

PMP – Particle Measurement Program UNECE Informal Group
Non-exhaust traffic related particle emissions

NON-EXHAUST TRAFFIC RELATED PARTICLE EMISSIONS (BRAKE AND TYRE/ROAD WEAR)

SUMMARY REPORT FROM THE PMP IWG

1. INTRODUCTION

Particles generated during braking events as well as by the interaction between tyres and road (hereinafter referred to as non-exhaust particle emissions) have been addressed within UNECE GRPE in the PMP IWG since June 2013 when new Terms of Reference were approved in the GRPE plenary sessions. The mandate was at the time limited to a literature survey with the aim to compile and summarize the current knowledge regarding the physical nature and size distribution of non-exhaust particle emissions. An extensive literature review was conducted and the main findings presented at the 68th GRPE session of January 2014. As a result of the discussion GRPE further requested the PMP IWG to propose in the June 2014 session a possible roadmap on how to proceed further with the issue of non-exhaust particle emissions. On the basis of the expertise and resources available, the PMP group decided to focus on information collection and identified four priority working items (WI):

1. Investigation of “typical” driving conditions with focus on those parameters relevant for particle emissions from brake (BW) and tyre wear (TW).

- An extremely wide range of driving conditions has been applied in non-exhaust related studies. This has often led to different results and/or contradictory conclusions. It was therefore considered essential to investigate “typical” driving conditions relevant for non-exhaust emissions and further identify those conditions that can be considered “extreme”. The aim of the current WI was to improve the comparability of possible future studies.
- **What has been achieved:** The approach involved the use of activity data collected in the framework of other projects and mainly from the WLTP vehicle activity database. The final report has been released and the data will remain available for whatever other purpose could be considered appropriate (i.e. comparison with industrial cycles, built of a brake related cycle, etc.).

2. Monitoring of relevant on-going research projects.

- With the aim of ensuring the continuous flow of information – as well as avoiding overlaps by discussing already answered problems – it was considered useful to compile a list of relevant on-going project and collect information regarding their scope, objectives, participants and timeline.

- **What has been achieved:** Several on-going projects in both fields have been identified. The organizations in charge of these projects have been invited and already participate in the PMP IWG meetings also by providing information on the projects' development. An overview of the projects can be found on the PMP IWG dedicated webpage in a document which is updated any time new info is provided.

3. Networking and exchange of information with experts in the fields, as well as with experts from related fields (i.e. air pollution and source apportionment).

- Networking and exchange of information with experts in the field of non-exhaust emissions as well as with experts from related fields (i.e. air pollution and source apportionment) was considered important since the PMP IWG used to rely mainly on experts on exhaust emissions.

- **What has been achieved:** Several experts from different origins have been invited and already follow the activities of the PMP group. A list of their names and details can be found online on the PMP IWG dedicated webpage.

4. Development of a set of recommended measurement techniques and sampling procedures for future reference and harmonization of studies.

- Many different sampling techniques have been employed when investigating non-exhaust particle emissions. Different methods have been used also for the physical and chemical characterization of the generated/sampled particles. This has frequently resulted in different and sometimes contrasting results. The purpose of the task related to this WI was to provide guidance for a better harmonization of future studies, and thus improve the comparability of the results. Further to that, the current WI aims at identifying the most promising methodologies that could be used in the future for possible regulatory purposes.

- **What has been achieved:** So far, a comparison of existing methods and an analysis of their advantages and disadvantages have been conducted and some preliminary conclusions have been drawn. A list of the methods can be found online on the PMP IWG dedicated webpage.

2. KEY FACTS AND MAIN KNOWLEDGE GAPS

TYRE AND ROAD WEAR PARTICLES

- Tyres lose roughly 1.0-1.5 kg in weight during their lifespan. 0.1-10% of this material is released in the form of particles smaller than 10 µm. The rest is deposited on the road with its fate being unknown. Studies mention that material coming from tyre wear is present in all environmental compartments including air, water and soils/sediments.

- Particles generated by the interaction of tyres with the road usually consist of a complex mixture of materials coming from tyre and road wear as well as from what is deposited on the road surface. It has not been fully clarified whether pure tyre wear particles exist in the environment and under what conditions.

- The estimated contribution in mass of wear particles to ambient PM₁₀ and PM_{2.5} varies between 0.8-8.5% and 0.25-3.0%, respectively. This wide range of estimated values depends on many factors, including the methodology applied and the fingerprints used for the source apportionment.

