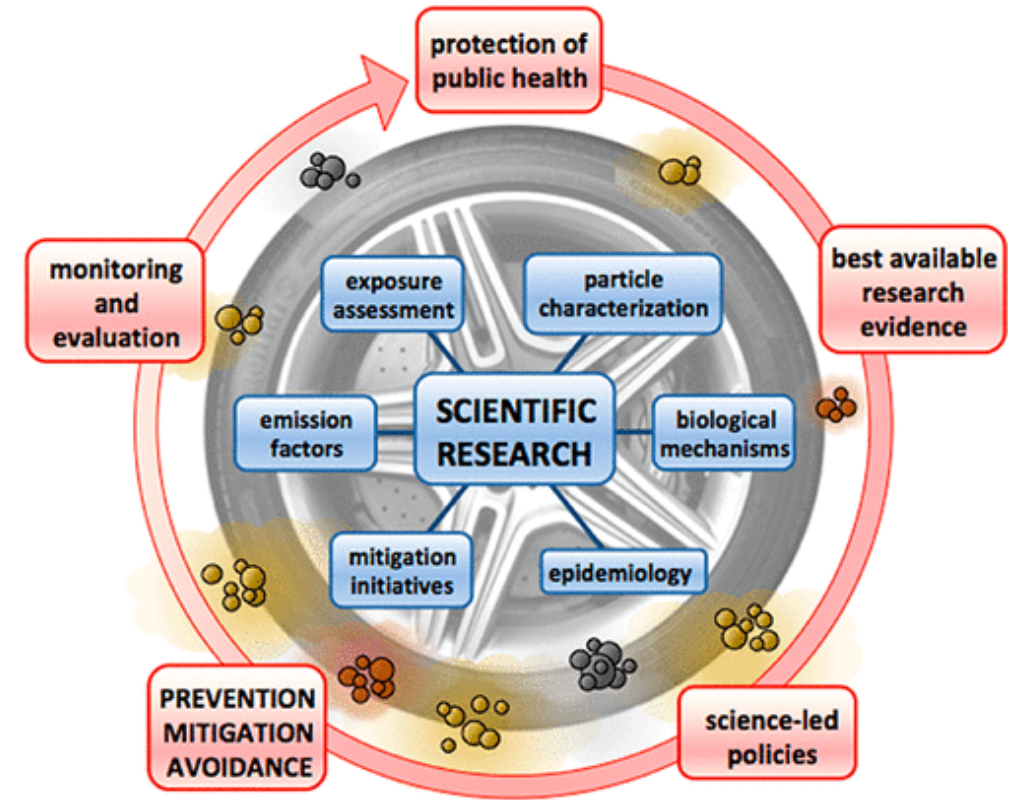


# Quantifying Tyre Wear in the Urban Aerosol Mixture



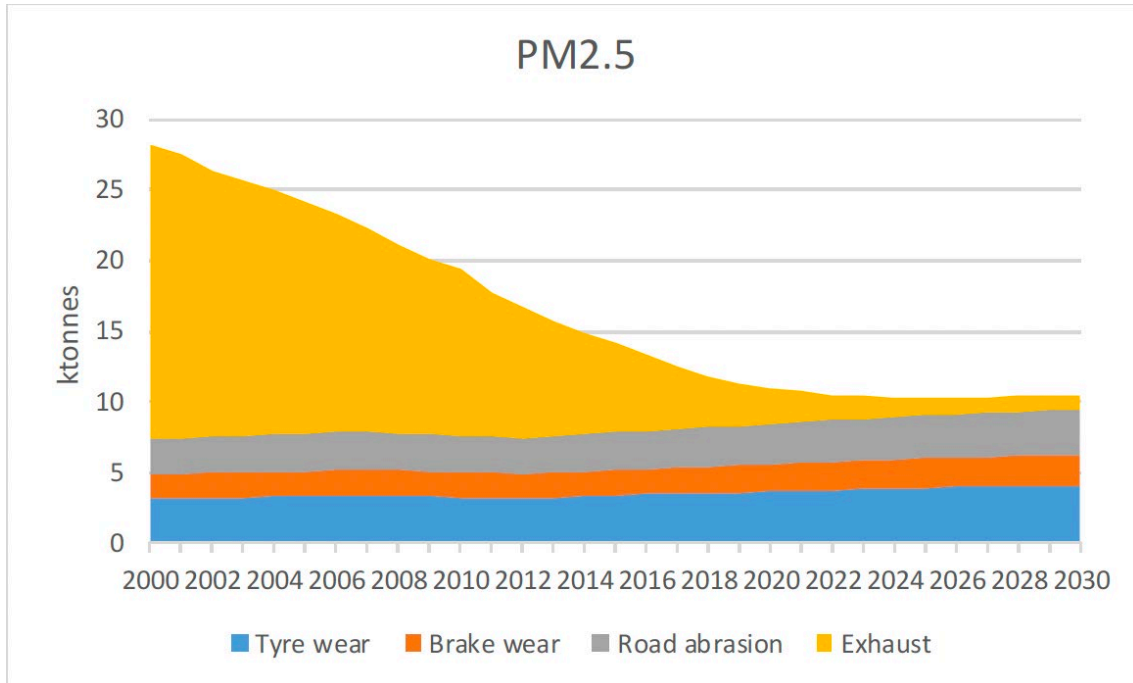
*David Green*

*Senior Research Fellow, Imperial College London*

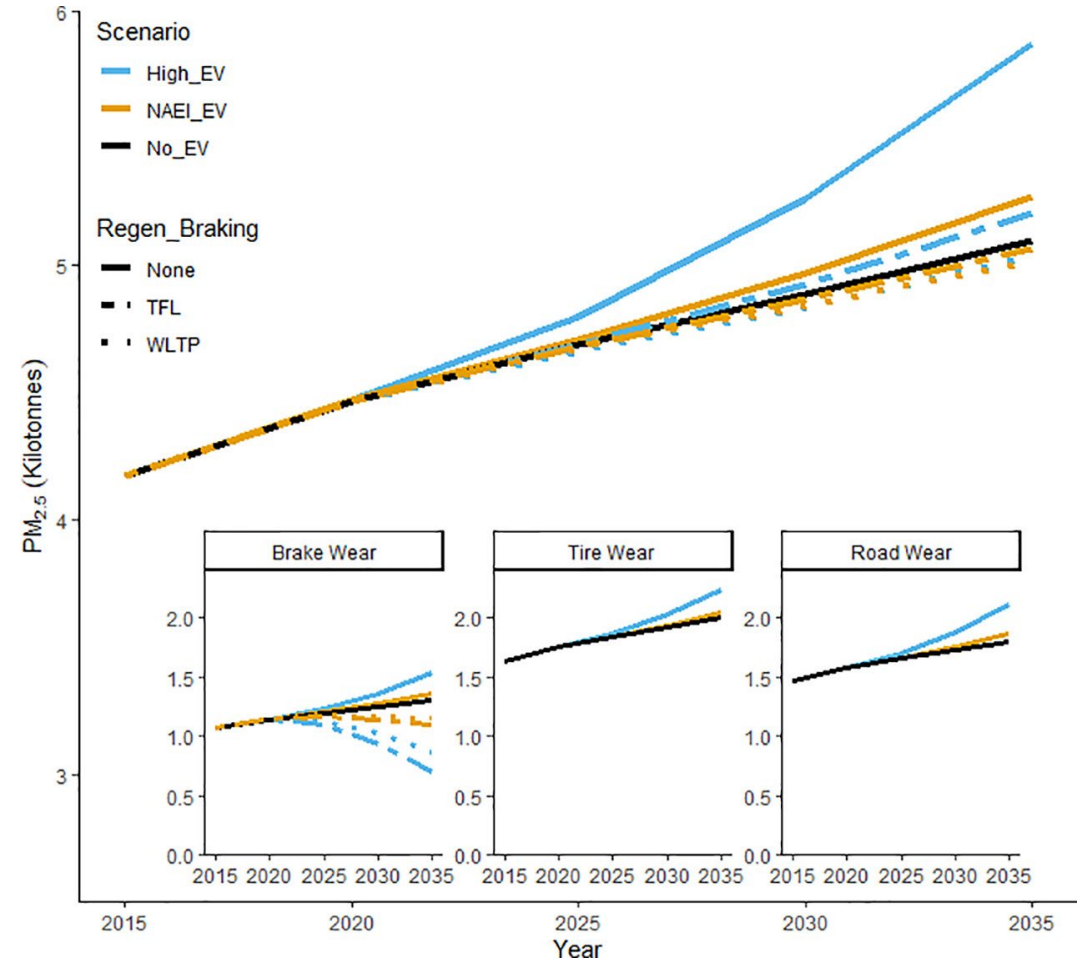
# Contents

- Background
- Measurement Challenges
- Established measurement approaches
- Current research and next steps

