INTERNATIONAL UNION
OF RAILWAYS

Welcome to the workshop

AIR QUALITY MANAGEMENT IN RAIL

Deepening the understanding of air pollution in rail, and how to manage it

Proposed by
the UIC Air Quality Sector

Organised by UIC & the Sector's core members

SUSTAINABILITY
Action Week

13 March 2025

WELCOME
& INTRODUCTION

by UIC sector leaders
Cora CRÉMEZI-CHARLET (SNCF)
Philippe CLÉMENT (SNCF Voyageurs)

& UIC advisor
Philippe STEFANOS

SUSTAINABILITY
Action Week

UIC Air Quality Sector

Priorities

- Railway system wears : brakes, pantograph / catenary, wheel / rail, type of tracks, tunnels

Objectives

- Sharing knowledge and best practices
- Analysing regulation in countries
- Sharing experience on solutions to reduce emissions , concentration
- Select and share actions (ex : report on solutions)
- Perform collaborative expertise sharing, cross analyses on results.

UIC Air Quality Sector

Members

Leaders

Linked activity

Work package #23
Covered platforms & tunnel air quality

UIC Air Quality Sector - Workshop timeline

10:00	**Welcome / Introduction**	UIC / SNCF / SNCF Voyageurs
10:10	**Understanding air quality in rail**	NS Ricardo
10:30	**Summary from AQ Sector and an overview of solutions**	SNCF Voyageurs
10:50	**Monitoring/measurement overview, prediction models, validating models vs measurements**	Trafikverkert RSSB SNCF Voyageurs
11:30	**Challenges in managing air quality**	INERIS All
12:10	**Focus on a selection of solutions**	All
12:30	Lunch	
13:30 **16:00**	**Air Quality Sector Meeting**	NDA AQ sector members only

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Understanding air quality in rail

Introduction & workshop: What influences Air Quality

NS Ricardo

Introduction & workshop: What influences Air Quality

- NS (Dutch railways)

Christa Gjaltema, NS

Consultant, christa.gjaltema@ns.nl

13-03-2025

Introduction

Air quality is determined by several pollutants:

Sulphur dioxide, nitrogen dioxide/nitrogen oxides, particulate matter (PM_{10}, $PM_{2.5}$), ozone, benzene, lead, carbon monoxide, arsenic, cadmium, nickel, and benzo(a)pyrene;

Focus is on particulate matter: Small particles in the air

Particles smaller than 10 µm (PM_{10}) can enter the lungs

Particles are produced by combustion engines or by wear of moving parts

The Air Quality group focusses on particulate matter due to wear

Introduction

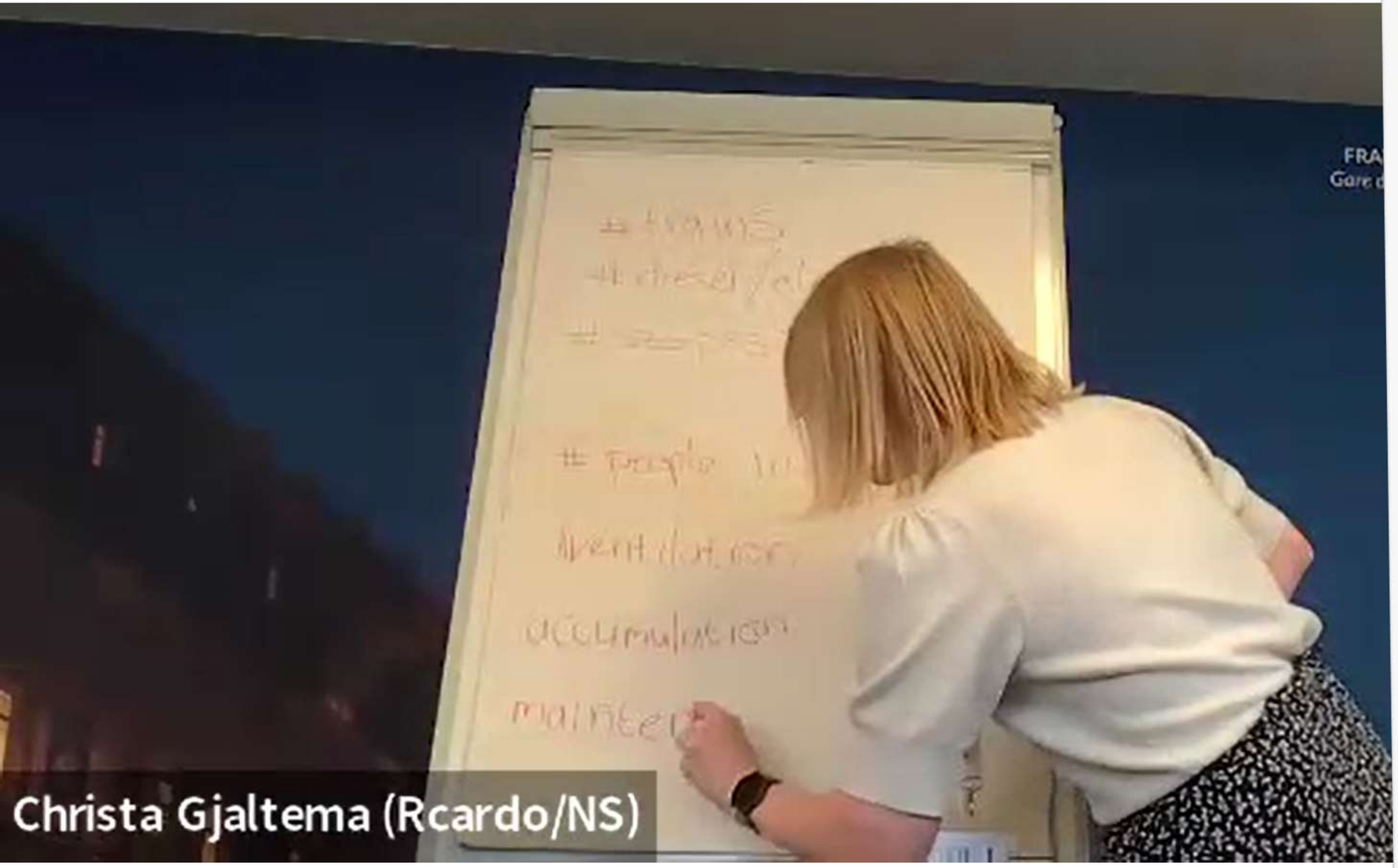
There is no European legislation for air quality in tunnels/underground stations

In tunnels/underground stations we have an almost closed system

Air Quality (due to $PM_{10/2.5}$) could become low

Workshop

What do you think has an influence on the air quality in a tunnel/underground station?



Volume station + depth + height ceiling
#trains p. hour
#diesel/elec
ballast type
#stops / how strong stop
#entrances
resuspension
#people in/out
type of materials
Ventilation
air capture
accumulation

maintenANCE

Speed

Workshop - result

- Train type
  - Exhaust, amount of braking, type of braking, number of wheels, number of pantographs, weight
- Tunnel/station lay-out
  - Curvature, slope, volume (=>concentration), number of entrances / open structures
- Train movement/speed
  - Resuspension of particles, level of friction
- Train-track train overhead wire materials & friction levels
  - The more friction, the more emissions
- Train frequency
  - More trains more particles
- Passenger flow
  - Recirculation, emission of organic compounds, breathed pollutants
- Tunnel/station ventilation/filtration
  - Spreading, humidity
- Maintenance
  - Ballast dust
- Outside/ambient air pollutant concentration
- Deposition of heavier particles

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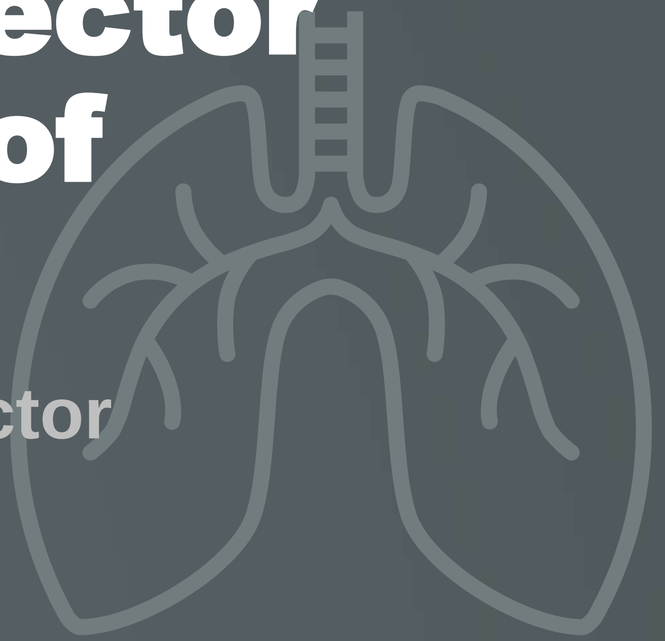
Summary from AQ Sector and an overview of solutions

SNCF Voyageurs, Air Quality Sector



Laurent Dupont, SNCF Voyageurs

Rolling stock engineering - Environment & AQ referent

Summary from Air Quality sector in the Underground Railway stations

Ingénierie du Matériel | SNCF VOYAGEURS

Air Quality

A growing concern worldwide

Air pollution : 4th leading cause of death worldwide

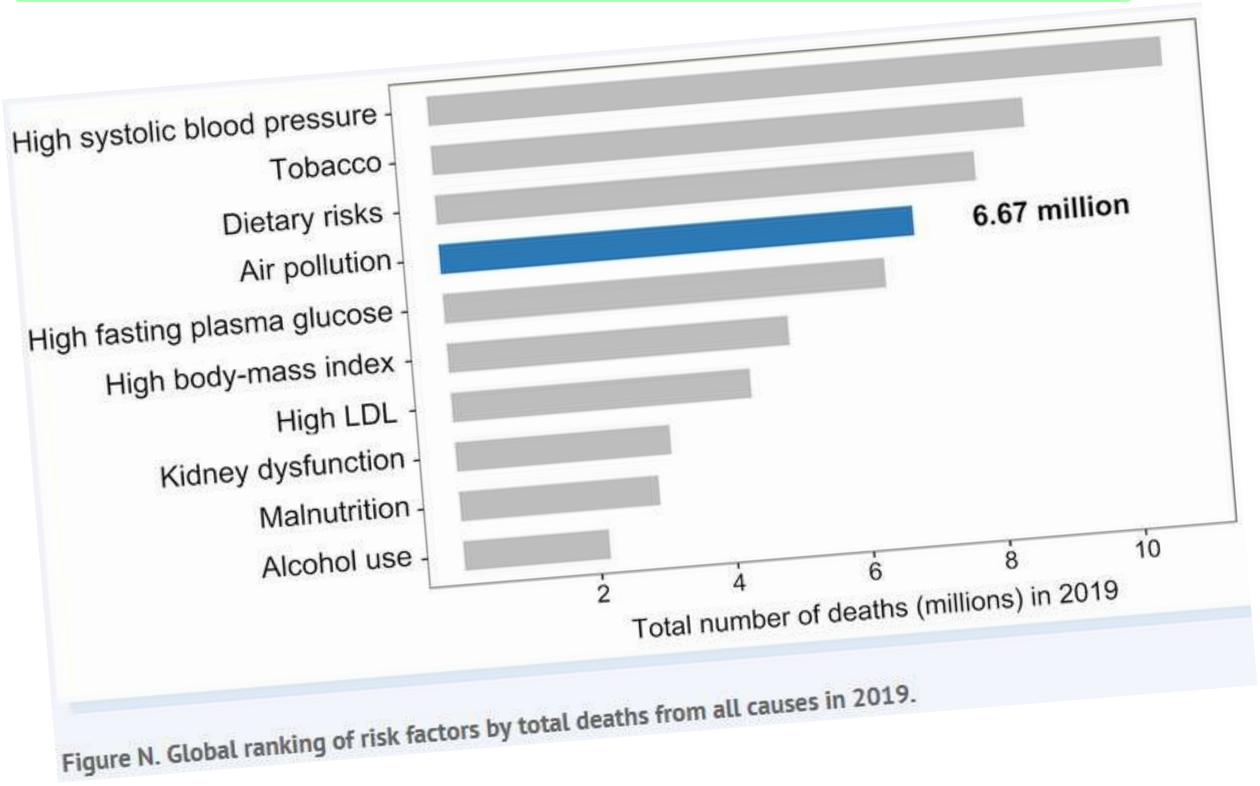
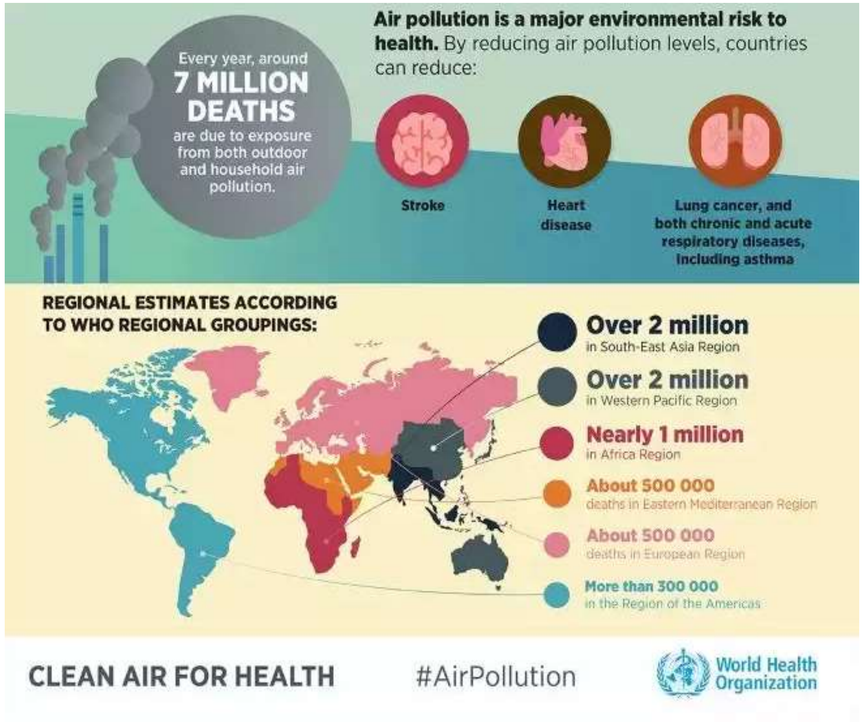


Figure N. Global ranking of risk factors by total deaths from all causes in 2019.

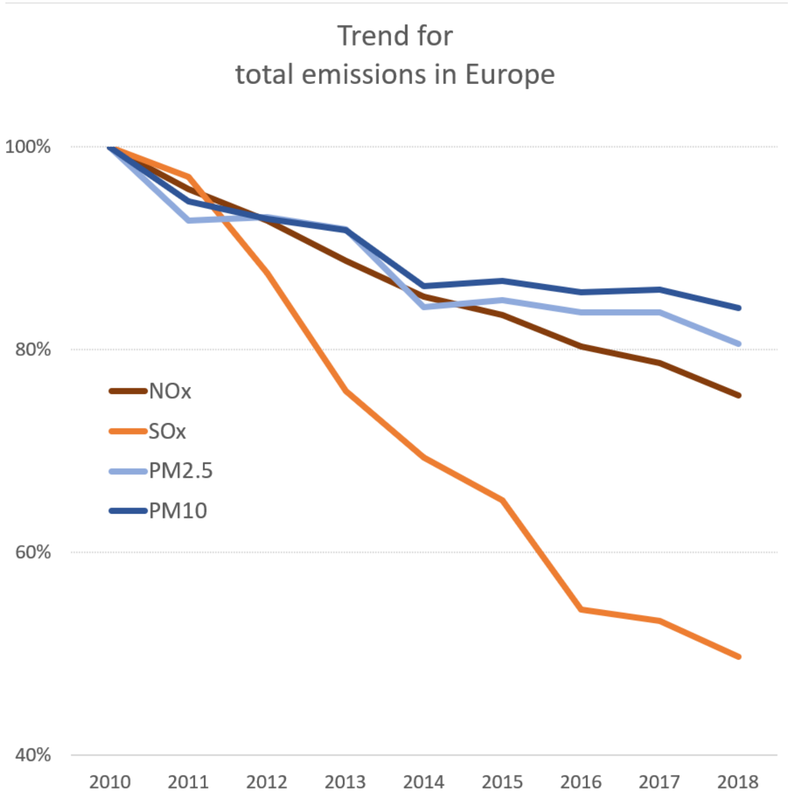
Source : State of global air



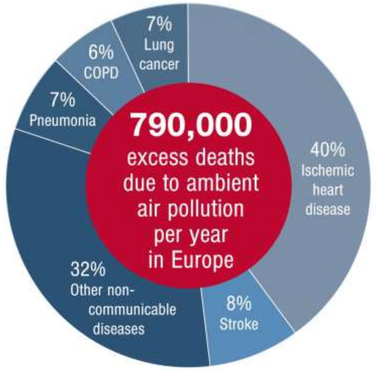
Source : WHO Regional office for Europe

Air Quality

In Europe, continued progress but more needs to be done

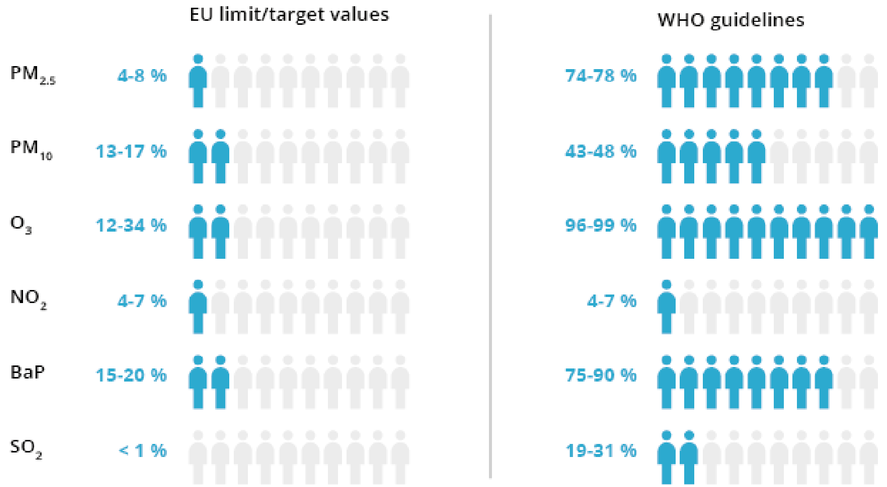


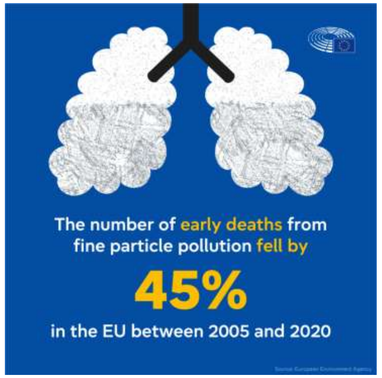
Source : European Environment Agency

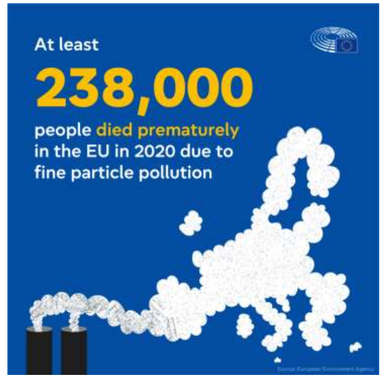


Source : Santelog

Share of the EU urban population exposed to air pollutant concentrations above EU and WHO reference values in 2016-2018







