Transmitted by the PMP Chair

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European Commission

PARTICLE EMISSIONS FROM TYRE AND BRAKE WEAR ON-GOING LITERATURE REVIEW SUMMARY AND OPEN QUESTIONS

Sustainable Transport Unit
Institute for Energy and Transport
Joint Research Centre

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ON-GOING LITERATURE REVIEW

- Approximately 100 peer-reviewed papers
- 10 papers presented in international conferences
- Several intermediate and final research project reports
- Technical publications from brake and tyre companies
- Several licentiate and doctoral thesis

Literature study : Main issues

- **Many studies available but difficult to reconcile due to:**
    - **Many different sampling methodologies/locations and measurement techniques - Representativeness of real-world emissions?**
    - **Important differences between LD and HD vehicles**
    - **Influence of driving conditions – Definition of "normal driving conditions"?**
    - **Lack of a clear definition of non-exhaust emissions especially for tyre and road wear and resuspended material**
- **Nevertheless, in general, there is consensus on the emission factors**

NON EXHAUST EMISSIONS - IMPORTANCE

- Exhaust and non-exhaust sources are estimated to contribute almost equally to total traffic-related PM_{10} emissions (2010)
- The relative contribution of non-exhaust sources is expected to increase the forthcoming years due to the tendency of decrease of exhaust emissions

Contributions of specific sources to non-exhaust traffic-related PM_{10} emissions

Source	PM_{10} (%)
Brake Wear	16-55*
Tyre Wear	5-30**
Resuspension	28-59

* Significantly lower contributions have been reported in freeways (~ 3%)

** Many studies don't distinguish from road wear

TYRE AND BRAKE WEAR – MASS SIZE DISTRIBUTIONS

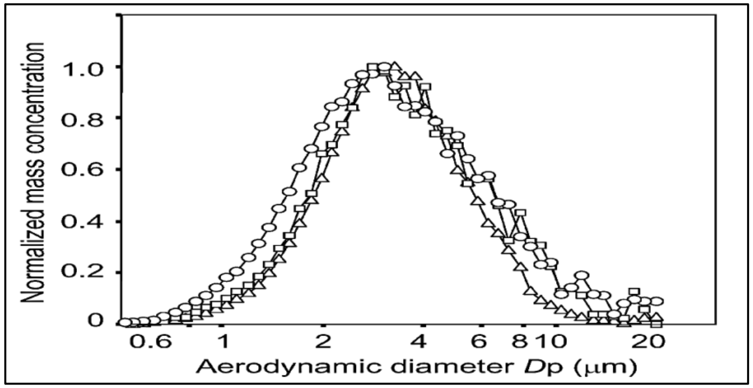
BRAKES

- 50% of generated BW particles (mass) become airborne. Among these 80% are PM_{10}. The rest may deposit on the road or nearby
- Mass weighed mean diameters of 2-6 μm have been reported

TYRES

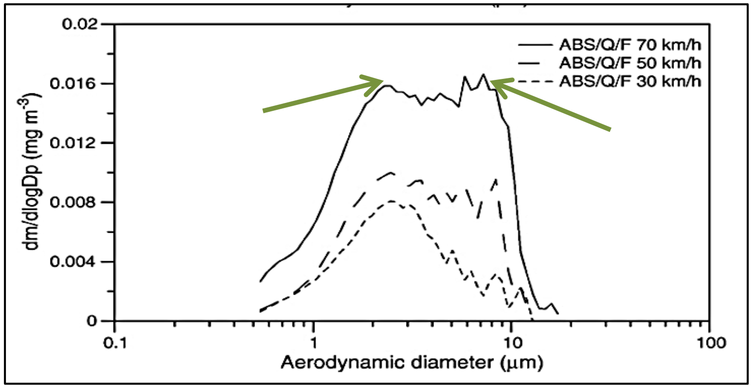
- 0.1-10% by mass of generated TW particles is emitted as PM_{10}
- TW mass distributions appear a clear mode at 50-80 μm, while PM_{10} mass distribution is bimodal with peaks at 2-3 μm and 5-9 μm

Aerodynamic Particle Sizer



[Example adopted from Iijima et al., 2007]

Aerodynamic Particle Sizer



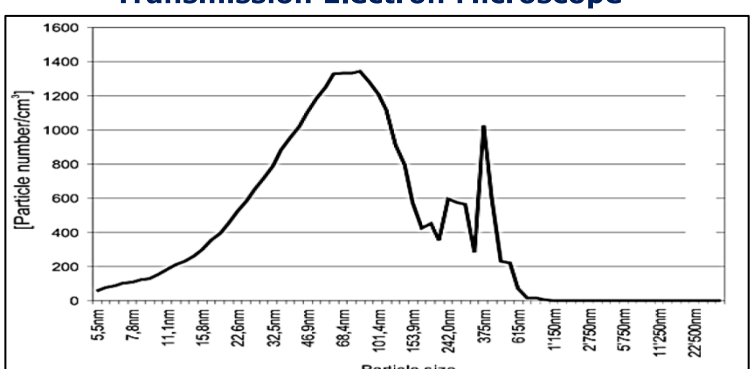
[Example adopted from Gustafsson et al., 2008]

