

Towards Online Detection of Tire Wear Particles: Mass Spectrometric Challenges and Future Directions



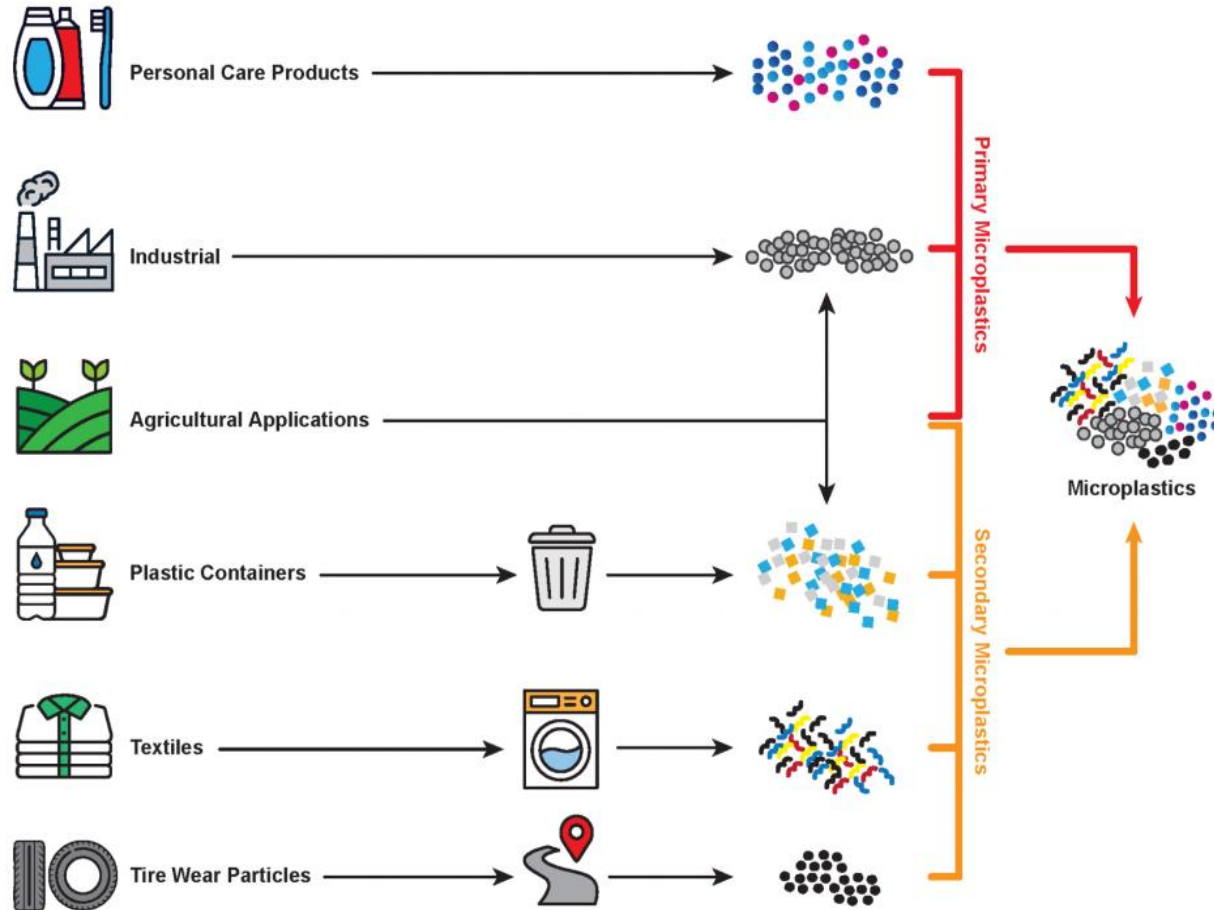
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Bedre Byluftforum

15 April 2026



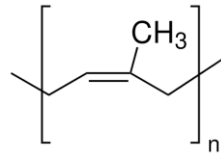
TWPs are a significant fraction of microplastics



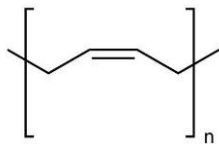
- Becoming more prevalent due to the increasing use of electric vehicles
- Diverse in size
- Complex matrix consist of polymers (rubber), organic additives and inorganic components such as carbon black and zinc oxide

ITRC MP Figure 2-1
Source: J. McDonald

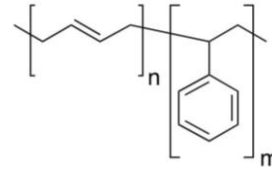
Methodological approach



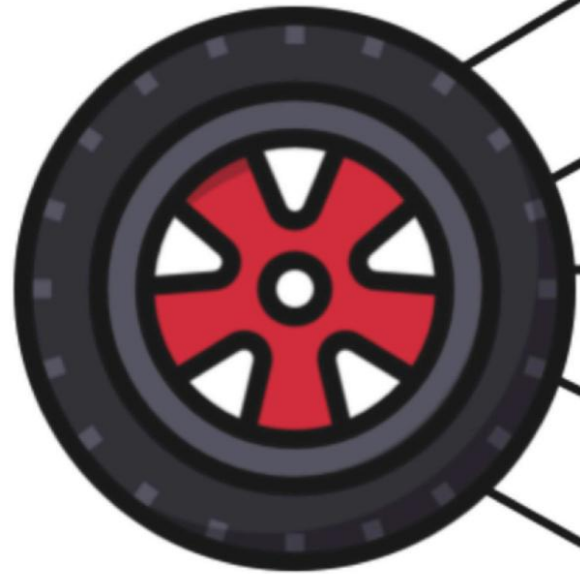
Polyisoprene (PIR)



Polybutadiene (PBR)



Poly(styrene-butadiene) (SBR)



40-50%

Polymeric material

30-35%

Fillers

15%

Softeners

2-5%

Vulcanization agents

5-10%

Other Additives

1. Detect synthetic rubber material in airborne PM

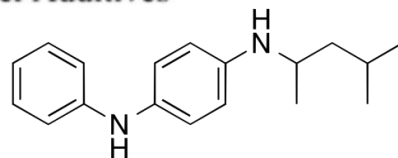
Pyrolysis PTR-QMS, Pyr-GC-MS

Why Online Detection?

