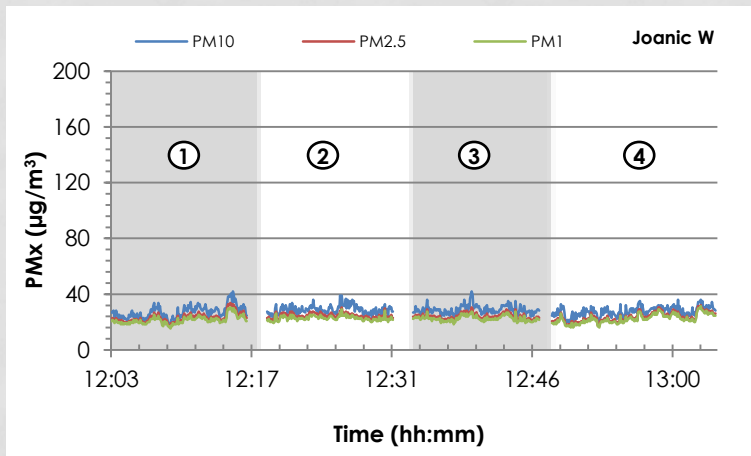
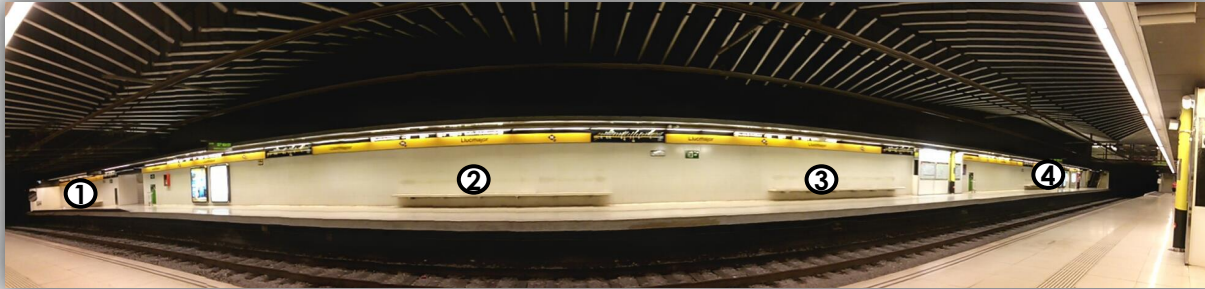
- PM₁/PM₁₀ and PM_{2.5}/PM₁₀ ratios were lower in the warmer period.



Ventilation was more efficient removing coarser particles

PM concentrations on platforms

Temporal and spatial variations (Representative cases)



