Air quality and Tire Road Wear Particles : myths and facts

Frédéric BIESSE

Senior Fellow Tyre Physics & Modelisation

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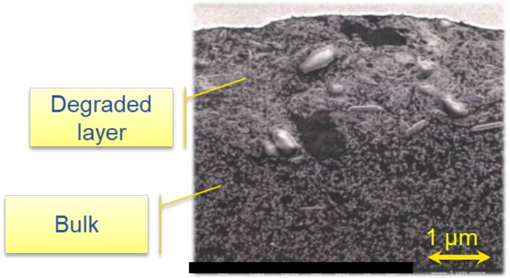
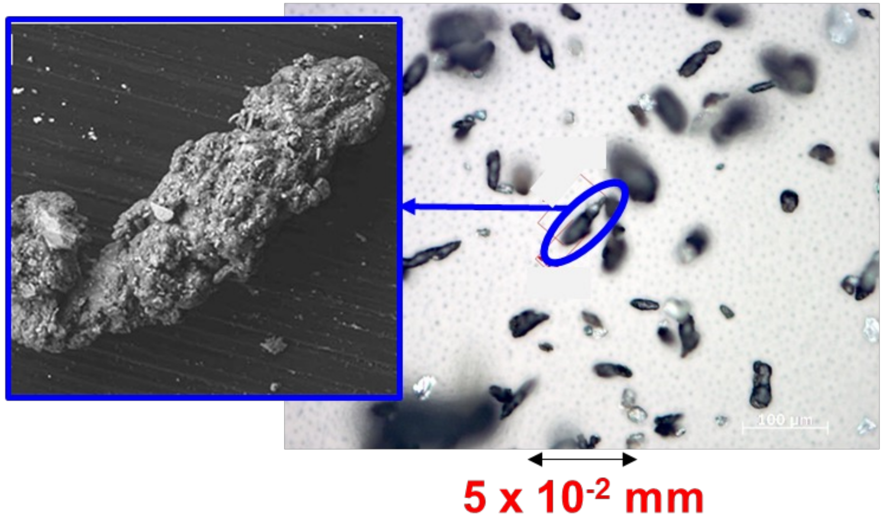
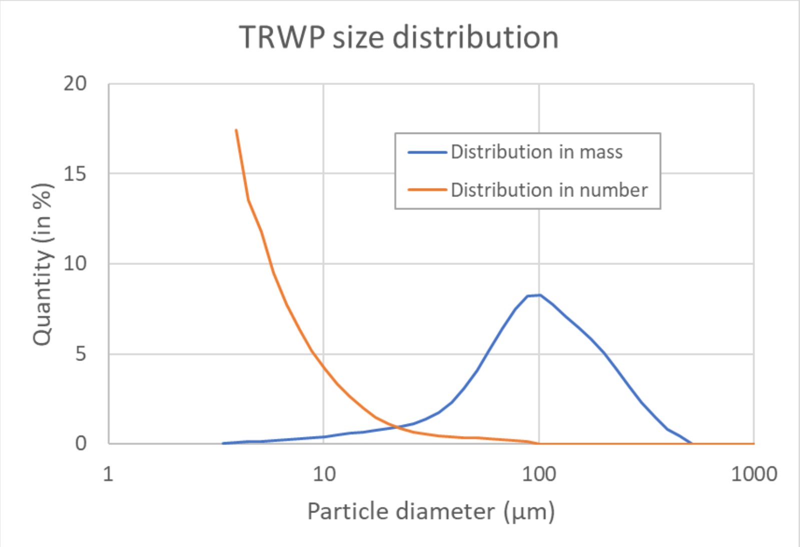
What are the wear particles generated by tires “Tire and Road Wear Particles” (TRWPs)?

➢ TRWPs are debris generated during the use of the tire, by the friction between the tire and the road surface. This phenomenon is the **physical consequence of the tire’s grip to the road**, which guarantees **driver safety.**



➢ These particles are a mixture, in equal parts, of **fragments of the tire tread** and elements from the **road surface**.





➢ These particles have **specific characteristics** that **differentiate** them from **usual microplastics**:

- ➢ **High density** : 1.2 to 1.7 [1] *(vs 0.9-1.4 for usual MP)*
- ➢ **Unimodal diameter** : average size of 100 µm (in mass)
- ➢ **Degradability :** 50% disappear within 16 month [2] *(vs decades to centuries)*

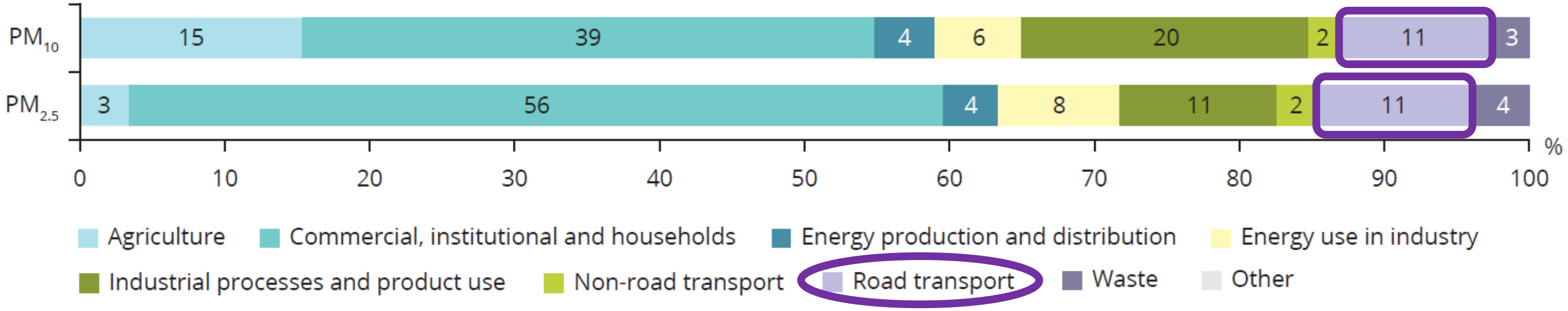
(1) Jung, U., & Choi, S. S. (2022). Classification and Characterization of Tire-Road Wear Particles in Road Dust by Density. Polymers, 14(5), Article 1005. https://doi.org/10.3390/polym14051005