2. Detect 6PPD in airborne PM as a specific tire wear marker

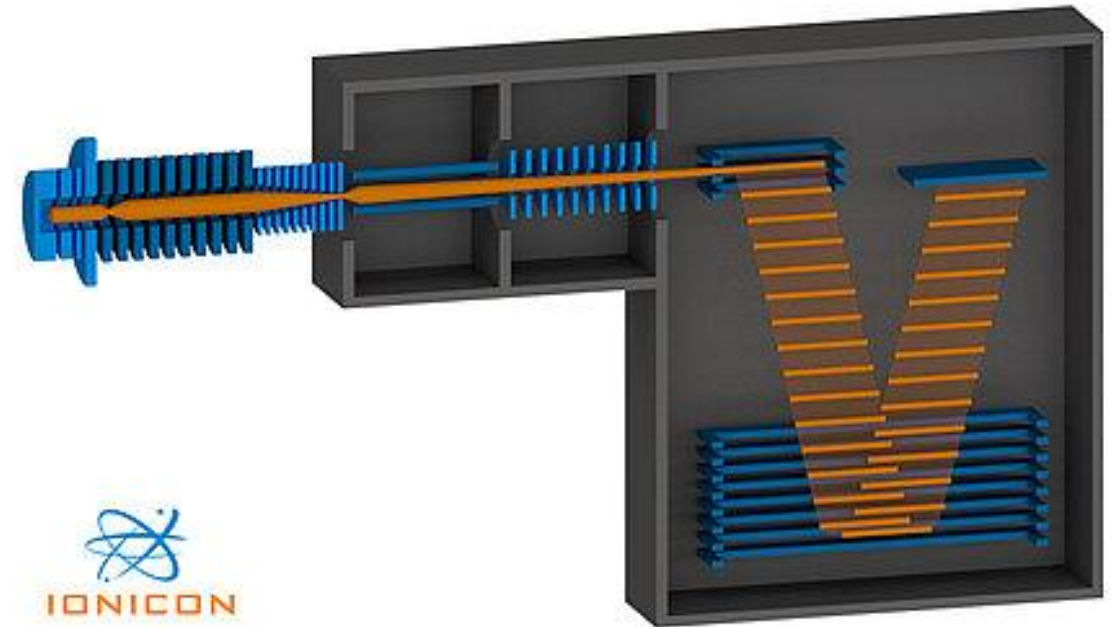
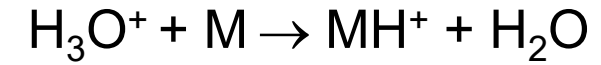
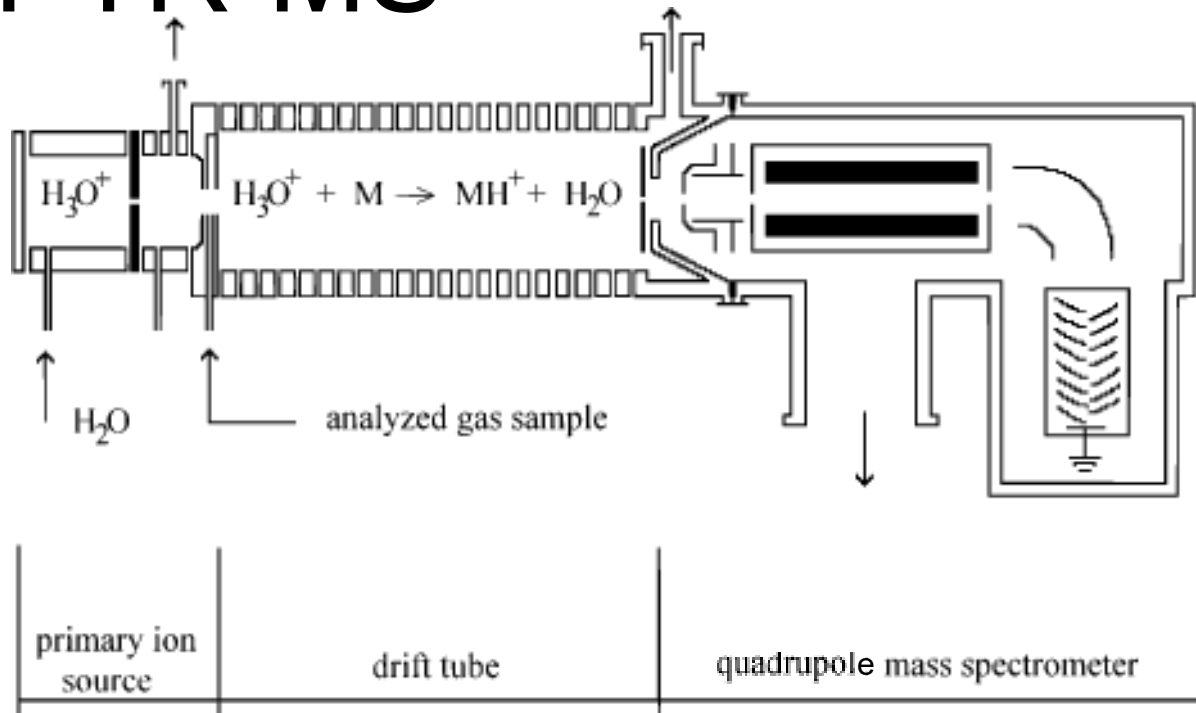
Thermal desorption PTR-ToF-MS, UHPLC-Orbitrap

Johannessen C., et al., Atmospheric Pollution Research., 2022.



6PPD (antiozonant)

Proton Transfer Reaction Mass Spectrometry PTR-MS



<https://www.ionicon.com/technologies/details/expert-information>

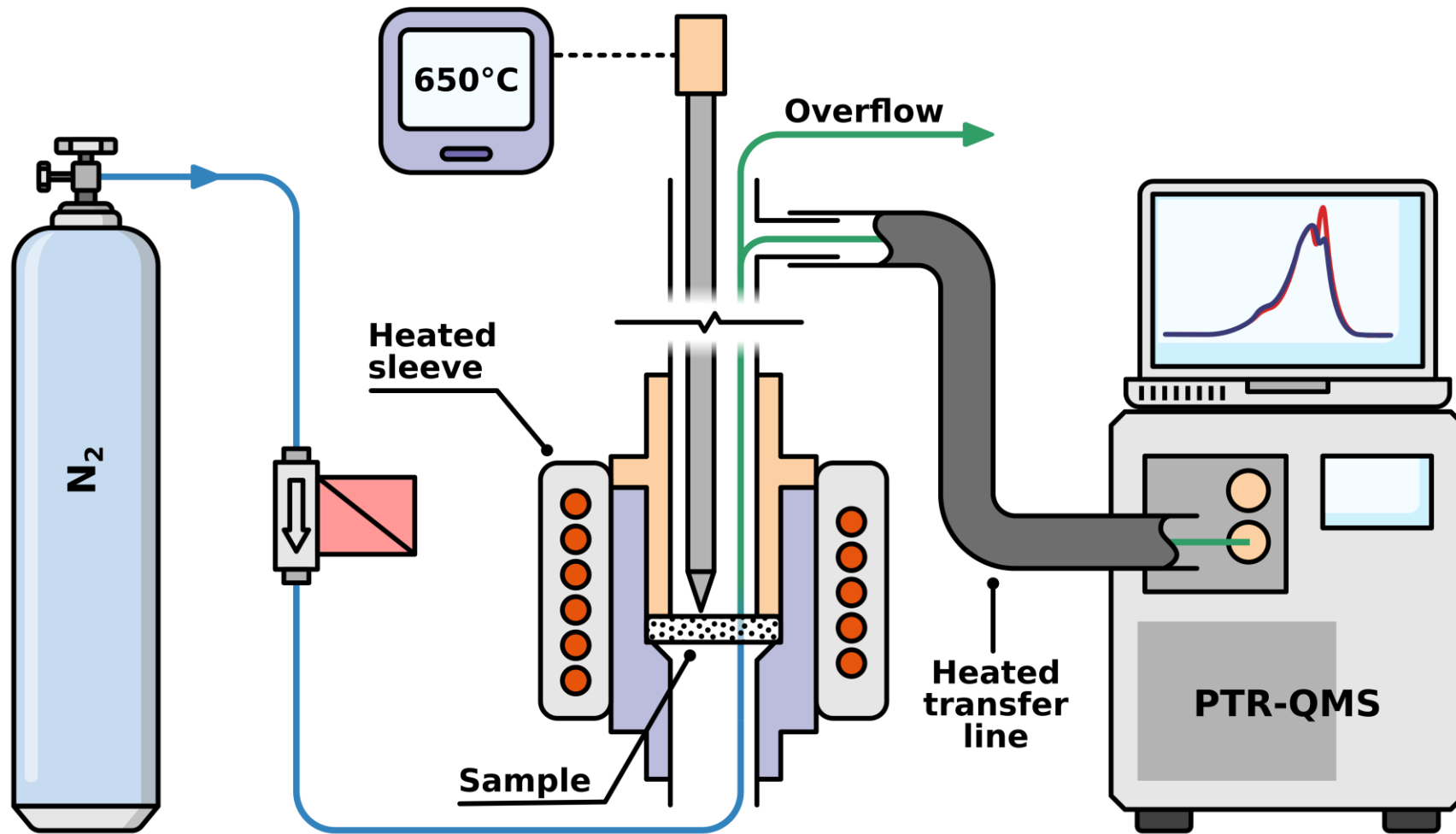
Amann A., et al., Measurement Science Review., 2010.

