Physico-chemical characterization of dust generated by a brake for light-duty vehicle applications

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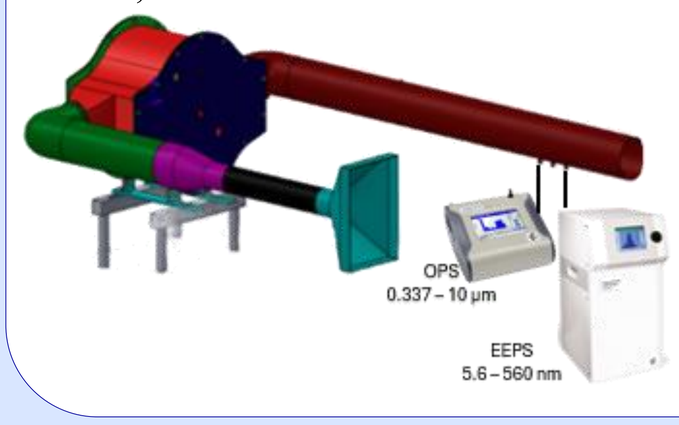
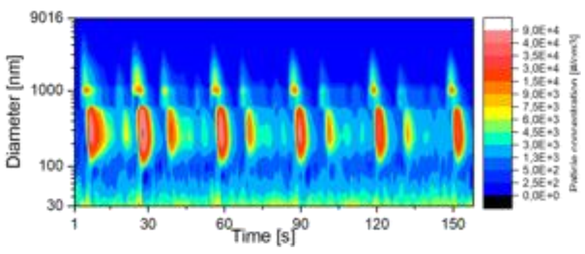
MOTIVATION

- Vehicle emissions are the major contributor to ambient PM.
- The decreasing trend of exhaust emissions has been accompanied by a gradual increase in the proportion of non-exhaust emissions such as the brake wear particles (BWPs).
- The threat to public health of BWPs has also been recognized by the European Commission that has introduced a limit in the next Euro7 standards.
- The adverse effects of PM depend on two factors that are the particle size distribution and their chemical composition.

METHODOLOGY

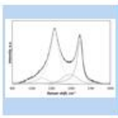
- **Physical particle characterization**, number and size, was conducted in a wide diameter range





- Investigation of the **chemical composition and morphology** of brake wear dust, collected at the end of the braking test on the surface of the chamber, was carried out through several techniques.

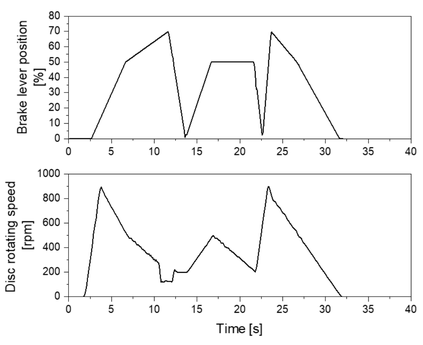
SEM, TGA, XRD
Iron and iron oxides



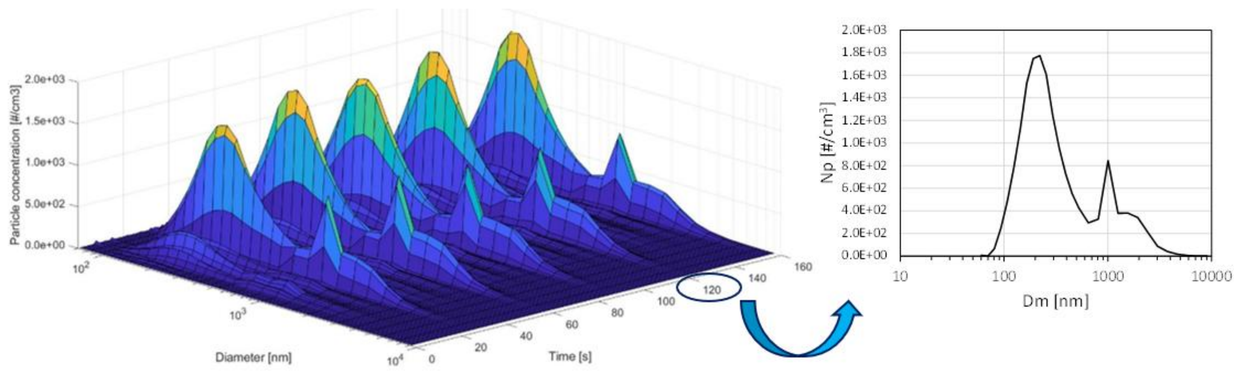
Raman Spectroscopy
Aromatic character

EXPERIMENTAL RESULTS

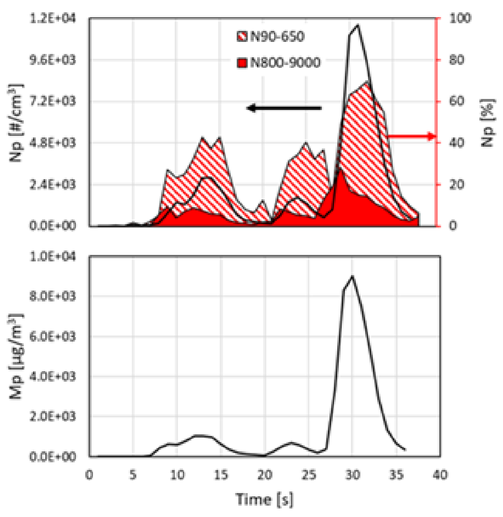
A braking pattern characterized by three sharp decelerations was developed to investigate the effect of harsh braking, not included in the standardized brake cycle, that can release a not negligible portion of total emissions.