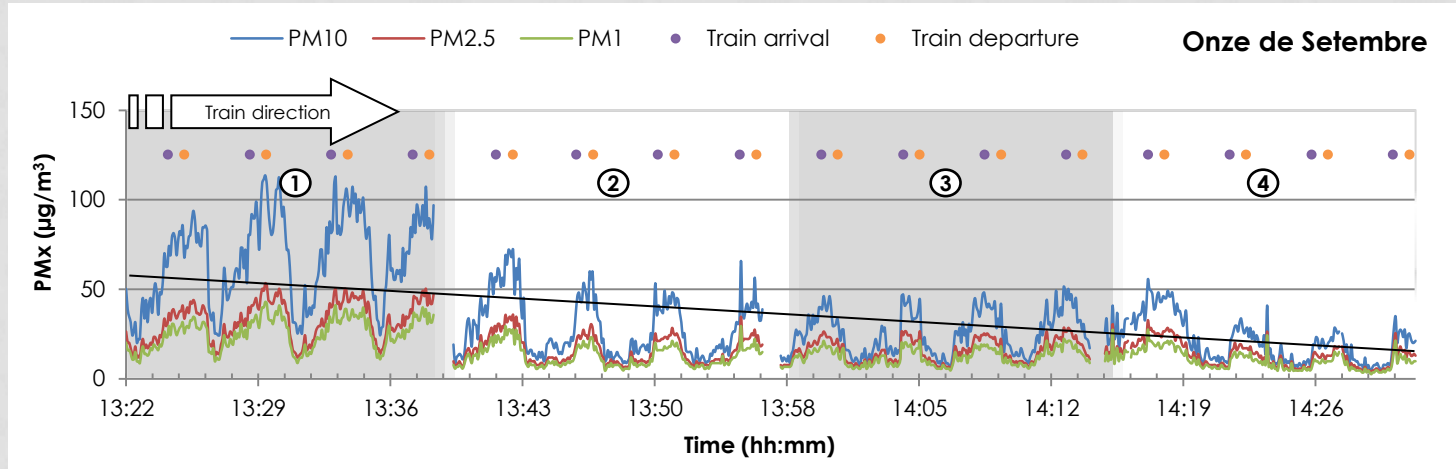
- **PM_x concentrations:**

- Higher in the colder period

- Larger in the colder period

PM concentrations on platforms

Temporal and spatial variations (Representative cases)



- **PM_x concentrations:**

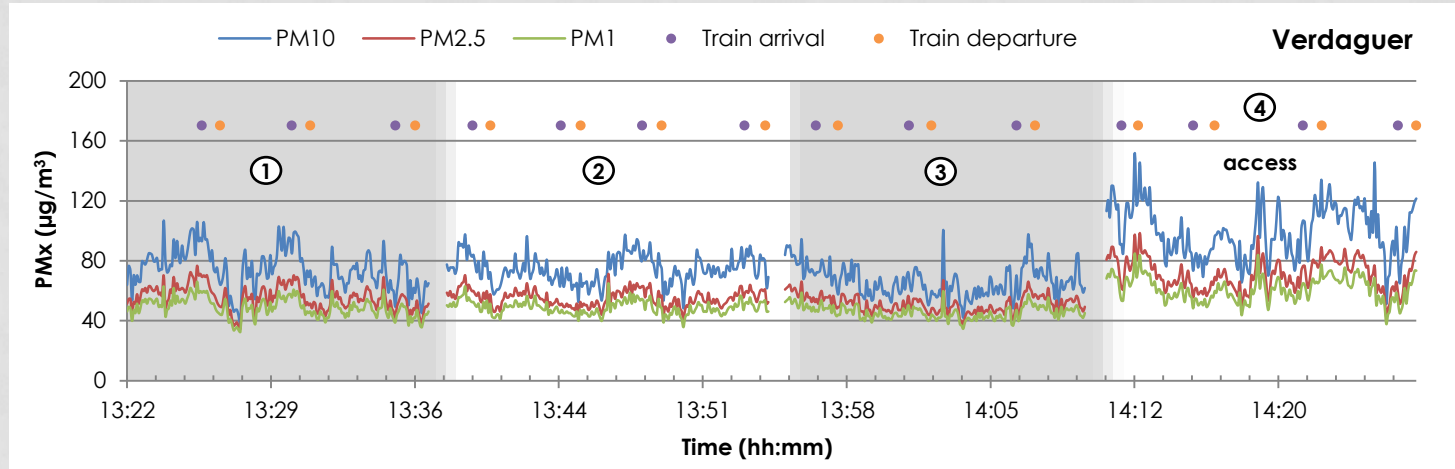
- Increase when train enters the platform
- Decrease when train departs
- Higher at the train entry point



**decreasing trend along
the platform**

PM concentrations on platforms

Temporal and spatial variations (Representative cases)



