

ABRASION AND RESUSPENSION FROM ROAD SURFACES – AN IMPORTANT SOURCE OF FINE PARTICLES IN THE ENVIRONMENT

R. Gehrig, K. Zeyer, N. Bukowiecki, P. Lienemann, L. Poulikakos

Empa, Swiss Federal Laboratories for Materials Testing and Research, Dübendorf, Switzerland

ABSTRACT

Specific quantification of PM₁₀ emissions due to abrasion and resuspension from road pavement is not easily obtained from field studies because a large variety of potential sources affect local PM concentrations. It is extremely difficult to quantitatively attribute the measured PM to the individual sources. In this study emission rates were derived from measurement with two road simulators of different size on two frequently used types of road pavement (asphalt concrete, porous asphalt). The experimental set-up allows for a separate characterisation of the emissions due to fresh in-situ abrasion and resuspension of previously deposited dust. The results show an important contribution of resuspension to the fine particle emissions of road traffic. Direct abrasion from the road surface is of minor importance for intact pavements. However, damaged pavement surfaces can cause significant fine particle emissions.

1. INTRODUCTION

Excessive load of the ambient air with fine particles (PM₁₀) is one of the most pressing issues of air pollution control. Particle emissions of road traffic are mostly associated with exhaust emissions (soot) only. Until recently particle emissions due to abrasion processes (from pavement, brakes, tyres and clutches) as well as resuspension of previously deposited dust were not considered. But there are clear indications that the contribution of these emissions to the PM₁₀ load of the ambient air near busy roads is important (Abu-Allaban et al. 2003; Gehrig et al. 2004; Imhof et al. 2005; Kupiainen et al. 2005; Hussein et al. 2008). But no detailed quantitative information about emission factors of the in-situ mechanically produced and/or resuspended fine particles is yet available. This, however, is necessary for effective PM₁₀ reduction scenarios.

Specific quantification of PM₁₀ emissions due to abrasion and resuspension from road pavement is not easily obtained from field measurements at traffic sites because a large variety of potential sources can affect local PM concentrations. It is quite difficult to quantitatively attribute the measured PM to the individual sources. For emissions with specific elemental composition (e.g. brake wear) it is possible to do so (Bukowiecki et al. 2009). But even with detailed chemical speciation locally produced abrasion particles from the road surface and resuspension of previously deposited dust from other sources can hardly be distinguished due to their similar composition and highly correlated variation in time. In this study emission rates were derived from measurements with two road simulators of different size on different types of road pavement (asphalt concrete, porous asphalt). The experimental set-up allowed for a separate characterisation of the emissions due to fresh in-situ abrasion and resuspension of previously deposited dust.

2. METHODOLOGY

Two different types of road simulators were employed. The MMLS (Model Mobile Load Simulator, Fig. 1) is a relatively small device simulating approximately 30% of the abrasion of tyres and road surface by a normal passenger car at a low speed of 9 km/h. The big device MLS (Fig. 2) simulates the abrasion processes of a full size heavy duty truck at a speed of 25 km/h. The operation principle of both simulators is to pull the wheels in a closed loop over a defined distance of road surface at a defined speed and with a defined axle weight.

For the abrasion particle study the devices were placed on the road pavement to be investigated and then started. The motion of the wheels created an air flow under the device in the direction of the moving wheels. In order to avoid this air stream to escape at the sides the free volume under the devices was canalised by attaching plastic screens along the sides. The measurements involved size fractionated particle measurements in the range of 0.5 – 20 µm with an aerodynamic particle sizer (TSI APS Modell 3321) and the dilution of a tracer gas (SF₆) (Fig. 3). This latter measurement allowed the calculation of the air dilution in the induced air stream under the road simulator and thus the establishment of absolute emission factors from measured particle concentrations.