Source : European parliament

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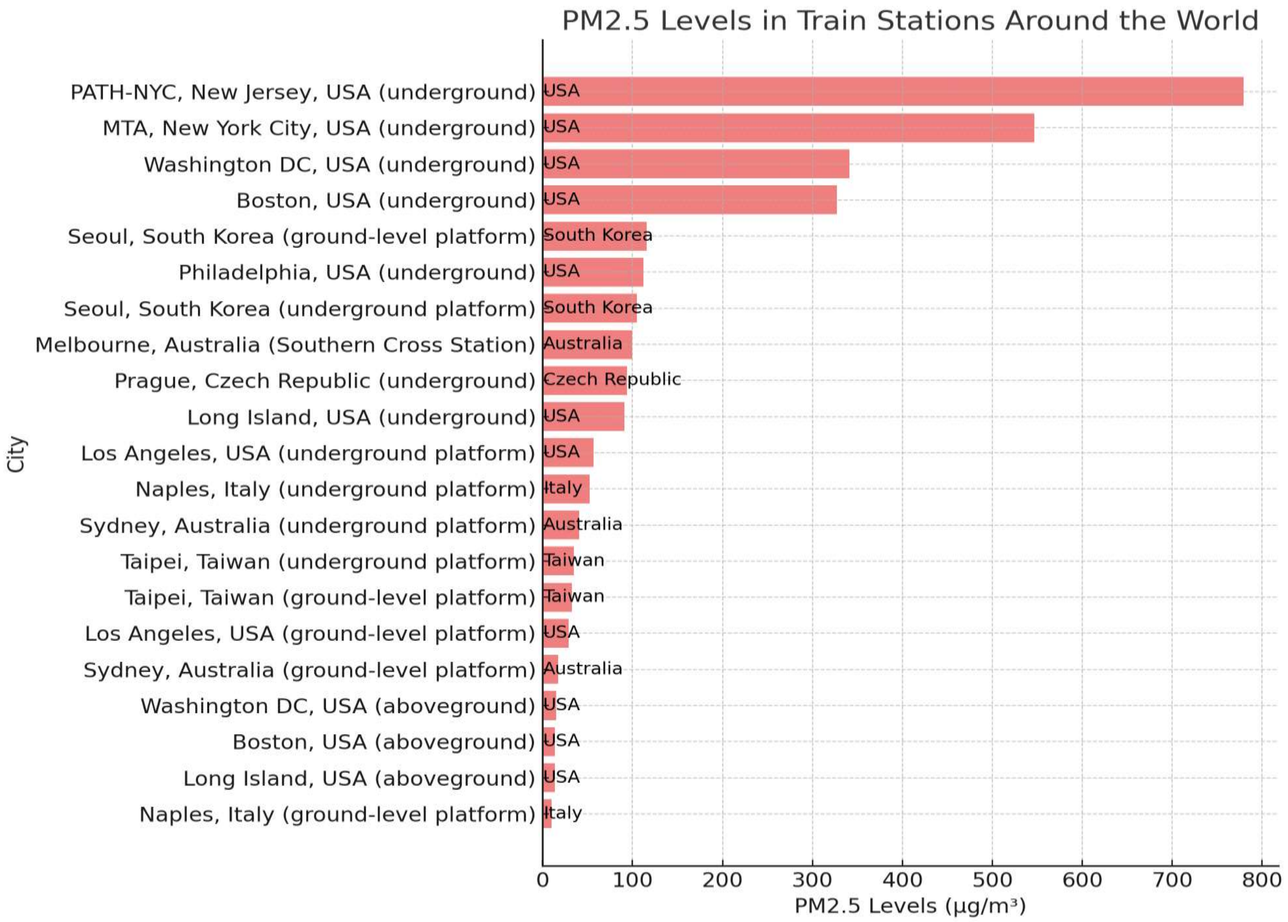
Air Quality in the Underground Railway Stations (URS)

Potentially high concentrations of fine particles

HEALTH

Toronto subway riders, workers breathing air 10 times worse than outside: study



NYC Subway Riders See 'Exceptionally High' Air Pollu

A new study finds that longer commutes mean higher levels of
Low-income riders face the highest burden.

Air pollution in subways is worse than you think

By Lauren Tousignant

April 26, 2017 | 2:59pm

Shutterstock

SANTÉ

Particules fines : l'air du métro parisien largement plus pollué que l'air extérieur

Air pollution at Philadelphia's 15th Street subway station 'considerably higher' than EPA standard

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Air Quality & Regulations

A wide range of regulations

Ambient (outside) air

WHO guidelines
EU Directive
French Environmental Code

annual & daily values

Inside air (Home - Offices - On board trains)

French Environmental Code

80% of the lifetime

Workplaces

EU Directive
French Labor Code

Underground stations

No regulation
Except South Korea / Taiwan

Pollutant	Duration (hours)	Regulatory limit values for underground railway stations
PM10	24	100 µg/m^3
PM2.5	24	50 µg/m^3

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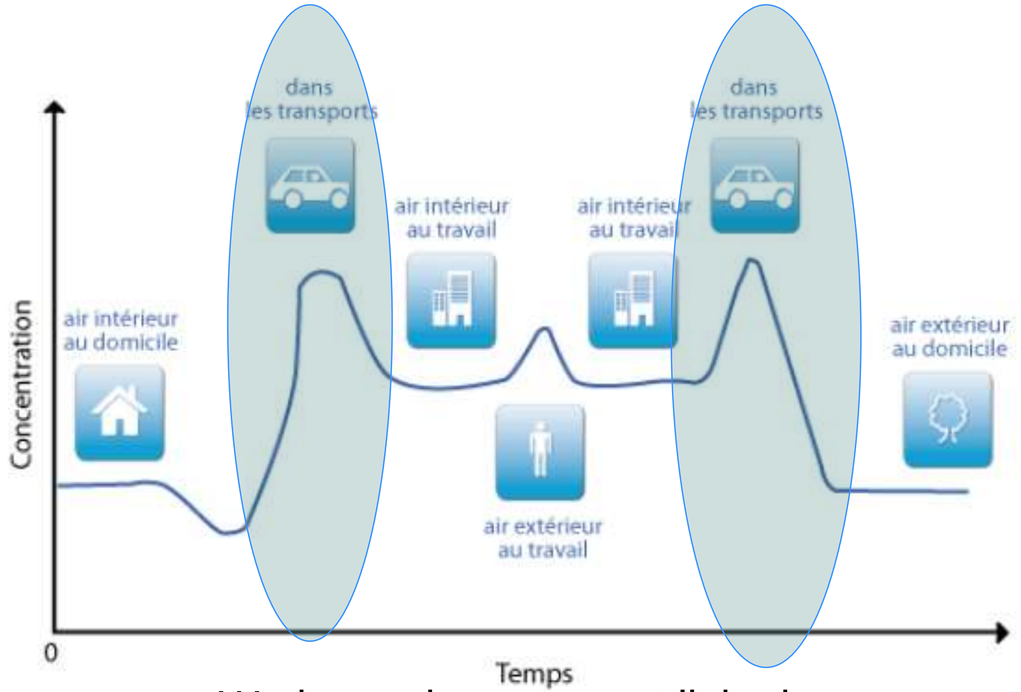
Underground stations - Guideline values

Recommended limits according to EU Directive on ambient air | WHO guidelines on ambient air

Polluant	Durée cumulée de fréquentation de l'EFS sur une journée	Concentration calculée à partir de la valeur limite journalière de la directive européenne 2008/50/CE * (C_{sout_Lim}) ($\mu g.m^{-3}$)	Concentration calculée à partir de la valeur guide journalière de l'OMS * (C_{sout_OMS}) ($\mu g.m^{-3}$)
PM_{10}	2h/j	260	80
	1h30/j	330	100
	1h/j	480	140
	30min/j	940	250
$PM_{2,5}$	2h/j	s.o.	50
	1h30/j	s.o.	60
	1h/j	s.o.	80
	30min/j	s.o.	140
*Valeurs calculées en assimilant les particules d'EFS aux particules de l'air ambiant			

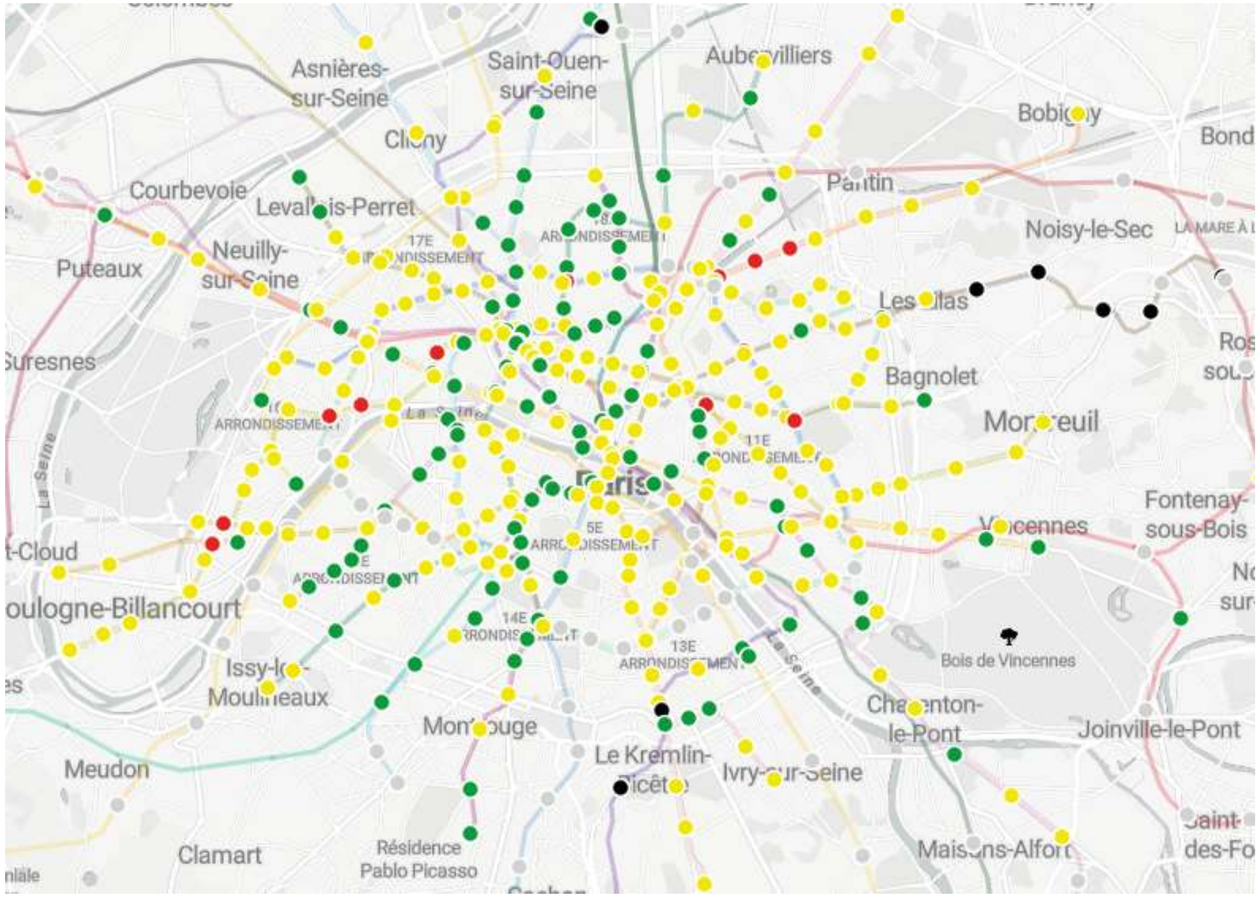
s.o. : sans objet



Works on dose concept linked to duration of exposure per day

Pollutant	Cumulative time in the URS (train + platform) over one day (minutes)	Calculated concentration based on the WHO annual limit value for 2021 ($\mu g/m^3$) with a ratio of 0.5	Calculated concentration based on the WHO annual limit value for 2021 ($\mu g/m^3$) with a ratio of 1
PM10	90+15	360	206
	90+20	332	197
	90+30	288	180
	70+20	393	240

Ile de France - Mapping air quality



Mapping air quality In the Ile de France transport network

Pollution levels (PM) in 426 stations

- 123 low levels (30%)
- 276 average levels (67%)
- 13 high levels (3%) : $[PM10]_{av} > 480\ \mu g/m^3$

Based on measurements in 44 stations

Modelling (“Machine learning”) based on the configuration of the station, traffic, rolling stock …

Pollution dans le métro parisien : 13 stations au-dessus de seuils recommandés

Selon une étude d'Airparif qui a analysé la qualité de l'air sur 426 quais de gares et stations souterraines du métro parisien, 13 dépassent les limites acceptables, tandis que des traces de pollutions plus légères ont été signalées sur 426 sites.

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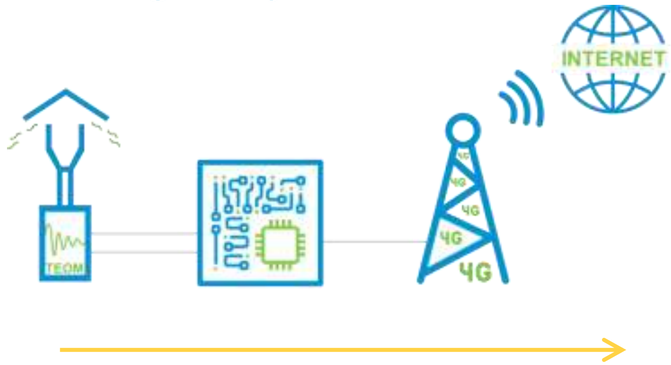
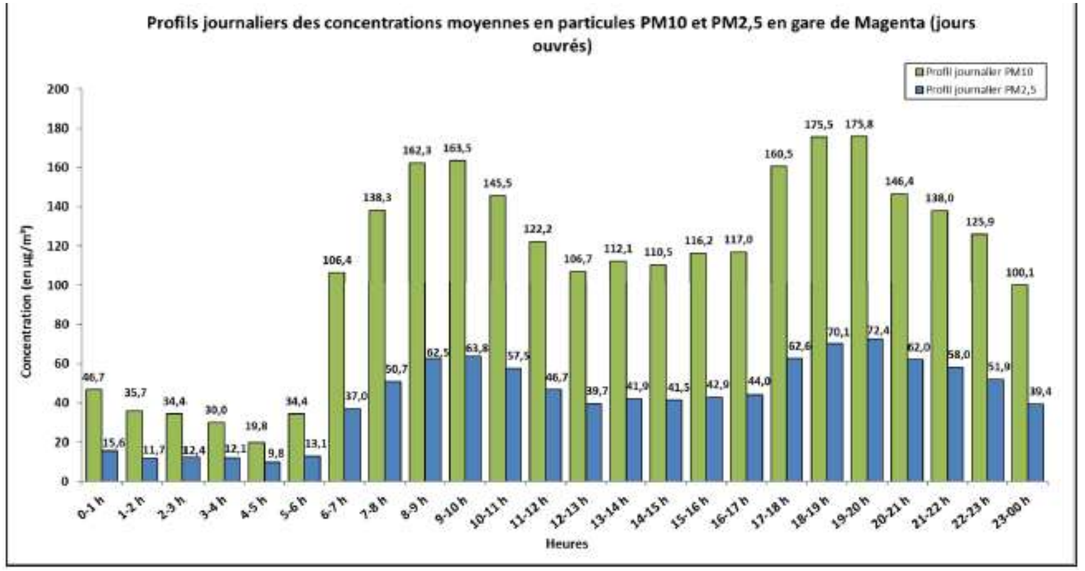
Air Quality monitoring in URS

3 stations with 24/7 measurements by SNCF Railway Test Agency





Real-time particles concentration and size distribution

Open access data

https://eqair.sncf.fr/

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Ongoing deployment of a micro-sensors network

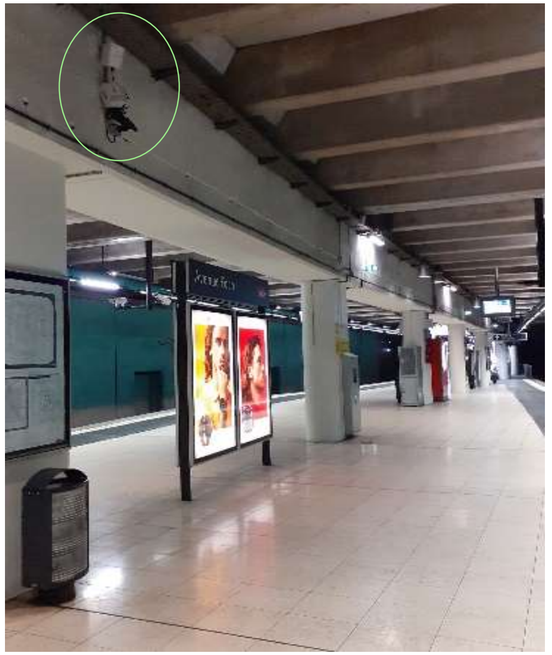
Calibrated for the PM density in the URS

Integration Into a

Monitoring station

CO2, HR, T, PM2.5/PM10
Power supply / Batteries
4G/Lora

Development of a low-cost sensor Next-PM URS – PM2.5 & PM10



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MATERIEL'S WEAR, THE SOURCE OF PARTICLES

Catenary / pantograph

Copper & carbon

Mechanical brakes

Metal, oxides…

Wheel / Rail

Iron

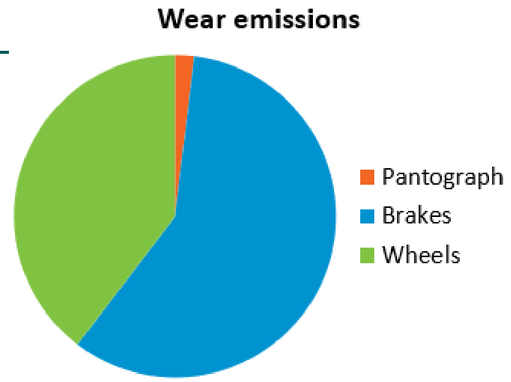
Infrastructure

Silica (ballast), limestone (concrete)

