Transport and Dispersion of Non-Exhaust Pollutants

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What is Particulate Matter?

Particulate matter (PM) are small particles generated from both natural and human activities. A major source of PM pollution in urban environments is traffic. Traffic generated PM can be divided into:

- Exhaust emissions - Combustion by-products which are emitted from the tailpipe
- Non-exhaust emissions - Vehicle emissions that are not combustion related

PM is generally categorised by aerodynamic diameter, particles with a diameter below 10 μm and 2.5 μm (referred to as PM_{10} and $PM_{2.5}$) are especially relevant to health, as they are small enough to be inhaled.

Health Impacts of Particulate Matter

The World Health Organisation estimates that PM pollution contributes to 800,000 premature deaths each year, and is associated with diseases shown in Figure 1.

The health effects of PM exposure can depend on the amount inhaled over time, the material of the particle, the particle's surface chemistry, as well as the size of the particle.

In 2019, the UK Atmospheric Emissions Inventory indicated that 8.5% of PM10 and 7.4% of PM2.5 emissions (by mass) were generated from road transport. Of those, 73% of PM10 and 60% of PM2.5 were from brake, tyre, and road dust.

Efforts to reduce vehicular air pollution have focused mainly on exhaust emissions, relatively little attention has been paid to non-exhaust PM.

As exhaust PM emissions are reduced over the coming years, understanding the behaviour and transport of non-exhaust PM will become increasingly important for public health.

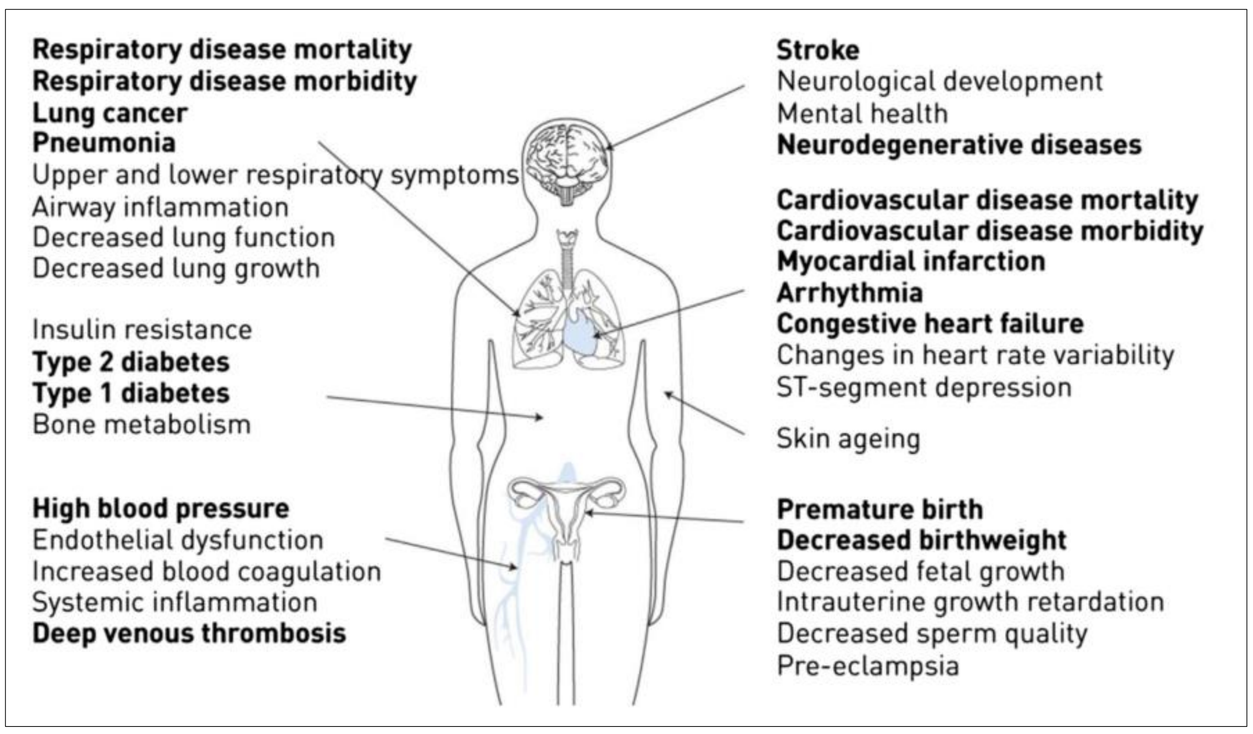
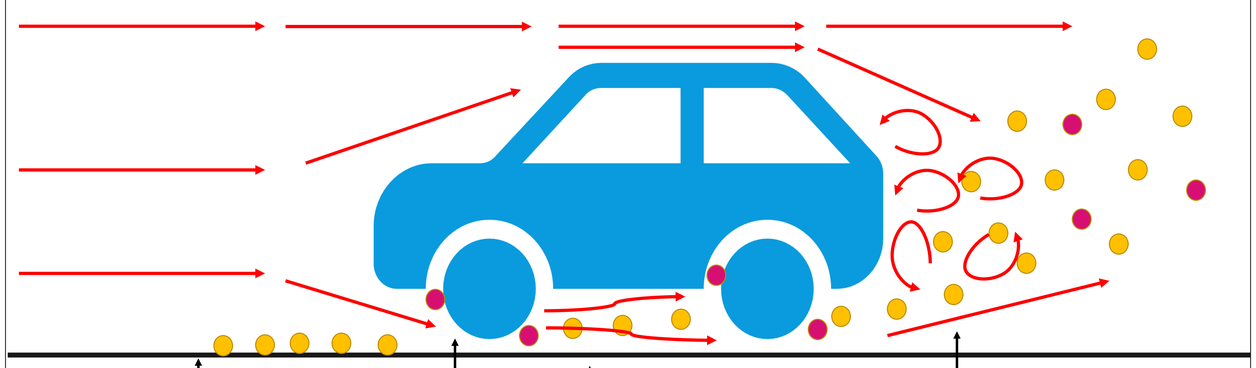