(2) Cadle, S. H., & Williams, R. L. (1980). Environmental Degradation of Tire-Wear Particles. *Rubber Chemistry and Technology, 53(4), 903-914. https://doi.org/10.5254/1.3535066*

Air pollution and Emission Factors

Contribution to EU-28 PM emissions from the main source sectors in 2017,

EEA. (2019). Air quality in Europe — 2019 report. https://www.eea.europa.eu/publications/air-quality-in-europe-2019

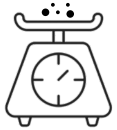


- Emission inventories are always based on Emission Factor (EF)
- Measuring tire airborne emission is a technical challenge

- Resuspension
- Exhaust
- Brakes & clutch
- Other (bio, industial, residential, ...)
- TRWP

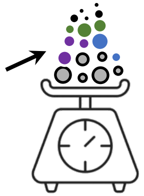
Relevant Emission Factor

Mass of TRWP < 10 µm



What many studies measure :

High bias due to other PM10 included



What the Michelin's method measures :

Reduced bias due to optimized test procedure

Our work : further reduce the EF measurement bias

Emission Factors direct measurement : test equipment

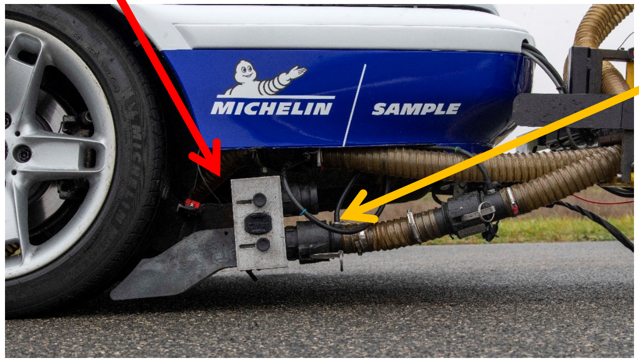
Main vacuum : to catch all the TRWP

- 3 vacuums, 1 400 W & 75 m^3/h each
- Total air flow rate = 225 m^3/h
- 6kw power generator

GPS + X/Y accel data

- Gathered in a cloud
- Allow to rebuild tire forces

Aspiration system located in the tire-road contact area



Connection to Real-time particles measurement : ELPI+ (1)

- Cascade impactor particle counter : 14 channels between 6 nm to 10 µm
- Sampling frequency = 1 Hz
- Air flow = 10 l/min

(1) ELPI : Electrical Low pressure Impactor

TRWP measurement : additional equipment, procedure

Procedure to limit the bias

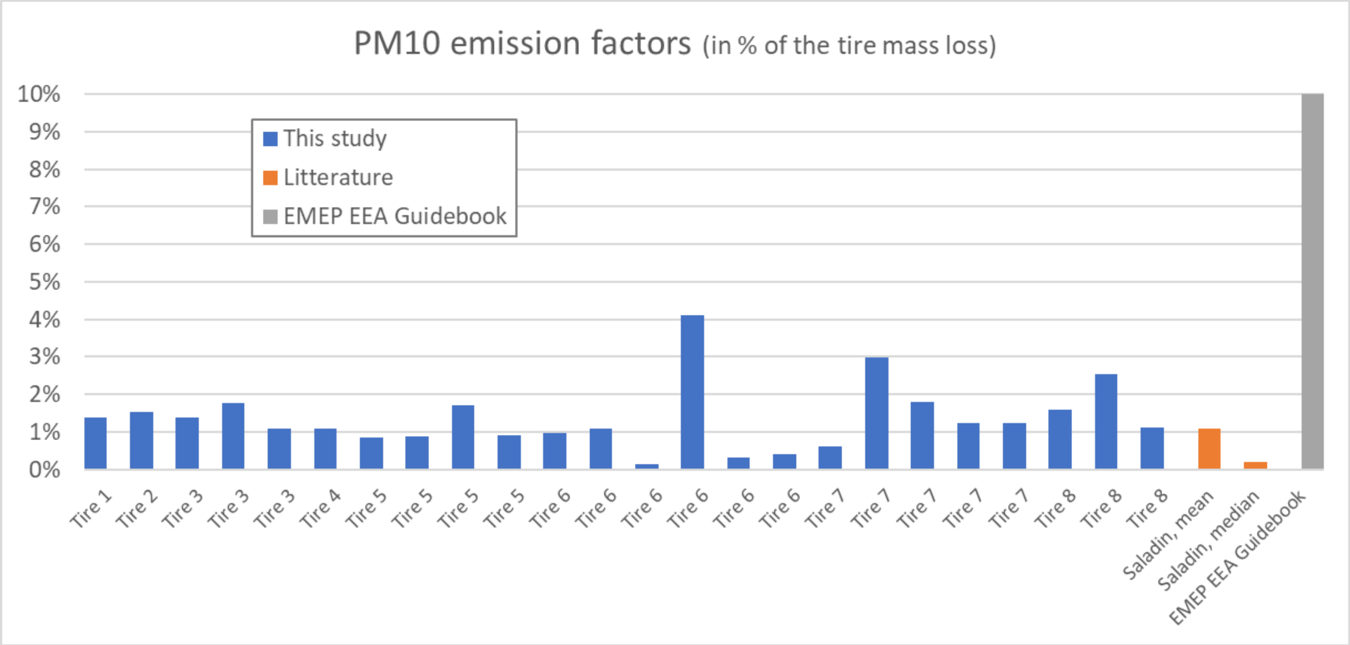
- Test on circuit (no open road)
- Privatized circuit : only the test vehicle is on the track
- Cleaned circuit to reduce re-suspension
  - 8h sweeping before each test
- Collect enough TRWP