# Why are we concerned?

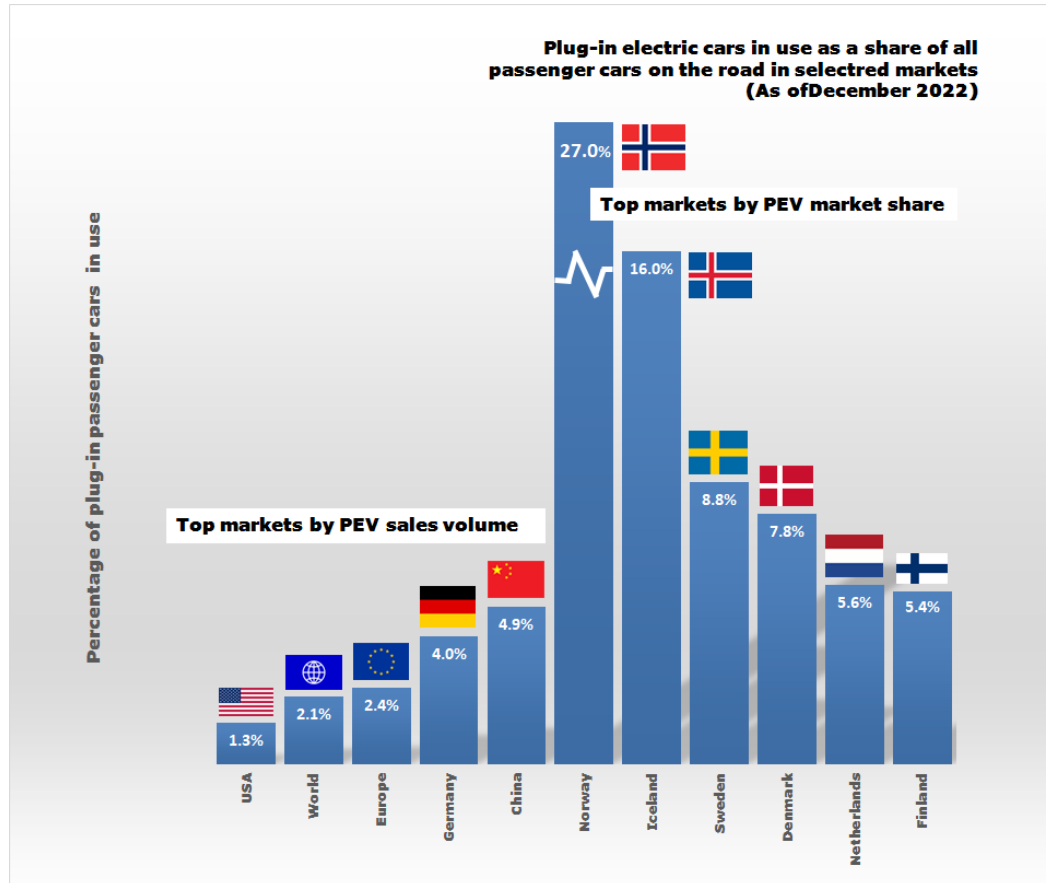


NAEI, 2018. UK National Atmospheric Emissions Inventory, <http://naei.beis.gov.uk/>

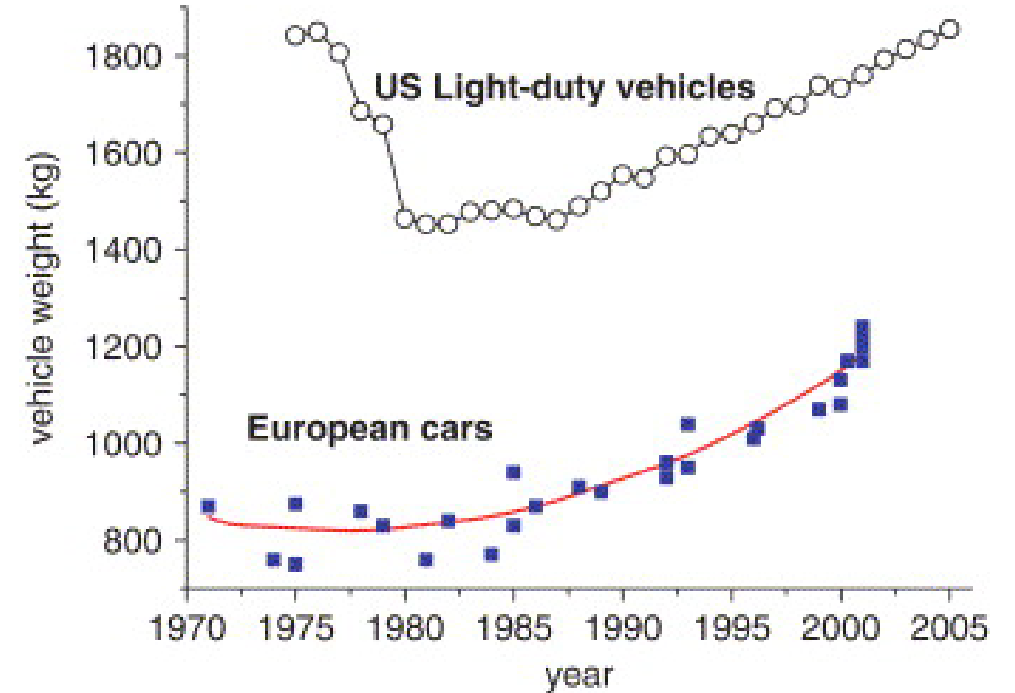


Fussell et al. 2022 A Review of Road Traffic-Derived Non-Exhaust Particles: Emissions, Physicochemical Characteristics, Health Risks, and Mitigation Measures DOI: 10.1021/acs.est.2c01072

