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Characterization of Volatile Organic Compounds (VOCs) in the emissions of representative railway braking systems

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Introduction

Air quality in confined railway stations is a public health issue worldwide. Studies have revealed poor air quality due to non-exhaust emissions, particularly braking. However, limited research has been conducted on Volatile Organic Compound (VOC) emissions in case of using organic pads. This work is aiming at improving a methodology to identify emitted VOCs at different scales.

Method

We measured the VOC emissions during braking using 2 benches (1:1 scale and 1:20 reduced scale in terms of energy), equipped both with a vented cast iron disc against organic pads (Fig. 1). The same 8h-long pathway (3 round trips) of a subway was tested on both benches. The presented results are from the 2nd round trip (around 100 brake events). The source of the flowing air varied depending on the bench.

VOCs emissions were collected on Tenax tubes under constant flow rate of 1 L/min and analyzed in the lab using thermal desorption-gas chromatography/mass spectrometry/flame ionization detector (TD-GC/MS/FID). The analysis output is a chromatogram showing peaks with different areas at different retention times. The lowest retention times correspond to light VOCs having the lowest boiling temperatures. The area of a peak is proportional to the quantity of the corresponding VOC.

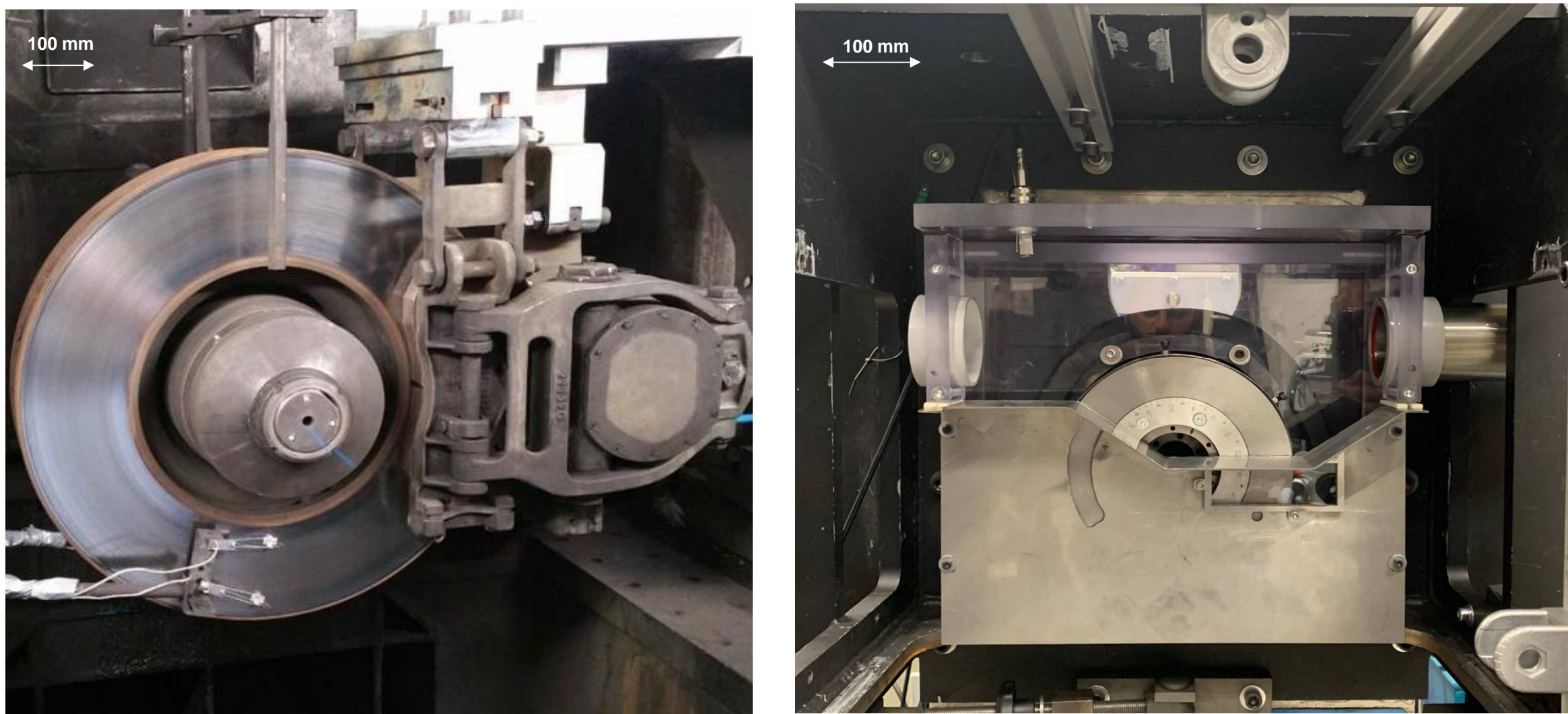


Figure 1. Two braking benches: (left) 1:1-scale bench at Alstom Flertex facilities and (right) a reduced scale bench at LaMcube laboratory.