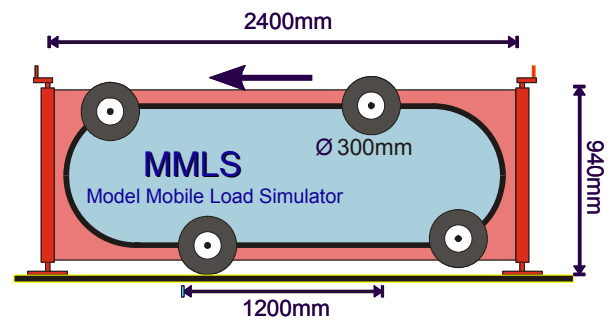
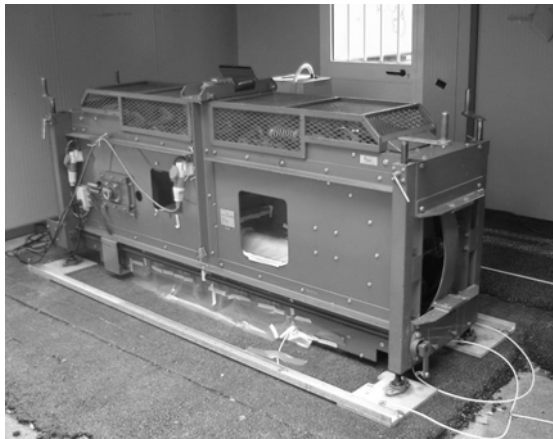


Fig. 1: View of the MMLS road simulator (left) and schematic view of the function principle (right)



Fig. 2: Views of the large MLS road simulator in service position. During operation the whole device is lowered to the level of the road surface.

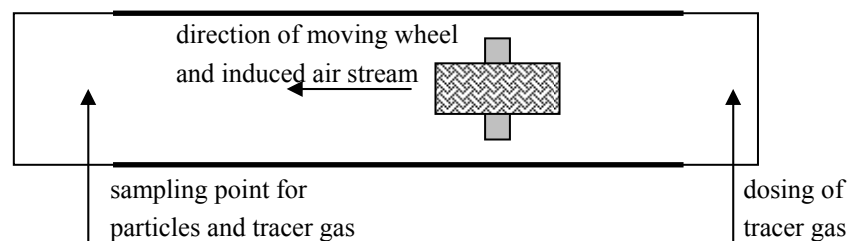


Fig 3: Schematic view of measurement principle at the road simulators

3. RESULTS AND DISCUSSION

Fig 4 (left) shows a typical particle size distribution of the abrasion particles. As expected it is clearly shifted towards the coarse side compared to the size distribution in the ambient air. Fig 4 (right) shows the total particle mass concentration during a measurement with the MLS on a pavement with an already slightly dam-

aged surface. Mass concentrations were calculated from the number size distributions by assuming a particle density of 1 g/cm^3 . While measurements of ambient air showed low particle concentrations, very high concentrations can be observed during the first minutes after setting into operation of the simulator. This initial peak is clearly caused by resuspension of dust on the road surface. After some time the concentrations decreased and levelled off on a concentration level still above the ambient air concentrations. The difference between this final concentration and the ambient concentration can be interpreted as the freshly produced abrasion particles. Together with the results of the tracer gas measurements a PM₁₀ emission factor of 8 mg/wheel/km was calculated which is quite substantial.

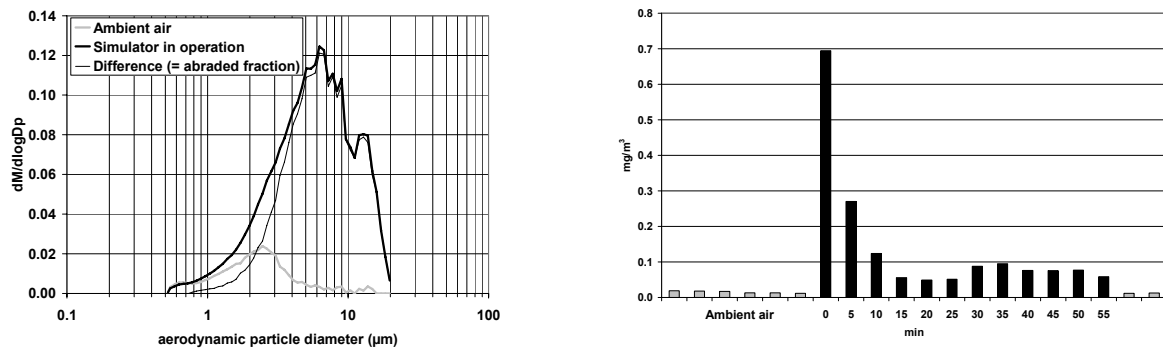


Fig 4: Particle size distribution (left); typical trend of resuspended and abraded particles during an experiment with the MLS (right)

Fig 5 shows a comparison of MMLS abrasion experiments on an asphalt concrete pavement (AC, left) and a porous asphalt pavement (PA, right). Again the higher concentrations at the beginning of the experiments caused by resuspension of earlier deposited dust are clearly visible, in particular for the AC pavement. In contrast to the experiment with the slightly damaged pavement (Fig. 4) the two investigated pavements shown in Fig. 5 were intact and of good quality. This is reflected in the low measured PM₁₀ concentrations which after some time are not significantly higher than the ambient air concentrations. The contribution of fresh abrasion particles is thus very low and the corresponding calculated emission factors were $<0.25 \text{ mg/wheel/km}$.