# What is causing this?

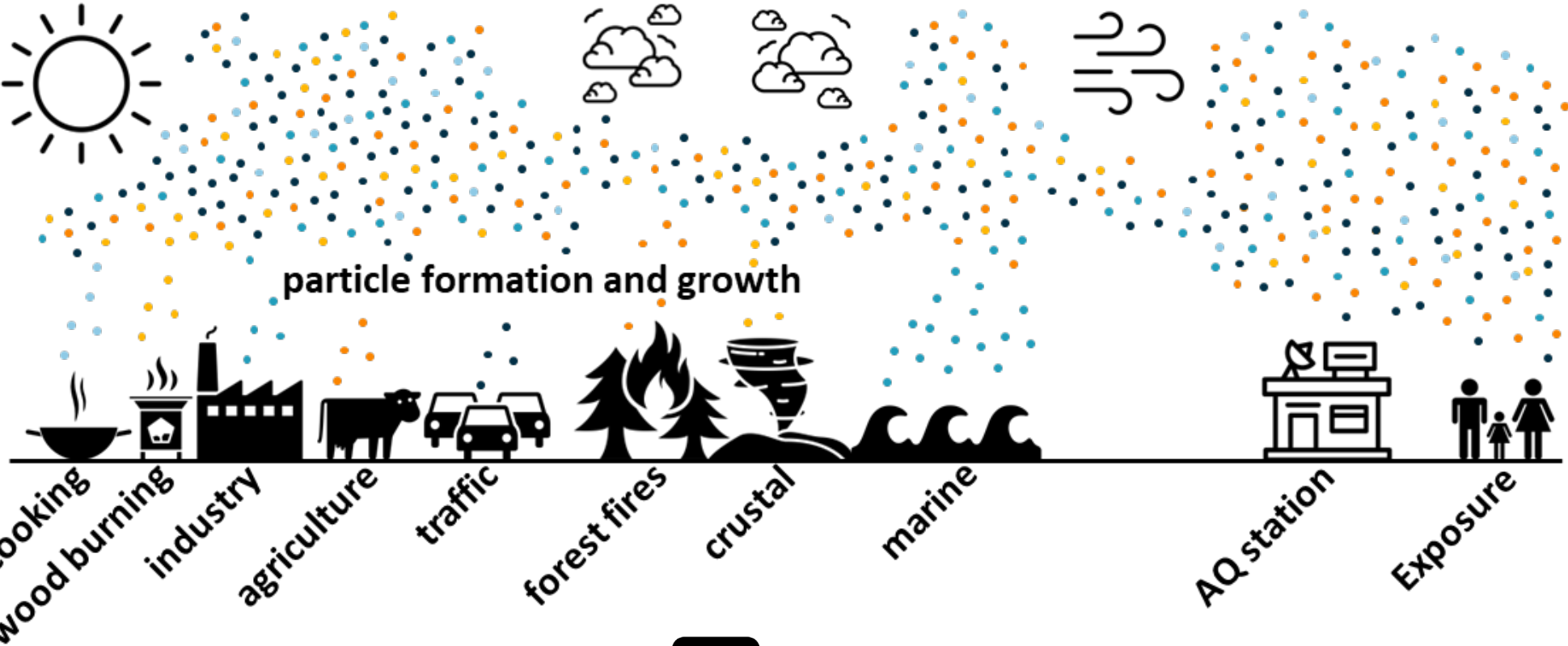


International Energy Agency Global EV Data Explorer



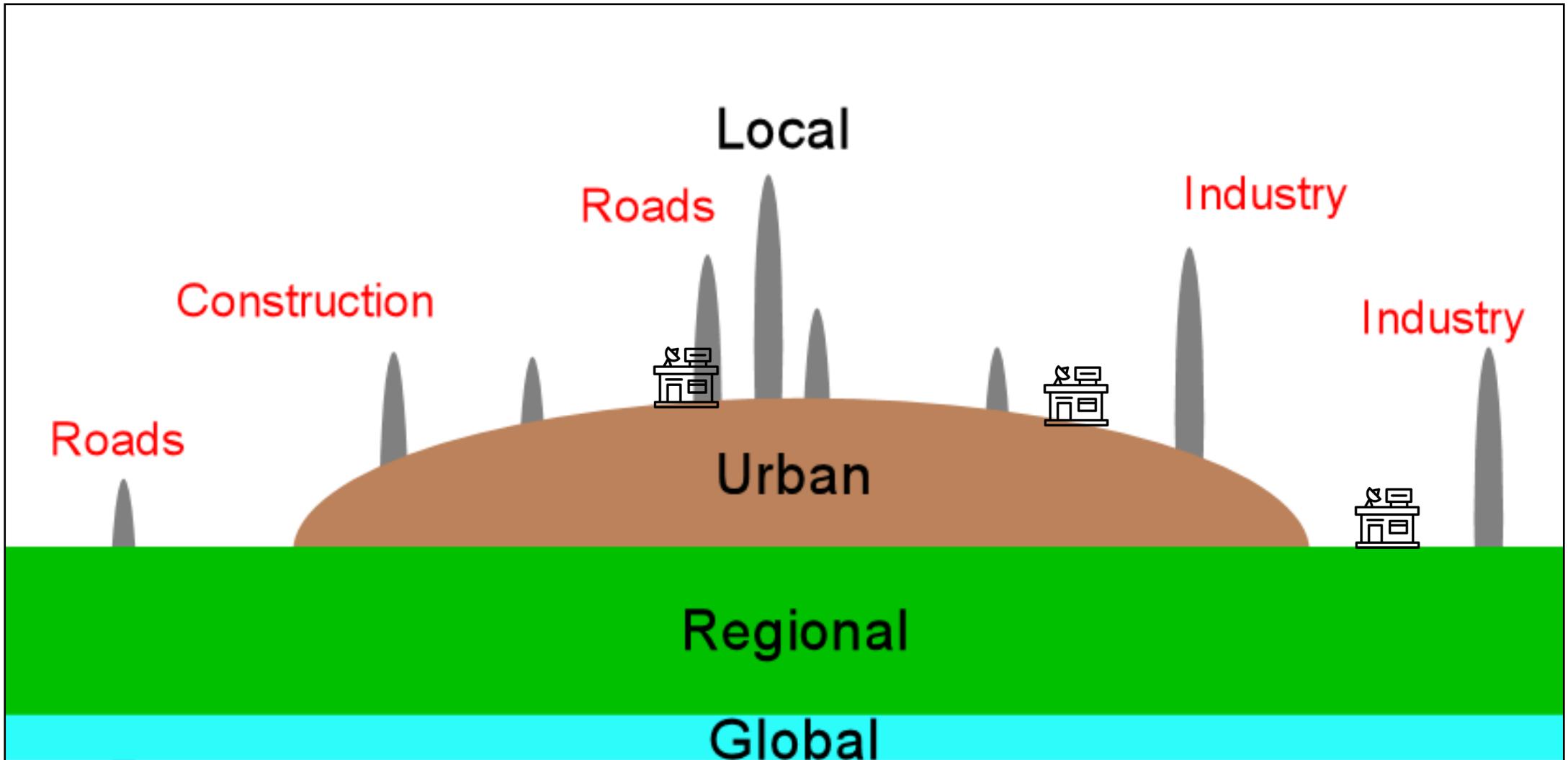
Average mass of new cars 2021  
EU 1,481 kg (ICCT, 2023)  
US 1,946 kg (EPA, 2023)