Diesel / Maintenance works

Diesel locomotives : PM 2.5, elemental C (Black carbon), organic C

Main source identified



External sources

Outside pollution : depends on the depth, ventilation…

Anthropic sources : Users

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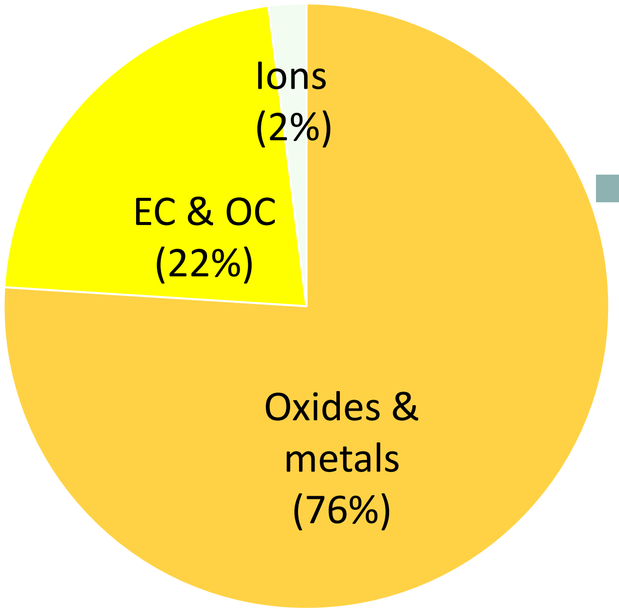
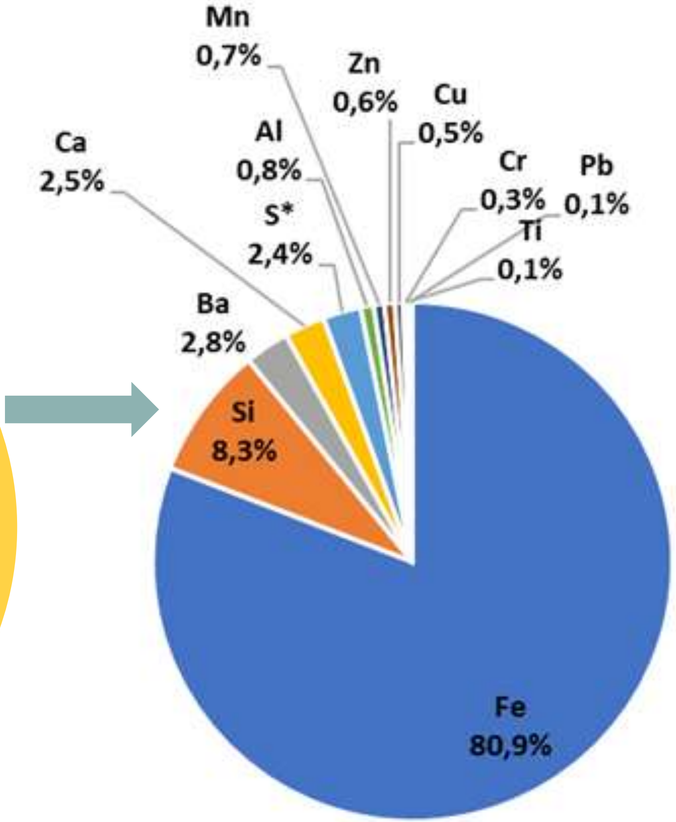
PM Chemical composition

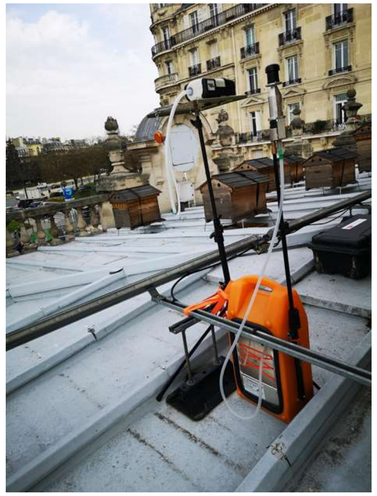
Station Av. Foch

- Measurement – Platforms, roof
  - 5 4-week campaigns
    - ✓ Statistical analysis (PMF)
    - ✓ Temporal / seasonal variability
  - Ultrafines particles (< 100 nm)





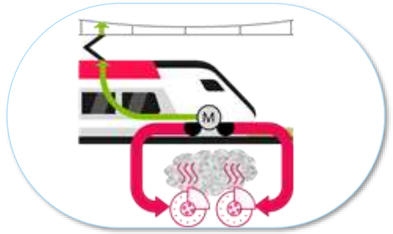
Metals



→Outdoor Air: 17,9% PM10
→Railway activities: 82,1% PM10

Mitigation Solutions

TRAINS

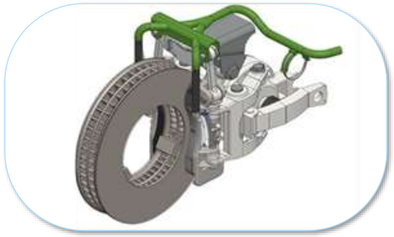


Regenerative braking

recovering electrical energy to catenary

Less emissive materials

for brake shoes and pads



Collecting

at source airborne particles

STATIONS

Ventilation

in stations with new motors/fans to improve the renewal of air

Air treatment on platforms

by ionization, humid filtration, etc…

Station/Tunnel cleaning

Vacuum/washing train
Station cleaning

Efficiency of solutions on air quality, costs and delay of implementation need still to be determined

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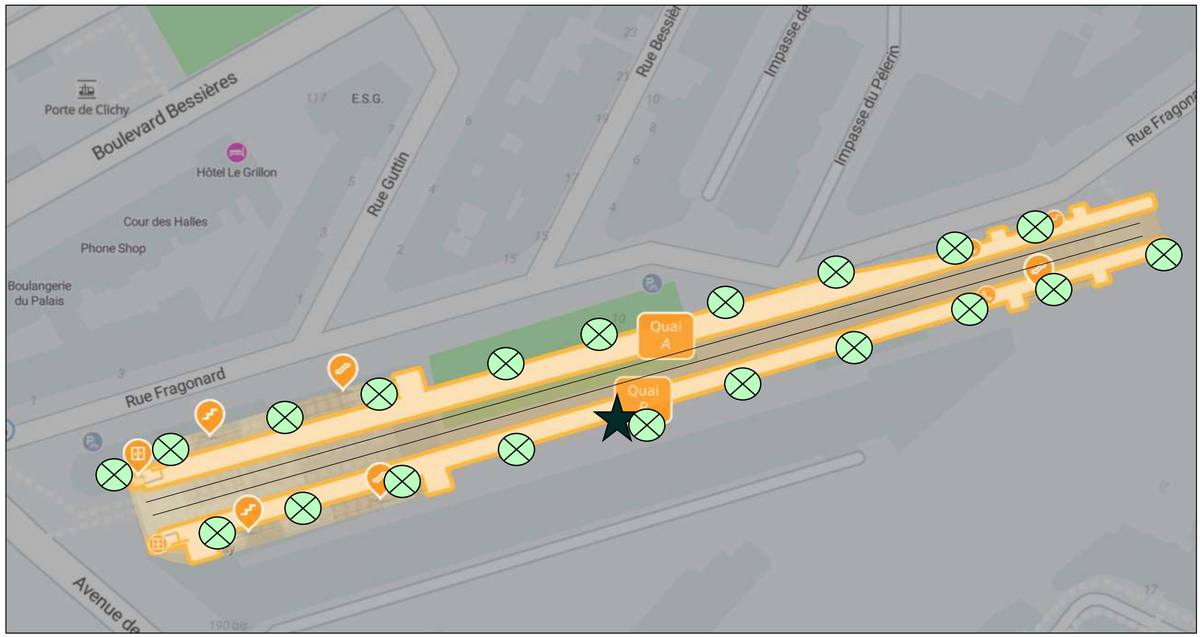
Mitigation solutions – Feedback related to experiments

Experimentation realised at the Sevran-Beaudottes station (RER B) including Mann+Hummel's system (mechanical filtration technology)

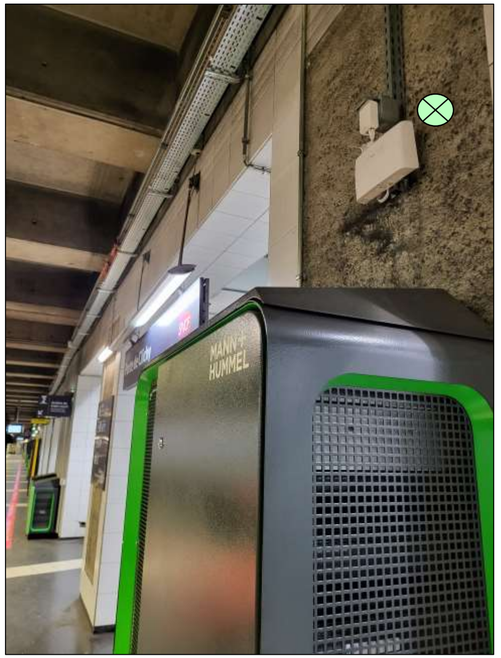
- Porte de Clichy station – Measurement devices



Low cost sensors

Reference devices (TEOM + FIDAS)

Reference measurement location on the platform



Mechanical filtration devices by Mann + Hummel and low-cost sensor

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Rail4Earth project

2023 - 2026

WP23 - Covered platforms & tunnels air quality

- Air quality measurement method
- Inventory of low-cost sensors
- Air quality prediction tool
- Air quality improvement solutions
- Railway activities emission calculation method

“The project is supported by the Europe’s Rail and its members”

Conclusions & Perspectives

Improving air quality in the Undergroud

Railway Stations is a necessity

- ✓ Increasing public pressure
- ✓ Precautionoray principle
- ✓ Forthcoming regulation in the URS and in the trains

- A global Issue in the world !
- In the future, better conception of new rolling stocks and stations = lower concentrations
- Solutions to develop for existing stations & rolling stocks
  - ➢ **Not a unique solution**
- ➢ Some evolutions to come soon…
  - ➢ **Generalization of Air Quality measurements (Microsensors, Bigdata…)**
  - ➢ **Developement of prediction tools / smart ventilation**
  - ➢ **Ultrafine particles Measurements**

Thank you

Contacts

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Monitoring/measurement overview, prediction models, validating models vs measurements

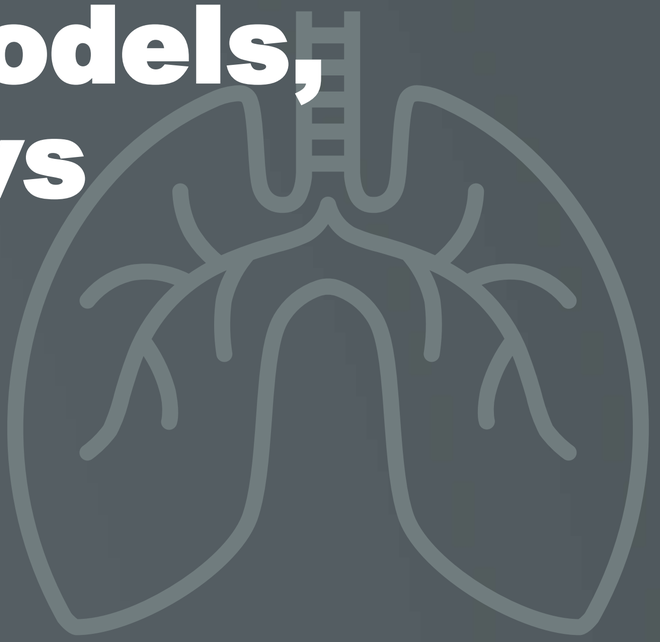
RSSB

&

KTH (Swedish Royal Institute of Technology)

Monitoring/measurement overview, prediction models, validating models vs measurements

RSSB



RAIL SAFETY AND STANDARDS BOARD

Air Quality Measurements in Great Britain Rail

Connor Wilkinson – Air Quality and Emissions Specialist, RSSB

13th March 2025

The Rail Safety and Standards Board (RSSB)

The independent safety, standards and research body for Great Britain's rail network

- Centre of Excellence for social and environmental sustainability
- The Sustainable Rail Blueprint: a comprehensive, Government-endorsed sustainability strategy for the rail industry across both environmental and social topics
- 11 sustainability topics, including **Clean Air**

Clean Air

A railway that supports a positive impact on local air quality

Introduction

What is Air Quality Monitoring?

- Measurement of key pollutants known to be harmful to human health such as nitrogen oxides (NOx) and particulate matter (PM), in addition to other pollutants such as carbon dioxide (CO_2) and volatile organic compounds (VOCs).
- Uses various monitoring techniques, such as diffusion tubes, reference monitors, low-cost sensors (LCS), and mobile monitoring units
- Tracking of pollutant levels in real-time or over defined periods. Observing trends (seasonal trends etc.)

Introduction

Key purposes for monitoring

- Provide information on the current state of air quality (**i.e. baseline**).
- Provide location specific air quality information to **prioritise improvement** measures in the highest risk locations;
- Capture the future changes in air quality due to policy changes and application of mitigation measure, so as to **assess their effectiveness** in improving air quality;
- To measure compliance against relevant standards
- Identification of pollutant risks to staff and passengers, supporting wellbeing initiatives.
- To support modelling & research – Provides data to help:
    - Verify model accuracy by comparing predictions with measured data
    - Inform ventilation strategies and future train/station design

RSSB Air Quality Monitoring Network (AQMN)

RSSB AQMN

Scope and coverage

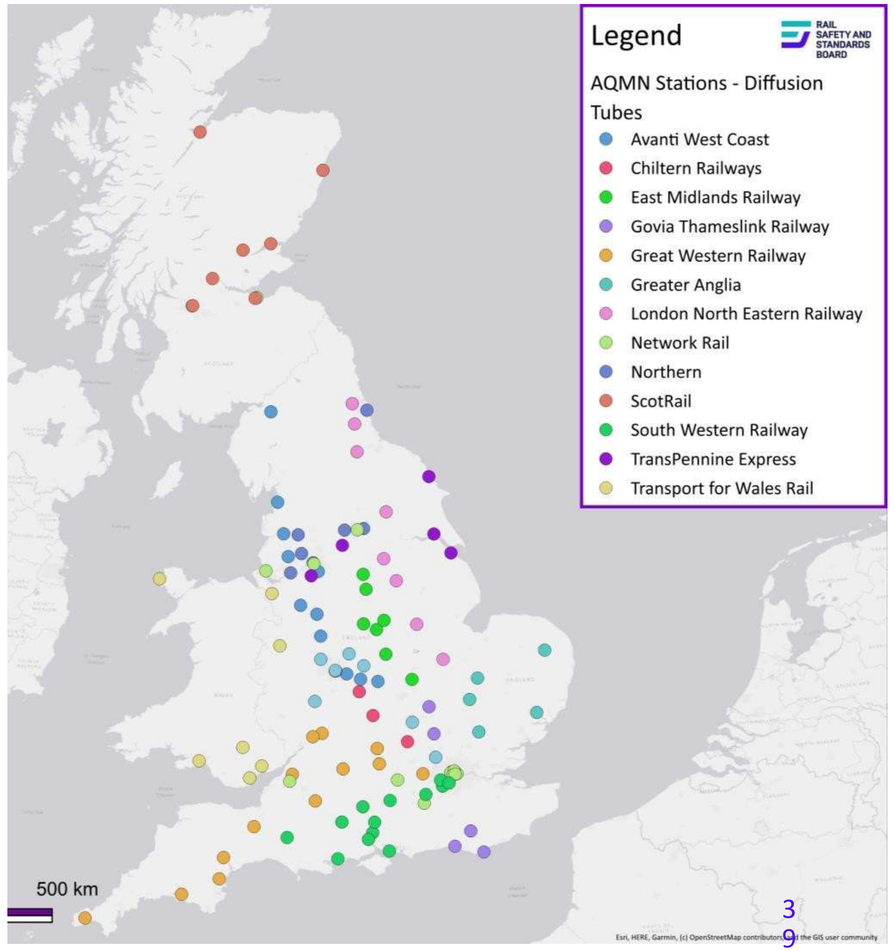
Focussing on pollutants from diesel exhaust: nitrogen dioxide (**NO_2**) **and particulate matter (**PM_{10} **and** $PM_{2.5}$**)**

Coverage

- Currently covering 72 stations in England, Scotland and Wales
- Project involves multiple stakeholders

Timeline

- Preparation started back in 2020
- Significant amount of time spent on early engagement with industry and stations to obtain consent
- The monitoring network commenced its operation in January 2022 (phased deployment of equipment)



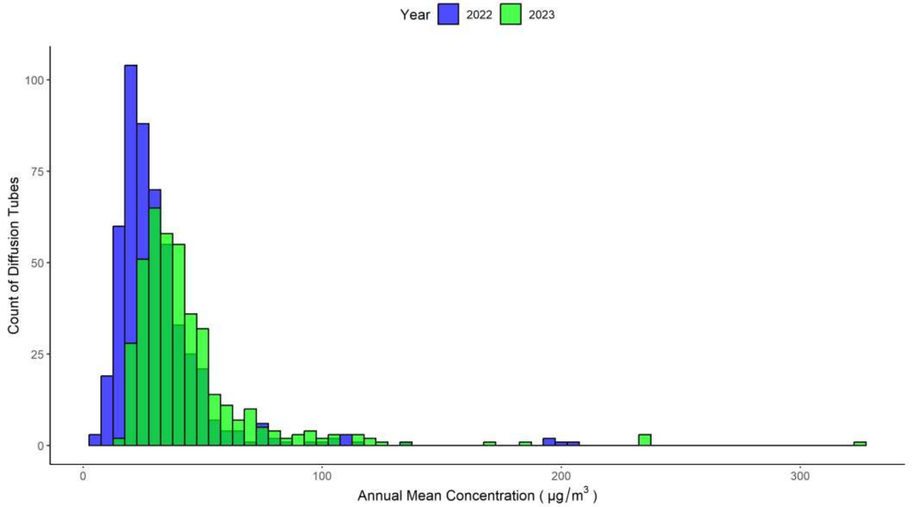
Monitoring equipment used in AQMN

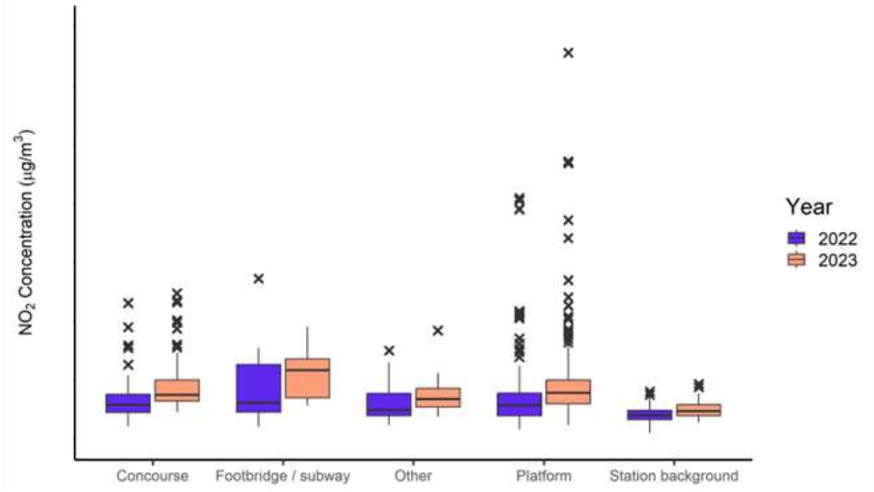
	Diffusion tubes (DTs)	Reference monitors	'Low-cost' sensors (LCSs)
			
Make and model	Gradko 20% TEA/Water (mesh-capped)	NOx: Aeris Model AE2041 PM: BAM 1020	AQ Mesh
Stations	All AQMN stations	5	16
Average per station	5	1	2-3
Location(s)	Platforms, concourse, subway, overbridge, background	Platform	Platform, concourse, background
Key purpose	Provides an average NO_2 concentration over a set period (e.g., 2-4 weeks). Simple, low-cost monitoring, and ideal for long-term trend analysis.	A high-cost method which offers highly accurate, real-time hourly measurements of NO_2 and PM. Good for short and long-term trend analysis.	A low-cost method providing real-time NO_2 and PM data (up to 15 mins). Less accurate than reference monitors but useful for trend analysis.