- **PM_x concentrations:**

- Higher in areas closer to passengers' access

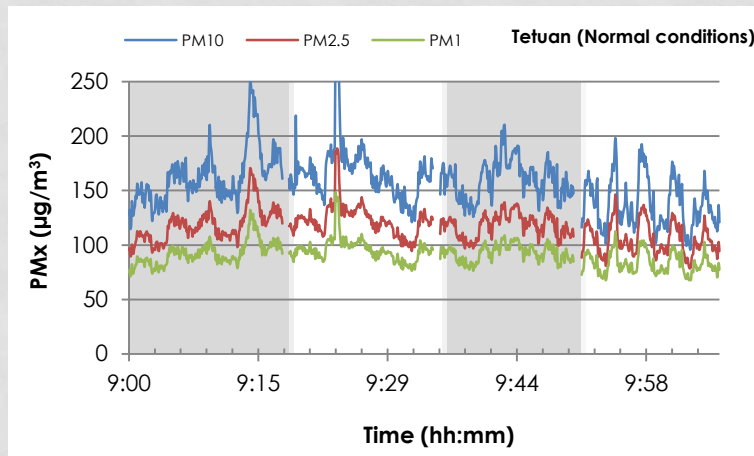


High probability of air turbulences

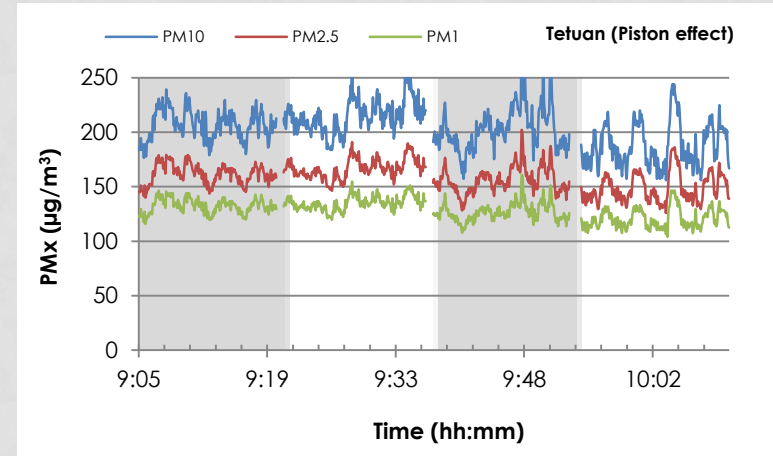
PM concentrations on platforms