# Aerosol Mixture



# Isolate Source

## *Increment Approach to Measurement Studies*





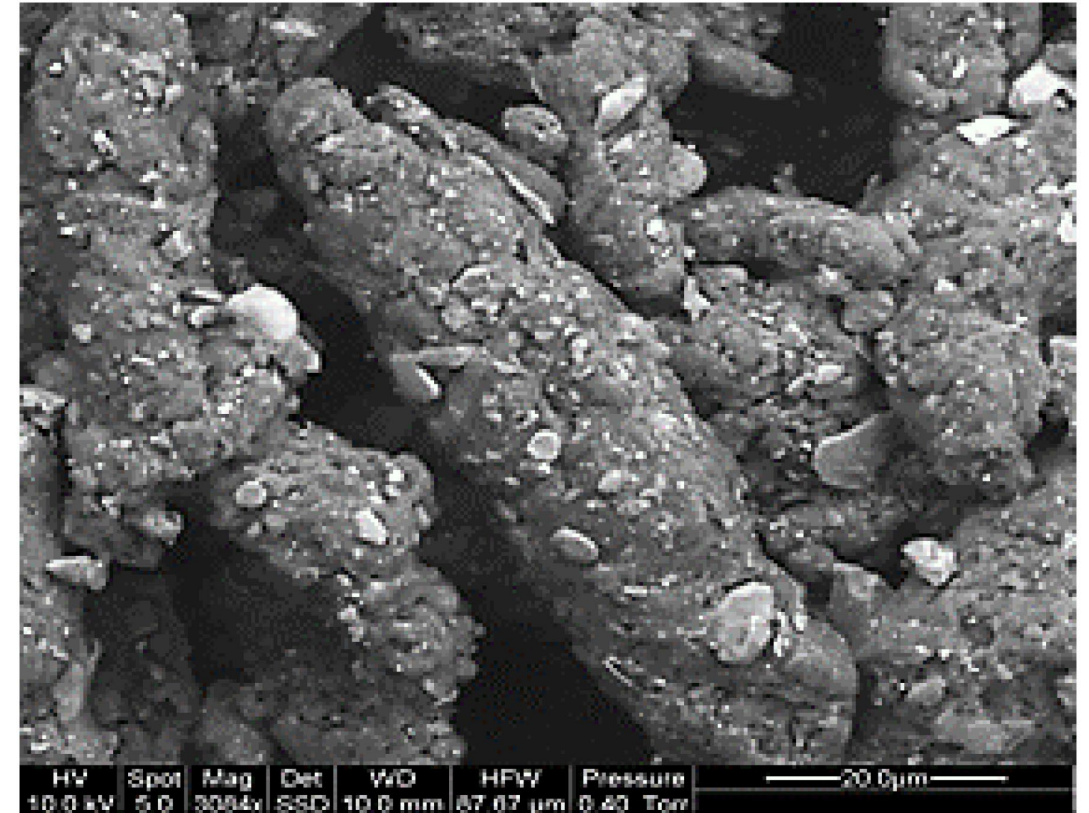
# Identify and Quantify Concentration

## Chemical Components

- Rubber hydrocarbons (40–60%), filler (20–35%), softener (15%), textile and metal reinforcement (5–10%), vulcanization agents (2–5%), other additives (5–10%).

## Physical Properties

- Less than 1% by volume of the particles in tyre wear emissions are  $PM_{10}$ .
- Within  $PM_{10}$ , more than 60% of tyre wear particles (by mass) are generally between 2.5 and 10  $\mu m$  in size.