RSSB AQMN

Key findings

- Data collected has shown that about 50 stations across the network (2%) have an air quality issue
- These **2% of stations account for 22% of all passenger movements** across the network
- Data suggests level of NO_2 within station is largely driven by diesel train activities, less so for PM.
- Difficulty measuring PM in train station environments.
- Publication of Annual Report for 2022 and 2023
  data subject to ministerial approval





RSSB AQMN

How will the data be used?

Air Quality Improvement Plans (AQIPs):

- Data used to produce plans for stations with identified air quality issues.
- Focused measures to reduce NO_2 levels, particularly from diesel train activities.

Consolidated Station Air Quality Plans:

- Data will be used to predict changes in future air quality (up to 2050), as well as recommending measures to improve air quality at stations.

Policy and Decision-Making:

- Data informs future policies to improve station environments.
- Helps guide investment in future rolling stock and improved ventilation systems.

RAIL SAFETY AND STANDARDS BOARD

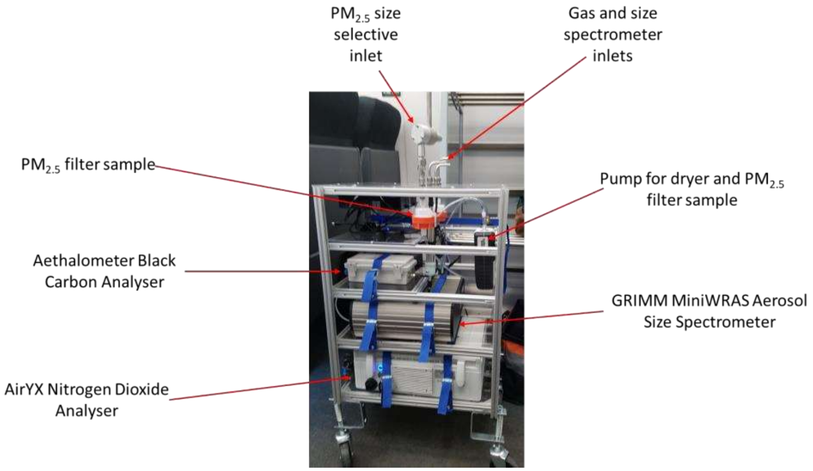
Measuring Air Quality Onboard Trains

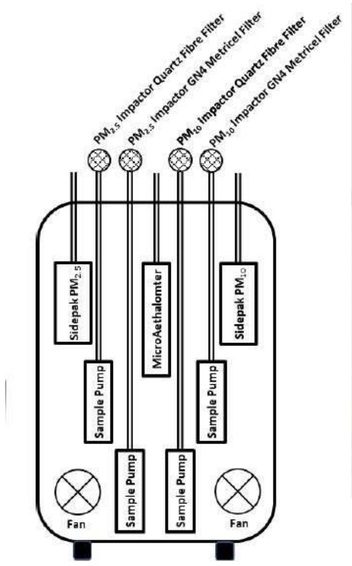
Monitoring Onboard Trains

RSSB Projects

Two projects undertaken to measure air quality onboard trains:

- **T1188 (Analysis of Air Quality On Board Trains)** – Measured NO2, PM and Black Carbon (BC) on six different train types on five separate journeys, 30 journeys in total
- **Onboard Particulate Matter Speciation Project** – Measured PM, CO2 and BC on six different train types on five separate journeys, 33 journeys in total. Chemical composition of PM analysed.

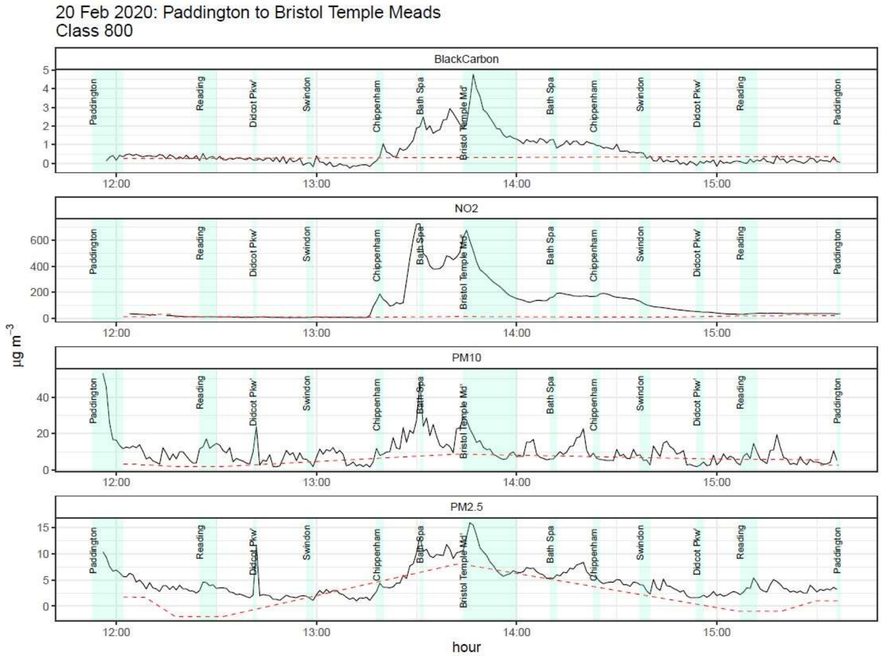




Key findings – T1188

Air quality onboard trains was different along the different routes

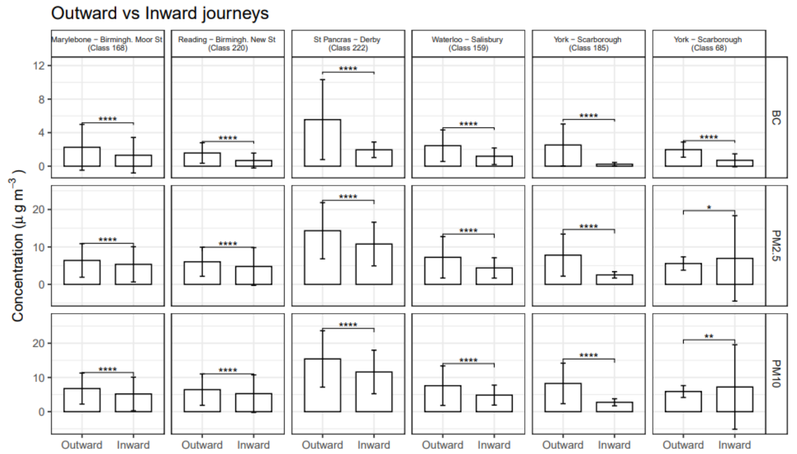
- The highest levels of NO2 were found between London and west of England (crossing city and suburban areas), on board a a new diesel-electric bimode intercity train, specified by the government (Class 800).
- There was a large difference in measured NO2 when comparing diesel mode to electric mode on both the Class 800 and a regional/local train (Class 755).
- The levels of these pollutants and the exposure of the passengers were found to vary depending on:
  - Train type
  - Location of the exhaust relative to Heating, ventilation, and air conditioning (HVAC) inlet
  - Track gradient
  - Whether the train was in a tunnel/station.
- Newer train types do not necessarily have better on-board air quality compared to older trains.

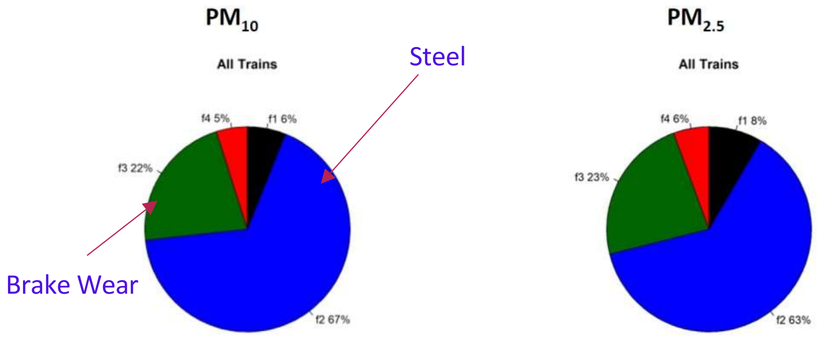


Key Findings – Onboard Speciation Project

Implications of Chemical Composition for Toxicity

- Variation in PM and BC concentrations on different trains and routes
- Metal concentrations were above levels seen close to roads in central London
- Metal contribution to PM mass was small (1-2%). Iron from steel largest contributor.
- Not enough health evidence to target mitigation of one PM component over another
- Diesel exhaust has significant influence on concentrations in carriages – reducing exhaust emissions should remain a priority

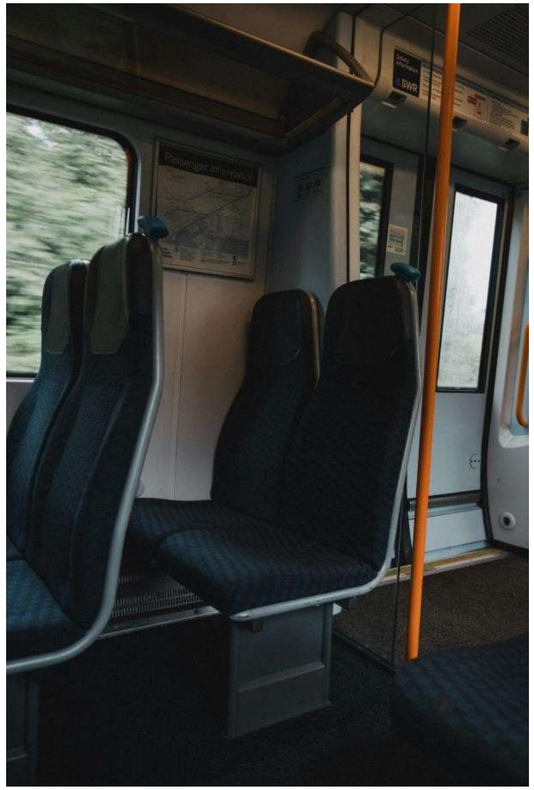




Monitoring Onboard trains

How will the data be used?

- Modification of HVAC system on intercity trains to reduce emissions entering train during certain parts of the journey (such as in tunnels).
- Reducing emissions when engines started up on bi-mode trains (ad- blue extended dosage).
- Repeated testing on same trains as previous studies where air quality was an issue.
- Further testing onboard other trains, including new diesel, bi-mode, electric and battery trains.



Thank you!

Any Questions?

Connor Albutt-Wilkinson – Air Quality and Emissions Specialist

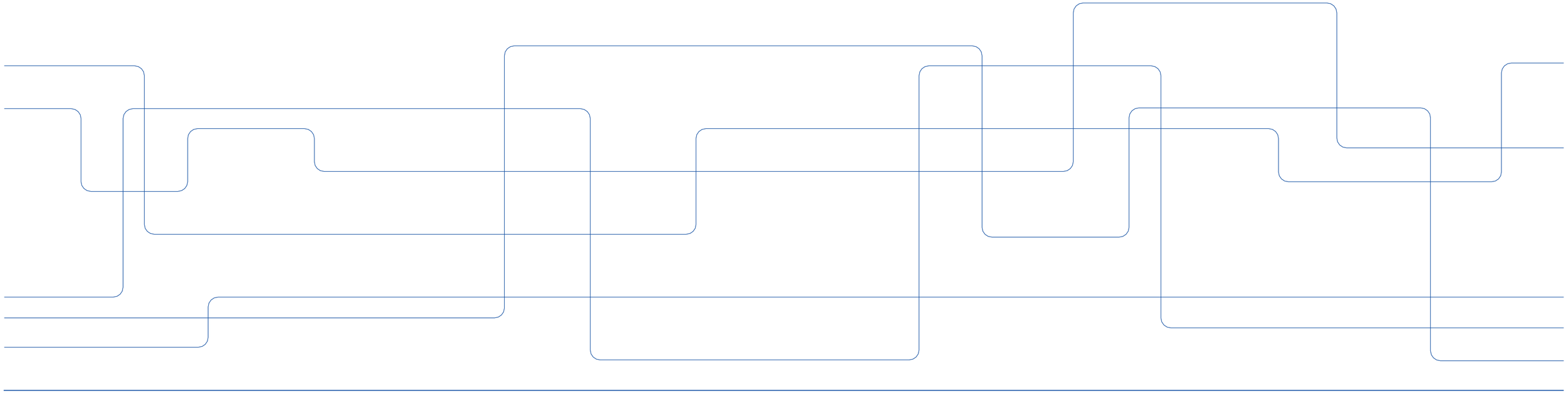
connor.albutt-wilkinson@rssb.co.uk

Monitoring/measurement overview, prediction models, validating models vs measurements

KTH (Swedish Royal Institute of Technology)

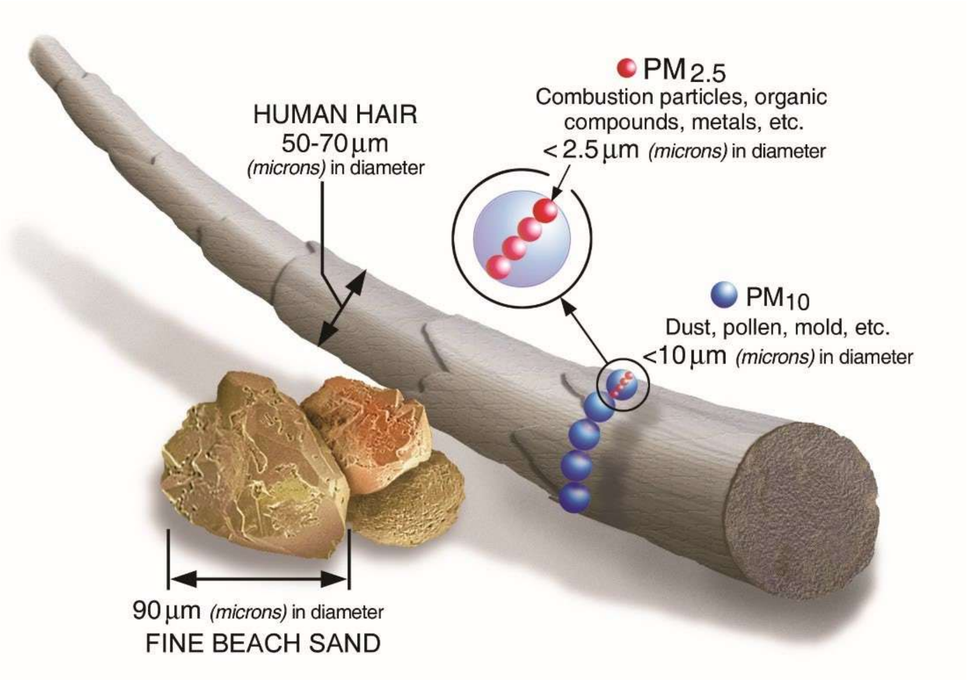
Modeling air quality in rail tunnels
Rail4Earth WP23.3

Minghui Tu, Theo Schwartz, Gerrit Jan Bruin, Astrid Manders-Groot, and Ulf Olofsson



Airborne particles

- **Airborne particles**: the term for a mixture of solid particles and liquid droplets found in the air
  - **PM10**: inhalable particles, with diameters ≤ 10 µm.
  - **PM2.5**: fine inhalable particles, with diameters ≤ 2.5 µm.