Figure 1: Overview of diseases conditions and biomarkers affected by outdoor air pollution [1]

Where Does Non-Exhaust PM Come From?

Non-exhaust PM can be classified as either:

- Direct wear emissions – newly generated PM from the vehicle
- Resuspended emissions – existing PM suspended from the road surface



Brake Wear
PM released through friction between the brake disk and pad

Turbulent Resuspension
Particles suspended by the aerodynamic effects around the vehicle

Road Surface Wear
PM released through abrasion of road surface by tyres

Mechanical Resuspension
Particles suspended from passage of the tyre over the road surface

Tyre Wear
PM released through abrasion with the road surface

Current Knowledge Gaps

- We currently have little understanding of how both directly emitted and resuspended non-exhaust PM is distributed within in a vehicle wake.
- There is considerable uncertainty about the contribution of vehicle aerodynamics to resuspension of road dust as well as interaction the between mechanical and turbulent resuspension.
- The empirically derived models for road resuspension are open to uncertainty and we do not currently have the data required to refine them.

References

[1] European Respiratory Journal Jan 2017, 49 (1) 1600419; DOI: 10.1183/13993003.00419-2016

[2] Images - Cambridge University Fluids Network - *Holger Babinsky* - https://www.cfn.group.cam.ac.uk/fluids-themes/aerodynamics

Will Electric Vehicles Reduce Non-Exhaust Emissions?

Electric vehicles are expected to replace combustion vehicles in order to meet climate targets. However, electric vehicles are predicted to be 280 kg (approx. 24%) heavier than an equivalent combustion vehicle.

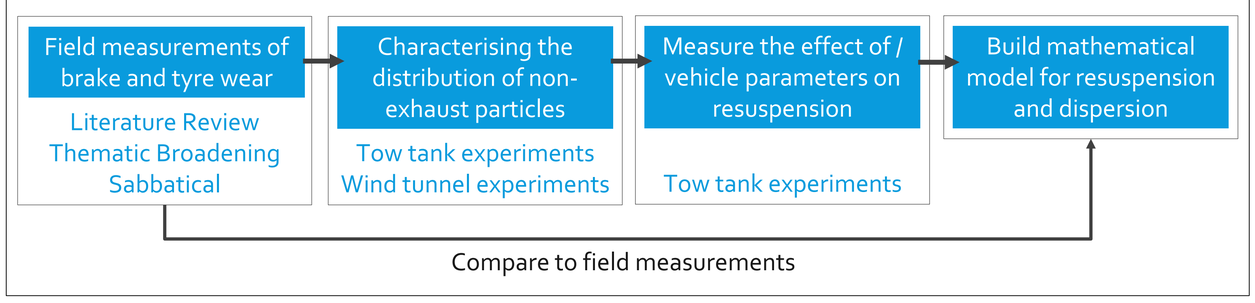
Vehicle weight is one of main factors affecting the amount of non-exhaust PM. Vehicles with greater mass will generate increased tyre, brake, and road abrasion PM.

We should expect the proportion of road transport emissions from non-exhaust sources to increase as older combustion vehicles are replaced with electric vehicles. **This means electrification could at best achieve a limited reduction in non-exhaust emissions, and may even increase them**.