Online mass spectrometry for analysis of gaseous samples

Soft ionization with formation of MH^+ and low fragmentation

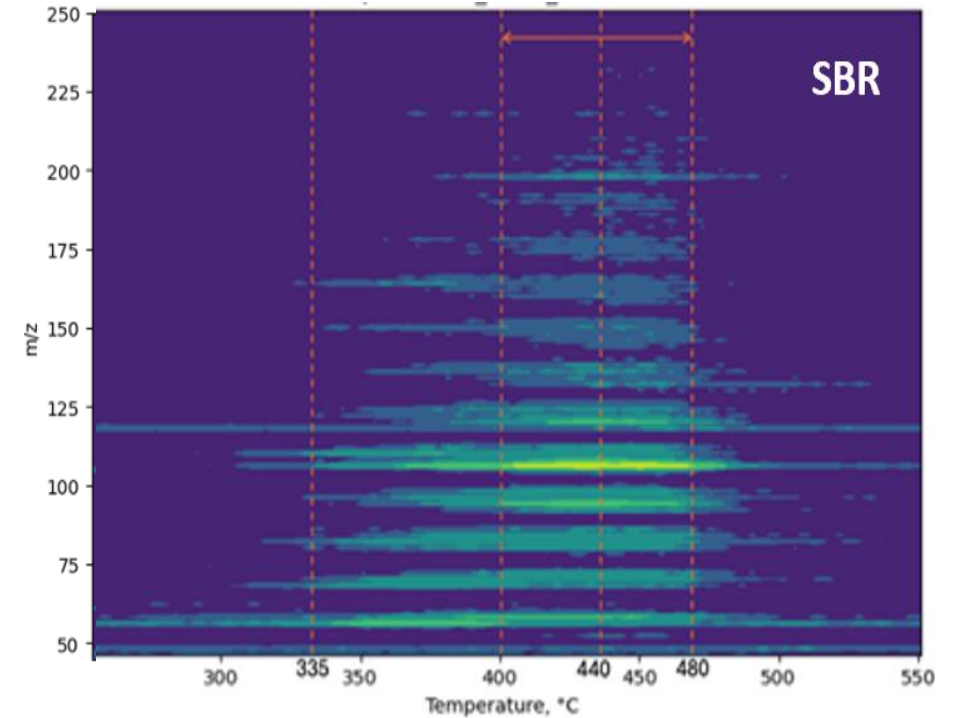
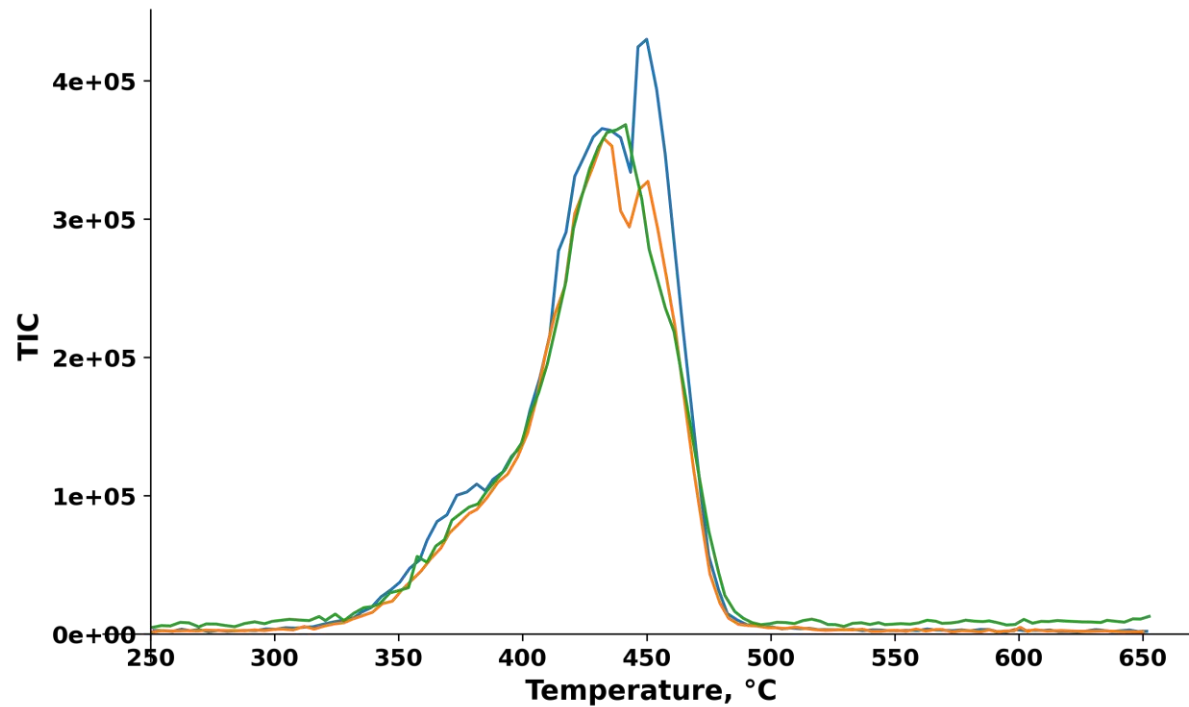
pptV level detection limit and up to 10000 $\text{m}/\Delta\text{m}$ resolution