From US EPA

Trains in the Stockholm metro system

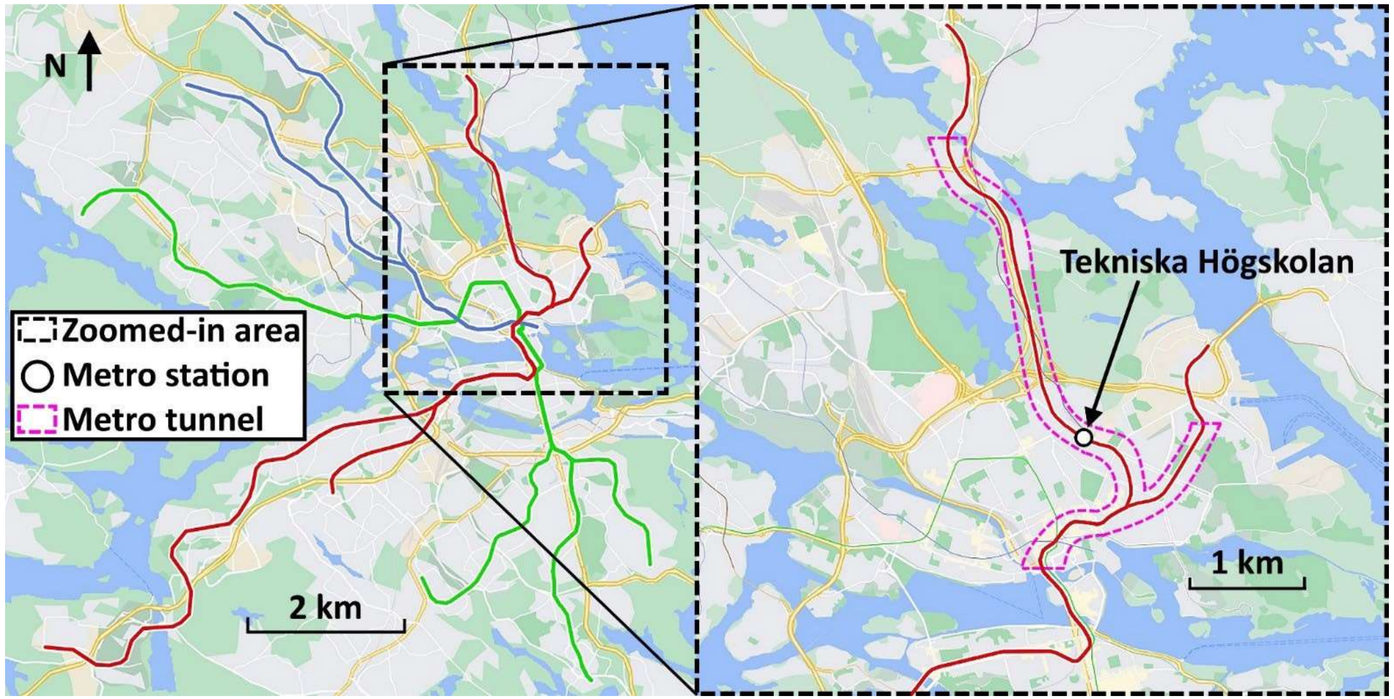
- **CX train**
  - Oldest and will be eliminated
  - Mechanical and resistance brakes
  - Weight 200 T
- **C20 train**
  - Main train type
  - Regenerative and mechanical brakes
  - Weight 201 T
- **C30 train**
  - New train type
  - More bogies
  - Regenerative and mechanical brakes
  - Weight 232 T

Sources of airborne particles

- High particle concentration can be found around rail traffic systems in tunnels
- The wear sources of the particle in rail traffic system can be:
  - wheel-rail contact
  - mechanical brake system
  - electrical power system

Field measurement

- Station: Tekniska högskolan (KTH)
  - Red line
  - Underground platform
  - Natural ventilation system
- Device: Fidas 200S



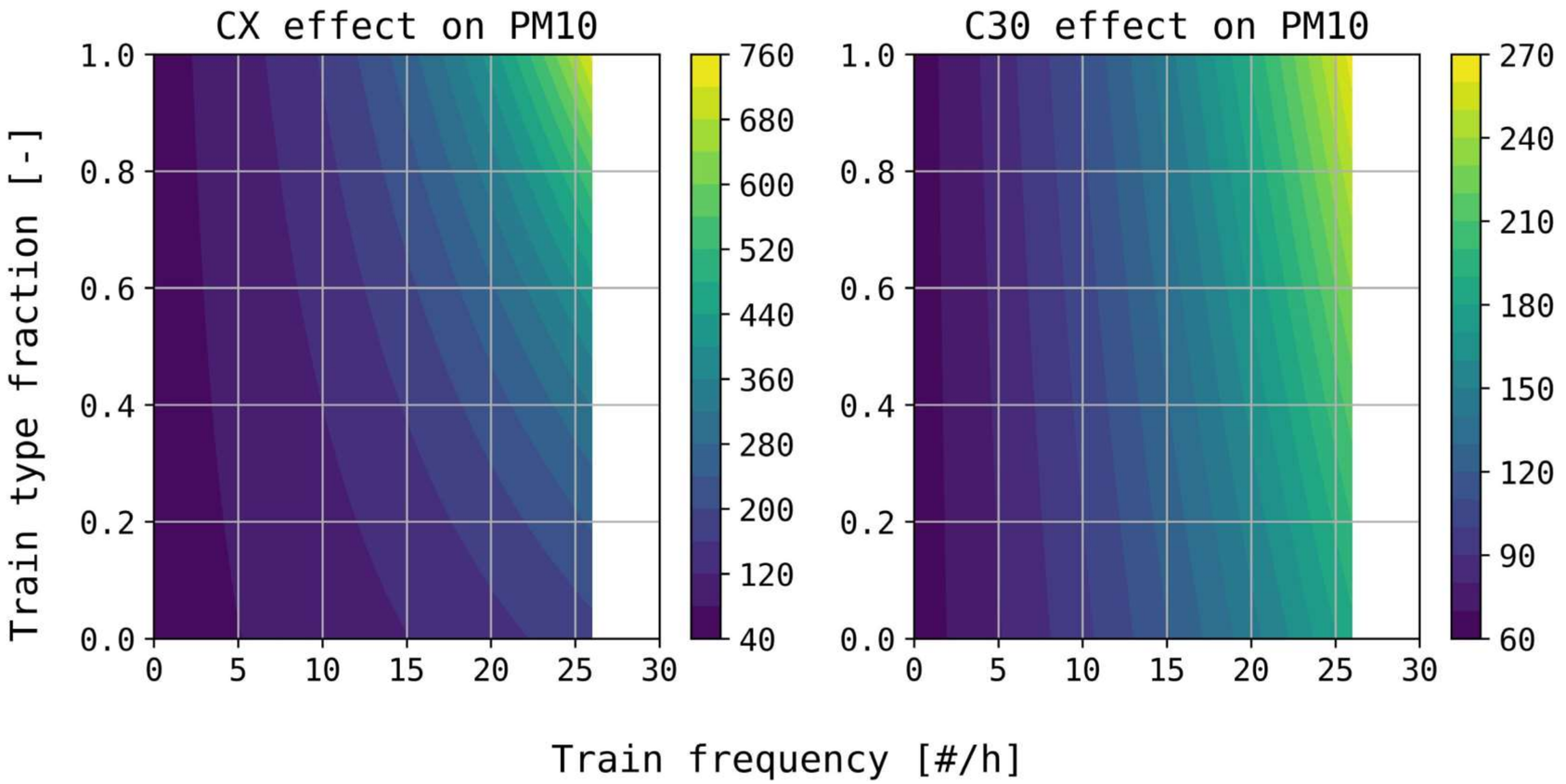
Platform PM modelling

$$C = \underbrace{\begin{matrix}\left(k_t + k_{CX} \cdot r_{CX} + k_{C30} \cdot r_{C30} + \left(k_{ut} + k_{utv}(v)\right) \cdot C_u + k_{tp} \cdot n_p\right) \cdot n_t + \\ \left(k_p + k_{up} \cdot C_u\right) \cdot n_p + \left(k_u + k_{uv}(v)\right) \cdot C_u + k_v(v) + C_0\end{matrix}}_{\text{fixed}} + \underbrace{C_{HoD}(mon, h) + C_m(m, h)}_{\text{random}}$$

- k_t – Train frequency factor
- k_{CX} – CX train type factor
- k_{C30} – C30 train type factor
- k_p – Passenger factor
- C_{HoD} – Hour of day factor
- C_m – Maintenance factor
- C_0 – Intercept
- n_t – Train frequency
- r_{CX} – CX train fraction
- r_{C30} – C30 train fraction
- n_p – Passenger flow
- *mon, h* – Month and Hour of the day
- *m* – Night maintenance day

Model results and train effects

- Estimation quality
  - $R^2 = 0.85$
- PM10 increases with train frequency
- Under a fixed train frequency
  - PM10 seriously increases with the CX train fraction
  - PM10 mildly increases with the C30 train fraction



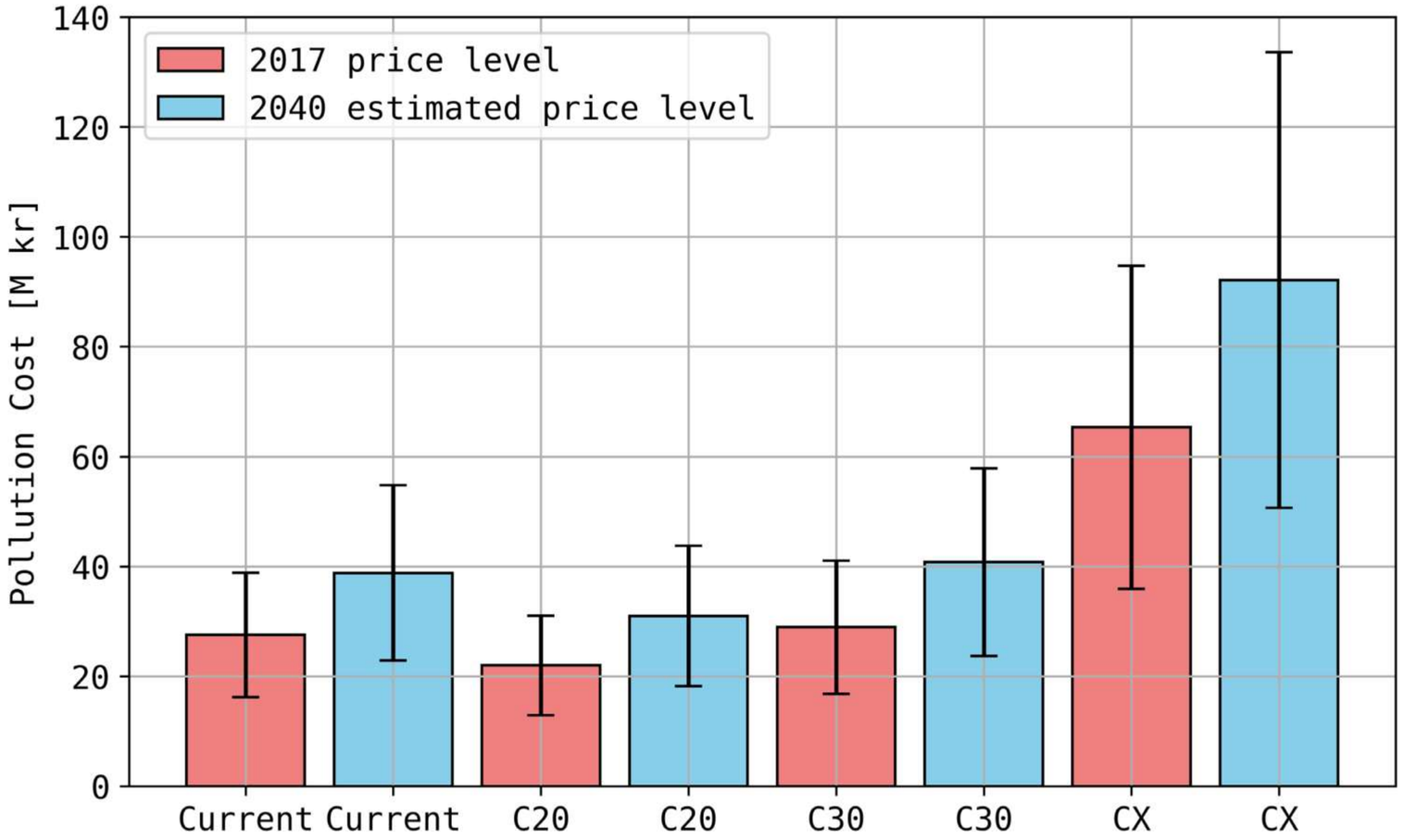
Pollution cost estimation

- According to the yearly estimated rail traffic PM10 pollution cost in ASEK
  - Based on 2017 price level: **1600** SEK/(µg/m^3)/person/year
  - Based on 2040 price level: **2256** SEK/(µg/m^3)/person/year
- Assumption: The average waiting time for a passenger on a platform
  - On workdays: **5** min
  - On Holidays: **10** min
- A yearly particle pollution cost on the KTH metro platform will be estimated in combination with the statistical model output

SEK/(µg/m^3)/person/hour	Workday	Holiday
2017 price level	0.015	0.030
2040 price level	0.021	0.043

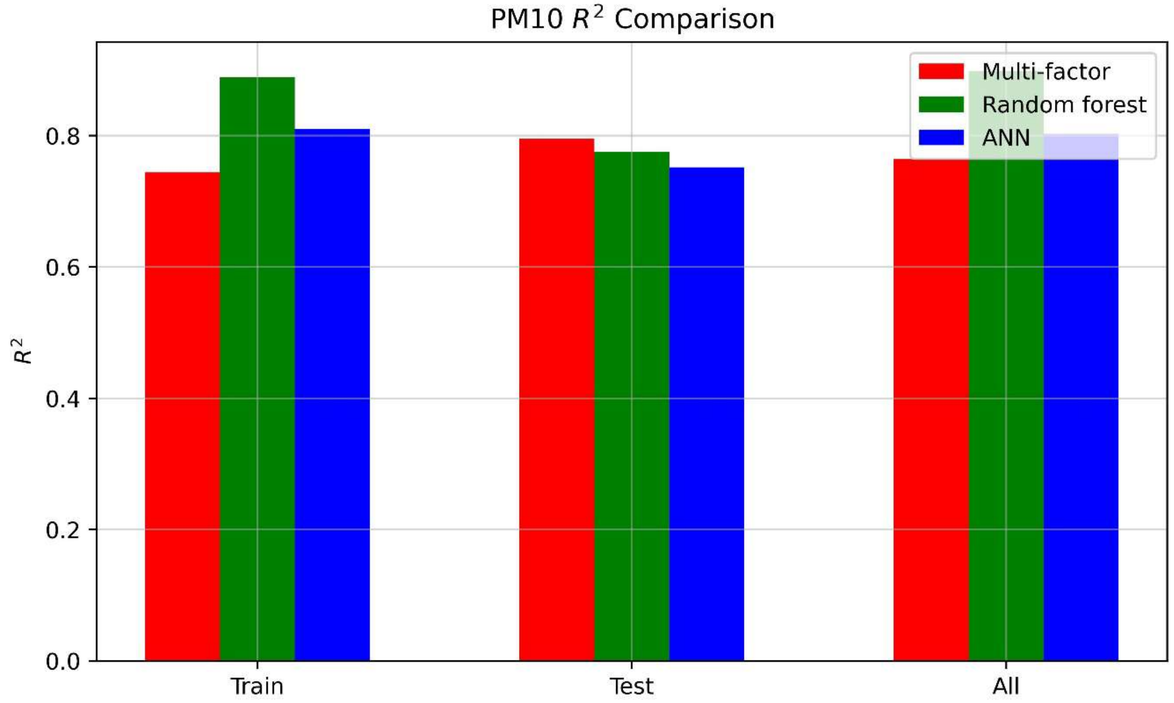
Estimated pollution cost

- Under 2022 situation
  - 27.5 M SEK (2017)
  - 38.8 M SEK (2040)
- Only use C20 trains
  - - 20% pollution cost
- Only use C30 trains
  - + 5% pollution cost
- Only use CX trains
  - + 137% pollution cost

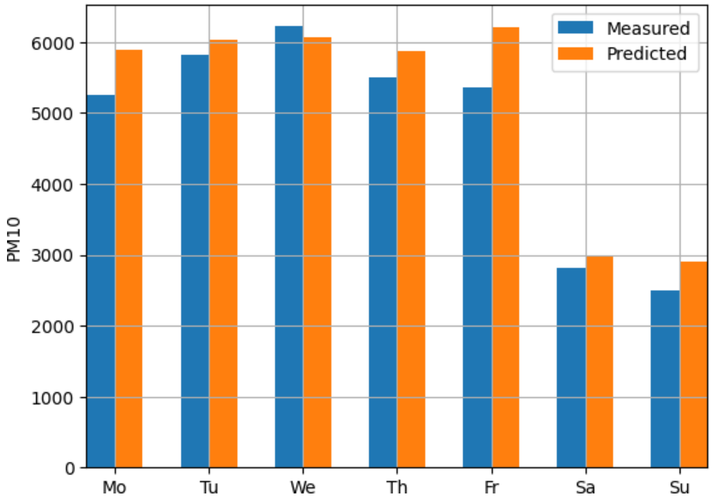


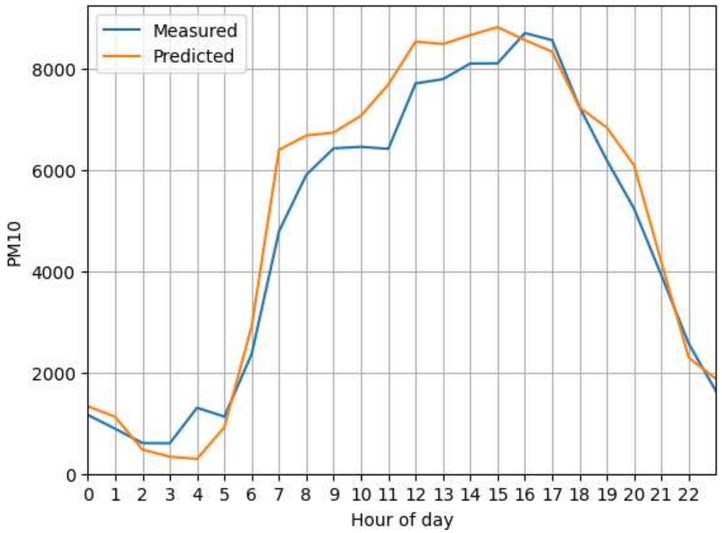
Comparison between models

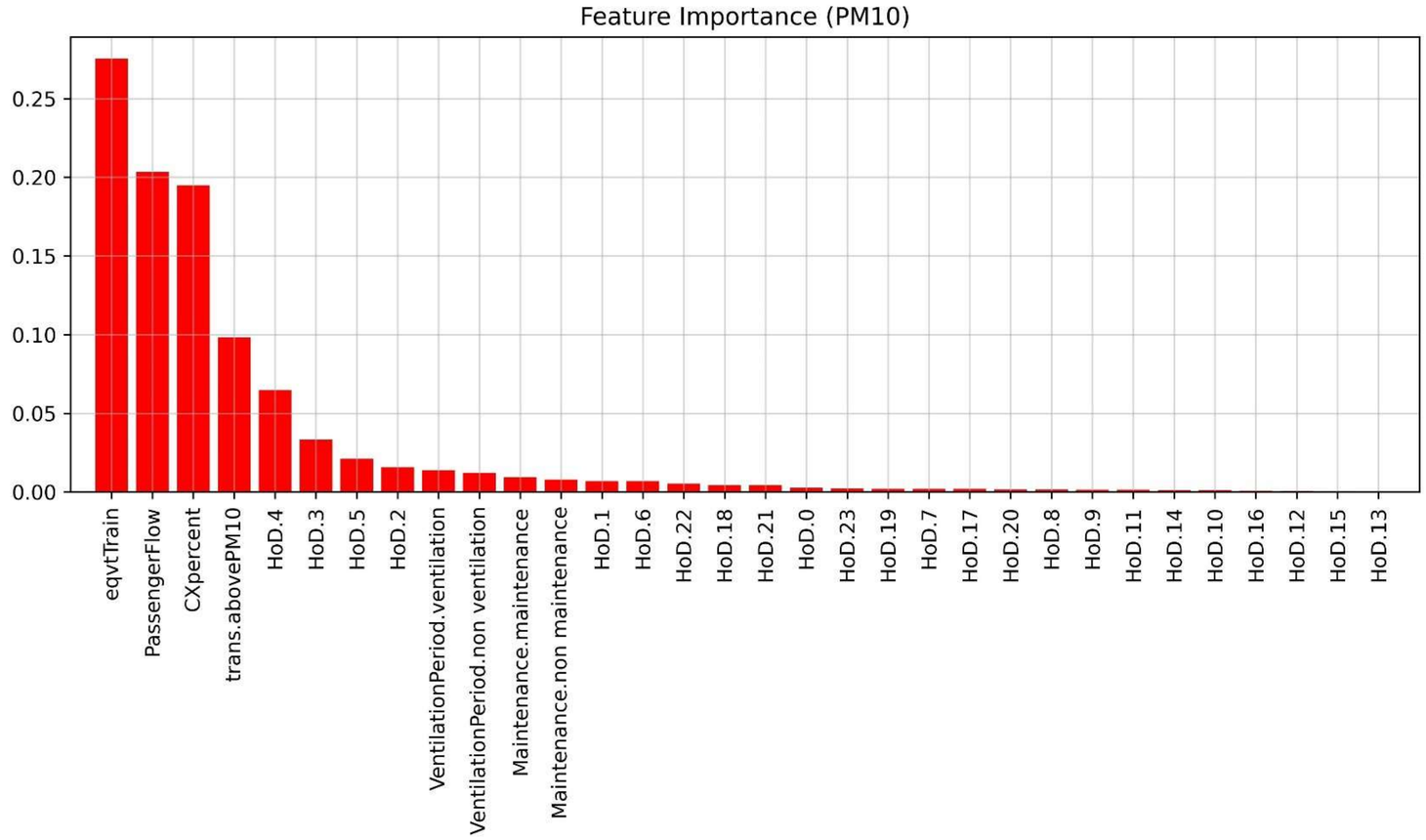
- Based on Stockholm KTH metro 2020
- Dataset
  - 70% for training
  - 30% for testing
- Models in the comparison (KTH, TNO, SNCF)
  - Linear mixed model
  - Random forest model
  - ANN model
  - CNN model