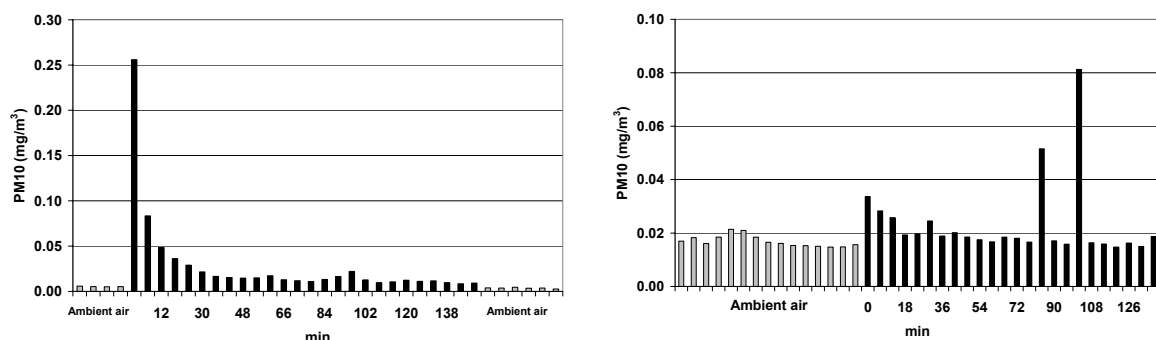


Fig 5: Comparison of MMLS abrasion experiments on an asphalt concrete pavement (left) and a porous asphalt pavement (right)

Resuspension of deposited dust from the road surface by vehicles seems to be an important source of PM₁₀. It would be interesting to know whether the porosity of a road surface influences the mobilisation of deposited dust. Fig. 6 shows a comparison of the PM₁₀ emission factors for resuspension as a function of time of a defined amount of fine dust placed on the AC pavement (compact surface, low porosity) and the PA pavement (high porosity of the surface) previously. It is clearly visible that the resuspension is higher for the AC

pavement during the whole observation period of approximately one hour. It seems that a porous surface is able to retain deposited dust better than a smooth surface.

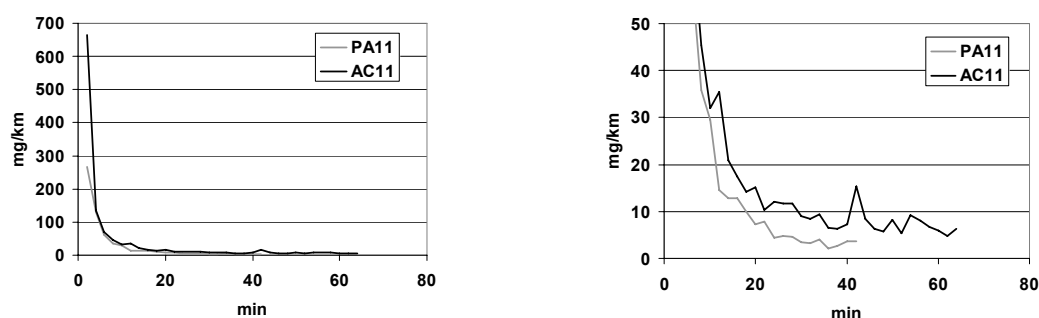


Fig 6: Emission factors as a function of time during a MMLS abrasion experiment comparing the resuspension of fine dust from an asphalt concrete pavement (AC) and a porous asphalt pavement (PA). Left: Fullscale graph. Right: Detailed view with enhanced y-axis.

4. CONCLUSIONS

The results show an important contribution of resuspension to the fine particle emissions of road traffic. Direct abrasion wear from the road surface is of minor importance for intact pavements. However, damaged pavement surfaces can cause significant fine particle emissions.

5. ACKNOWLEDGEMENTS

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