Pyrolysis PTR-MS



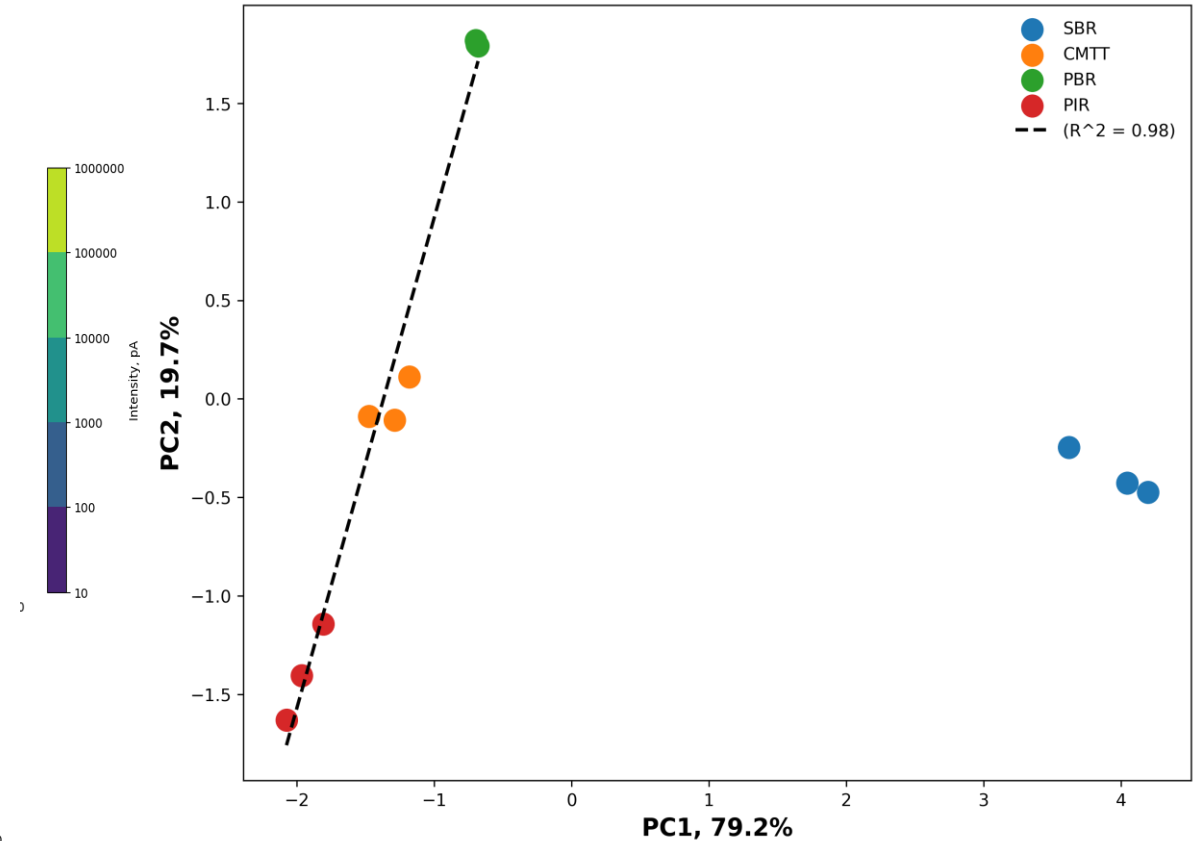
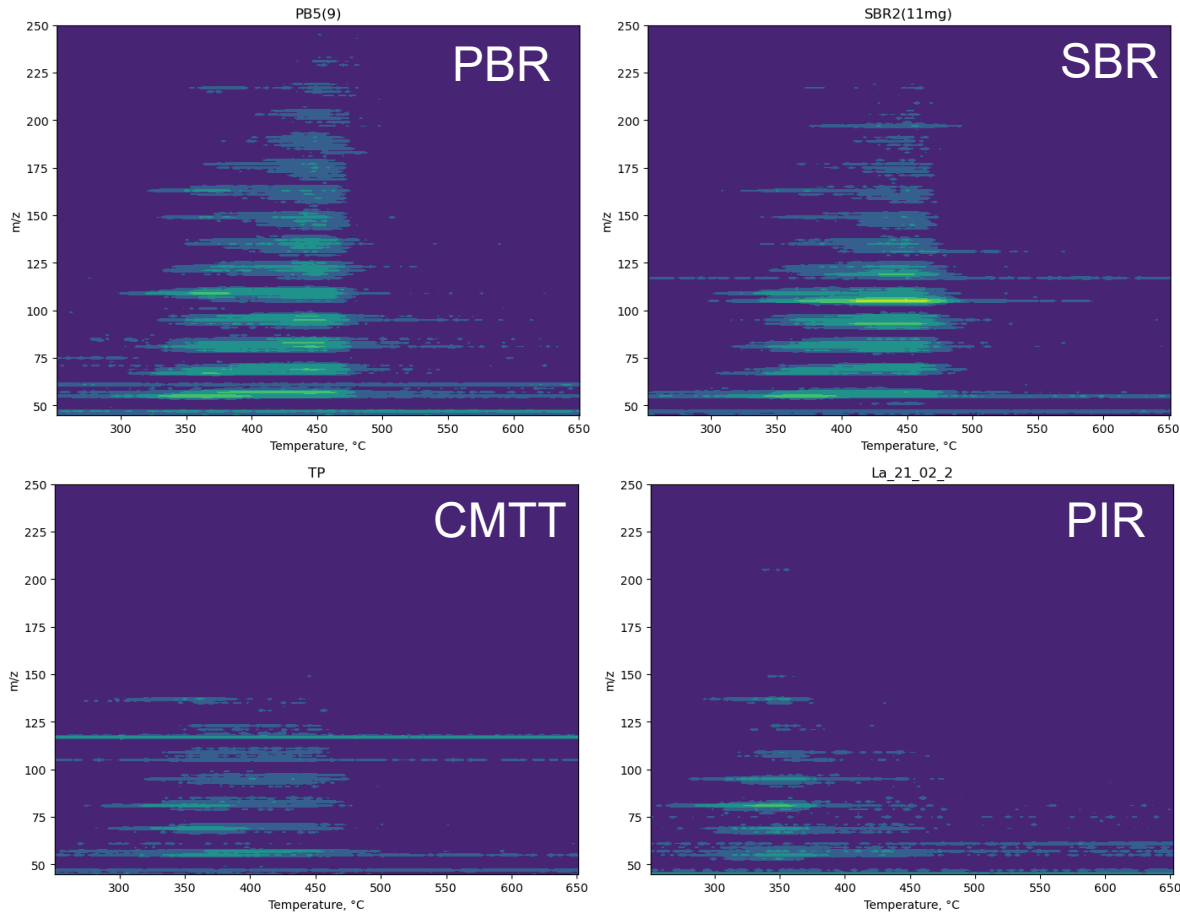
Pyrolysis PTR-MS

Styrene – butadiene rubber (SBR)



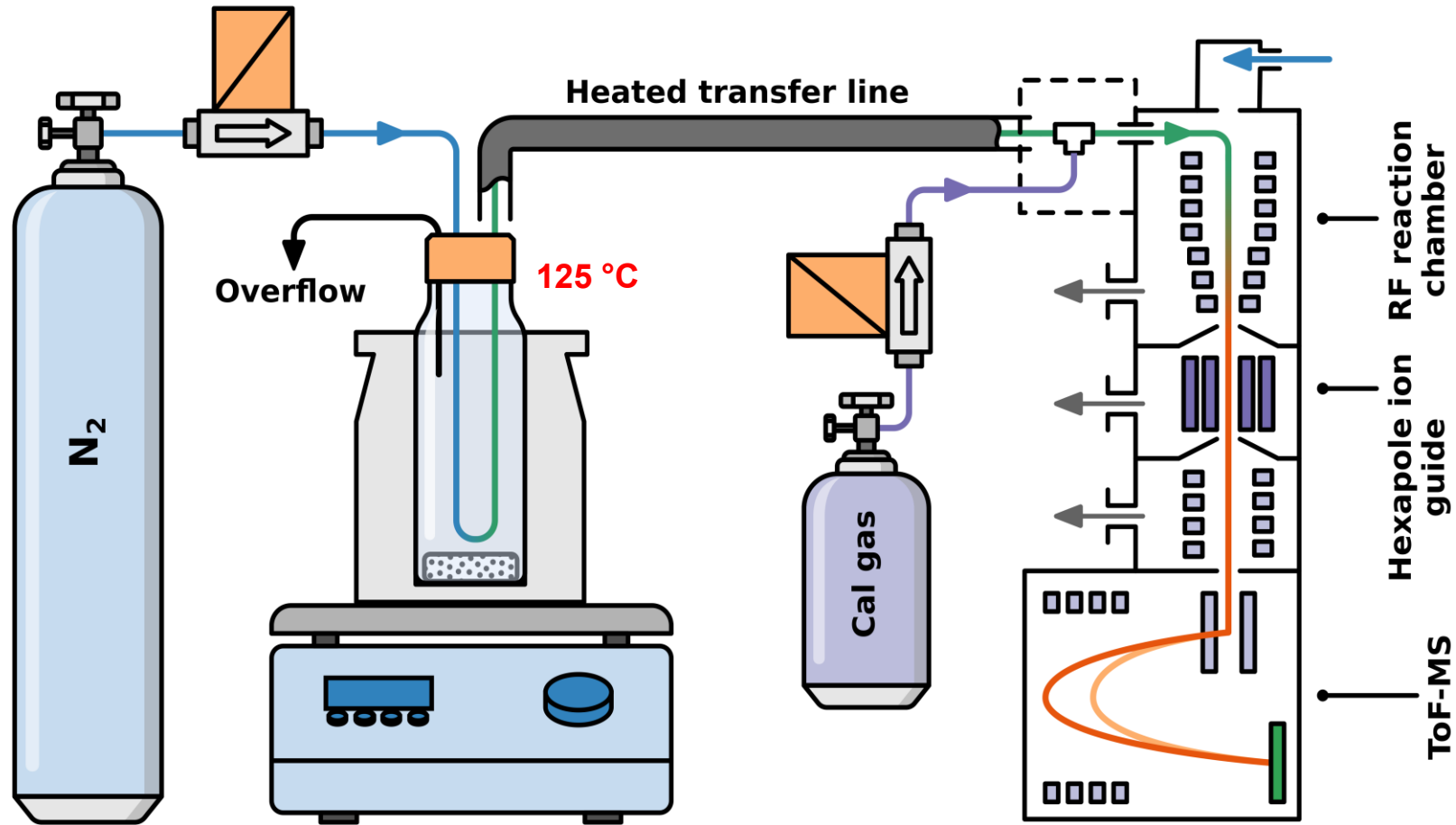
Pyrolysis PTR-MS

PBR – polybutadiene rubber, **SBR** – poly styrene-butadiene rubber
PIR – polyisoprene rubber, **CMTT** – cryomilled tire particles