Tunnel ventilation: Piston effect

Normal ventilation



Without tunnel ventilation



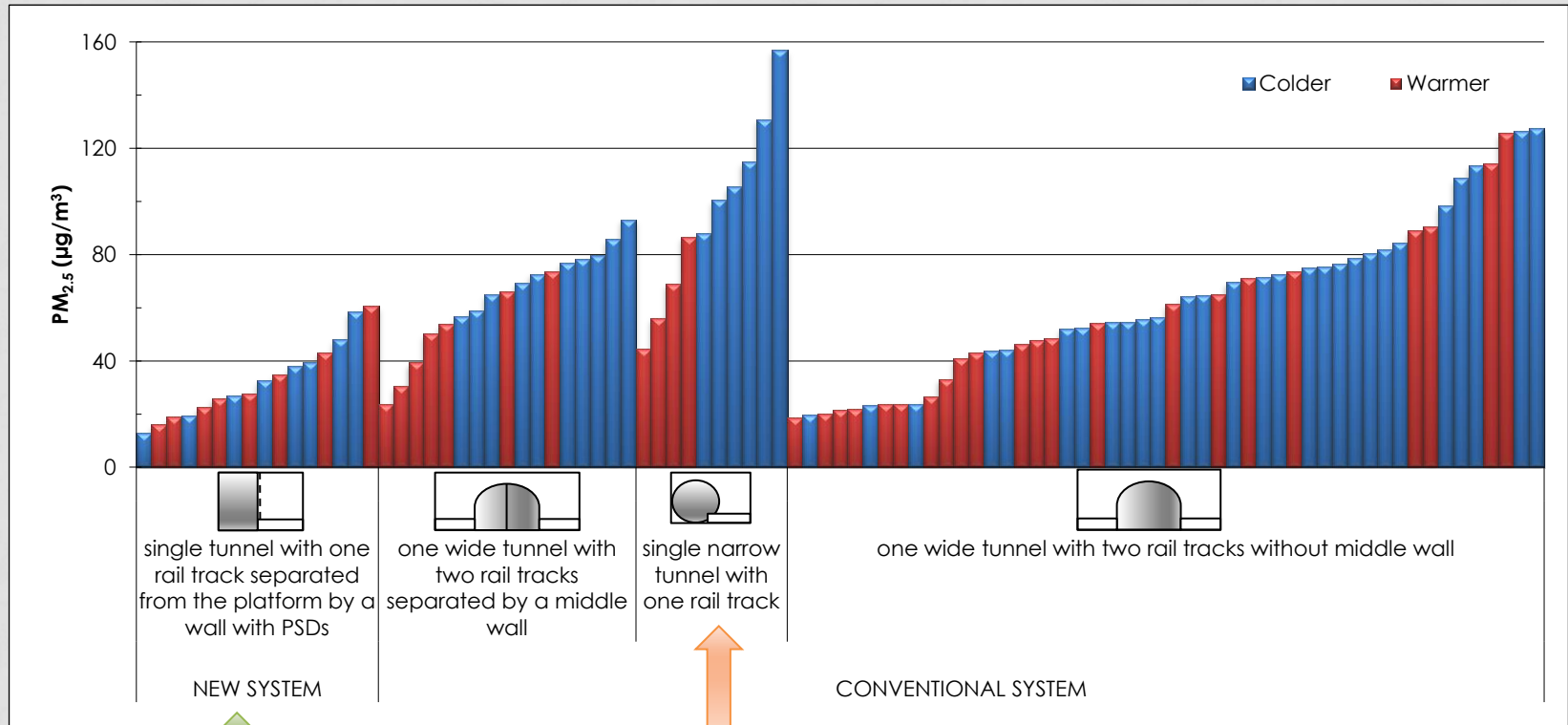
- **When the ventilation of the tunnel was turned off:**
 - higher concentrations were observed on the platform.
(about 26% higher)