## Tyre and Road Wear Particles

Mixture of tyre wear, road surface and other material



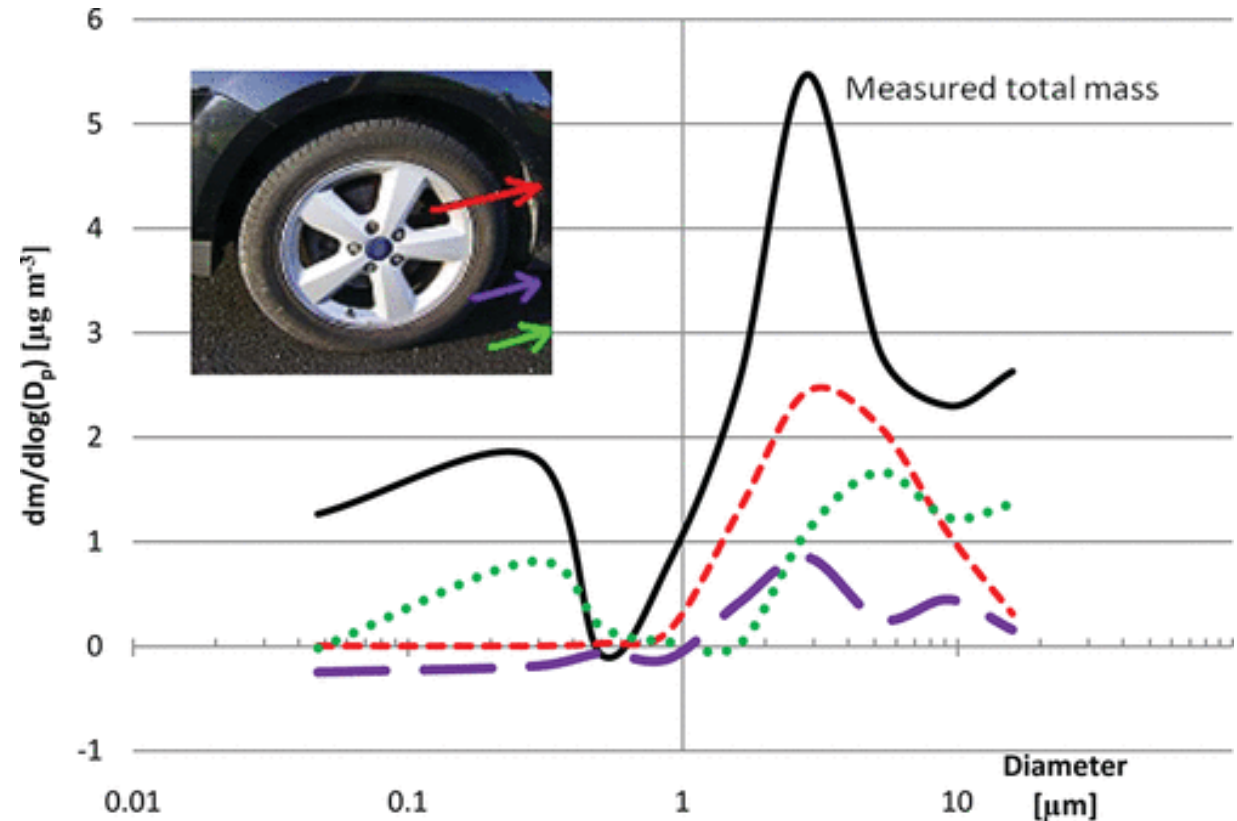
# Air Quality Supersites





# Elemental Markers

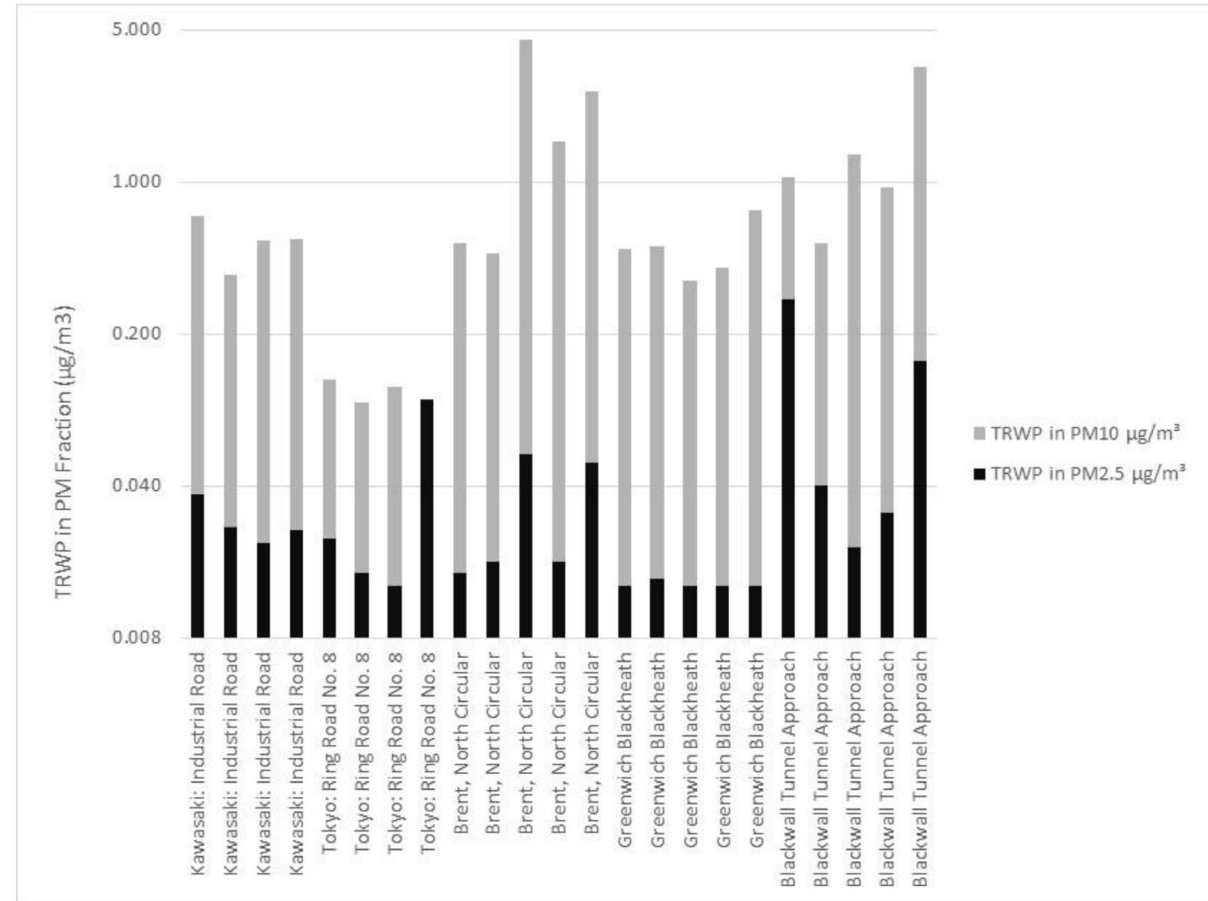
- Increment Approach
- Cascade Impactor
- Brake Wear - Barium
  - 1.1% brake dust
  - 55% PM<sub>10</sub>
- Tyre Wear - Zinc
  - 1% of tyre rubber
  - 11% PM<sub>10</sub>
- Resuspended Dust - Silicon
  - 28% of earth's crust
  - 38% of PM<sub>10</sub>



Harrison et al. 2012 Estimation of the Contributions of Brake Dust, Tyre Wear, and Resuspension to Nonexhaust Traffic Particles Derived from Atmospheric Measurements DOI: 10.1021/es300894r

# Polymer Markers

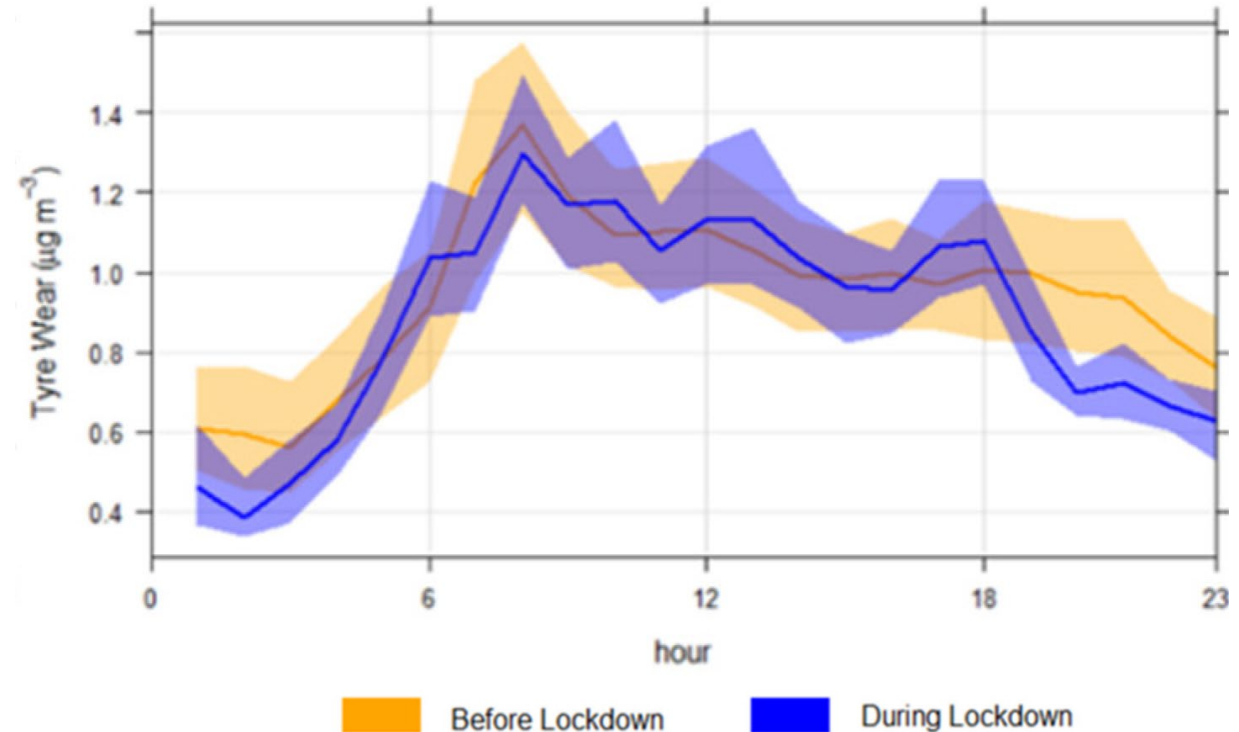
- Increment Approach
- PM<sub>2.5</sub> and PM<sub>10</sub> samplers
- Styrene butadiene rubber, butadiene rubber & natural rubber using GC/MS
- PM<sub>2.5</sub> contribution of Tread
  - 0.06–0.25% (London)
  - 0.05–0.17% (Tokyo)
  - 0.05–0.34% (Los Angeles)
- PM<sub>10</sub> contribution of Tread
  - 0.45–2.48% (London)
- TRWP assumed to be 2 x tread