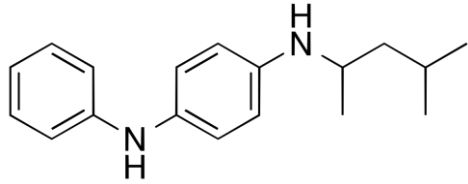


Different types of rubber generate distinct “fingerprint” mass spectra
This method has not yet been tested on ambient air filter samples

Thermal desorption PTR-ToF-MS

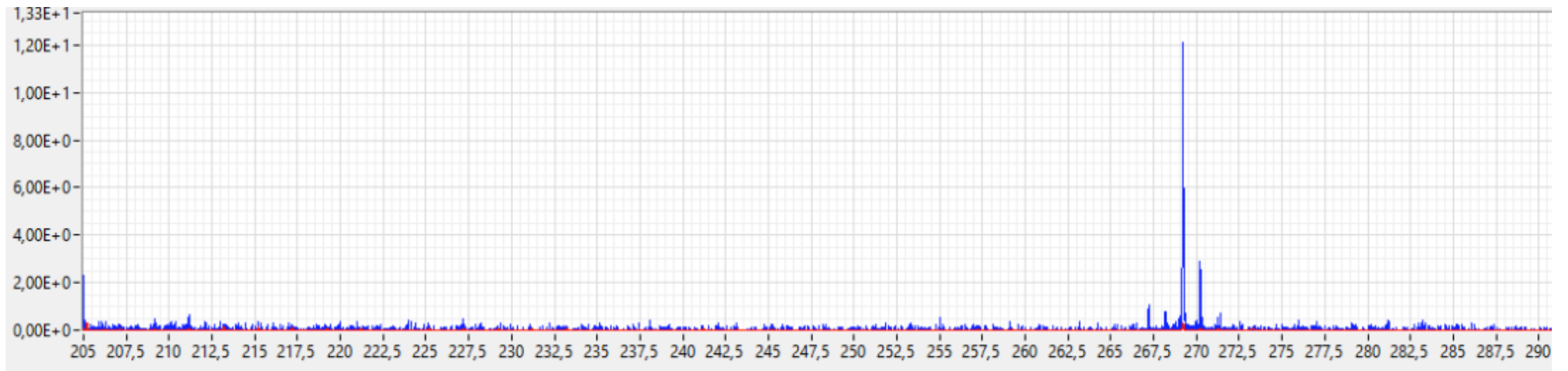


PTR-ToF mass spectrum of pure 6PPD

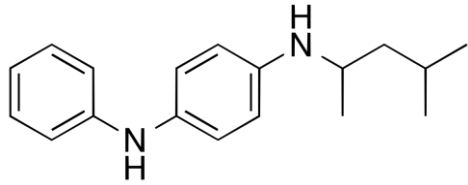


[M+H]⁺ : *m/z* 269.201
(little fragmentation)

common rubber antiozonant in vehicle tires

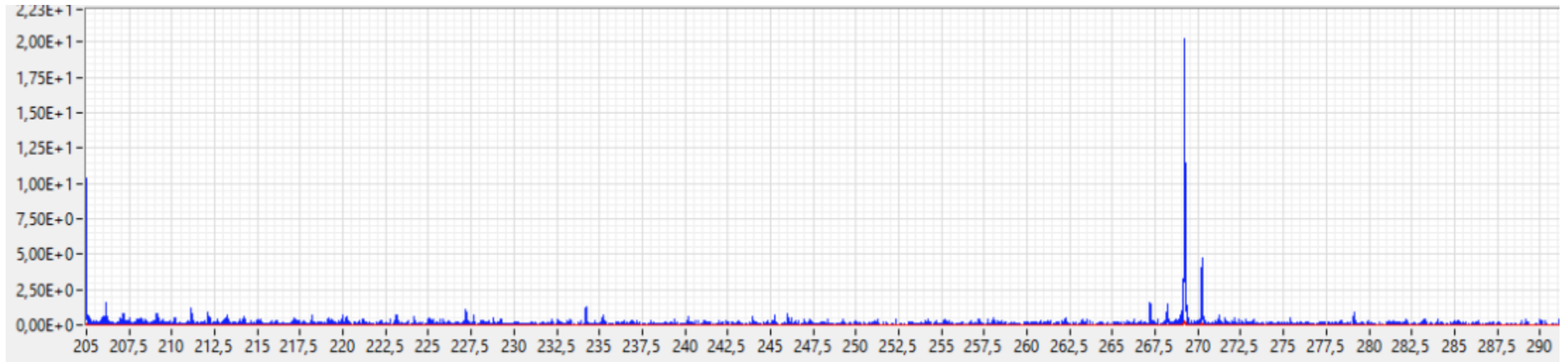


PTR-ToF mass spectrum of cryo-milled TWP

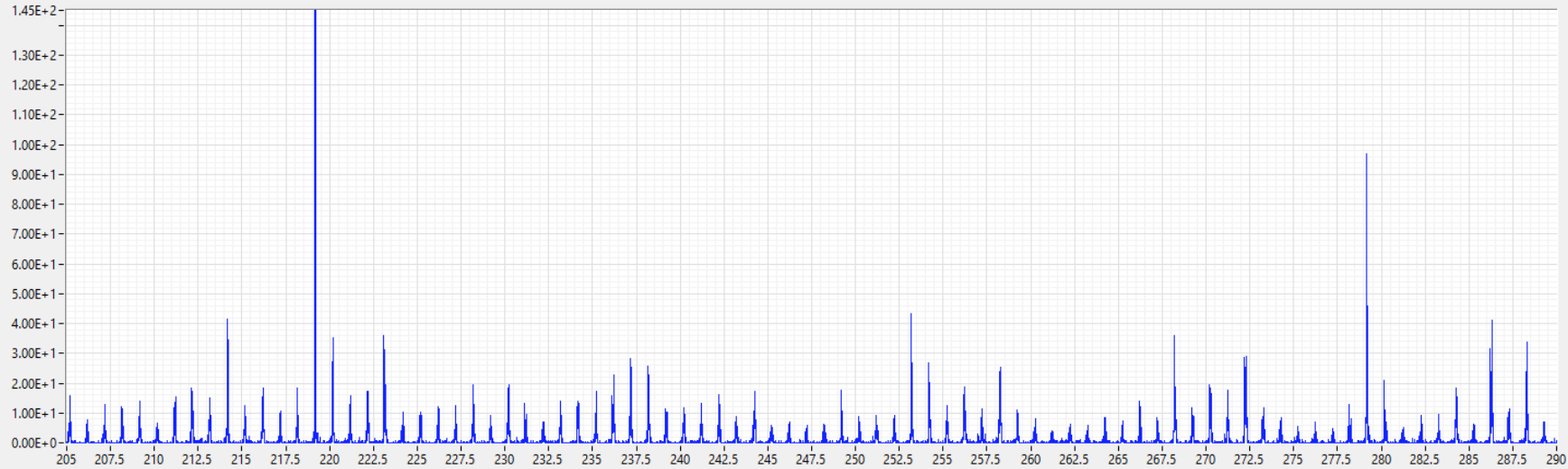
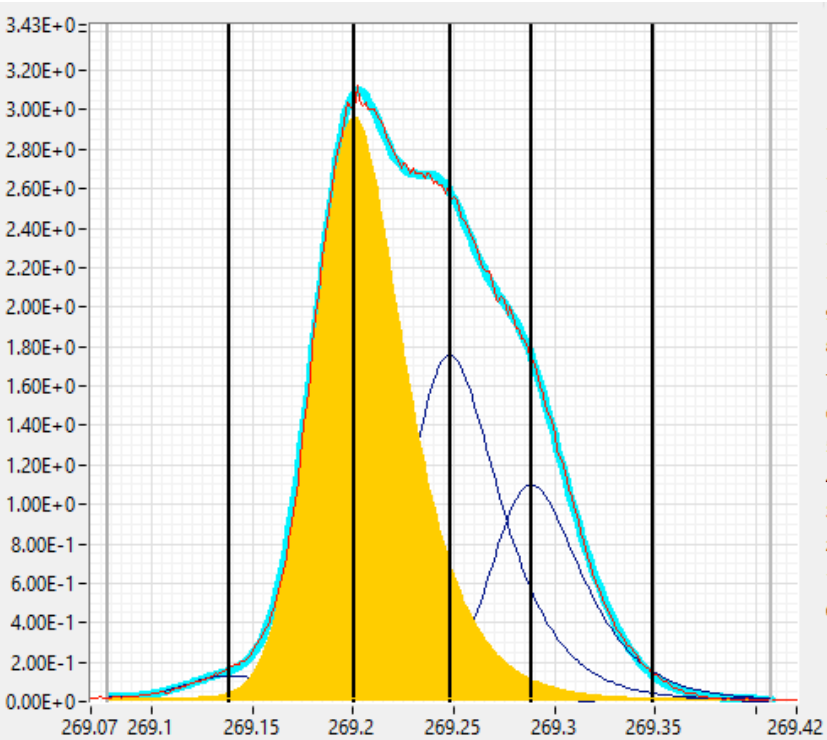