Random Forest

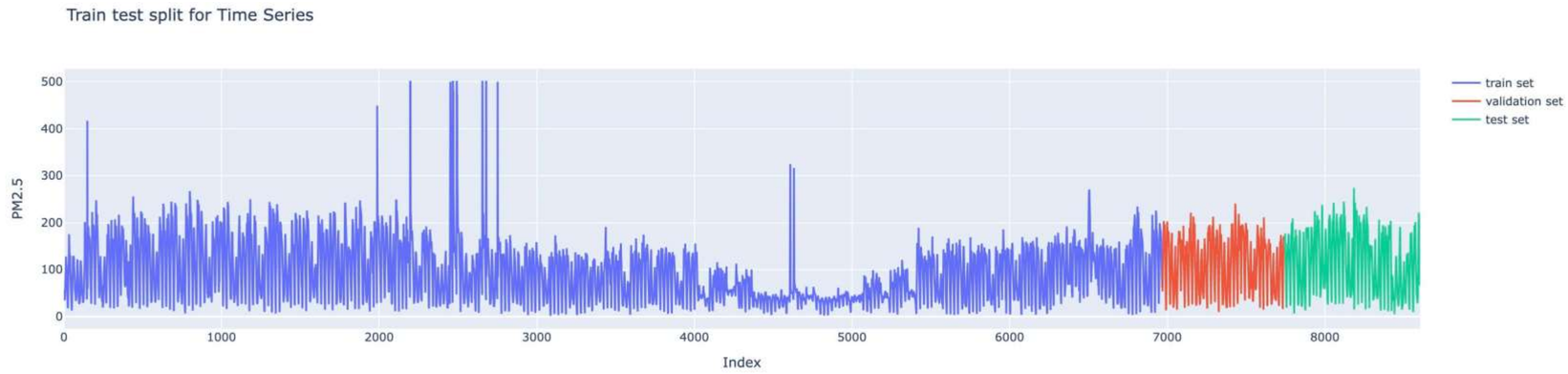


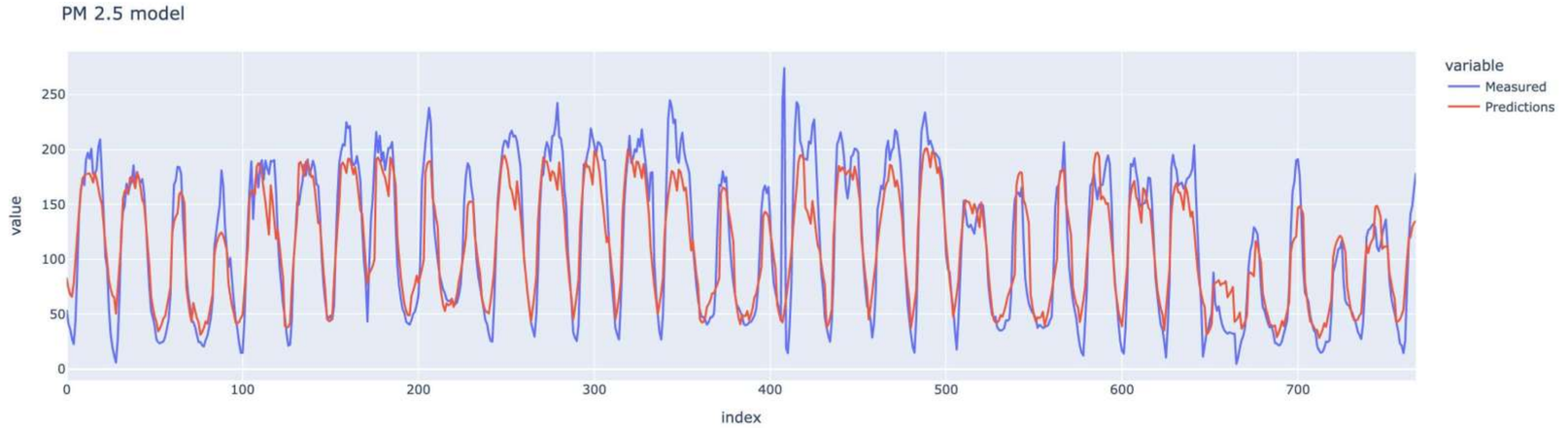




Convolutional neural network (CNN)

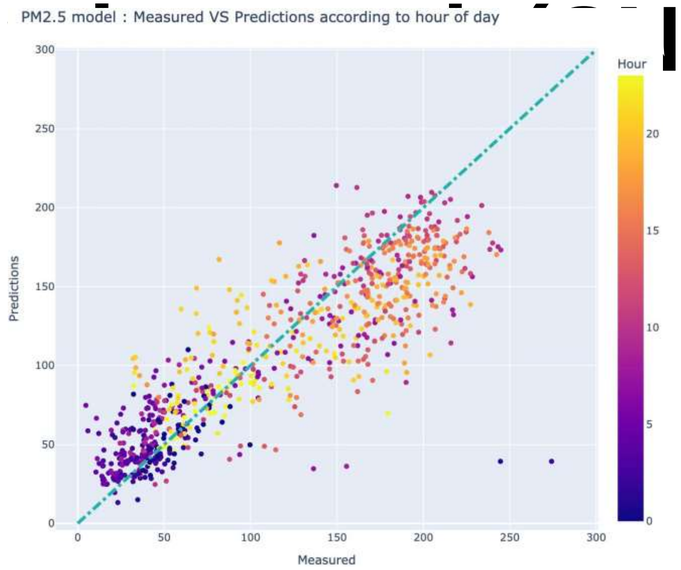
- Deep Learning methods
  - Convolutional neural network
  - 30 steps as features
  - All features except platform PM levels
- Scoring - 1 step:
  - R^2 score = 0.86
- Scoring - 4 steps:
  - R^2 score = 0.80

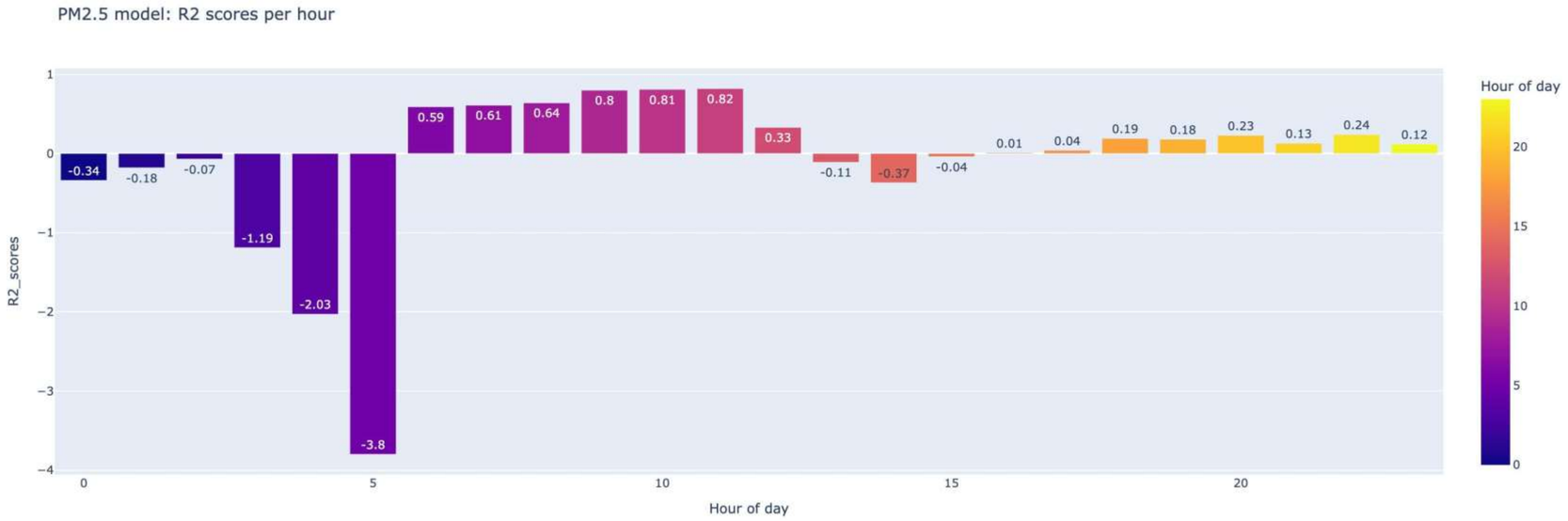




Convolutional neu [illegible] IN)

- Deep Learning methods
  - Convolutional neural network
  - 30 steps as features
  - All features except platform PM levels
- Scoring - 4 steps:
  - R^2 score = 0.80
  - RMSE = 29.73
- Scoring on last step:
  - R^2 score = 0.73
  - RMSE = 34.36





Conclusions and Future works

- Linear mixed model
  - Underground PM10 levels increase with rising train frequency
  - The PM10 emission rate is highest for CX trains, while C20 trains have the lowest rate
  - The annual PM10 pollution cost from the KTH metro platform is estimated at 27 to 39 M SEK
  - Replacing all trains with C30 trains is projected to increase pollution cost by approximately 5%
- Machine learning models
  - Developing a Random Forest model to assess the transferability of the model to other stations
  - Determining the minimum dataset size required to train a model with acceptable quality
  - Identifying crucial time periods for training to ensure high-quality model performance

Thanks for your attention!

INTERNATIONAL UNION
OF RAILWAYS

Challenges in Air Quality

INERIS

Jessica Queron

RÉPUBLIQUE FRANÇAISE

Liberté
Égalité
Fraternité

INERIS

maîtriser le risque
pour un développement durable

Project TOXinTRANSPORT

toxicological, chemical and physical characterizations of particles in railway environments

INTERNATIONAL UNION OF RAILWAYS

Jessica Quéron

Head Of The Ambient Air Characterization Close To Source Unit

jessica.queron@ineris.fr

ADEME AGENCE DE LA TRANSITION ÉCOLOGIQUE

AGENCE D'ESSAI FERROVIAIRE SNCF

IGE Institut des géosciences de l'environnement

LSCE Laboratoire des sciences du climat & de l'environnement

david

UNIVERSITÉ DE VERSAILLES ST-QUENTIN-EN-YVELINES université PARIS-SACLAY

unisanté Centre universitaire de médecine générale et santé publique - Lausanne

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INERIS
maîtriser le risque pour un développement durable

Ineris: the French public expert for industrial and environmental risk management

Ineris is an industrial and commercial public institute (EPIC) acting under the aegis of the Ministry in charge of the Environment.

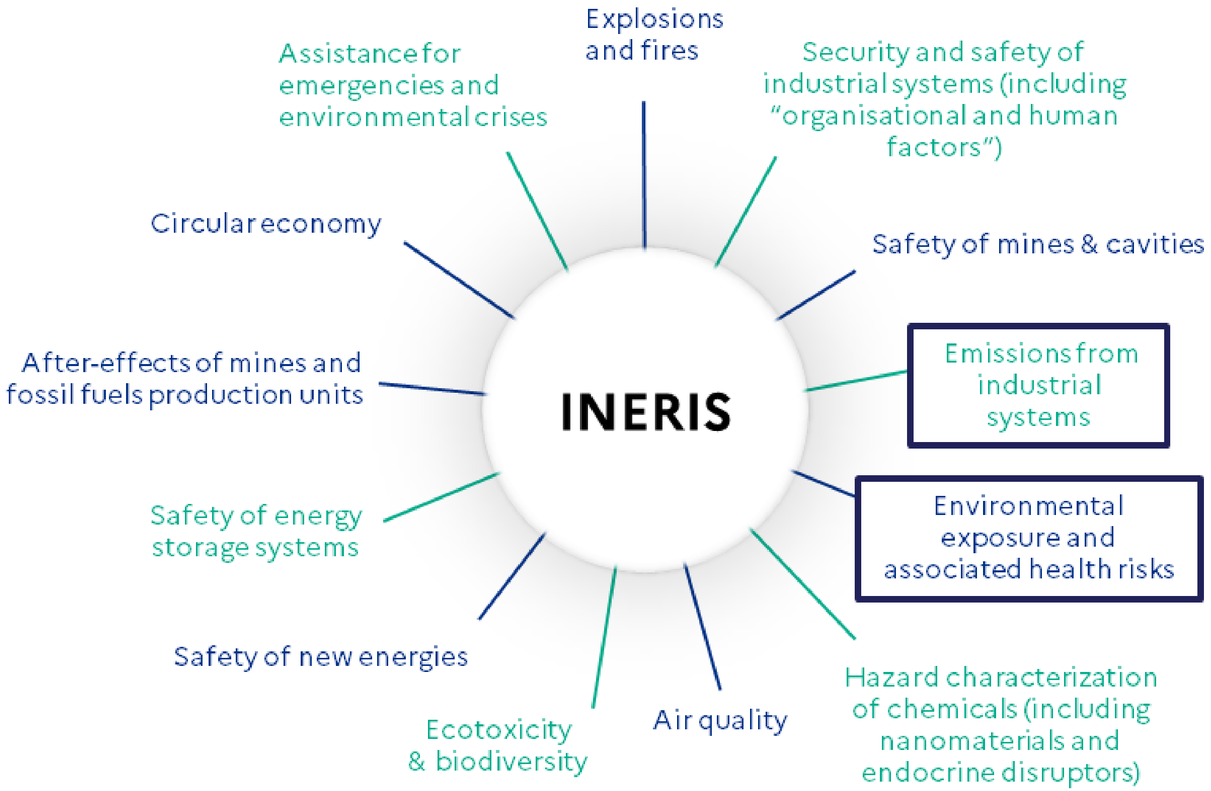
Approximately 550 people.

Located in Verneuil-en-Halatte (Oise), 40 ha, including 30,000 sq. m of laboratories.

Ineris model is based on three core elements:

- **support for public policies,**
- **high-level applied research,**
- **consulting and service activities.**

Among our missions to support the ministry



Monitoring strategy to characterize atmospheric fallout from industrial facilities emissions and also to characterize air in microenvironments such as transport => **assess chronic exposure of the population**

- Writing national guides
- Technical support
- Studies
- Training of regional environmental inspectors
- …

TOXinTRANSPORT: project about toxicological, chemical and physical characterizations of particles in railway environments

Context

- Effects and physico-chemical nature of particulate matter (PM) are **not well known** in underground railway stations *[ANSES (French Agency for Food, Environmental and Occupational Health & Safety) report on air pollution in underground railway stations, 2015]*

- In addition to physico-chemical characterization measurements made by railway operators in underground railway stations *[Ineris guidelines, 2023]*, there is a need to **characterize chemical and toxicological reactivity of inhaled PM**, as a marker of their potential effects on the pulmonary system

- There is a need to **develop characterization methods under real conditions** in order to gather data on physico-chemical compositions of pollutants and their associated toxicology in different environments in the field

ToxInTransport,
a multidisciplinary and exploratory project

Project (2018- 2022)

Lot of partners :

Funded by the French Environment and Energy Management Agency (ADEME)

The final report is available on the **Ineris website** : https://www.ineris.fr/fr/projet-toxintransport-synthese-caracterisations-toxicologiques-vitro-chimiques-physiques-particules

Objective of the project

Assessment of the contribution of toxicological characterization methods of PM toxicity in addition to physico-chemical characterization methods in underground railway stations

In vitro cellular tests *(e.g. oxidative stress, inflammation)*

Acellular tests *(oxidative potential)*

Physical and chemical characterization

=

Ranking PM with respect to the relative toxicological response and physico-chemical response

ToxInTransport : 2 campaigns of experiments in Paris

2nd campaign: railway rolling stock
From the 15th to the 24th of September 2020
10-minute tests at 2 pm
Climatized and non-climatized coaches

1st campaign: underground railway station
From the 4th to the 13th of March 2020
2 to 4 hours tests
Off-peak and rush hour tests

Physics

Mini Particle Sampler (MPS)