Generating more TRWP than background particles requires:

- To drive with enough severity to capture enough wear particles
  - Total abrasion will be higher than the normal usage one’s
- To collect & measure the background particles

➔ addition of another nozzle + a second ELPI

Our 2025 update of tire's Emission Factors results

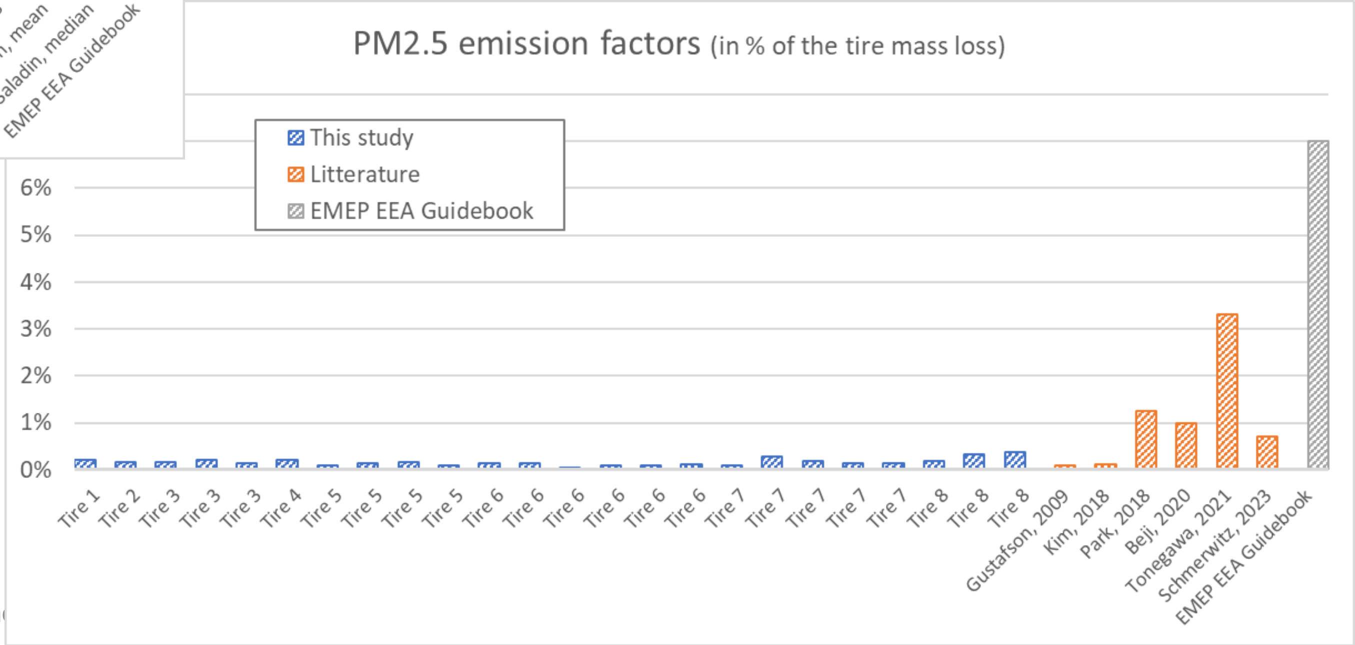


This experiment results :

- PM10 : in average 1.38% of the tire mass loss
- PM2.5 : in average 0.18% of the tire mass loss

Our results are in line with recent literature:

- PM10 : **35 publications** analyzed by Saladin, average = 1.1% of the tire mass loss



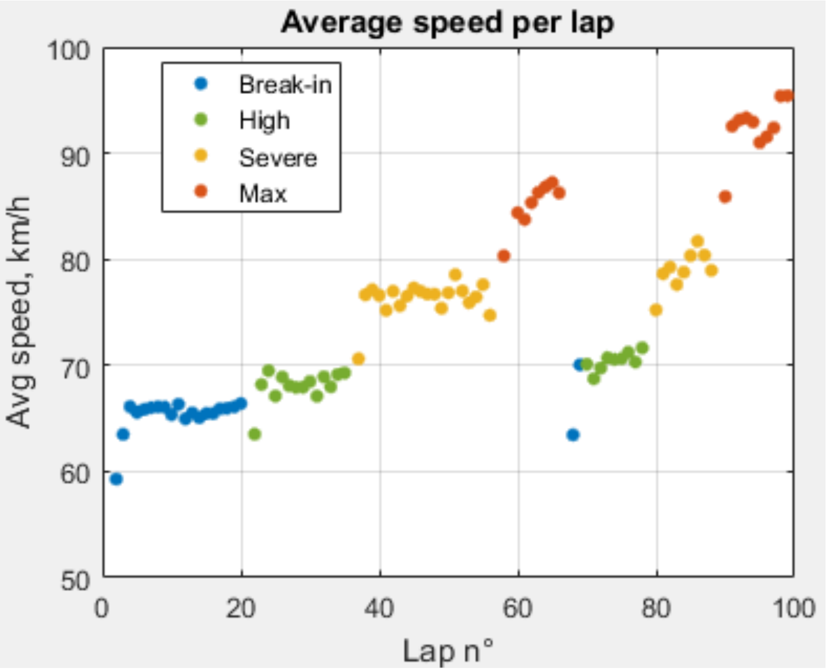
EMEP EEA Guidebook data for tire emission

