Automotive particulate emissions

Growing knowledge in a complex area

Particulate matter (PM) in the air continues to be the focus of increased attention due to concerns over potential health effects. Under the EU Air Quality Framework Directive an air quality standard has been defined with respect to PM_{10}[1] with a review planned in 2003.

Legislation to control the overall mass of automotive particulate emissions has been progressively tightened over the years. While there is evidence that adverse health effects are associated with current ambient PM concentrations, it is as yet uncertain which feature of the particulate matter, chemical or physical, has the most relevance for health. Further work is needed to understand health effects. In the automotive area, extensive studies have been carried out on the number-based size distribution of particulate emissions. This article provides an update on recent activities and CONCAWE's current understanding on automotive particulate emissions.

SCOPING STUDIES ON AUTOMOTIVE PARTICLES COMPLETED

CONCAWE embarked early on the study of automotive particulate emissions by mass, number and size. Initially a thorough literature survey was carried out to identify suitable measurement methodologies for both mass and number distributions of particles[2]. This work was followed by a scoping exercise to improve the understanding of particulate emissions using a range of light-duty diesel and gasoline vehicle technologies with a wide range of market fuels[3]. A heavy-duty engine test programme was then carried out covering two engine technology levels (Euro 2 and 3) and using a fuel matrix similar to that used for the light-duty diesel vehicle study[4]. More recently the final reports from the collaborative work between the UK DETR[5], SMMT[6] and CONCAWE have been published[7]. The major findings from this latest study are reviewed below and put into context with CONCAWE's current understanding on automotive particulate emissions.

UK DETR/SMMT/CONCAWE STUDY HAS BROADENED THE KNOWLEDGE BASE

The DETR/SMMT/CONCAWE Particulate Research Programme investigated the effect of engine technologies and fuel specifications on regulated PM emissions, as well as particle number, mass and size distribution. Emissions from a range of light-duty vehicles (diesel, gasoline and LPG), a range of heavy-duty diesel engines and one heavy-duty CNG engine were characterized. Euro 1, 2 and 3 engine and vehicle technologies were tested with a range of market fuels. The

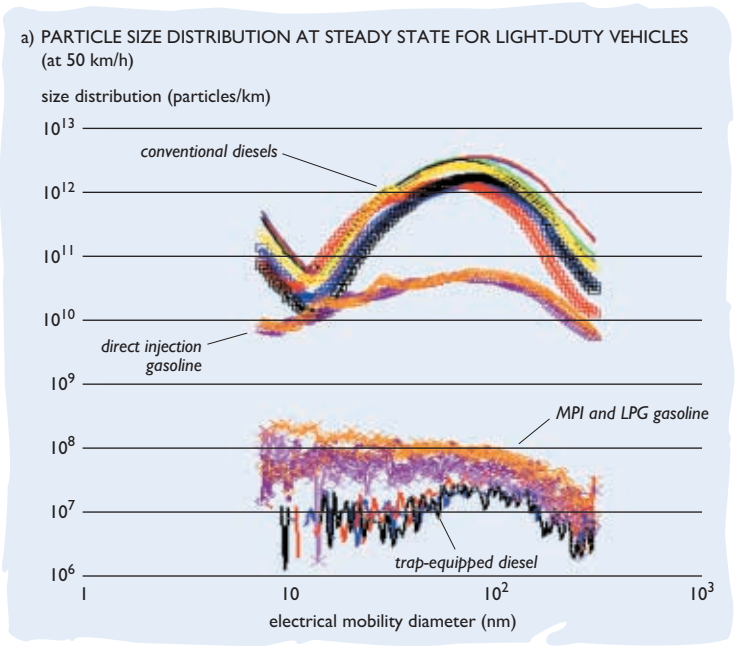
[1] *Particulate with an aerodynamic diameter less than or equal to 10 μm*
[2] *CONCAWE report 96/56, SAE 982602*
[3] *CONCAWE report 98/51, SAE 982600*
[4] *CONCAWE report 01/51, SAE 2000-01-2000*
[5] *DETR: Department of the Environment, Trade and the Regions*
[6] *SMMT: Society of Motor Manufacturers and Traders*
[7] *May 2001, www.ricardo.com*

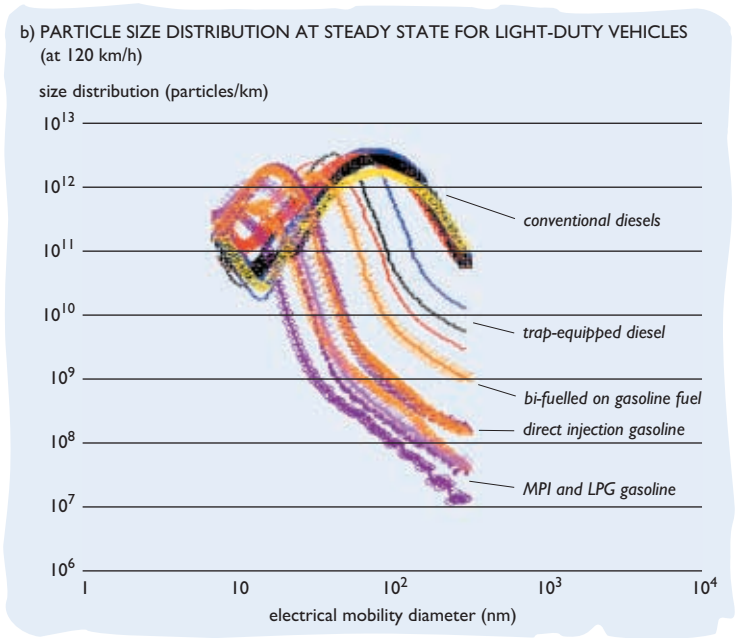
study also addressed the application and limitations of current sampling and measurement techniques and led to recommendations regarding instrumentation and sampling methods.