Panko et al. 2019 Evaluation of Tire Wear Contribution to PM<sub>2.5</sub> in Urban Environments DOI: 10.3390/atmos10020099

# Elemental Markers at High Time Resolution

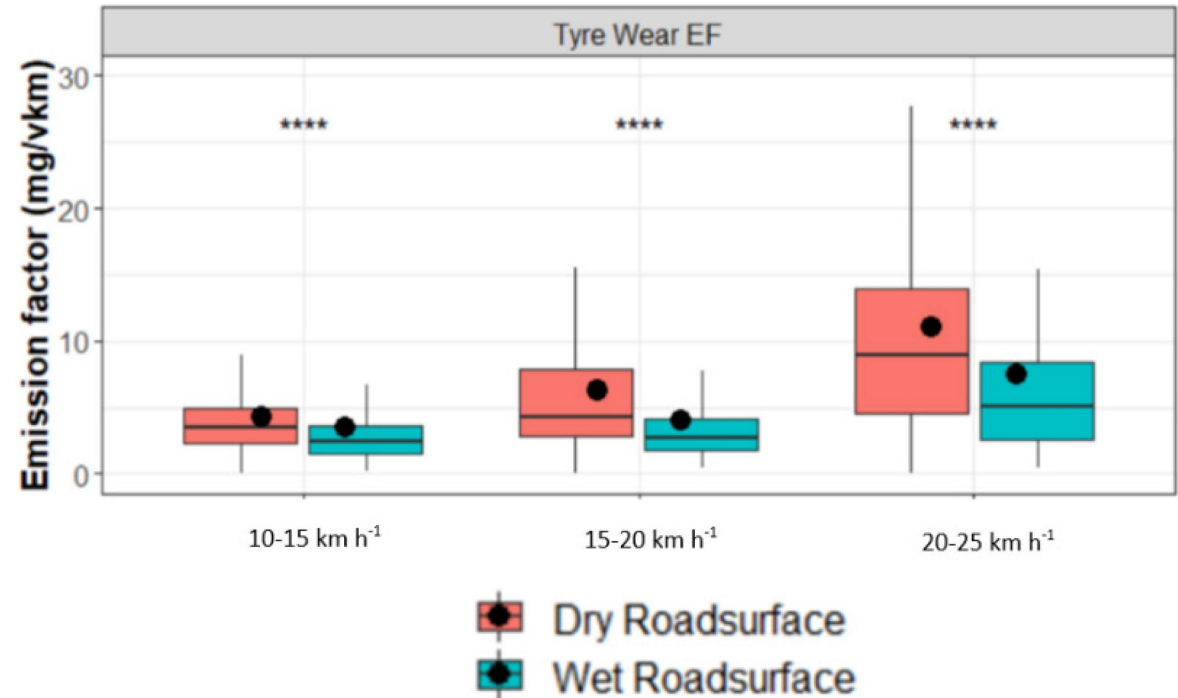
- Increment Approach
- 19 elements hourly  $PM_{10}$  using Xray fluorescence
- Zn as a marker for tyre wear
- Tyre wear contributed 6% to  $PM_{10}$
- Lockdown
  - 32% reduction in traffic volume
  - 15% increase in average speed
- Non exhaust emission factors (mg/vkm) calculated using fleet  $CO_2$  emission factors
- Speed and road surface wetness specific emission factors



Hicks et al. 2021 Quantification of Non-Exhaust Particulate Matter Traffic Emissions and the Impact of COVID-19 Lockdown at London Marylebone Road DOI: 10.3390/atmos12020190

# Elemental Markers at High Time Resolution

- Increment Approach
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- Speed and road surface wetness specific emission factors



Hicks et al. 2021 Quantification of Non-Exhaust Particulate Matter Traffic Emissions and the Impact of COVID-19 Lockdown at London Marylebone Road DOI: 10.3390/atmos12020190



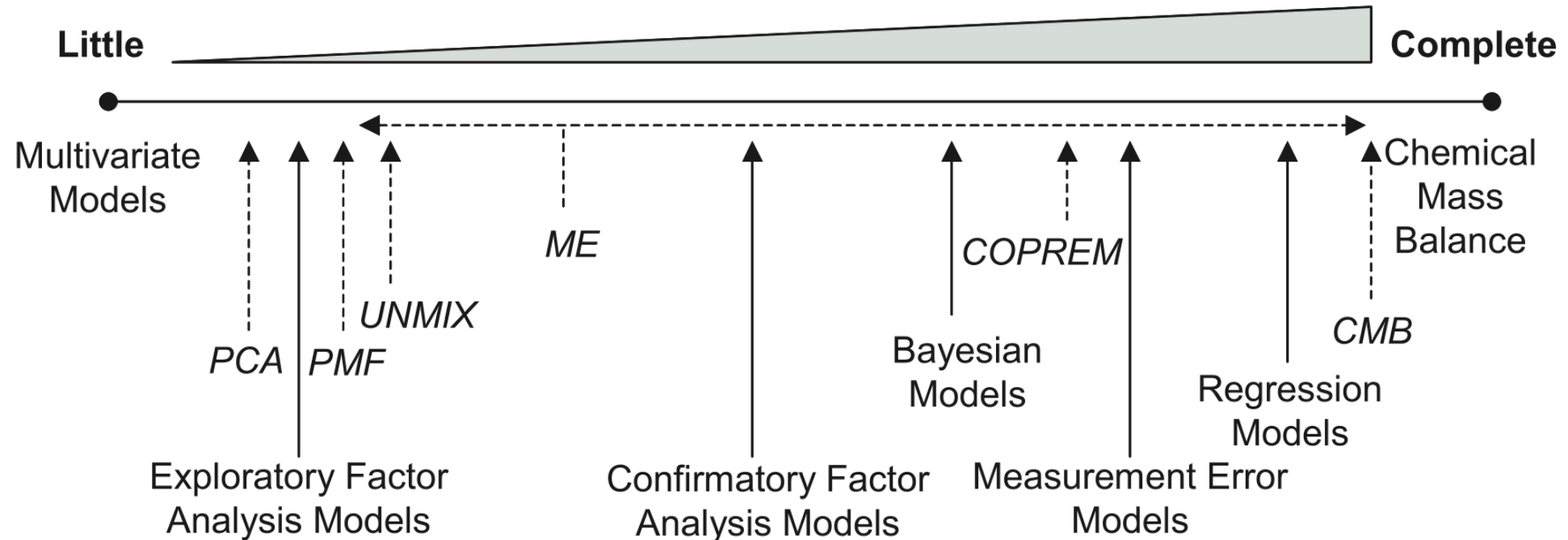
# Receptor Modelling / Source Apportionment