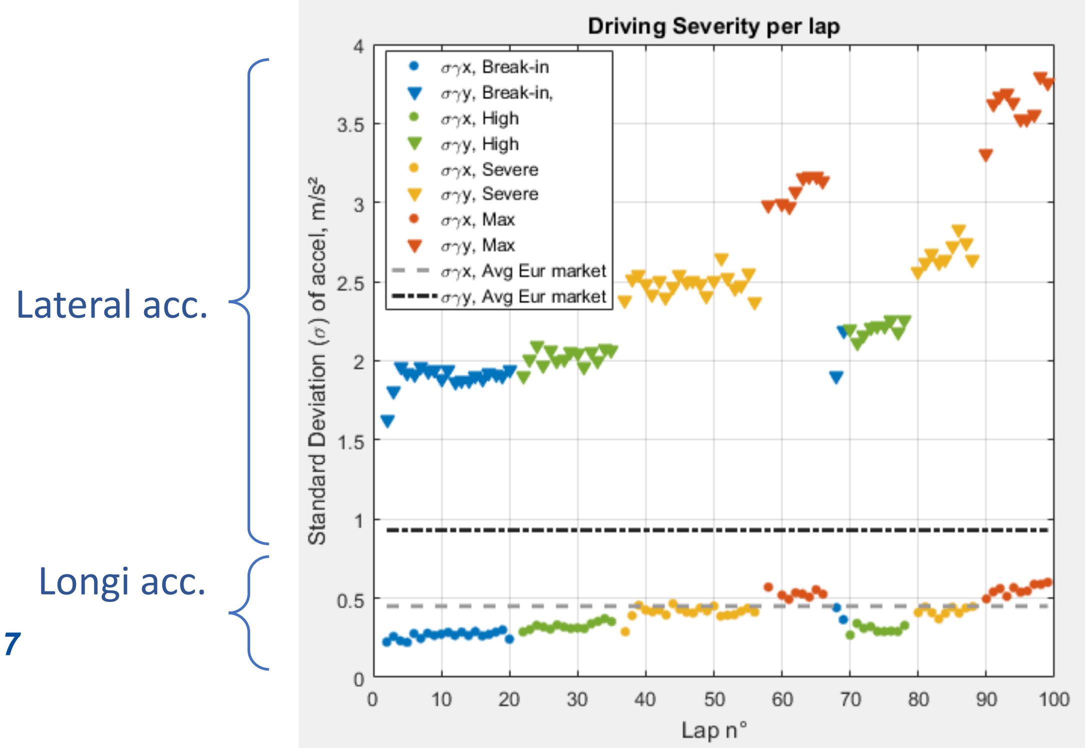
- Data established 20 years ago
- With indirect measurement only
- The tire Emission Factors deserve an update

New test protocol : usage severity effect

The objective is to analyze different driving severities

- To increase the vehicle speed between the laps
- We designed 3 severity levels : high, severe, max
  - A break-in phase is made at the beginning of the test
- Two repetitions among a test session.





Severity results

- Increasing the vehicle speed (on the same track) increases vehicle accelerations (because the curves radius are unchanged)
- The driving severity is above the European market average severity
  - Equivalent severity for longitudinal
  - 2 to 4 times more severe for lateral