Elemental composition

PM sizes and morphologies

MA350 sensor

Black Carbon

Cairsens sensor

NO_2

AE51 sensor

Black Carbon

Xact 625i analyzer

Metals

Chemistry

HPEM Filters

Metals

Anions/Cations

Microvol Filter

PAH

EC/OC

DA80 Filter

Metals

EC/OC

Anions/Cations

PAH

Acellular oxidative potential

TEOM 1405-D

Mass $PM_{2,5}$ and PM_{10}

Capteur CANARIN II

Mass $PM_{2,5}$ and PM_{10}

COP GRIMM

Size distribution in number

0,3-20 µm diameter

SMPS Nanoscan

Size distribution in number

0,01-0,42 µm diameter

Toxicology

Coriolis Compact

Coriolis Micro

Cytotoxicity

Cellular oxidative potential

Inflammation

Endotoxins

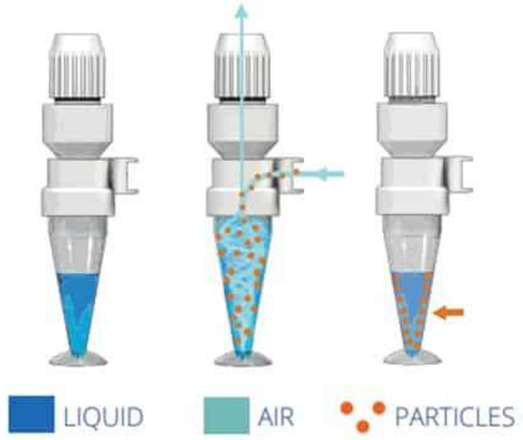
On-line analyzer

Acellular oxidative potential

Project originality

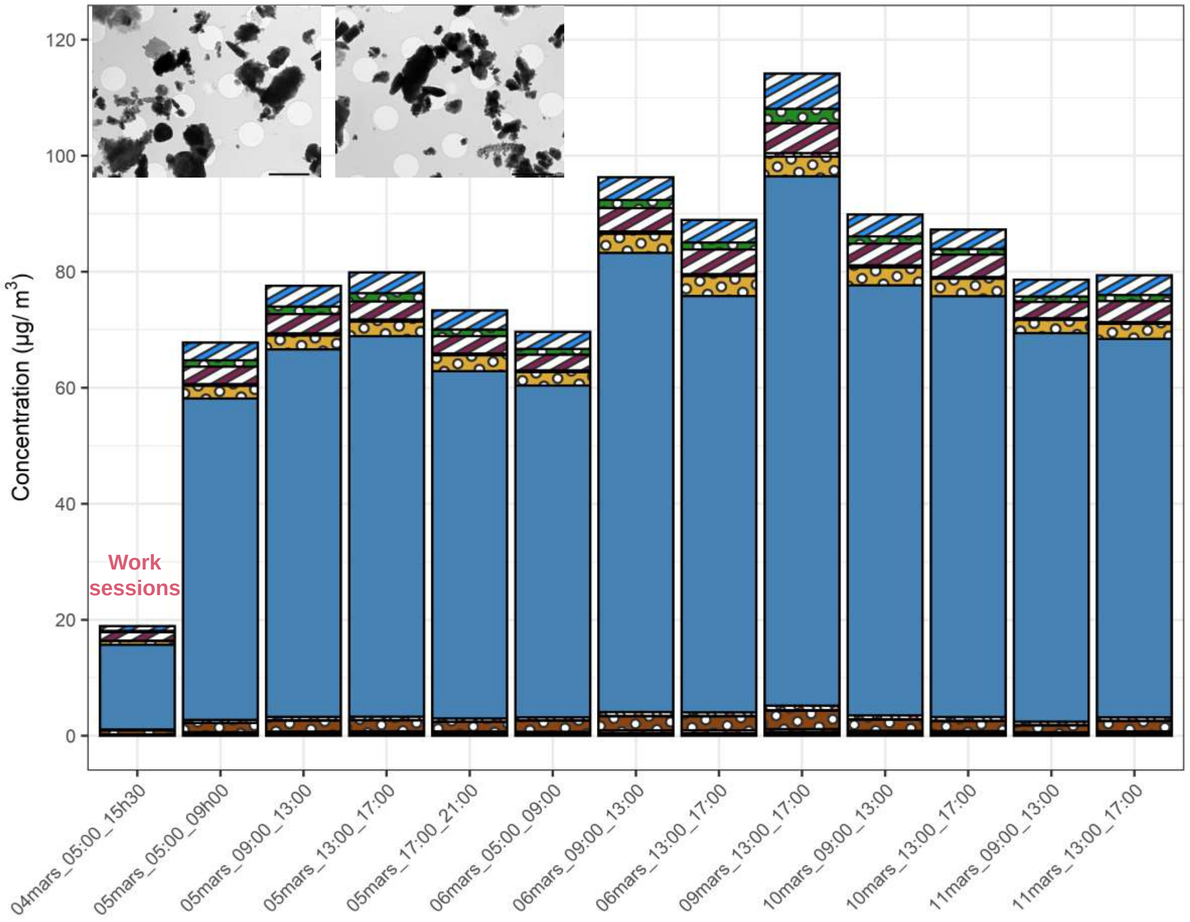
Utilization of **samplers developed for bioaerosols**

→ a method for particle sampling **directly in the medium used for cell exposure**



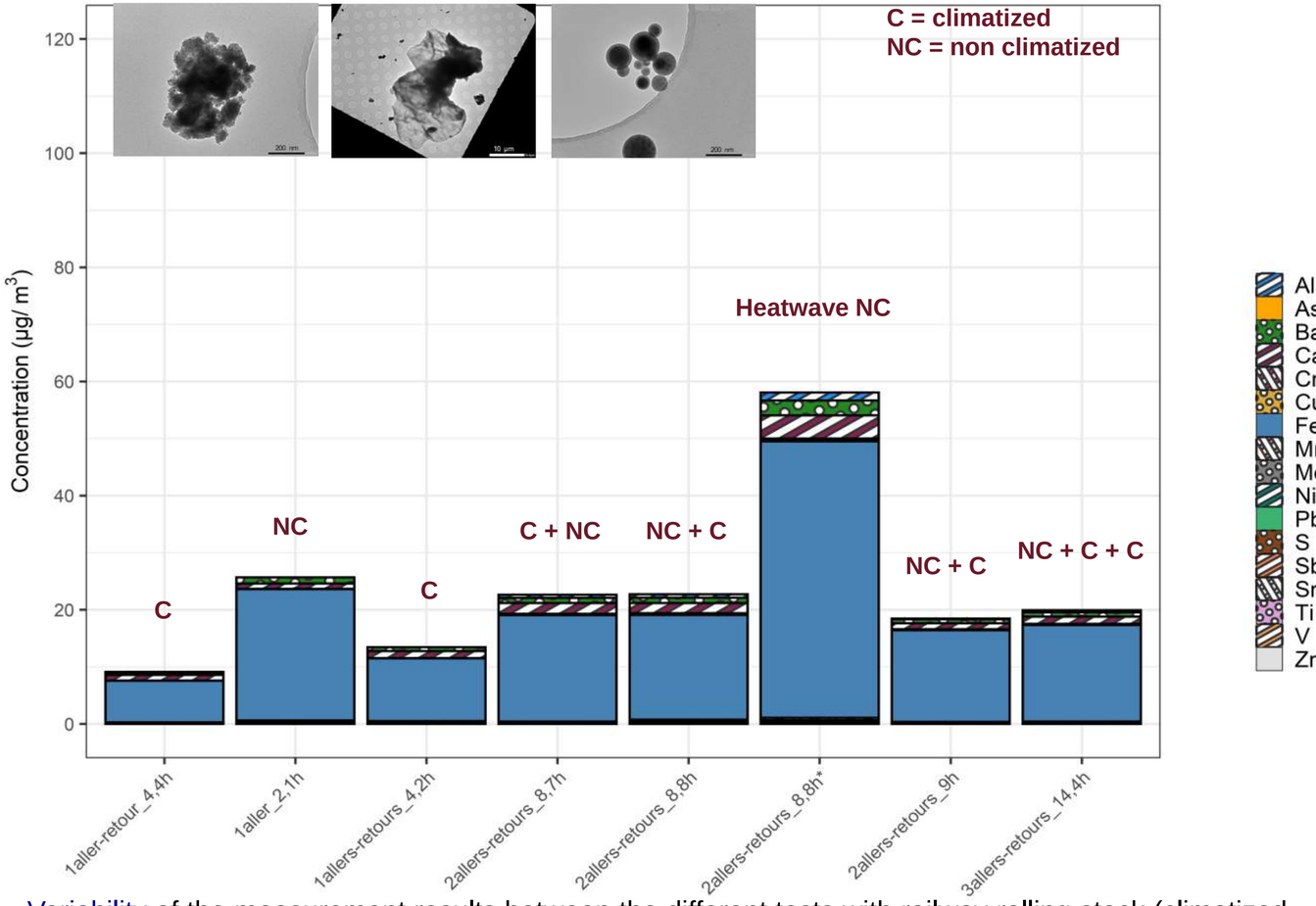
https://www.bertin-instruments.fr/produits/biocollecteurs-air/coriolis-biocollecteur-air/

1st campaign : underground railway station



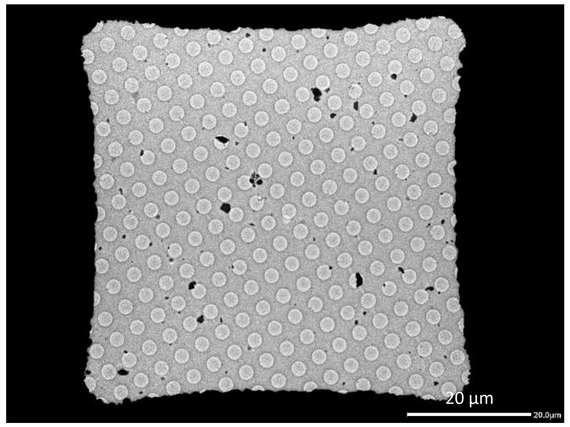
Low variability of result measurements made between the different days of tests (except during the work sessions)
Homogeneous observations on the TEM grids (iron oxide from braking)

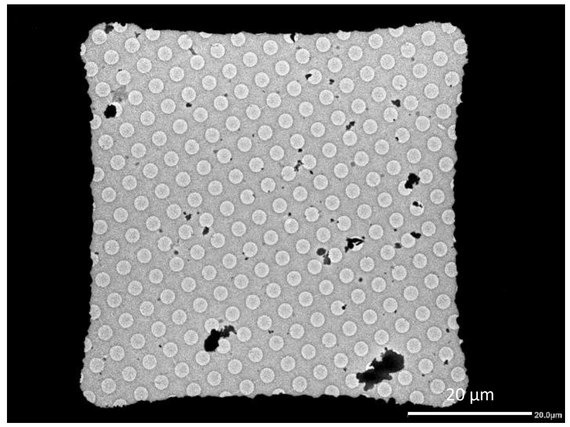
2nd campaign : railway rolling stock

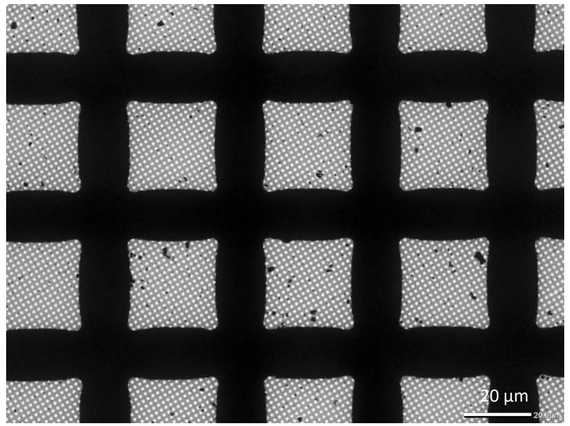


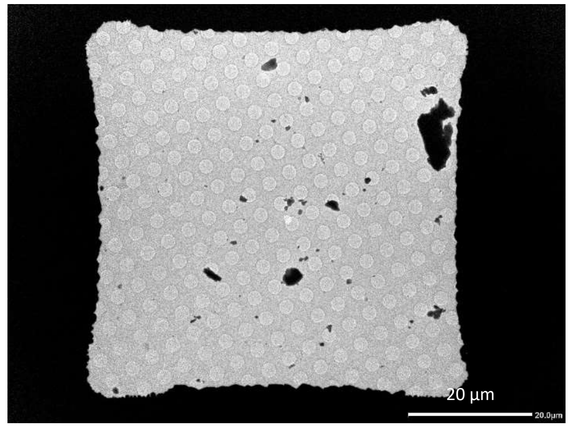
Variability of the measurement results between the different tests with railway rolling stock (climatized or not). The operating conditions may also have an impact along with concentration levels in ambient air.
Heterogeneous observations in PM compositions / shapes / sizes inter- et intra- journey (mainly iron oxide, but also objects from the outside air and from passengers).

Climatized



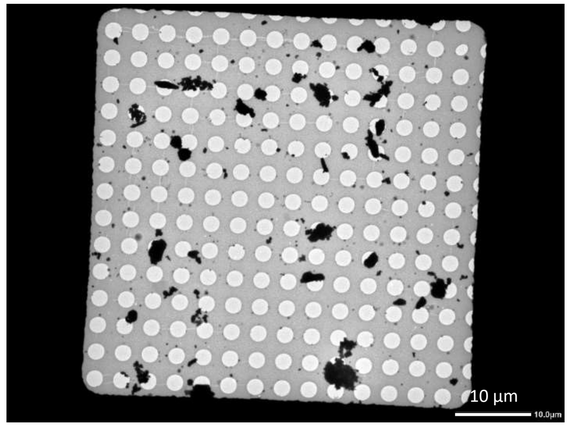


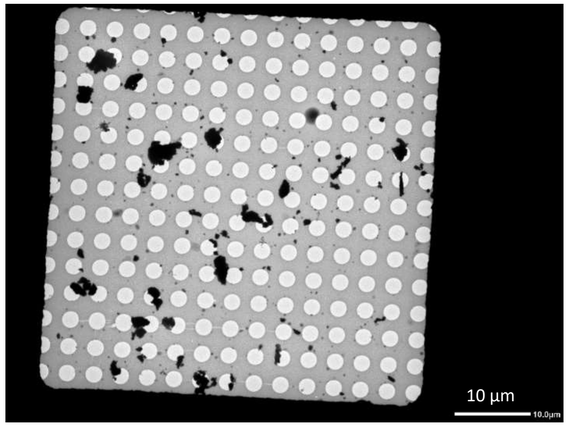


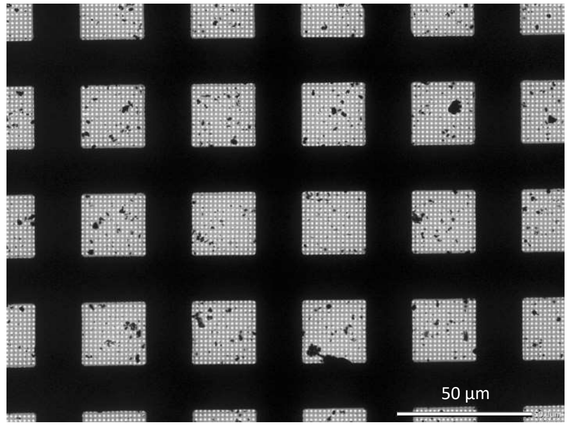


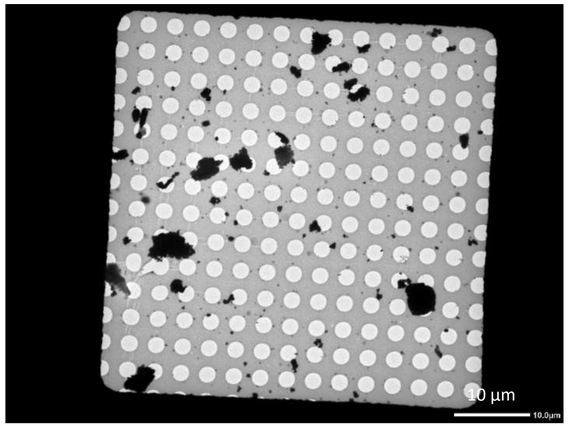
18/09/2020	09h13-09h19 am	• Underground railway station • Climatized

Non-climatized









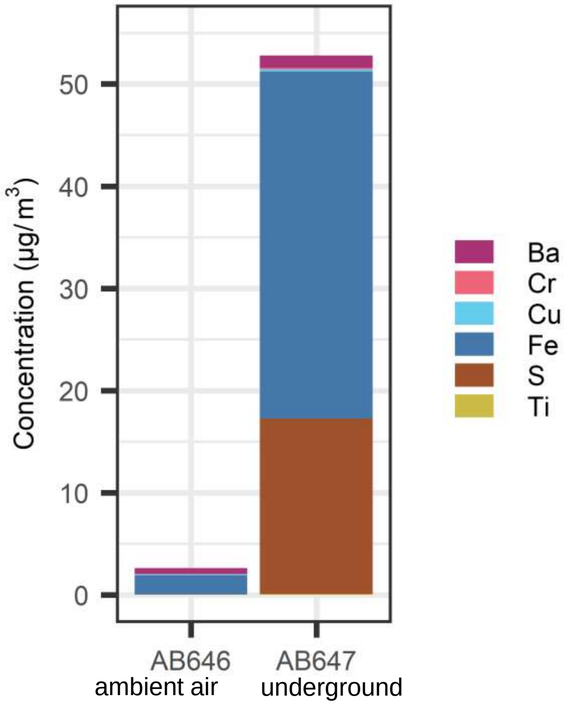
22/09/2020	03h41-03h47 pm	• Underground railway station • Non-climatized

Toxicological results

- More ***homogeneous on platforms*** than in the trains

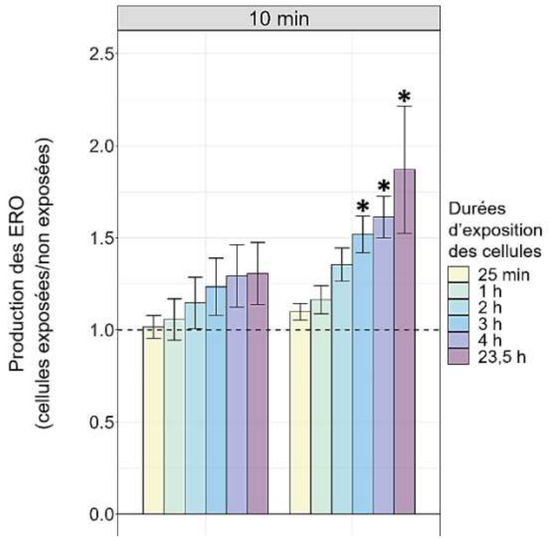
- In the same train, we compared samples taken in ambient air and underground

Sample	Time	Duration	Configuration
AB646	05h10-05h20 pm	10 min	Stations in ambient air Non-climatized train
AB647	05h48-05h58 pm	10 min	Underground stations Non-climatized train



In the train, ***significant production of intracellular Reactive Oxygen Species*** (ROS) for the samples originating from the underground railway stations were observed contrary to tests made with stations in the open.

Acellular oxidative potential values higher than those usually found in French cities.



Conclusions

- Toxicological effects have been linked to the presence of certain physico-chemical parameters and their concentration levels.
- New markers of particle toxicity allow classifying microenvironments according to their effects on human health.

Perspectives

- **Carry out another campaign in** underground railway station to consolidate toxicological results obtained in this project
- **Carry out comparison of different microenvironments**, including particles of a different nature to those from underground stations, such as those from **road vehicles or aircraft.**

a French national guide

harmonizing air quality measurements in underground stations and railway rolling stocks

Since 2013, the French government has been working on an ***action plan aiming at improving indoor air quality*** in underground stations and railway rolling stocks

Recommendations to harmonize air quality measurements in underground public places

Priority pollutants : particles PM_{10} and $PM_{2,5}$, metals, CO_2

Written by Ineris and gathering several stakeholders such as ministries, railway companies, diverse authorities

Passenger exposure

Available : https://www.ineris.fr/fr/recommandations-realisation-mesures-harmonisees-qualite-air-enceintes-ferroviaires-souterraines

An **English version** of the guide is available !

Thank you for your attention !