$[M+H]^+ : m/z 269.201$

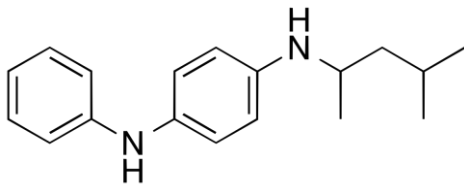
common rubber antiozonant in vehicle tires



PTR-ToF mass spectrum of ambient air PM

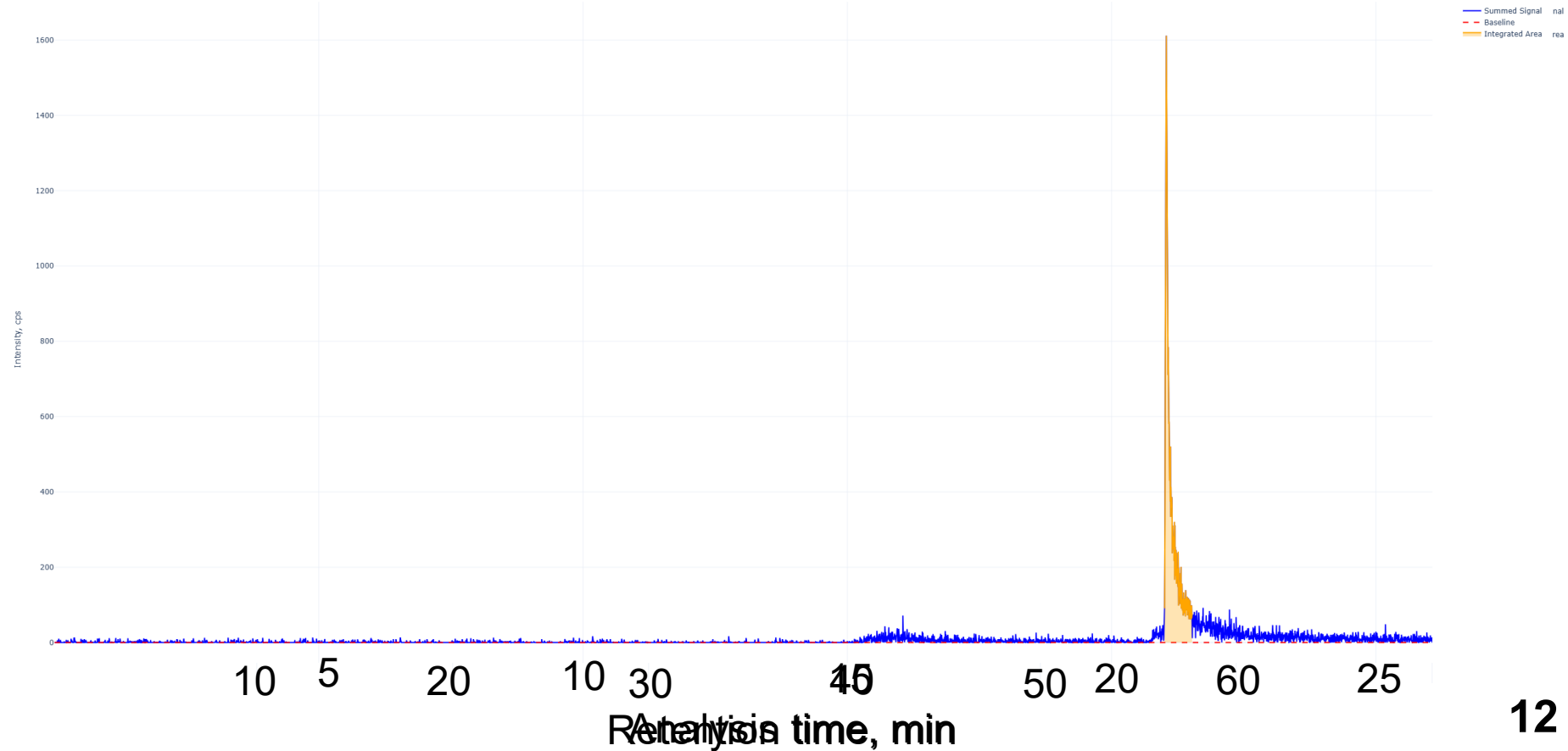


[M+H]⁺ : m/z 269.201

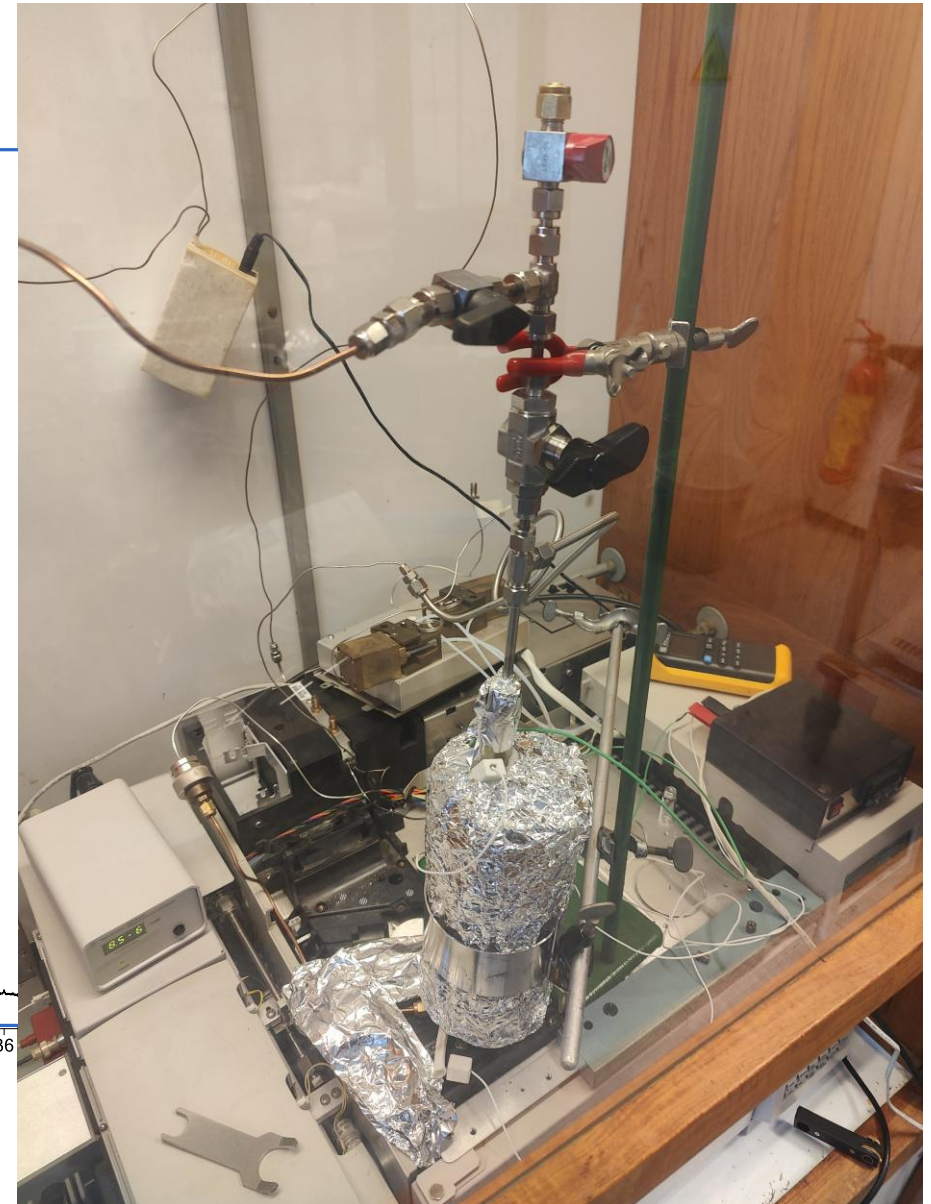
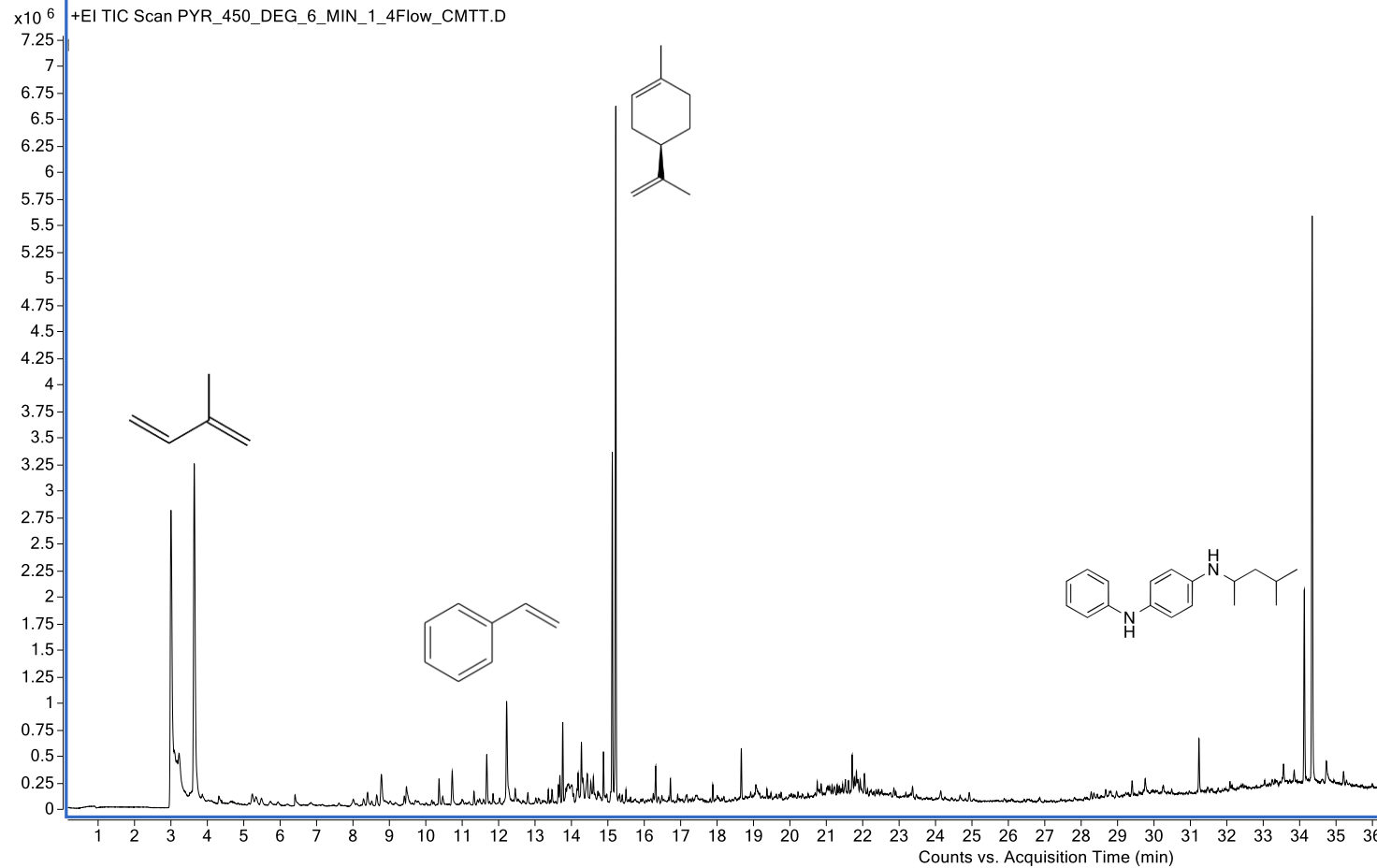