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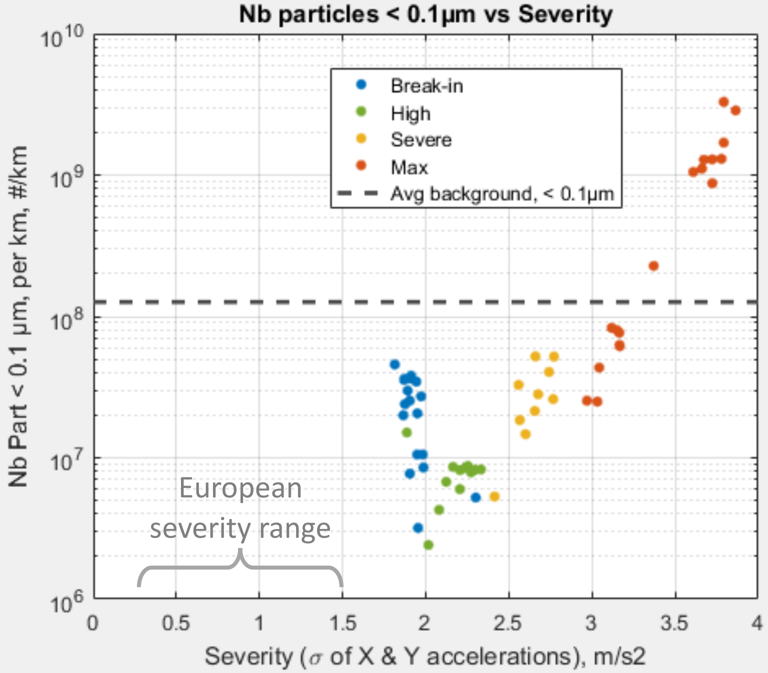
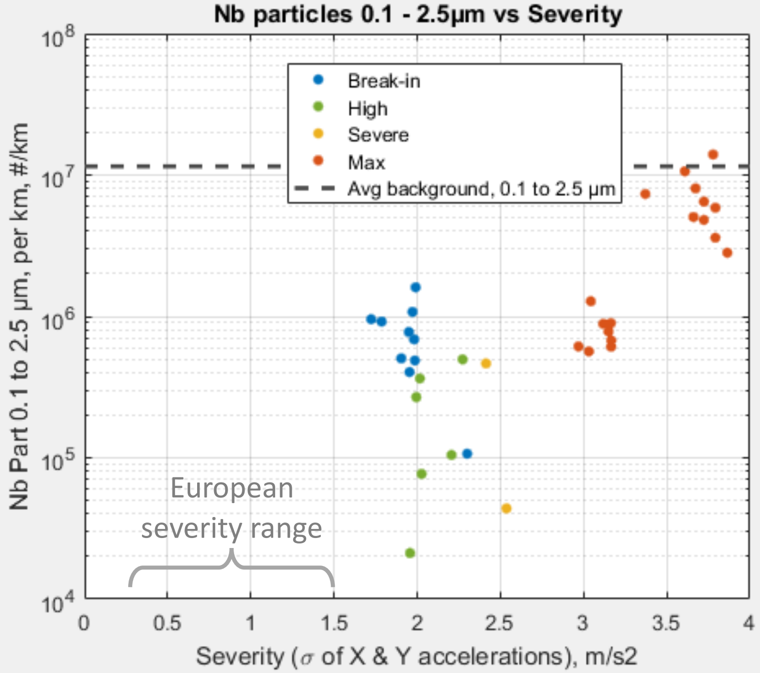
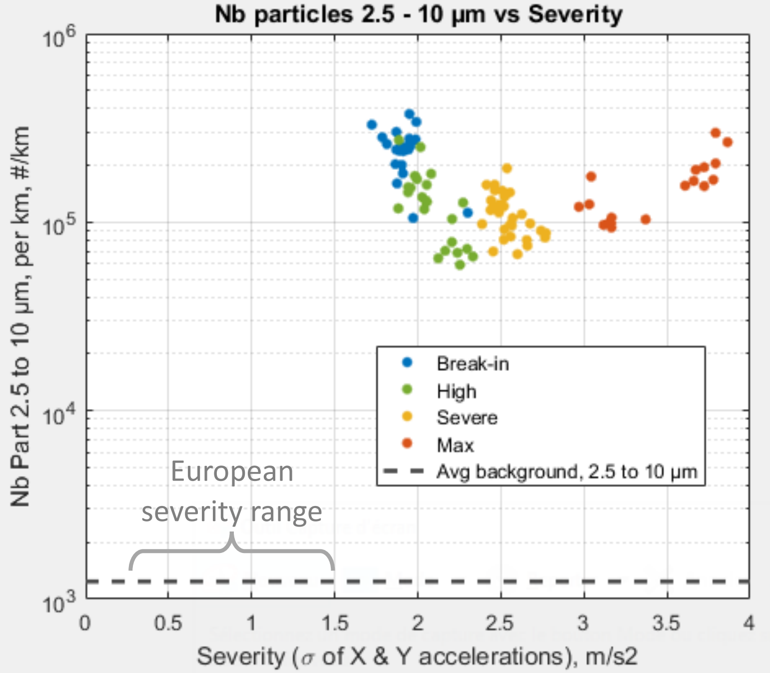
Tire's airborne particle emission depends on driving severity







A clear link observed between driving severity and particle emission

- Tire nano particle emission is above background for a severity 3.5 times higher than European usage
- Tire Fine particle emission (0.1 – 2.5 µm) almost never above the background particles
- Tire Coarse mode (2.5-10 µm) don't depend much on severity