↓

Accumulation of PM

PM concentrations on platforms

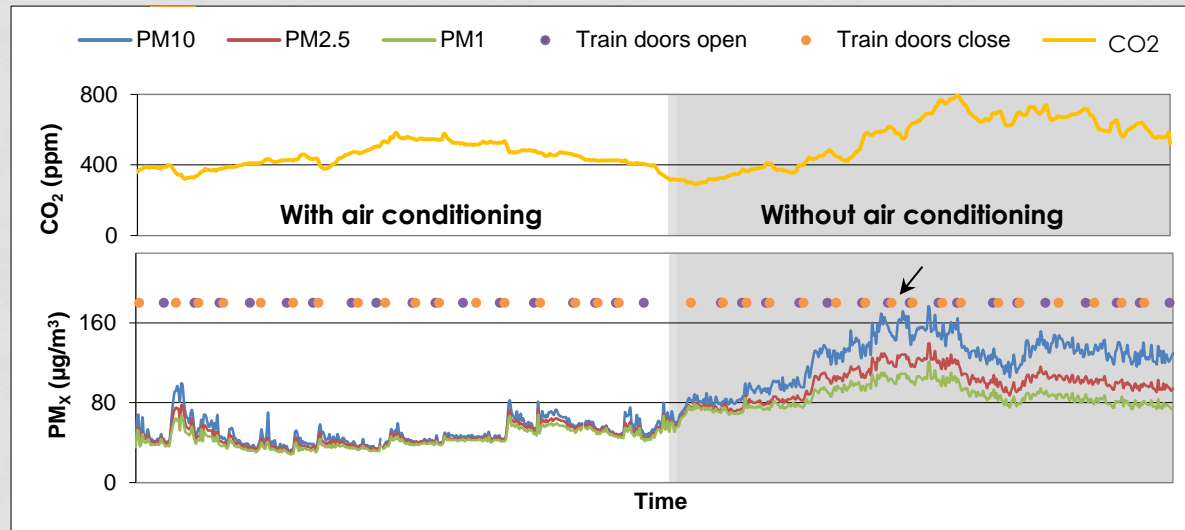
Stations design



lower
PM_{2.5} concentrations

higher
PM_{2.5} concentrations

PM concentrations inside trains



- With air conditioning ⇒ Lower PM concentrations and mostly fine.



Air conditioning system was capable of removing the larger portion of coarse particles.

- Maximum influx of people in the central part of each line.



Maximum peak in the PM and CO₂ concentrations.



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Exposure to airborne particulate matter in the subway system



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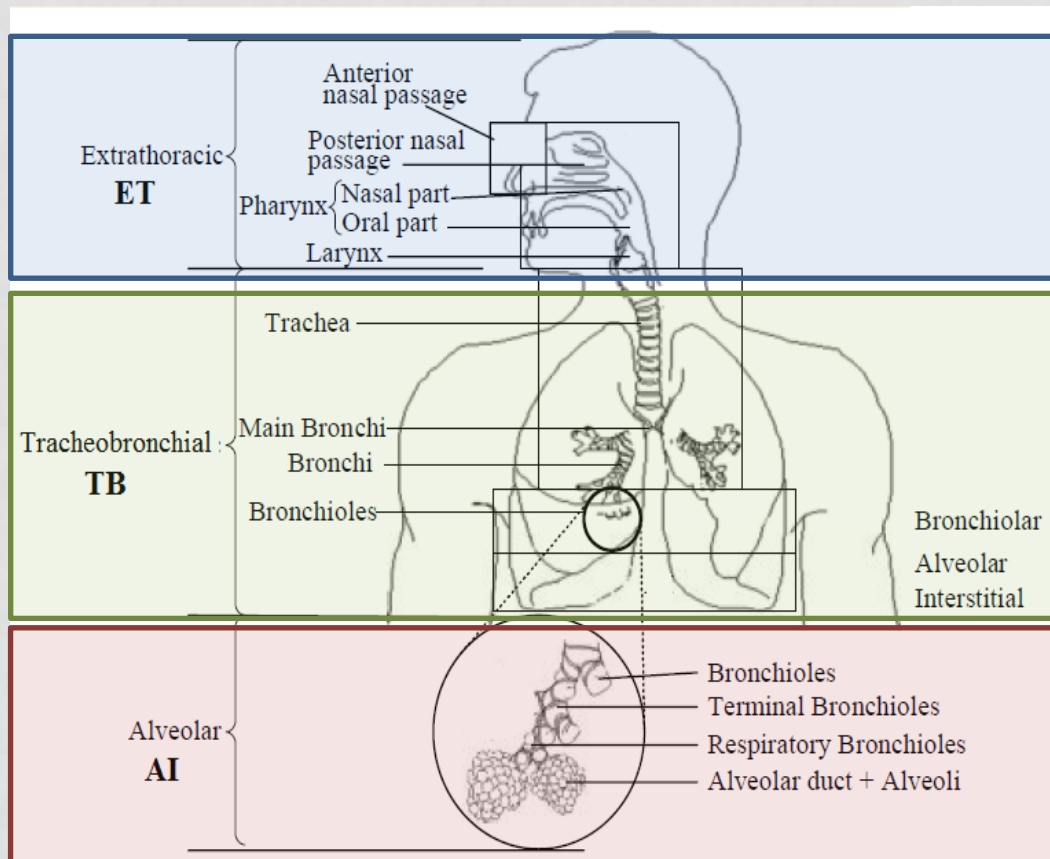
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HIGHLIGHTS

- Higher PM concentrations were found on platforms compared to outdoor.
- Air quality was better in the new lines with PSDs.
- PM concentrations were higher in the colder than in the warmer period.
- Ventilation and air conditioning systems improve air quality in the subway system.
- Time commuting in the subway contributes substantially to the personal exposure.