Two distinct particle types were observed: solid, carbonaceous (accumulation mode) particles and volatile (nucleation mode) particles. It was shown that good repeatability can be achieved for measurements of both accumulation and nucleation mode particles. However, nucleation mode particles were confirmed to be highly sensitive to sampling conditions, dilution parameters and pre-conditioning of engines/vehicles. Limitations inherent to the instrumentation used to measure particle size and number highlighted the difficulties in comparing data derived from different studies. The importance of standardized and representative sampling and measurement methodologies was highlighted.

The study showed that both fuel and engine technology influence particle number emissions. Stricter emission standards have resulted in reductions in particulate mass and this is generally reflected in reductions of accumulation mode particles. However, none of the fuel or engine technologies tested reduced all nucleation and accumulation mode particles as well as particle mass under all operating conditions.

Figure 1
Trends in particle size distribution for light-duty vehicles at:
a) 50 km/h; and
b) 120 km/h





Diesel particulate filters (DPFs or traps) showed the largest effect of a single technology in both light- and heavy-duty applications, reducing particle mass and number by several orders of magnitude. At high exhaust temperature conditions, however, trap-equipped diesel engines produced significant numbers of nucleation mode particles.

In the light-duty fleet, the highest particle numbers were emitted from conventional diesel vehicles. Particle number emissions from conventional MPI gasoline vehicles, the LPG vehicle and the diesel vehicle fitted with a particulate filter system were several orders of magnitude lower than those from conventional diesel. Gasoline direct injection vehicles gave particle number emissions between the conventional gasoline and conventional diesel vehicles. The heavy-duty CNG engine produced significantly lower particle mass and number emissions compared to the heavy-duty diesel engines. Examples of the trends in the light-duty fleet are illustrated in Figure 1.

Fuel effects were small compared to the effects of engine technologies. Swedish Class 1 diesel fuel showed a small but significant reduction in particle mass and number compared to the

other diesel fuels tested. Gasoline quality effects were minimal in conventional engines, while UK specification ultra low sulphur fuel reduced particulate mass in direct injection engines.

CONCAWE'S CURRENT UNDERSTANDING ON MEASUREMENT METHODOLOGY

The science surrounding the measurement of automotive particle size and number emissions and their potential health effects is still under development. Generically, automotive particle emissions can be classified into two types:

- accumulation mode, solid carbonaceous particles, representing most of the particulate mass and found mainly in the size range 30 to 1000 nm; and
- nucleation mode, volatile particles, generally smaller than ca. 30 nm.

Instrumentation and measurement techniques are still being developed and it remains difficult to compare data from different instruments and studies. With due care and attention, measurements of the accumulation mode particles can be relatively robust and repeatable. On the other hand, measurements of the nucleation mode particles are very sensitive to exhaust gas dilution conditions, such as temperature, humidity and dilution ratio, as well as to engine/vehicle pre-conditioning.

Recent studies continue to provide evidence of the complexity of sampling and measuring the full range of particles. There is a greater understanding of the measurement of accumulation mode particles, while more research is needed to understand the complex nucleation processes and the resulting nucleation mode particles. A key challenge remains to develop consistent, practical measurement methodologies which are representative of real-world operating conditions.

MEMBER STATES NOW FOCUSING ON DEVELOPMENT OF TEST SUITABLE FOR TYPE APPROVAL USE

Member States have initiated a new two-year programme under the GRPE[8] to develop a test to measure particulate size and number emissions that is suitable for future type approval testing. A practical test procedure is required for use in routine regulatory emissions testing. It is expected that such procedure will focus on the measurement of the accumulation mode particles, with the ultimate objective of controlling diesel particulate emissions at a level currently achievable by trap-equipped vehicles.

CONCAWE is also participating in work in the DG TREN[9] particulates consortium which aims to further extend knowledge on automotive particulates and should include the development of a representative, harmonized sampling and testing methodology as well as the establishment of emissions factors for current and future vehicles and fuels.

Through its continued involvement in automotive particulate emissions CONCAWE is committed to assisting in the development and application of sound science in a complex and rapidly developing area.

[8] *Groupe des Rapporteurs pour Pollution et Energie*

[9] *EU Commission's Directorate General for Transport and Energy*