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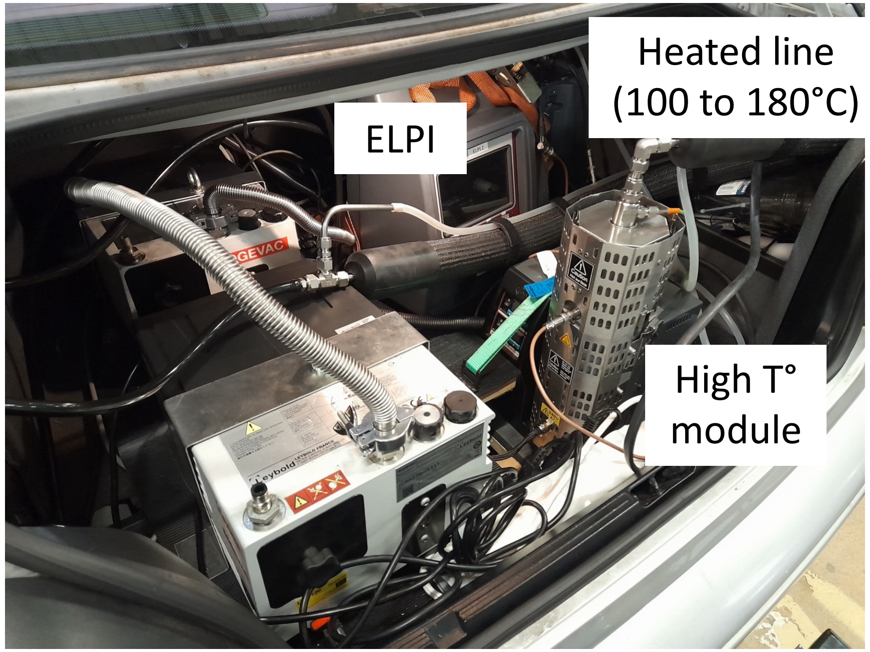
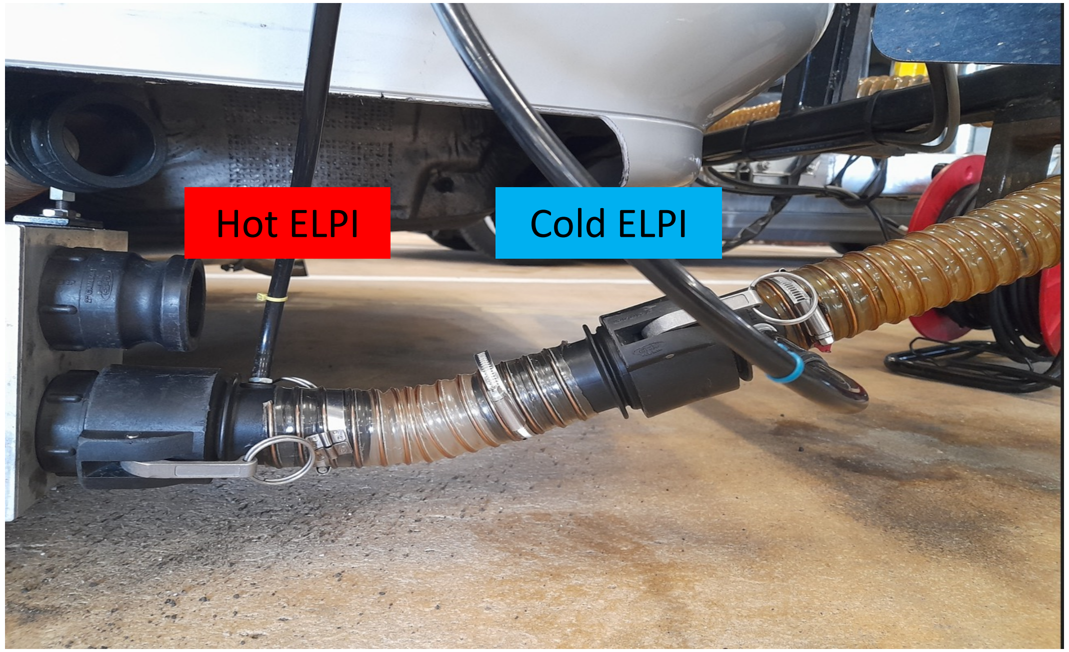
NB : all particles are counted, it probably includes non TRWP particles (resuspension, …)

Analysis of the nature of particles captured behind a tire

Experimental setup :

- Heating module on the ELPI, to evaporate liquid in the particles.
- Simultaneous and independent measurements, on the same sampling line.
- The cold ELPI is similar to the previous measurements and is used as reference.



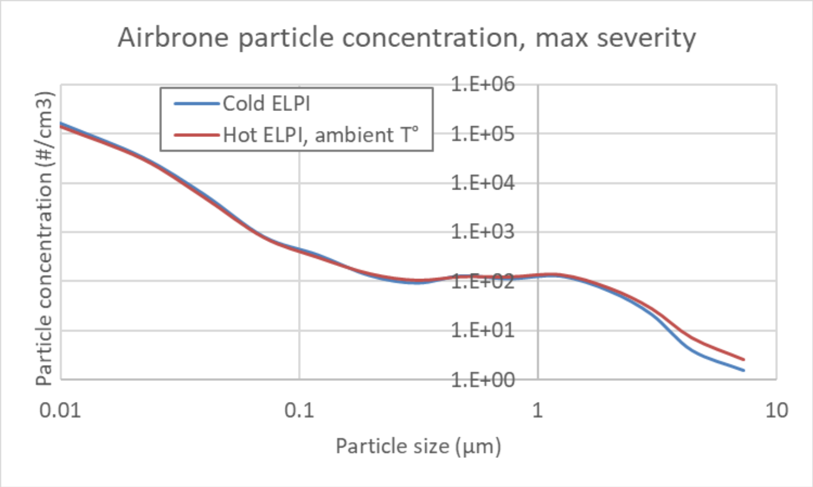


Analysis of the nature of particles captured behind a tire

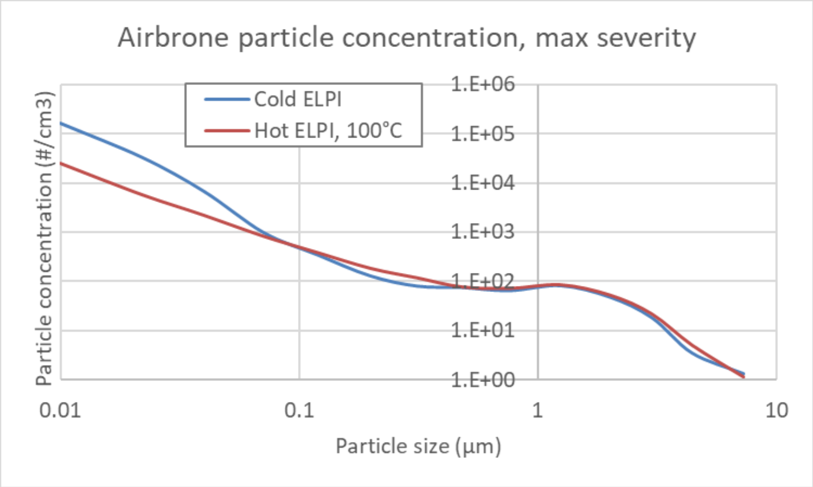
During these experiment, the nucleation phenomenon appears clearly