Receptor models

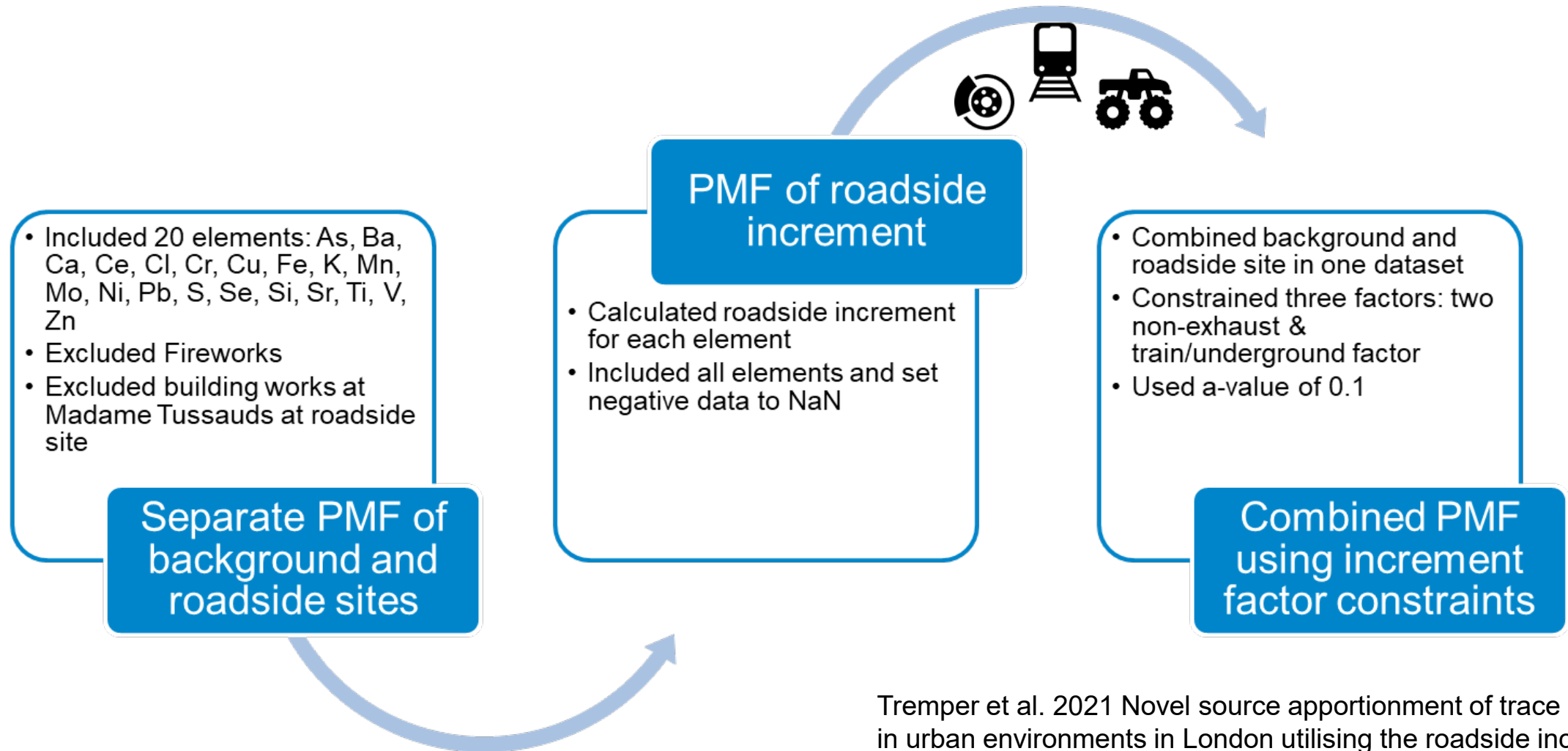
$$\mathbf{X}_t = \Lambda \mathbf{f}_t + \mathbf{e}_t$$

$p \times 1$      $p \times k$      $k \times 1$      $p \times 1$

Knowledge required about pollution sources  
prior to receptor modelling



# Receptor Modelling / Source Apportionment

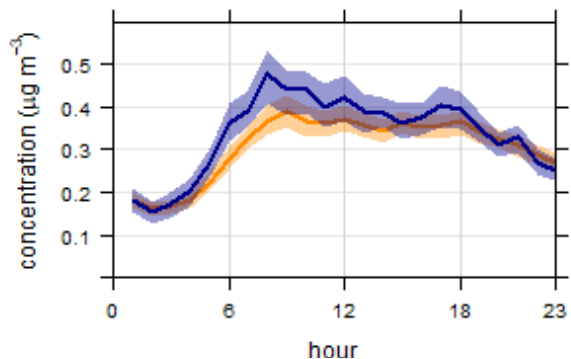


Tremper et al. 2021 Novel source apportionment of trace elements in urban environments in London utilising the roadside increment data - In preparation

# Receptor Modelling / Source Apportionment

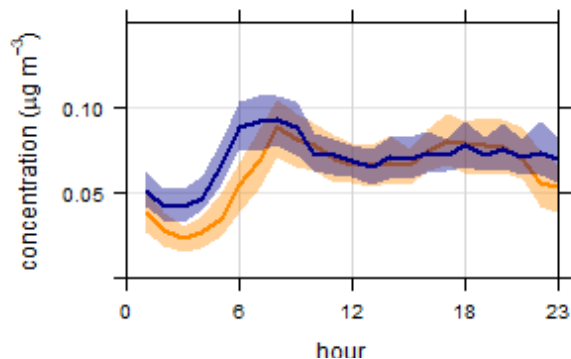
- Increment Approach
- 20 elements hourly  $PM_{10}$  using Xray fluorescence
- Data / statistical driven assessment of TRWP
- Only represents measured elemental components not mass contribution