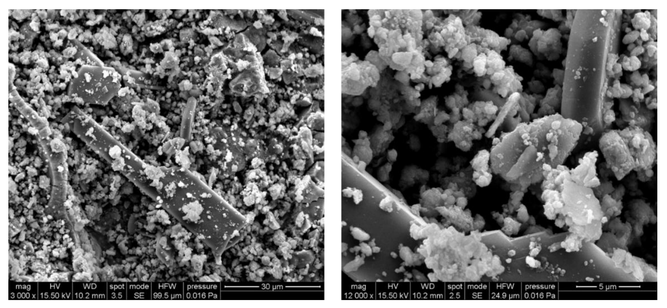


BWPs range between 90 nm and 0.4 µm. The time series data for number concentration exhibits a two-peak pattern, at 200 and 1000 nm, during each braking event.

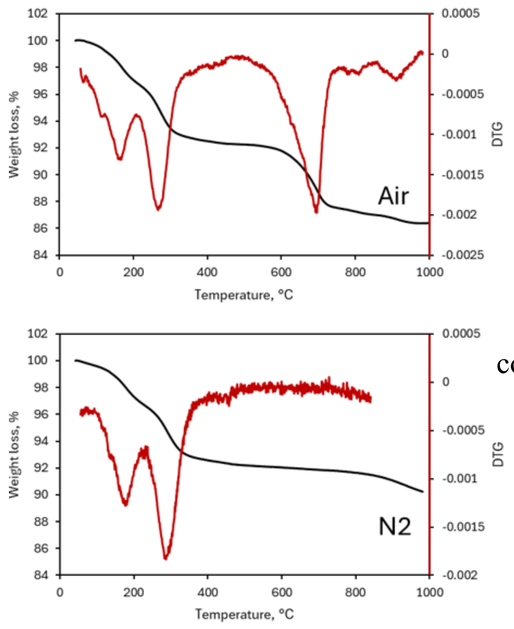


A significant fraction of the particles falls in the 90 – 650 nm size range while particles larger than 800 nm gives a smaller contribution.
The different sizes of the particles suggest they originate from different formation mechanisms: the high disc temperature is responsible for the emission of smaller size particles; the larger particles are generated by the mechanical abrasion.





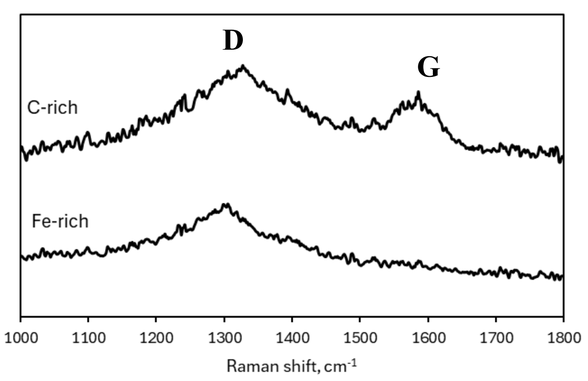
The presence of both smooth and fractured surfaces implies different wear and transformation mechanisms, such as thermal degradation, adhesion, and abrasion.



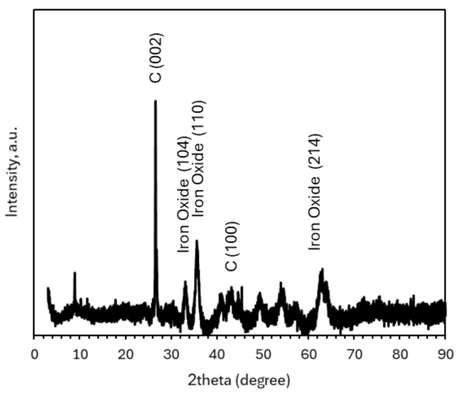
Thermogravimetric analysis distinguished between organic and inorganic fractions: the former represents about 15% by weight of the sample (8% volatile compounds and 7% solid carbon particles), while the remaining 85% by weight is composed of inorganic materials.

Element	Weight, %	Atomic, %
O	39.2	52.5
Fe	34.7	13.3
C	15.8	28.2
Ca	3.3	1.8
S	2.7	1.8
Si	1.3	1
Cu	0.8	0.3
Al	0.6	0.5
Ti	0.6	0.3
Ba	0.4	0.1
Mg	0.2	0.2
K	0.2	0.1
Cr	0.2	0.1

Raman spectroscopy also highlighted the simultaneous presence of disordered structures of carbon and iron oxides



XRD patterns evidenced the presence of peaks which are typical of oxidation of carbon and iron oxides



RESULTS UNDERLINE THE CHEMICAL HETEROGENEITY OF BWPS AND THEIR POTENTIAL FOR PERSISTENCE AND ENVIRONMENTAL TOXICITY

FUTURE PERSPECTIVES

- The research focused on the BWP fraction deposited on roadsides due to its potential for resuspension and environmental contamination. Future work will examine the airborne fraction that is directly released into the atmosphere.
- The findings of this study can contribute to improve the knowledge about BWPs offering data drive support to guide the implementation of effective mitigation actions, development of new materials for disc and pads and the optimization of driving behavior.

REFERENCES

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- Russo C, Gautier di Confiengo C, Magnacca G, Faga MG, Apicella B. Insights on non-exhaust emissions: An approach for the chemical characterization of debris generated during braking. Heliyon 2023;9:e20672.