Objectives

This project aims to characterise the transport and dispersion of non-exhaust pollutants in the wake of a vehicle, by:

- Characterising the distribution of PM10 and PM2.5 emissions from the brakes and tyres in the wake of a vehicle under experimental conditions.
- Observing how vehicle parameters such as size/shape, and ground clearance impact mechanical and turbulent resuspension of road dust.
- Building a mathematical model of resuspension using the experimental results generated in the first and second parts of the project, and comparing the results to field data collected during the thematic broadening sabbatical.



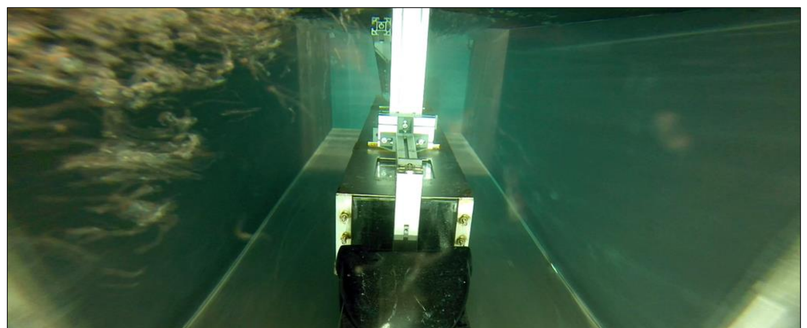
Experimental Techniques

The transport and dispersion of PM will be examined with reduced-scale laboratory experiments using a tow tank and a wind tunnel, eliminating external conditions that could affect field measurements. It will also capture the entirety of the flow around the vehicle and the turbulent air in its wake, to build a complete picture of PM distribution around the vehicle.

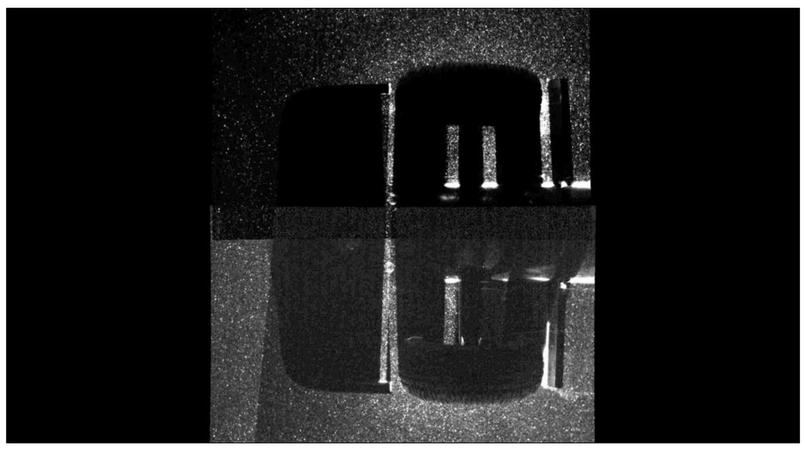
- In the wind tunnel the intent is that a continuous stream of a gas tracer can be released from the model in the location of brake or tyre emissions to model PM distribution.
- To model resuspension from the road surface tow tank experiments will be conducted.

Tow Tank Experiments

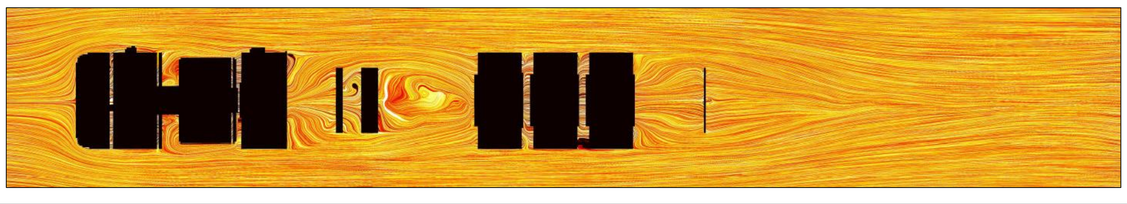
- The bottom of the tow tank will be seeded with TiO_2 tracer particles and the vehicle model dragged through the tank



- As the model is dragged over the particles resuspension occurs. A light sheet is used to illuminate the TiO_2 tracer particles and their movement will be tracked using Particle Image Velocimetry (PIV)



- The particle data will be processed to develop a understanding of how PM will be distributed in the wake of a vehicle [2].



Policy Implications

At present legislation in the UK does not aim to limit or reduce non-exhaust PM emissions.

Better modelling of non-exhaust emissions could help to protect public health by significantly aiding a wide range of policy developments, such as:

- Planning new roads or traffic interventions
- Justifying the creation of better public transport networks
- Taxing non-exhaust PM on a polluter pays principle
- Developing informed vehicle regulation.