Remote sensing of vehicle particulate failures using portable exposure instruments

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Project summary

This project aims to deploy two types of low-cost personal exposure instruments to monitor vehicle emissions at Imperial College London. Emissions standards for modern cars, vans and heavy duty vehicles include a solid particle number (PN) limit. This has led to the widespread adoption of diesel particulate filters (DPFs) on diesel vehicles. For petrol vehicles, gasoline direct injection (GDI) engines can also produce significant particle emissions and to comply with the PN emissions standard, some GDI vehicles are fitted with a gasoline particulate filter (GPF). Previous research has shown that DPFs and GPFs effectively control solid PN emissions, which mainly comprise black carbon (BC). However, failure of DPFs and GPFs, which may be due to thermal or mechanically induced cracking, leads to significantly higher emissions. D/GPF failure cannot be detected by the MOT test and the failure rate of D/GPFs is unknown. Given that these vehicles have PN emissions that may be 2-3 orders of magnitude higher than the emissions standard, they could be a significant source of ambient air pollution. This project will remotely sample vehicle emissions (i.e. non-invasively) on entry and exit to the Imperial College campus. The car park already records vehicle number plate information, which will be used to look up the vehicle details, including age, fuel type and emissions standard. Two different low-cost instruments will be used for this study; (i) two AethLabs Micro-Aethalometers measuring BC mass concentration, and (ii) two Naneos Partectors that measure particle surface area reported as lung-deposited surface area. In previous work, we have shown that the correlation between simultaneous BC and LDSA measurements indicates the fraction of ambient aerosol that is BC, and that the ratio of LDSA to BC gives a measure of the mean particle size as it is a proxy for the surface area to mass ratio. This combination of measurements will therefore be able to detect D/GPF failure as BC mass concentrations will be non-zero for plumes containing BC and showing a higher BC to LDSA correlation. Secondly, the ratio of LDSA to BC will indicate the average size of BC particles that are present. Thirdly, the presence of semi-volatile particles, that are not filtered by D/GPFs, will be detected by the Partector, and are expected to depend on vehicle type and ambient conditions, which influences nucleation processes. The project is expected to last 10 weeks (with additional institutional funding to cover weeks 7-10). The student will write up a final report which will be shared with contacts at Transport for London (TfL), Department for Transport (DfT) and Department for Environment Food and Rural Affairs (Defra).

Project objectives

1. Design the experimental procedure and positions of the instruments to be able to sample vehicle emissions plumes as vehicles enter and exit the campus.
2. Verify that individual vehicle plumes can be extracted over the background concentrations. Investigate data smoothing/processing steps that account for instrument response times and sensitivities and improve the signal to noise ratio.
3. Measure vehicle emissions over several days and align with vehicle registration plate data.
4. Analyse the BC-LDSA correlations and ratio for individual vehicles and aggregate the analysis by vehicle category, fuel type, vehicle age and emissions standard. Quantify the D/GPF failure rate for vehicles entering into campus.
5. Write up the project findings into a report that can be shared with contacts at TfL, DfT and Defra.

Student selection process and career development

The bursary was advertised to >350 Civil Engineering undergraduates. Two students expressed an interest and were interviewed by myself. The most promising student was selected. This student has also indicated an interest in further research in the field, which could be pursued through the fourth year project and potentially PhD.