- Most of the ultrafine particles (< 0.1µm) are eliminated by the hot ELPI ➔ no solid particle, liquid instead

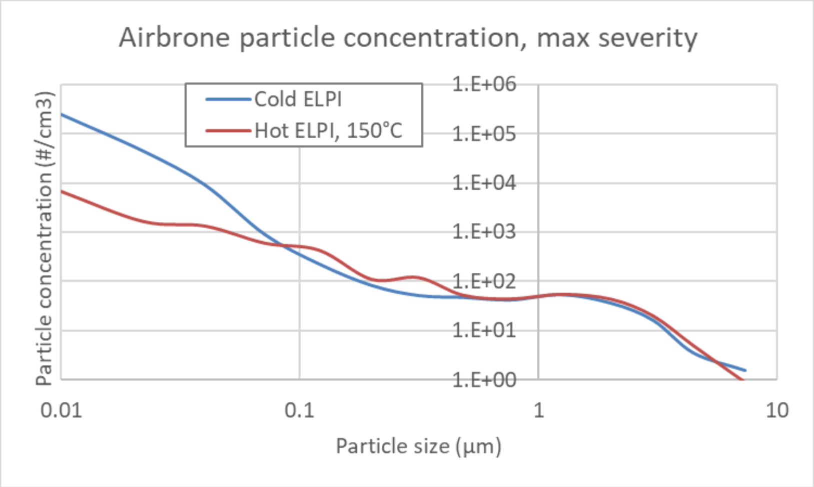
Hot ELPI @ ambient T° (cold = hot)



Hot ELPI @ 100°C



Hot ELPI @ 150°C



23.1 times less particles on the hot ELPI (150°C) for sizes < 50 nm

➔ 4.1% of the particles < 50nm are solid ones, 95.9% are liquid ones (for a driving severity ≈4 times higher than European average)

- What these particles are is unclear, and deserves further researches
- Both ELPI includes in the measurement many other particles than TRWP (brake, exhaust, resuspension, background particles)

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Link between tire abrasion rate and fine particle emission

It is sometime claimed that when tire abrasion will reduce, finer particle will be emitted

- This statement is based on engine exhaust emission, because the experience is that the deployment of anti-pollution system transformed the emission of big particles into the emission of smaller particles

We tested 3 tires with very different abrasion level

- Tire A = lowest abrasion (= 100%)
- Tire B = intermediate abrasion (≈150% of tire A)
- Tire C = high abrasion (≈200% of tire A)
- 2 tires are manufactured by MICHELIN company, 1 tire is from a competitor

The Abrasion values comes from ADAC 2023 tests on 50 summer tires (1)

We applied our protocol

- All-size particle capture in the main vacuum cleaners ➔ size distribution above 10 µm
- Small particle measurement with the ELPI device ➔ from nano particle to 10 µm
    - Relevant for airborne particles analysis
    - Basis for the Emission Factor calculation

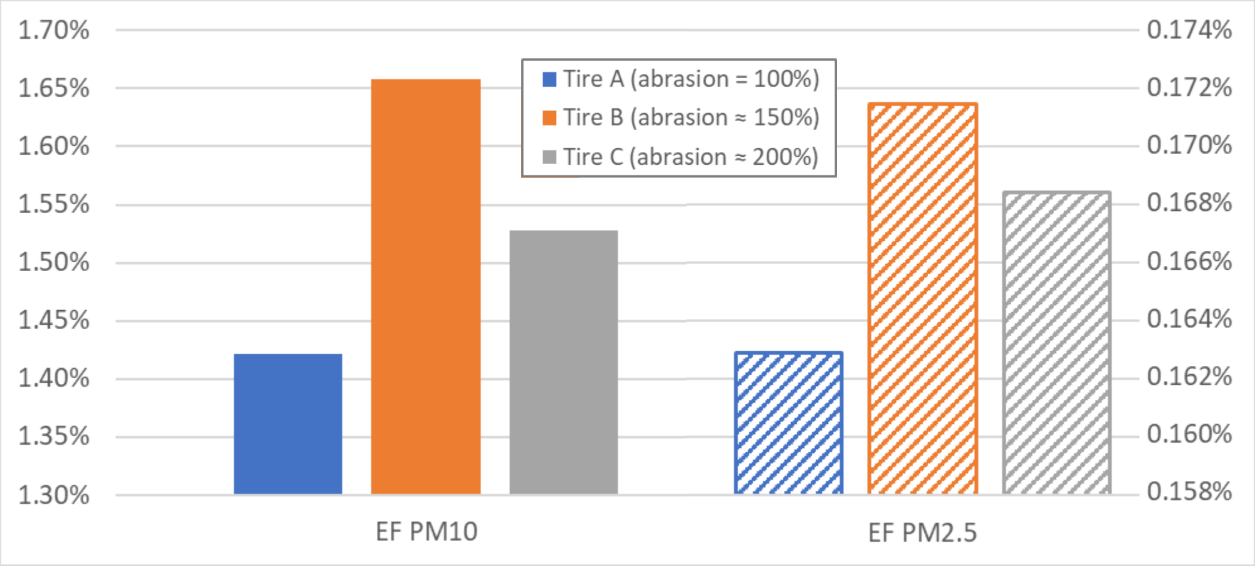
(1) https://assets.adac.de/image/upload/v1677073403/ADAC-eV/KOR/Text/PDF/adac_bro_reifenratgeber_sommer_2023_2302_emq2td.pdf