Detailed methodology and results in the published research article.



Respiratory tract is divided into different anatomical regions:

Extrathoracic region (ET)

Tracheobronchial tree (TB)

Alveolar-interstitial region (AI)

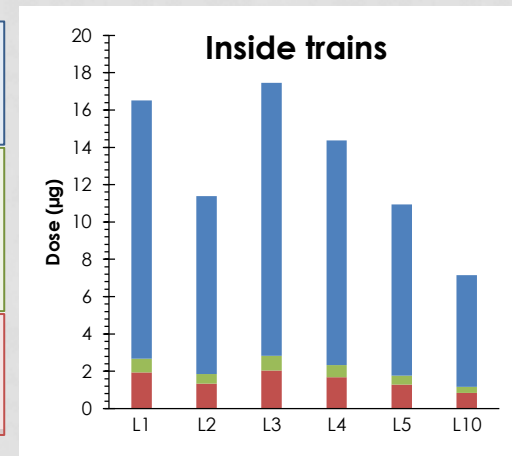
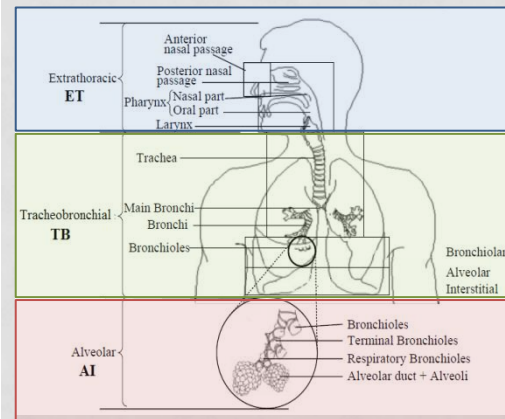
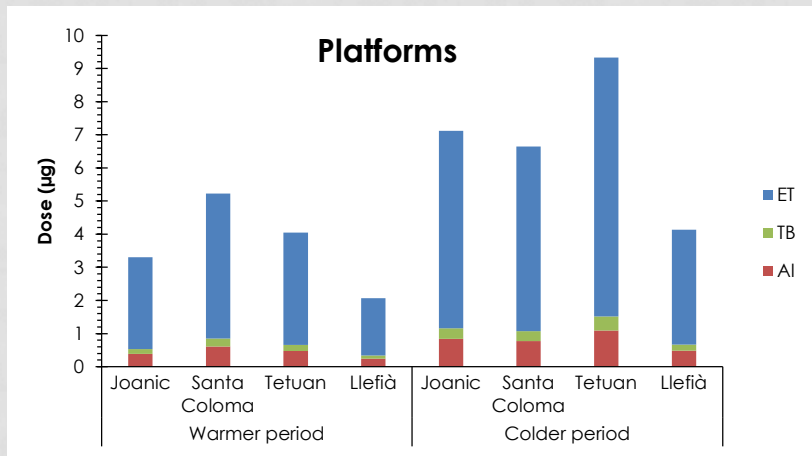
DOSIMETRIC STUDY



Deposition of subway PM_{2.5} in the human respiratory tract applying the Exposure Dose Model (ExDoM)

Deposition of PM_{2.5} in the human respiratory tract

During a subway commuting travel of 5 min on the platform and 15 min inside the train:



- Particle deposition is proportional to the exposure concentrations.
- 80% of the inhaled subway PM_{2.5} deposited in the human respiratory tract.
- The largest fraction of the PM_{2.5} deposited in the **extrathoracic region**.
- Highest dose was observed inside the trains due to longer exposure time.



THANK YOU FOR YOUR ATTENTION

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