TYRE AND BRAKE WEAR – NUMBER SIZE DISTRIBUTIONS

BRAKES

- BW PN distributions appear to be bimodal with both peaks lying within the fine mode
- Some studies report 1st peak at the UF size, while others find at ~ 350 nm

Transmission Electron Microscope

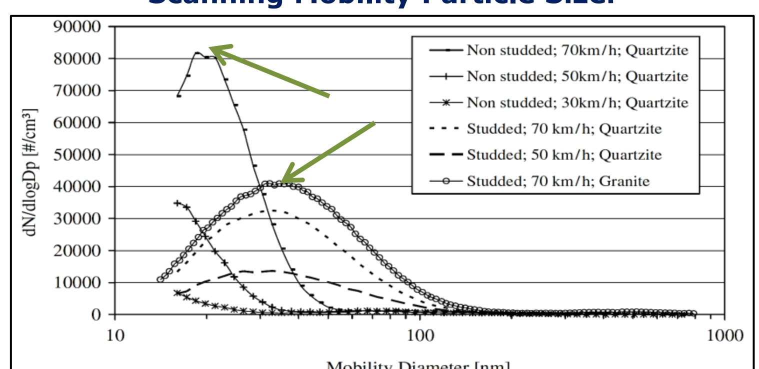


[Example adopted from Gasser et al., 2009]

TYRES

- PN distributions are unimodal. Some studies report a peak at the UF size (~ 15-50 nm), while others mention that under "normal" driving conditions no UF particles are emitted

Scanning Mobility Particle Sizer



[Example adopted from Dahl et al., 2006]

TYRE AND BRAKE WEAR - CHEMICAL CHARACTERIZATION

Most important chemical constituents of wear particles

	$PM_{2.5}$	$PM_{2.5-10}$	Wear particles
Brake Wear	Transition metals (Cu, Fe), Sb (III, V), Sn, Ba, Zr, Al, S, OC>>EC	FeO, Fe_2O_3, Cu oxides, Sb (III), Sb (V), Sn, Ba, Zr, Al	Cu, Fe, Sb (III, V), Sn, Ba, Zr, Al, S, PAHs, n-alkanes, n-alkanoic acids, benzaldehydes
Tyre Wear	Zn, organic Zn, Cu, S, Si, Organic compounds, EC	Zn, organic Zn, Cu, Si, Mn	Zn, Cu, S, Si, PAHs, benzothiazoles, natural resins, n-alkanes, EC

NEED FOR: Identification of organic constituents in PM_{10} brake and tyre wear particles and investigation of the chemical composition of modern lining materials

TYRE AND BRAKE WEAR – EMISSION FACTORS

EFs derived from road simulation studies

	$PM_{2.5}$ (mg km^{-1} veh^{-1})	PM_{10} (mg km^{-1} veh^{-1})
Brakes LDV	2.1-5.5	2.0-8.0
Tyres* LDV	-	3.5-9.0

* Friction tyres

EFs derived from receptor modeling

	$PM_{2.5}$ (mg km^{-1} veh^{-1})	PM_{10} (mg km^{-1} veh^{-1})
Brakes LDV	0.0-5.0	1.0-8.8
Tyres* LDV	0.3-5.0	6.0-13

* Friction tyres

- Brake and tyre wear PM_{10} EFs of HDVs are estimated to be approximately one order of magnitude higher compared to LDVs
- Much higher PM_{10} EFs have been reported in case of studded tyres

Health effects of non-exhaust particles

- Non-exhaust traffic related PM emissions significantly contribute to ambient PM10 and PM2.5
- Several studies carried out on animals or in-vitro cells with sometimes contradictory results (different techniques and methodologies used) – Difficulties in extrapolating the results to humans
- Fate of non-exhaust particles: Residence time? Dispersion? Exposure?
- Soil and water contamination? (Not considered in the JRC literature study and apparently not well investigated)

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What abatement measures?

- **Minimizing particle generation by changing chemical composition/physical properties of brakes and tyres?**
  - **Are particle generation mechanisms and influencing factors sufficiently known?**
  - **Only in the case of particles from brake wear the source is linked exclusively to the vehicle**
- **Traffic and/or driving behaviour control measures? (e.g. speed limits, Low Traffic Zones, congestion charges,...)**
- **Road conditions/characteristics? (e.g. road material, road maintenance, wetting/cleaning,...)**
- **Cost/effectiveness?**

On-going research activities

- Brake industry involved in research studies to better understand particle generation mechanisms and to evaluate the possibility of reducing particle generation (e.g. EU funded REBRAKE)

- WBCSD (World Business Council for Sustainable Development) - Tire Industry Project (TIP)
- Goal : Anticipate the potential long term environmental and health issues relating to tyre materials, Tyre & Road Wear Particles, end of life tyres and recycling management