Link between tire abrasion rate and fine particle emission

No link is observed between abrasion rate and share of fine particle emission

- The best tire of this panel emit the lowest share of PM10 and PM2.5

ELPI : nano to 10 µm particles



Total amount of fine particles

	PM10	PM2.5
Tire A (abrasion = 100%)	100% (ref)	100% (ref)
Tire B (abrasion ≈ 150%)	180%	162%
Tire C (abrasion ≈ 200%)	226%	218%

Total amount of airborne particles :

- The lower abrasion tire produces the lower total amount of fine particles

Synthesis

Measuring accurately tire airborne particle emission is a technical challenge

- Because tire is an open system, other particles are captured behind the tire and counted in the results (brake, exhaust, resuspension, background particles, …)

Tire’s Emission Factors are overestimated and deserve an update

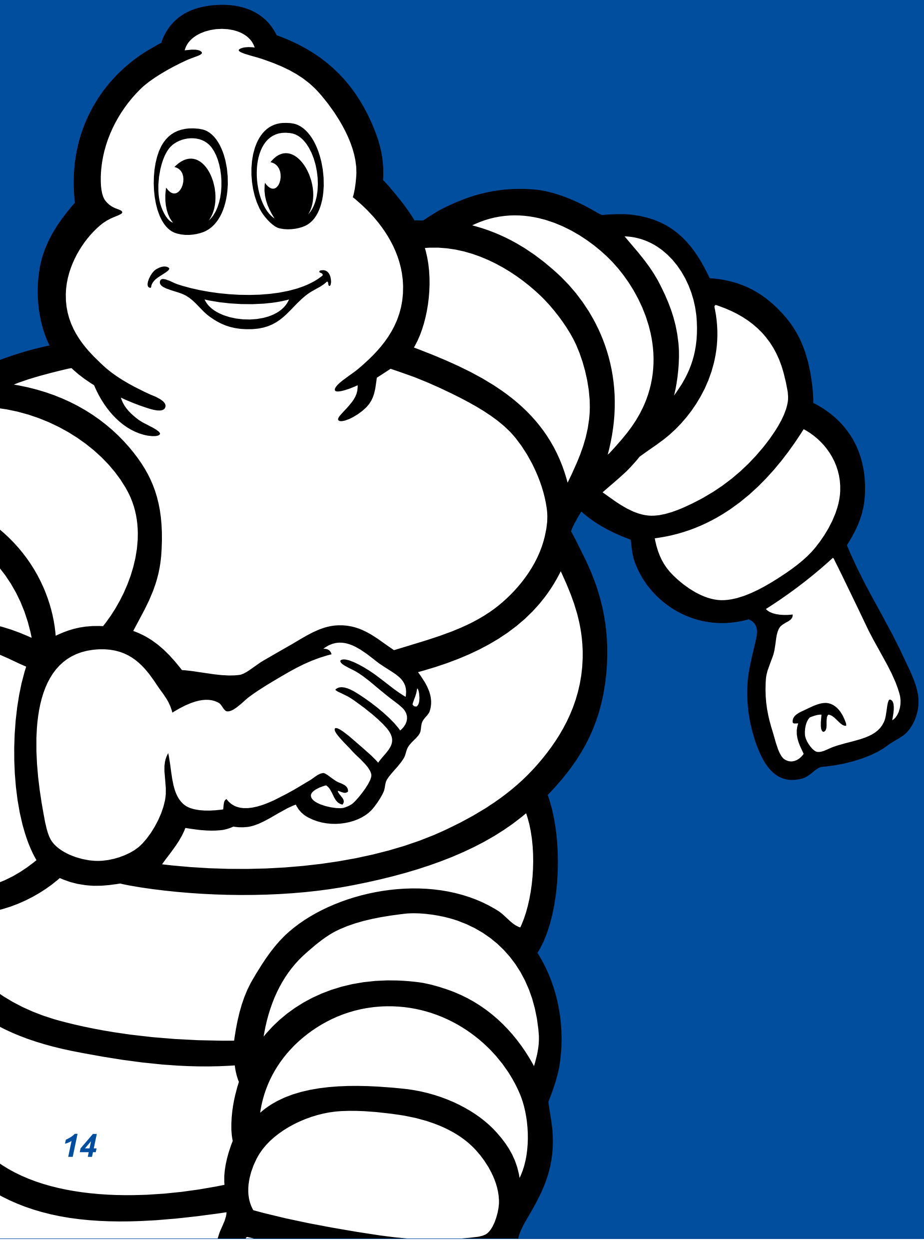
- Tire Emission Factor = 1.38% of tire mass loss for PM10, 0.18% for PM2.5
- Our results are confirmed by 35 other peer-reviewed publications (Saladin et al paper)

The tire’s PM2.5 and nanoparticles emissions are strongly influenced by driving severity

- For standard driving, 10 to 100 times less tire’s PM2.5 & nanoparticles than the background particles
- 96% of nano particles are volatile or semi-volatile particles

Better tire abrasion performance (lower abrasion rate) do not lead to finer particle emission

- The share of PM10 or PM2.5 compared to mass loss is quite stable with lower abrasion
- The total amount of PM10 and PM2.5 reduces for lower abrasion rate tires



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