Do not hesitate to share your practices by email

jessica.queron@ineris.fr

Acknowledgments :

Funded by the French Environment and Energy Management Agency (ADEME) and by the French ministry in charge of ecological issues

Air Characterization : A. Delater, C. Dutouquet, O. Le Bihan, S. Fable, L. Meunier

Toxicology analysis : G. Lacroix, C. Tebby

Discussion on challenges

Challenges

- Katharina Stern-Gottfried, DB:
  - Air Quality directive comes into force: It will be a challenge for construction sites to not exceed the limit values.
  - Using water for cleaning is also prevented by the water pollution rules.
  - Limit values around stations might become a problem overall (in addition to the already problematic situation for tunnels)

- Giulio Magi, Origins.earth for Suez:
  - Low cost sensors' accuracy: how to decide when to use low cost sensors for a situation that requires more granularity?
  - Laurent Dupont, SNCF: AirLab with AirParif regularly control low-cost sensors' reliability in UAS (next campaign May or later in 2025)
  - Katharina SG, DB: Use of low-cost sensors is heavily discussed. Decision to use low cost sensors needs to be justified (& motivated)
  - Connor AW, RSSB: Low-cost sensors measures are compared to more accurate monitoring systems to validate measurements.

- Gabriel Castanares, Renfe:
  - Regulatory frame starts making restricted the use of polluting systems in cities (diesel cars or standalone generators)
  - Rolling stock might need to be replaced even before end of lifecycle.
  - That's why Renfe studies local pollution caused by diesel trains.
  - Cars EURO specifications are also improving, thus reducing the edge.

Challenges

- Ludovic Kasperski, Wabtec:
  - Rolling stock life and costs are a heavy factor that influence capacity to implement technology to avoid emissions
  - It is also useful to link pollution to their cost to society to be able to create a business case for investments in pollution mitigation
  - GC/PS: The internatilisation of external costs by the EC includes considerations for air pollution. They have made data available
  - Wheel slide

- Laurent Dupont, SNCF Voyageurs:
  - Ultra fine particles (PM0.1) will be challenging to monitor because common gravimetric measuring methods can’t apply.

- Linking measurements to emission source(s)

- Alexandre Vivier, SNCB:
  - 96% electrified: How to demonstrate the benefits of rail as collective transport compared to cars and planes
  - CG: Emission factors per pkm for cars compared to rail pkm factors by emission source
  - KSG: In Germany comparisons are made at the scale of PM emissions with assumptions
  - Philippe C., SNCF Voyageurs: It is important to consider the « Dose » approach, to only consider harmful pollutants. So railway should only consider controlling these.

INTERNATIONAL UNION
OF RAILWAYS

Media to be made available on the event page

Thank you for your attention

Philippe Stefanos
Energy & CO2 and Data, SFERA, Energy Settlement, Air Quality, Sustainability advisor
Stefanos@uic.org

Credits:
Workshop funded and proposed by the:

UIC Air Quality Sector

Co-organised by UIC & the Sector's core members

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Posters

AIR QUALITY IN RAIL

THE UIC AIR QUALITY SECTOR

Is a working group dedicated to air quality management in rail.
It especially addresses understanding of pollution from wear and management of ambient air pollutants.

The Sector has set a detailed list of priority focus for the current and upcoming period, in its “ambition paper”:

- List of Air Quality improvement solutions into a catalogue of solutions [report].
  - To avoid or reduce wear/exhaust emissions from all sources
  - To manage Air Quality:
    - for underground stations/tunnels: solutions tested or not, technological watch, expert opinion, etc.
    - onboard trains (air pollutants, virus, bacteria, if relevant)
    - in open environment if relevant to rail operation
- Air Quality measurement (Common situations, ventilation, filtering efficiency, …)
- Wheel/rail wear related emissions
- Unified method to define Particulate Matter from wear (brake, contact line, wheel/rail wear)
- Communication on Air Quality in stations
- Low-cost sensors for stations for monitoring
- Cleaning (dust/filters): Downstream impact on environment/water (water framework directive: Substances [emitted to air] that get evacuated to water)
- Legislation (worldwide) overview/comparison: Country specific regulation for platforms / closed environments
- Future handling of construction sites and works’ dust (not using water to clean)
- Reasons to fund Research on Air Quality (Emission of dust and related health issues)

SOURCES OF POLLUTION FOR TRANSPORT

- Brake system
- Wheel / tyre / track
- Pantograph / catenary / connector
- Exhaust

POLLUTANTS

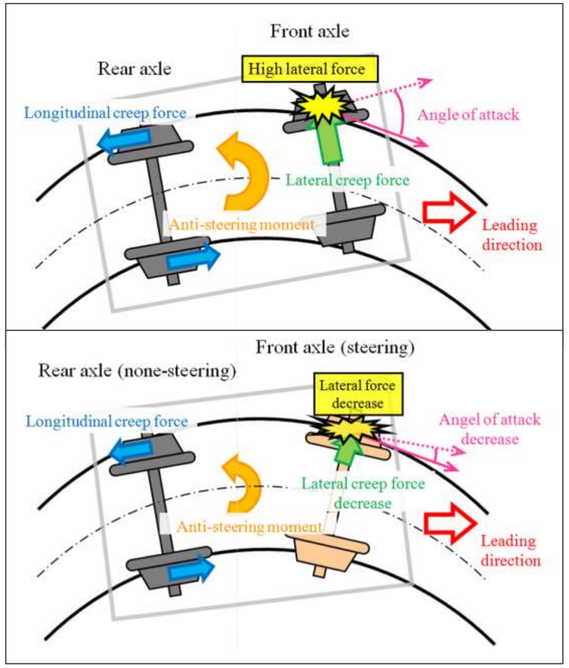
- Particulate matter (plastics/metals/…)
  - PM10 (Fine dust)
  - PM2,5 (Very fine dust)
  - PM0,1 (Ultra fine dust)
- Volatile organic compounds
- Nitrogen oxides
- Hydrocarbons
- Carbon monoxide
- Formaldehyde

What influences emission?
How to reduce emissions?
How to avoid emitting?
How harmful?
How to improve Air Quality?

Explore these by joining the Air Quality workshop on 13 March 2025 morning

Platform screen/edge doors (PSD/PED or automatic platform gates):
It helps containing air masses surrounding tracks to not spread on passenger platforms, thus reducing the risk of dust being breathed in by passengers

SUSTAINABILITY
Action Week



Steered bogies and driving style
Track curves, with train speed, influence wheel and track wear intensity. This is correlated to dust emission.

PROMISING SOLUTIONS!

Avoiding emissions:

- **Electrodynamic/electromechanical braking**

Reducing emissions:

- **Driving Advisory System (DAS) & efficient driving**
- **Steering bogies**

Improving Air Quality:

- **Mechanical filtration (air purifying)**

AIR QUALITY MANAGEMENT IN RAIL

SOLUTIONS for AIR QUALITY management

1. Avoiding emissions

1.1. Cross-cutting/general

1.1.1. Influence of efficient driving: eco-driving and Driver Advisory Systems (DAS)

1.1.2. Electrification and alternatives to combustion engines

1.2. Brake system wear

1.2.1. Brake system pollution prevention

1.2.2. Electrodynamic/electromechanical braking

1.3. Wheels/track wear

1.3.1. Steering bogie

1.3.2. Maximise track curve radius

1.4. Pantograph/catenary wear

1.4.1. Rolling pantograph

1.5. Maintenance works (Grinding, ballast management)

1.5.1. Work zone air flow control with vacuum cleaning

2. Reducing emissions

2.1. Brake system wear

2.1.1. Mechanical brake system management

2.1.2. Low emission brake pads

2.2. Wheels/track wear

2.2.1. Lubrication of wheels and tracks

2.3. Pantograph/catenary wear

2.3.1. Optimising emission-influencing factors in pantograph-overhead contact line (OCL) system

2.4. Exhaust

2.4.1. HVO

2.4.2. Electrification (see 1.1.2.)

3. Reducing concentration

3.1. Capture onboard trains

3.1.1. Vacuum cleaner train

3.1.2. At source brake dust collection system

3.1.3. Filtration via the HVAC system

3.2. Capture inside stations

3.2.1. Station/tunnel cleaning

3.2.2. Plant filtration (green wall)

3.2.3. Particle traps

3.2.4. Liquid filtration

3.2.5. Filtration by ionisation

3.2.6. Passive trap filtration

3.2.7. Mechanical filtration

3.2.8. Filtration with the existing station HVAC system

3.3. Ventilation/ barriers / doors inside stations

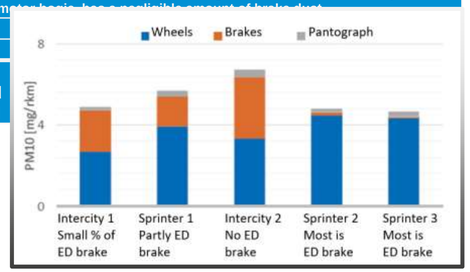
3.3.1. Ventilation

3.3.2. Platform screen/edge doors (PSD/PED or automatic platform gates)

PROMISING SOLUTION:

- **Electrodynamic/electromechanical braking**

Field	**Air quality, wear, dust, rolling stock, brake system, Electrodynamic braking (ED)**
Solution	**Prioritise the use of electronic braking systems over other (friction based) braking systems (Electrodynamic/electromechanical/regenerative braking)**
Description	**These braking mechanisms, by nature, do not use friction to reduce the momentum of the wheel.** **Braking using the electric engine up to a few kilometres per hour, braking to stand still is still done using the mechanical brakes.**
Objective	**Reduce brake dust emissive wear from friction of brake pads and disks (from mechanical braking)**
How to	**Maximise electrodynamic braking by allocating braking needs to electrodynamic brakes before using mechanical braking, and this to the further possible braking point.** **To do so, it is possible to define a notch on the brake handle at the point where only regenerative braking is applied for the majority of the time (approx. -50%). The train's TCMS must be programmed accordingly. Safety & training aspects are to be considered for efficient implementation.**
Costs and resources required	**Costs for** • **TCMS programming plus testing and approval** • **Installing notches on brake handles** • **Safety & training considerations** • **New rolling stock**
Benefits Effects	• **Avoided emissions from mechanical brakes** • **Reduce the wear of mechanical brakes** • **Maximise regenerative brake energy being fed into the grid** • **Impact on noise**
Ease of implementation	**Already a standard option in new trains. Existing trains can be modified to optimise the electronic braking**
Constraints, challenges, or lessons learnt	• **Sole use of regenerative braking and the possibility of feeding back the regenerated energy into the grid may be limited in some countries** • **TSI Requirement, see EN 50388-1**
S/M/L term	**Short to medium term**
Efficiency	**Below are the PM10 calculations given for different types of trains with different amounts of ED braking. The PM10 was calculated using the number of worn brake pads and an average wear profile. The intercity (stops every 35 km) with almost no ED-braking, due to it being older trains, show a large percentage of brake dust. The new sprinters (stops every 5 km) with ED brakes in every motor bogie, has a negligible amount of brake dust.**
Maturity	**TRL 9**
Mentioned by	**NS, SBB (brake handle notch)**
Experience	**SBB: Notable effects on amount of recovered energy, thus related mechanical wear is also reduced**



SUSTAINABILITY Action Week

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AIR QUALITY MANAGEMENT IN RAIL

PROMISING SOLUTION:

- **Driving Advisory System (DAS) & efficient driving**

Sources: Paper 1 Paper 2

Field	Driving, friction, wear, exhaust, particles
Solution	Efficient timetabling and gentle driving to reduce emissions from wear and exhaust. Brake system wear is reducing with an efficient management of the speed profile and braking phases.
Description	Efficient timetabling and gentle driving have a significant number of benefits, including punctuality and customer satisfaction, energy saving and reduced wear of all components. On the specific braking wear aspect, the idea is to optimise the speed profile to fit the timetable, and then the braking phases, from a better coasting management, are less intense on mechanical brakes, and the mechanical brake use can be delayed even more as the longer brake phase can efficiently make use of the electrodynamic/regenerative braking. The same strategy (adapted speed) will also have a beneficial influence on the wear caused by wheels and track friction, as speed and speed in curves is the most important factor in speed or G force transmission into wear. In paper 1 different driving strategies were investigated and their impact on the energy consumption, safety, timeliness, workload of the driver, environment (noise and brake wear) and cost of maintenance. It shows that the maximal coasting strategy causes the least environmental pollution, i.e. brake wear,
Objective	Adapt driving strategy to punctuality and balanced driving to reduce intense use of components, especially avoiding intense use of mechanical brakes, causing friction (but also traction system solicitation for energy saving and reduced exhaust emission for combustion powered trains).
How to	Implement DAS and/or eco-driving to increase accuracy for punctuality, enabling a comfortable margin of manoeuvre for a smooth driving profile. In the Netherlands such a method has been developed by the largest passenger operator NS. A tablet was introduced to the driver which shows the RouteLint and RolTijdAdvies. The RouteLint gives the occupancy of the track and if there are delays. The driver can use this to anticipate how to drive. RolTijdAdvies shows when the driver can turn off traction and arrive on time at the station. The main goal was to improve the punctuality and energy saving. For more information on the method, results and how the change was accepted by drivers and management can be found in paper 2
Costs and resources required	DAS implementation cost And/or Eco-driving trainings
Benefits Effects	Eco driving & DAS also prioritise balanced coasting & smooth braking over intense braking phase so it somehow makes the most of train's kinetic energy to saving traction energy & braking the optimal way (usually also favouring regenerative braking) DAS can help achieve ATO benefits earlier, hence the similar expected improvements. ATO would make it perfectly reliable but DAS can already help achieve optimal driving profiles. A harmonised data exchange protocol to be used with DAS, as generic data exchange framework for seamless cross-border activities and DAS compatibility between RUs and IMs (IRS 90940) would enable achieving these benefits, regardless of the DAS products provided through the use of the harmonised data structure. • Improved regenerative braking • Reduced brake system wear • Reduced particle emission • Energy saving • Reduced maintenance costs (reduced solicitation of traction components and braking system) • Improved punctuality & customer comfort and satisfaction
Ease of implementation	Medium It will require an implementation strategy where it is important that drivers and management will accept it. Thus, expect to spend a significant amount of time on achieving positive support to ease the introduction of DAS. It will also require a program that shows the driver what is possible during their drive (between maximal coasting or as fast as possible to keep the timetable). Development and testing of such a system can take considerable time, which can be done parallel with ensuring the acceptance in the organisation.
Constraints, challenges, or lessons learnt	To improve the adoption of the system by the driver it is very important that it must not seem that the system will be used to evaluate the driving or that it will increase workload. The method used by NS to increase acceptance can be found in paper 2,
S/M/L term	Medium term for eco-driving Medium/long term for DAS implementation
Efficiency	Medium The use of ED-braking will make this method less effective for reducing the brake wear. This is due to the fact that ED-braking does not produce a significant amount of non-exhaust. The ED-brakes will work down to a speed 5 km/h. Braking to standstill will then be accomplished by mechanical braking. Thus, coasting up to the station will not have a large effect on the non-exhaust emission when using ED-brakes.
Maturity	TRL 9
Mentioned by	NS, SBB, SNCB, SNCF
Experience	NS/ProRail/SNCF

AIR QUALITY MANAGEMENT IN RAIL

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PROMISING SOLUTION:

- **Mechanical filtration (air purifying)**

	Innovation	Ease/rapidity/aff.	Benefits
Level	Low	High	High
Special note	Mature solution		
Field	Air quality, filtration, stations, etc		
Solution	Classical filtration		
Description	This air purification technique consists in drawing air in and pass it through a series of filters to trap particulate matter.		
Objective	Reduce the PM10 and PM2.5 concentrations in the underground stations air.		
How to	Implementation purification units on platforms. Large capacity needed. Efficiency testing		
Costs and resources required	Industrial air purifier, installation, monitoring and maintenance		
Benefits Effects	Reduction of ~ 35 % for PM10 and PM2,5 for station's ambient pollution levels		
Ease of implementation	First phase was tested with prototypes. It will be tested in a second phasis with full scale modules		
Constraints, challenges, or lessons learnt	Difficulties to evaluate the efficiency as underground stations concentration are fluctuating on time		
S/M/L term	Short term		
Efficiency	High efficiency (system dedicated to air purification)		
Maturity	TRL 9		
Mentioned by	SNCF		
Experience	SNCF: This filtration system has been tested in Sevran Beaudottes station. Implementation of 8 purification units regularly installed on 2 platforms. Total capacity of 76 000 m3/h Test made during ~9 months		

SUSTAINABILITY Action Week

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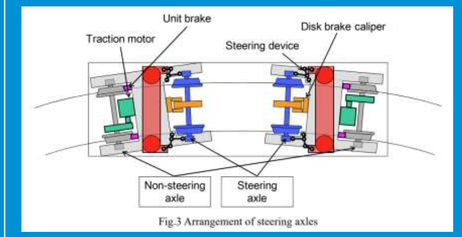
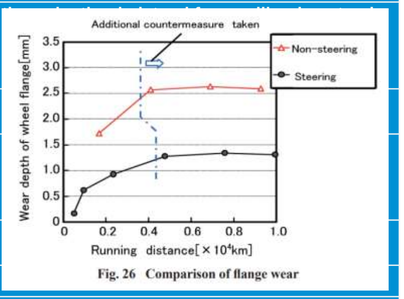
AIR QUALITY MANAGEMENT IN RAIL

PROMISING SOLUTION:

- **Steering wheelset / bogie**

Sources: Paper 1 Paper 2

	Innovation	Ease/rapidity/aff.	Benefits
Level	High	Low	High
Special note	Inventive solution		
Field	Air Quality, rolling stock, wheel/rail wear		
Solution	Steering Bogie  Fig.3 Arrangement of steering axles		
Description	In sharp curves the bogies tend to understeer, causing the front wheels to angle outward, pressing the outer wheel against the outer rail. Meanwhile, the rear wheels tend to stay centered on the track, creating a longitudinal force between the rear wheels and the rails. These dynamics result in strong lateral forces pushing the front wheels toward the outer rail. Steering bogies were developed to reduce this lateral force and to address wheel/rail wear and noise issues.		
Objective	Reduce wheel/rail wear and noise at sharp curves.		
How to	Dissociating's carriage & bogie axis for a better lining of wheels to tracks.		
Costs and resources required	The increased complexity of the bogie structure and changes to the braking system (tread brakes cannot be used on steered axles) are likely to increase the manufacturing costs.		
Benefits Effects	In addition to reducing wheel and rail wear, it is expected that maintenance and suppress rail corrugation.  Fig. 26 Comparison of flange wear		
Ease of implementation	Dedicated bogies are required.		
Constraints, challenges, or lessons learnt	Wear reduction is not only from a dynamics perspective, but also has a large impact from optimized wheel/rail lubrication.		
S/M/L term	Medium/Long (New or retrofit rolling stock)		
Efficiency	High efficiency		
Maturity	Currently in use on 152 subway trainsets (992 cars) in Tokyo.		
Mentioned by	RTRI		
Experience	Tokyo subway		