- Emission factors (EFs) for tyre and road wear particles less than 10 μm are reported to be 3.5-9.0 $\text{mg km}^{-1}\text{veh}^{-1}$ (friction tyres). Most studies find values close to 6.0 $\text{mg km}^{-1}\text{veh}^{-1}$ (passenger cars). This is very close to the current limit for Euro 5 diesel passenger cars (5.0 mg km^{-1}). Much higher EFs have been reported for studded tyres.
- Both unimodal and bimodal mass distributions have been reported for tyre and road wear PM_{10} . The first peak is found at the fine particles size fraction ($\text{PM}_{2.5}$), regardless the shape of the distribution. In the case of bimodal distributions the second peak is found between 4.0-8.0 μm . There are strong indications that no UF particle generation occurs with friction and summer tyres under non-extreme driving conditions.
- A variety of driving conditions and sampling methods have been applied to investigate tyre and road wear particles. As a consequence sometimes contradictory results are reported in the literature.
- There is no epidemiology study directly linking tyre and road wear particles to adverse effects on human health. In-vitro and animal studies have shown contradictory results.
- Main knowledge gaps:
 - No simple sampling and measurement method is available today to distinguish particles strictly emitted by tyres from those coming from the road and material deposited on it.
 - The influence of road material and maintenance state on emissions and physicochemical properties of wear particles is largely unknown. Also the influence of material already deposited on the road is unknown.
 - The Influence of tyre characteristics (i.e. size, material, durability) on emissions and physicochemical properties of wear particles is unknown.
 - Relevance for human health.

BRAKE WEAR PARTICLES

- Approximately 50% of brake debris becomes airborne with the majority of this fraction contributing to PM_{10} and $\text{PM}_{2.5}$. The rest is deposited on the road or nearby and its fate is unknown.
- There is a lack of data regarding BW actual contribution to ambient PM_{10} and $\text{PM}_{2.5}$ concentrations. Source apportionment studies appear to be inadequate due to the lack of unique chemical tracers.
- EFs for brake wear particles less than 10 μm are found to be 2.0-8.8 $\text{mg km}^{-1}\text{veh}^{-1}$, depending on the applied conditions and the pad's material. Most studies report values close to 7.0 $\text{mg km}^{-1}\text{veh}^{-1}$. This is similar to the current limit for Euro 5 diesel passenger cars (5.0 mg km^{-1}).
- Mass distribution of BW particles is typically unimodal with the peak lying between 2.0-5.0 μm . On the other hand, PN distribution of brake wear is typically bimodal with the two peaks lying at the fine and ultrafine particles size fraction. Depending on the driving conditions, the first peak has been reported to be at the nanoparticle size range between 10-30 nm.
- A variety of driving conditions and sampling methods have been applied to investigate BW particles. The lack of harmonized procedures has often led to not consistent or even contradictory results and conclusions.

- There is no epidemiology study directly linking BW particles to adverse effects on human health. In-vitro and animal studies have suggested possible negative effects of BW particles.
- Main knowledge gaps:
 - Standardized test procedure to measure particles emitted during single or a sequence of braking events.
 - Influence of different pad and disk materials on emissions and physicochemical properties of wear particles. This is being investigated by industry in several projects.
 - Relevance for human health.

3. FURTHER STEPS

TYRE AND ROAD WEAR PARTICLES

- A full scale investigation to address the main knowledge gaps would require a time and resource consuming large scale project including experimental activities. At the moment the PMP IWG does not have the necessary expertise and resources to embark in such a project.
- The PMP IWG will continue collecting information regarding particles generated by the interaction of tyres with the road and monitoring the on-going research projects. In case of new findings and/or developments modifying significantly the current picture, the PMP group will submit to GRPE a request for a new mandate with specific tasks and objectives.

BRAKE WEAR PARTICLES

- All involved parties agree that a standardized test procedure for sampling and investigating brake wear particles, both in terms of mass and number, would be beneficial for the research and the development of low emitting brake systems.
- Two main approaches for a standardized procedure have been discussed within the PMP group. In one case the attention is focused on particles generated at **brake system level** while in the other case at **vehicle level**.
- While measuring brake particle emissions from a whole vehicle would better reflect real world conditions and would enlarge the range of possible technologies for particle emission reduction (vehicle-to-vehicle communication, hybridization, etc.), this represents a very complex challenge from a scientific and technical point of view. Issues like the representativeness of sampled particles and contribution from other sources (tyres, road, exhaust gas) appear very difficult to resolve.
- Test rigs are considered a much simpler solution to investigate particle emissions from brake systems. Industry (brake system suppliers as well as instrument manufacturers) is actively working on the development of test rigs based on a brake dynamometer to generate, sample, and characterize particles. It appears that a commonly accepted test rig configuration with standardized sampling/measurement methodologies is an objective that can be achieved in a reasonable time frame. On the other hand, a test procedure based on a test rig would put the emphasis on particle technologies for particle emission reduction strictly linked to the brake system (e.g. pad and disk composition and design, filters attached to the caliper, etc.).