Markus Knoll

Advancing Aerosol Characterisation: Methods for Exhaust and Non-Exhaust Emissions

Aerosols are of critical importance due to their influence on the climate and their negative health impacts, such as the penetration of ultrafine particles (smaller than 100 nm) into the body. Aerosols are often inadequately monitored, and their health implications are not fully understood. This is because current ambient air monitoring primarily targets mass-based indicators dominated by coarse and fine particles (PM10 and PM2.5), while the number concentration of ultrafine particles and the chemical composition are largely neglected.

My research focuses on developing new instruments and methods to improve the characterisation of aerosols and their sources. This will provide reliable data, improve our understanding and support future regulations. Aerosols are a complex matter because they involve various parameters, making them very difficult to characterise or quantify. The concentration is one of the main parameters, but aerosols differ in terms of their physical parameters, such as size, morphology, density and light interaction, as well as their chemical parameters, such as composition and reactivity (see Figure 1). Various aerosol measurement techniques already exist, especially with respect to monitor particle mass and number, but there are still various blank spots that need to be researched to get a better understanding of the influence on health and climate.

Vehicle emissions still make a significant contribution, particularly in congested areas such as cities. The introduction of diesel particle filters has largely mitigated the ultrafine particle emissions of diesel vehicles. The main remaining issue is identifying vehicles with faulty CO_2 missing filters – so called "high emitters" – because they emit up to a thousand times more ultrafine particles than vehicles with functioning filters. As more vehicles become electric, the contribution of diesel vehicle emissions will decrease, yet petrol and hybrid vehicles will continue to dominate fleets for many
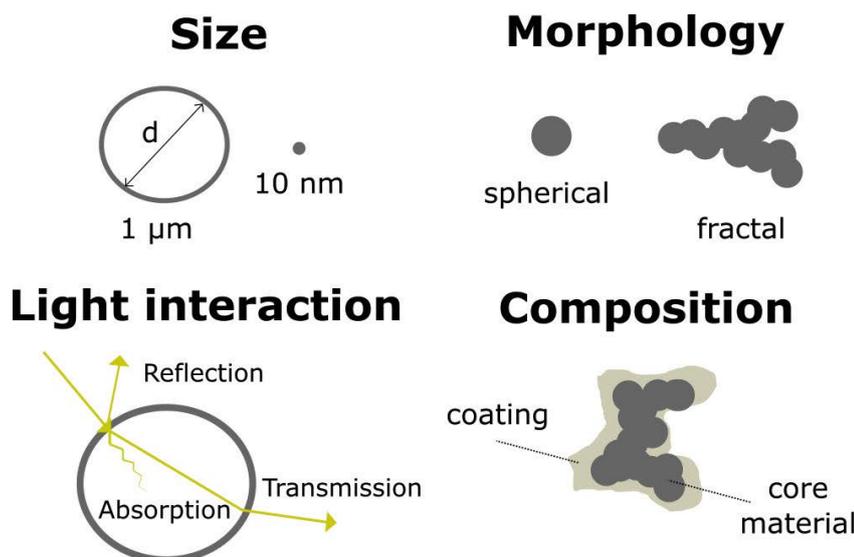
Figure 1: Visualization of several important aerosol attributes.
Source: Markus Knoll
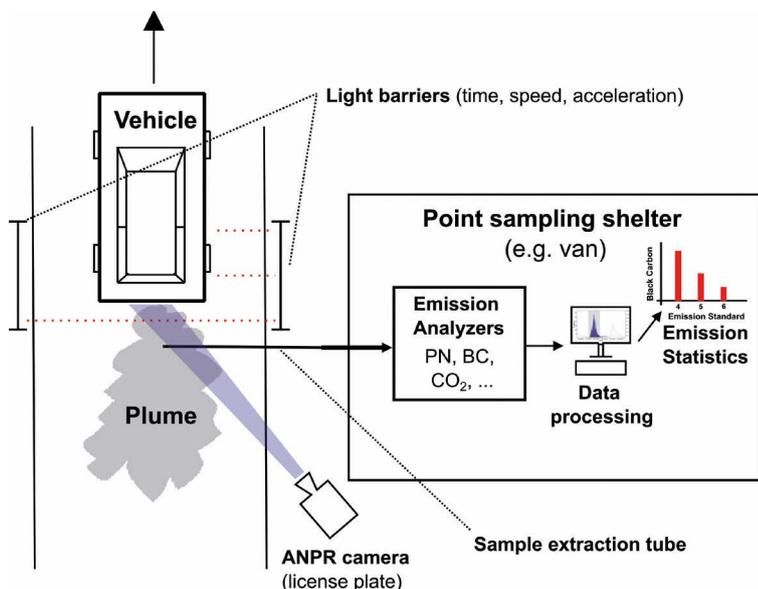
Figure 2: Emission screening by point sampling.

years. These vehicles emit even smaller particles that are chemically different and more difficult to measure accurately. It is particularly important to ensure that vehicles maintain low emissions throughout their lifetime, and to monitor emissions during real-world driving situations, i.e. in urban areas. Together with other research partners in EU Horizon projects, I have further developed a roadside measuring technique called "point sampling" that can measure both direct emissions and ambient concentrations (see Figure 2).