*Roadside*

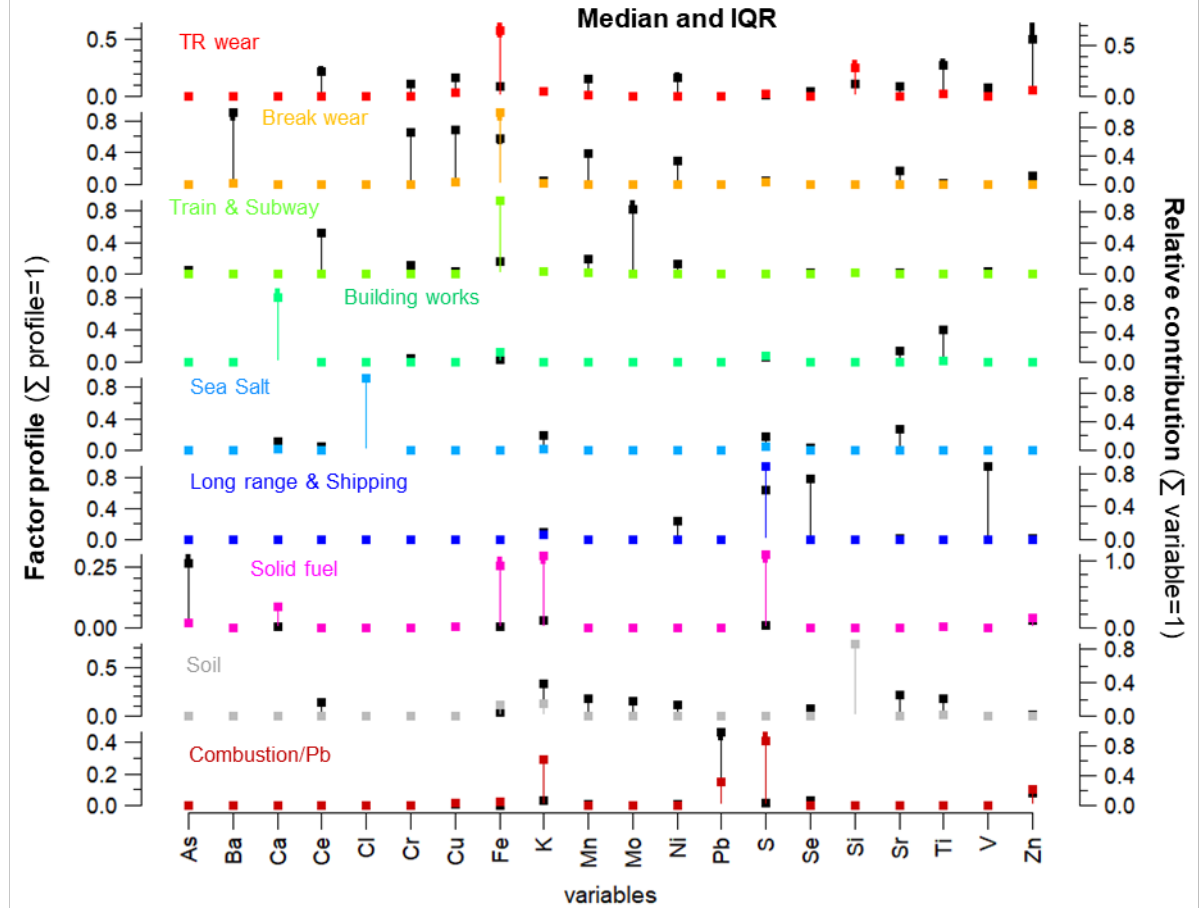


hour  
■ Before Lockdown  
■ During Lockdown

*Background*



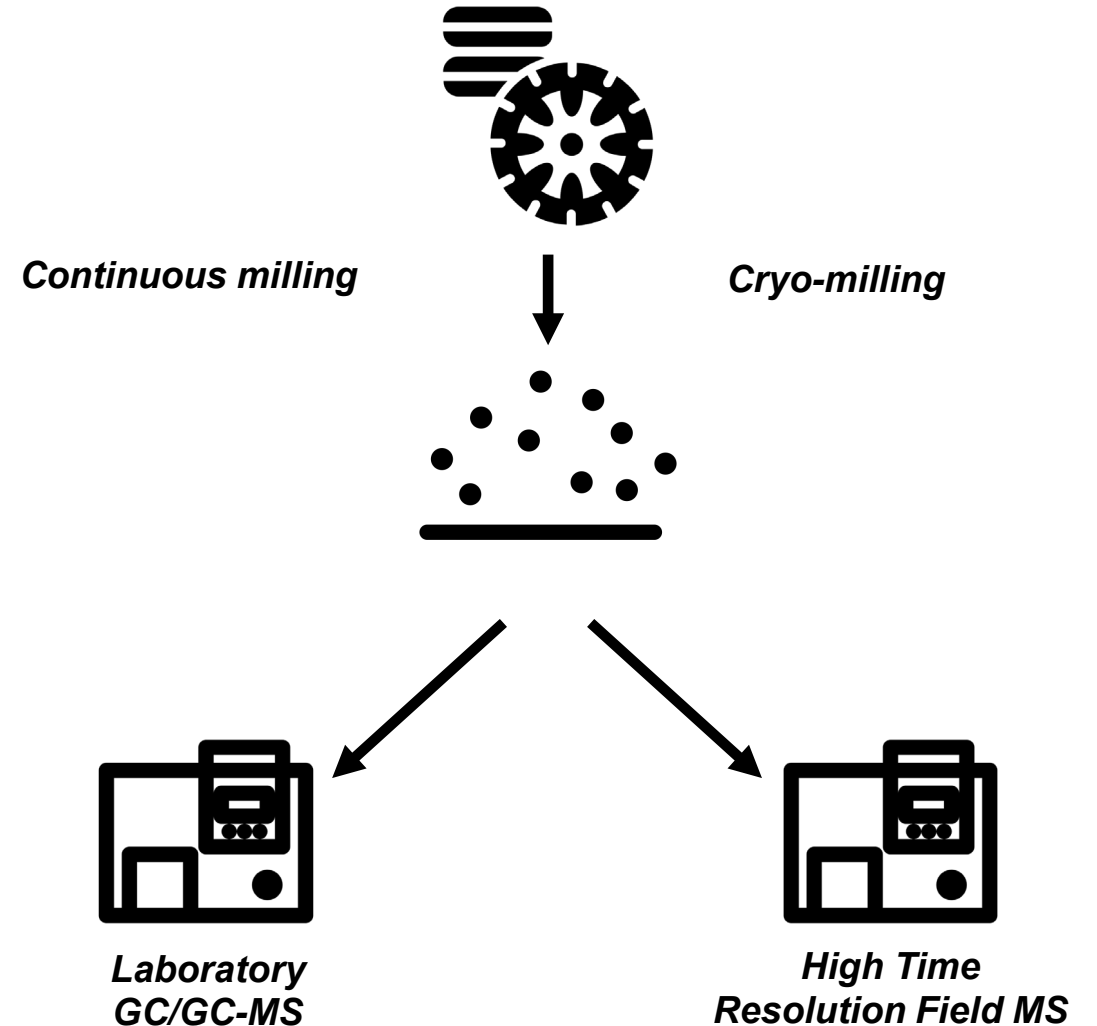
hour  
■ Before Lockdown  
■ During Lockdown



Tremper et al. 2021 Novel source apportionment of trace elements in urban environments in London utilising the roadside increment data - In preparation

# Developing Mass Spectral Factor Profiles

- Establish fingerprints for tyre wear in high time resolution field-based mass spectrometers
- Quantify tyre wear contribution in established supersite instrument suite
- Sub hour time resolution in PM<sub>1</sub> or PM<sub>2.5</sub>





# Establishing Health Impacts

- Assessing the Impact of Non-exhaust Emissions on the Asthmatic Airway (IONA) Protocol for a randomised three exposure crossover study
- US Health Effects Institute Study
- Acute impacts of NEE on the lung function and airway immune status of asthmatic adults
- Using source apportionment outputs from supersites + high speed road



# Take Home Messages

- Quantifying tyre wear in ambient PM<sub>10</sub> and PM<sub>2.5</sub> is challenging
- Assessments using elemental markers show good agreement with established EF
- Polymer markers provide lower estimates
- High time resolution measurement approaches capture complex emission profile, meteorological and emission variability
- Further work needed to establish polymer tracers for use in established instrumentation
- Human exposure trials are in progress to assess health impacts...