1:1 scale

Air source: Atmospheric air coming from the roof of the building was filtered and directed into the tribometer. VOCs were sampled at the outlet of the tribometer. Background VOCs were sampled before the braking test for 30 min with flowing air.

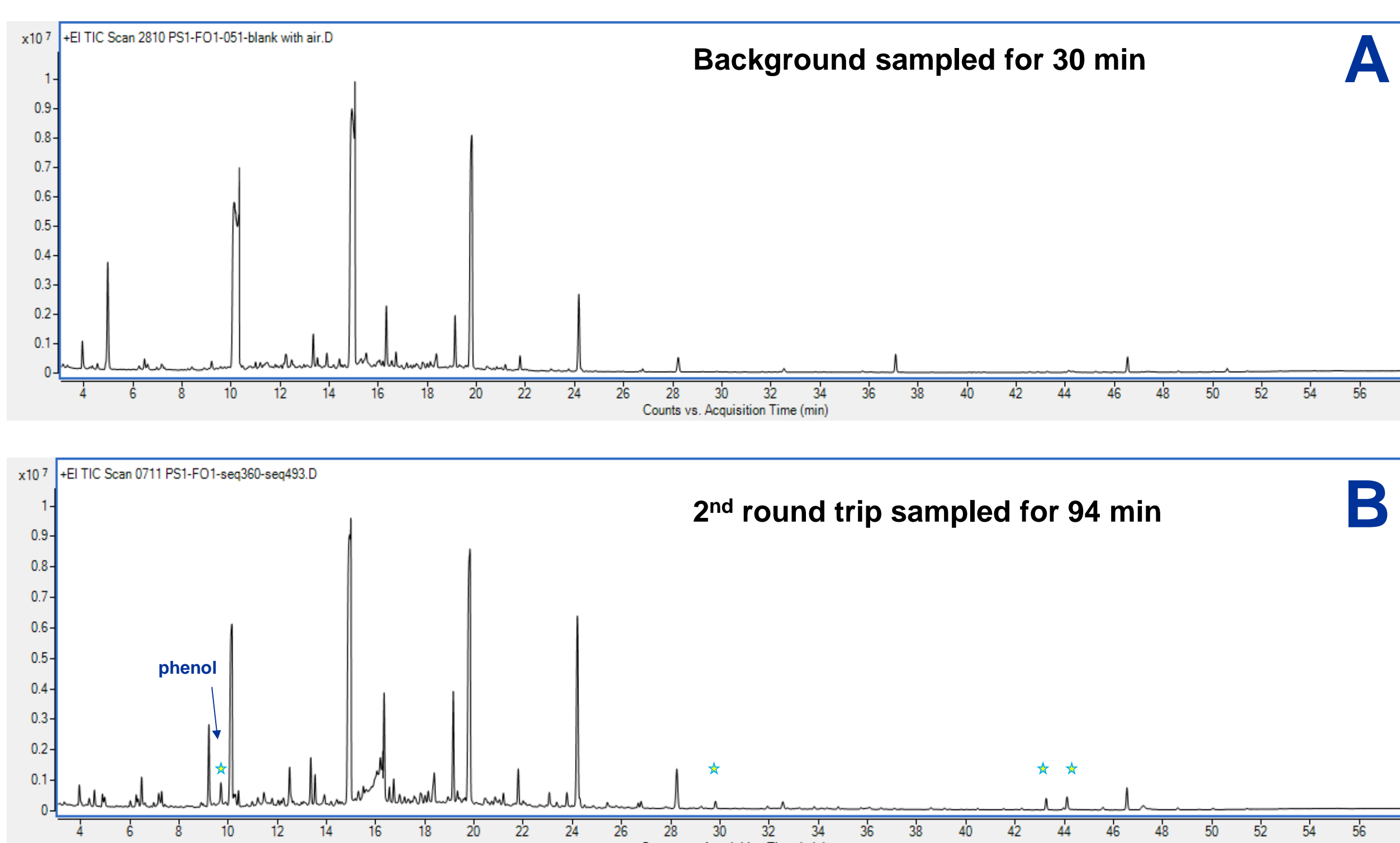


Figure 2. VOCs chromatograms obtained at the 1:1 scale: back-ground air without braking events (A) and during braking tests (B). Star symbols indicate VOCs identified only during the braking test.

Identification of VOC emissions at 1:1 scale

The comparison of A and B chromatograms shows that many VOCs (>10) are present in both background air (without braking) and air exiting the braking dynamometer. Only 4 VOCs were detected during braking events. Among them phenol was identified with 100% probability.

1:20 reduced scale

Air source: We used a high-purity commercial air (Alphagaz 1, Air Liquide) fed into an air unit to provide a constant, humid (at ~40% relative humidity) air flow. VOCs sampling was performed simultaneously at both the inlet and outlet of the tribometer chamber.