In point sampling, fast and highly sensitive emission analysers, such as the black carbon tracker (see Figure 3), are used to measure various exhaust metrics of by passing vehicles. This method can be used to screen vehicle emissions on a large scale and identify the emission patterns of specific vehicle types. Using this method and sophisticated data processing methods we could successfully reveal that certain Ford diesel vehicles exhibited significantly higher emissions than other makes due to particle filter failures. The next stage of this work is to refine the technique in order to make a clearer distinction between exhaust and non-exhaust emissions, and to reliably identify vehicles with high emissions. The aim is to provide more accurate source attribution and deeper insights into emissions and immissions. These aspects are covered for example by the EU Horizon project 'Net4Cities' (https://www.net4cities.eu/), in which we will be participating over the next few years.

Figure 3: The black carbon tracker is a fast-response analyser used to measure black carbon and CO_2.
Source: Markus Knoll
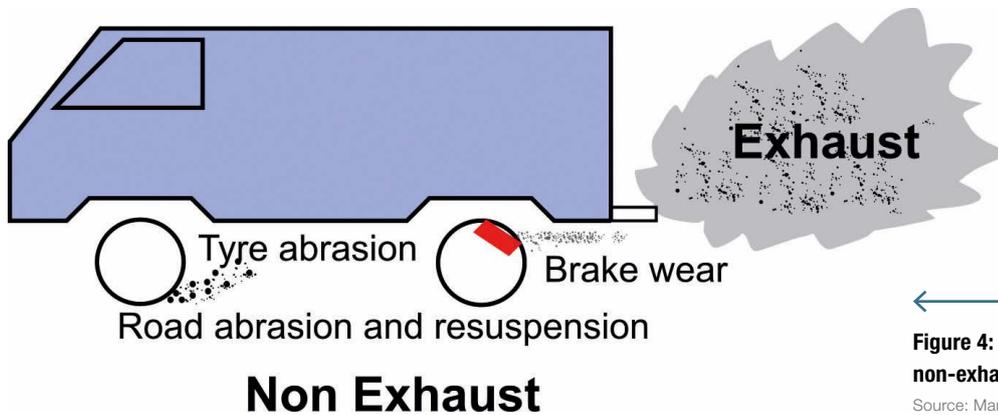
Figure 4: Exhaust and non-exhaust emissions.
Source: Markus Knoll

It is well known that with the modernisation of vehicles and electrification, other emission sources are becoming more important. Studies have already shown that vehicle non-exhaust emissions account for a higher proportion of emissions in specific areas than combustion-based emissions do.

Therefore, and due to new legislation, non-exhaust emissions, such as brake wear, tyre abrasion and resuspended road dust (see Figure 4), are becoming increasingly important. Tyre abrasion in particular is considered one of the largest contributors to microplastic pollution. Although regulations for vehicle type approval are being developed to measure particle mass, methods for size-dependent classification and particle number measurement in the case of non-exhaust emissions are lacking. Non-exhaust particles range in size from a few nanometres to hundreds of micrometres, and their diverse chemical compositions require more comprehensive study and improved characterisation. These aspects are covered by the NExT project at TU Graz, in which I am participating. The project aims to develop new instrumentation and methods for characterising non-exhaust emissions.

To address these challenges, I will establish a research group and collaborate with national and international partners to advance knowledge and develop transformative solutions. ●

REFERENCES

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Source: privat

Markus Knoll received his Bachelor of Science in Telematics in 2015 and his Master of Science in Information and Computer Engineering in 2018, both from TU Graz. Between 2014 and 2018, he worked at NXP Semiconductors, where he developed hardware and software for mixed-signal systems for the testing of integrated circuits. He went on to teach and conduct research in the field of aerosol science at the Institute of Electrical Measurement and Sensor Systems at TU Graz within the EU H2020 projects SensMat and CARES. He obtained his PhD in 2024 with a thesis focusing on point sampling of particulate matter, a remote emission sensing technique to monitor vehicle emissions. Over the past two years, he worked as a technical project lead at AVL DiTEST, researching and developing instrumentation for vehicle emissions, with a particular focus on particle number measurements.