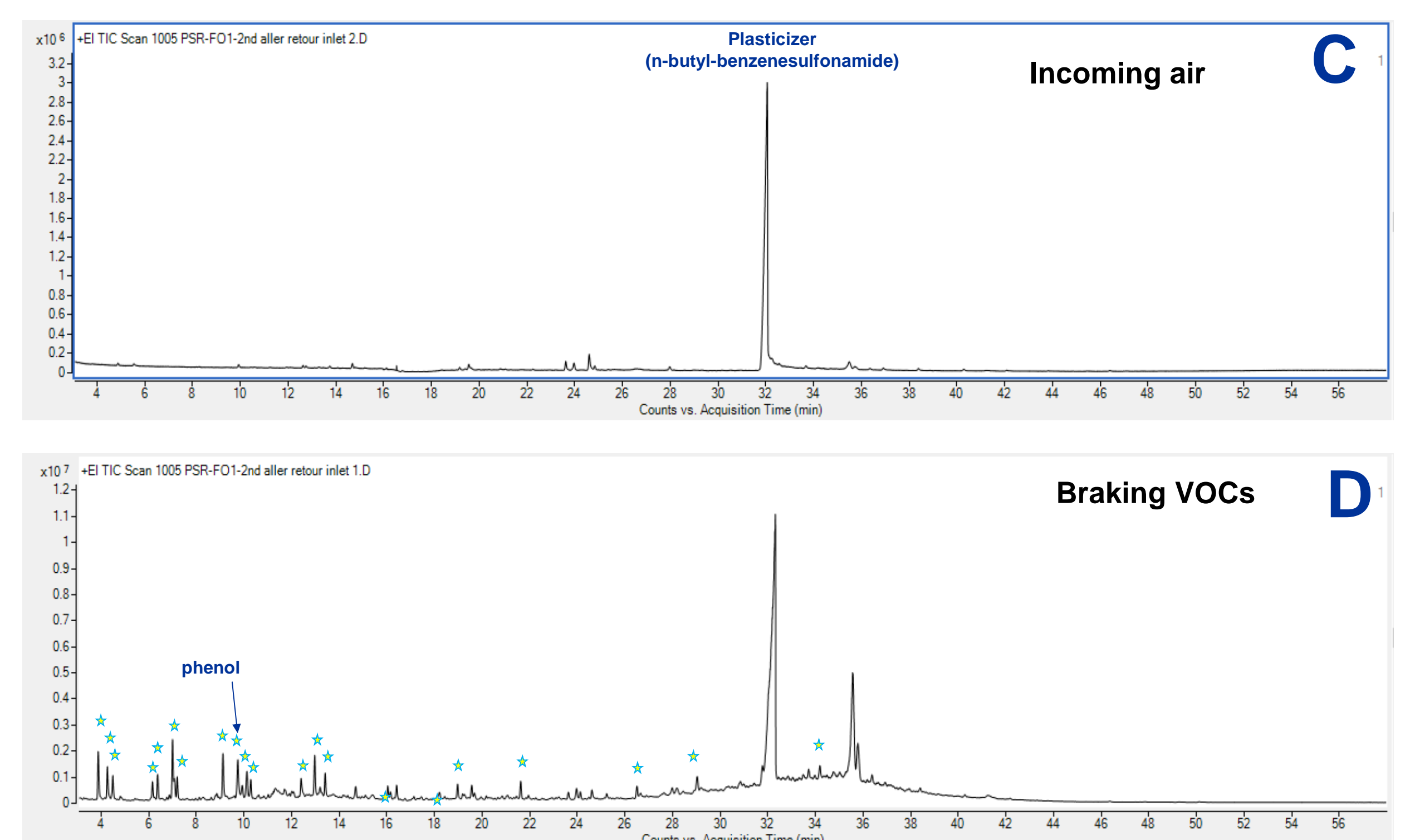


Figure 3. Typical VOCs chromatograms obtained at reduced scale during braking tests: pure air entering the tribometer chamber (C), and polluted air exiting the tribometer chamber (D).

Identification of VOC emissions at reduced scale

The chromatogram of the inlet air (C) shows no VOC, except a plasticizer likely coming from a plastic material used in the air unit. The number of VOCs increases (>20) after braking events (D), containing hydrocarbons (C6 to C17), monocyclic aromatics with different substituents, aldehydes, and alcohols including phenol.

Conclusions & Perspectives

- Atmospheric roof air used at scale 1:1 → VOCs from the outside environment (Paris area): difficult to distinguish whether the sampled VOCs originated from braking emissions or the outside air. Reduced scale bench setup: purer chemical environment → detection of more braking-related VOCs.
- A common VOC was found in both scales, phenol, which may originate from organic pads (containing phenolic resins) in braking systems or through the oxidation of aromatic compounds during brake pad heating.
- Quantification of VOCs in progress. Origin of VOCs to be unraveled (tribochemistry? other sources from the braking system?).
- Analysis of particle measurements (number concentration, chemical speciation) in progress.

Bibliography - Acknowledgements

Martins et al, Exposure to airborne particulate matter in the subway system, STotEn 511 (2015); Yang et al, A review on characteristics and mitigation strategies of indoor air quality in underground subway stations, STotEn 869 (2023) The present work takes place within the BREAQ project funded by the French government as part of the PIA, invest for the Future Plan, now integrated into France 2030, and operated by ADEME, the French ecological transition agency.