From on-line to off-line

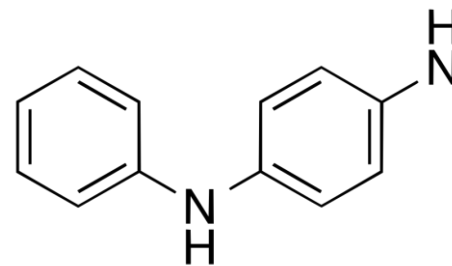
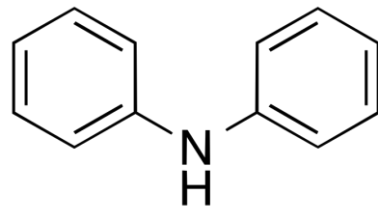
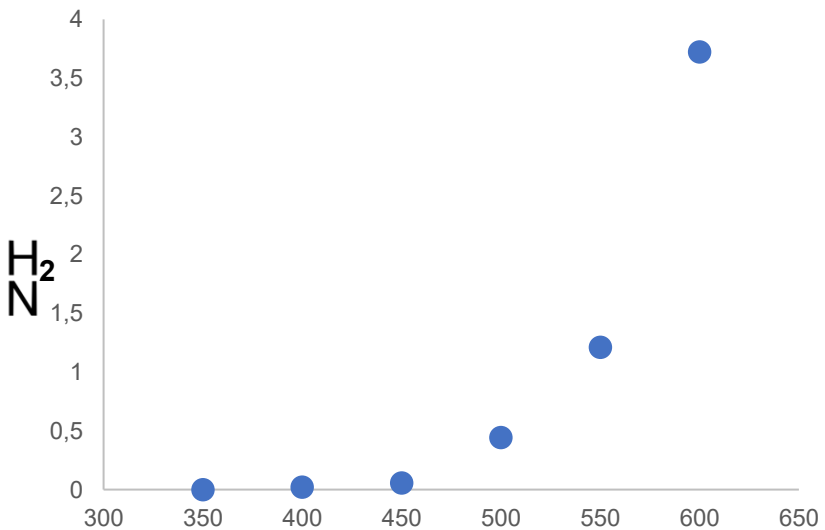
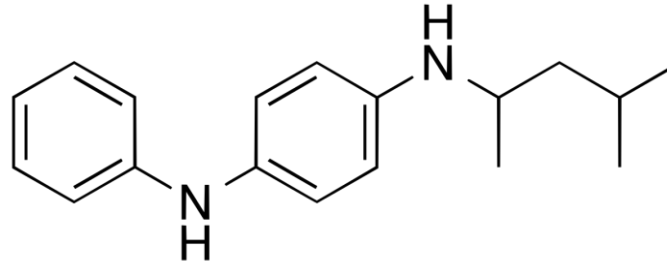
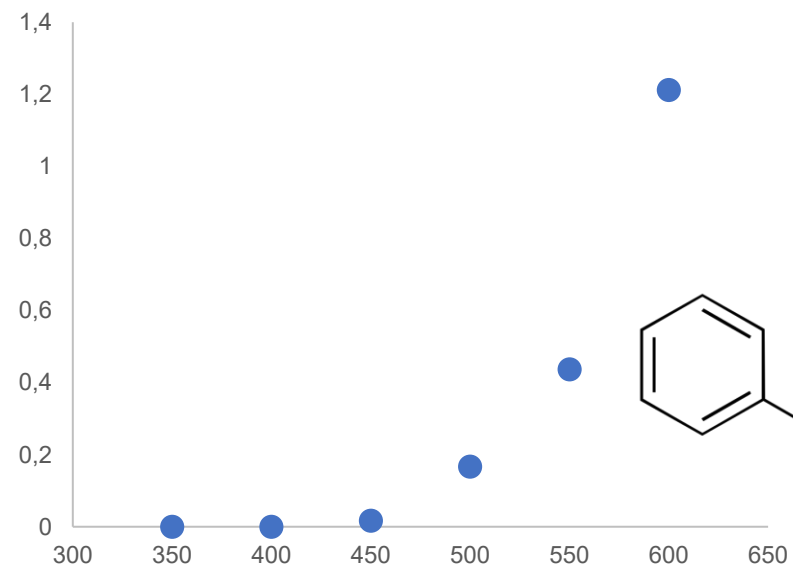
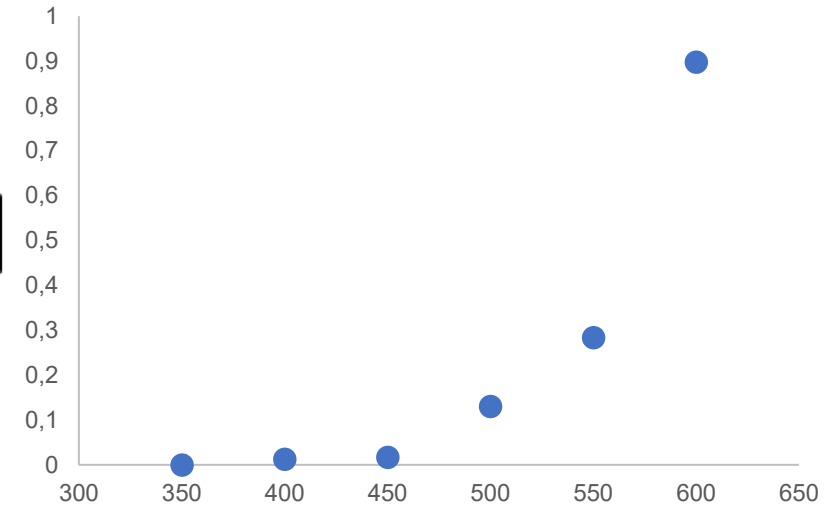
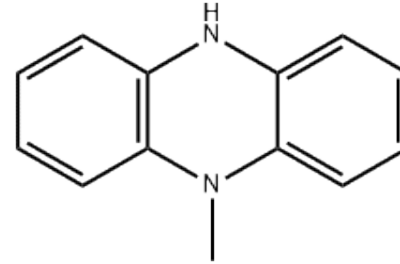
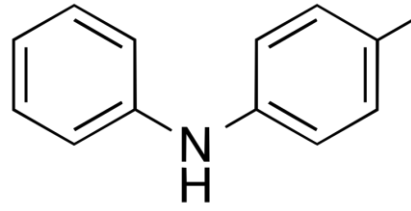
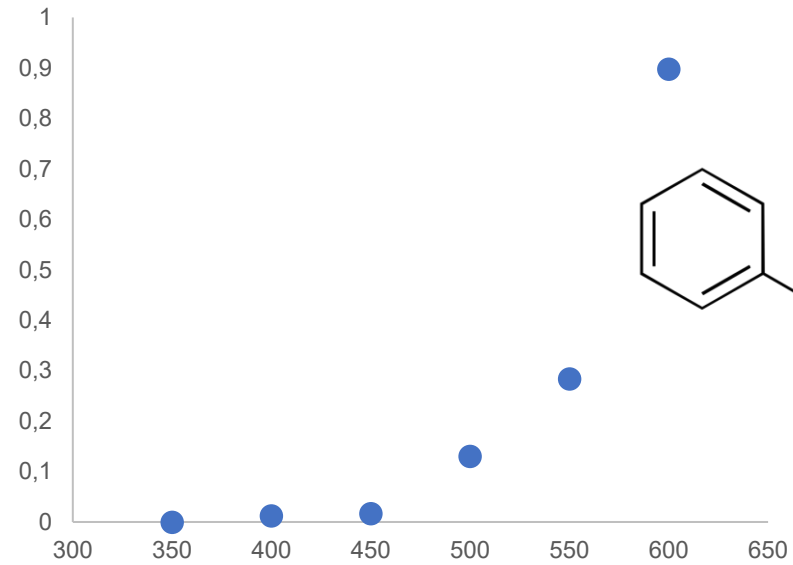
- ~~0.02 mg/m³ LOOQ~~
- ~~20 minutes peak width~~



Home-made pyrolysis unit



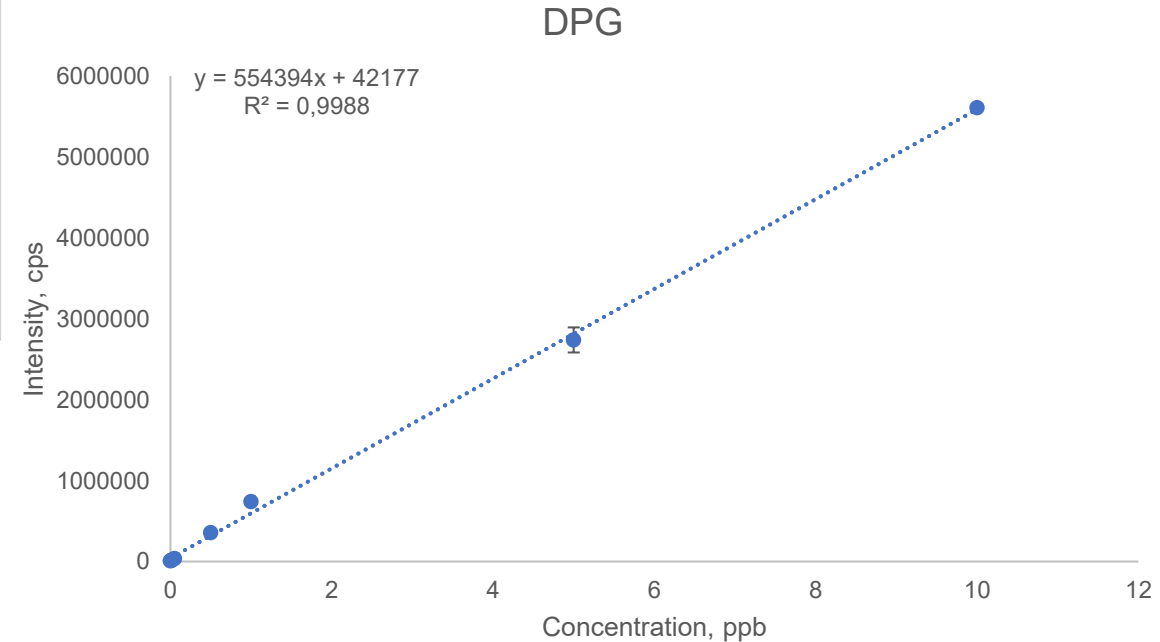
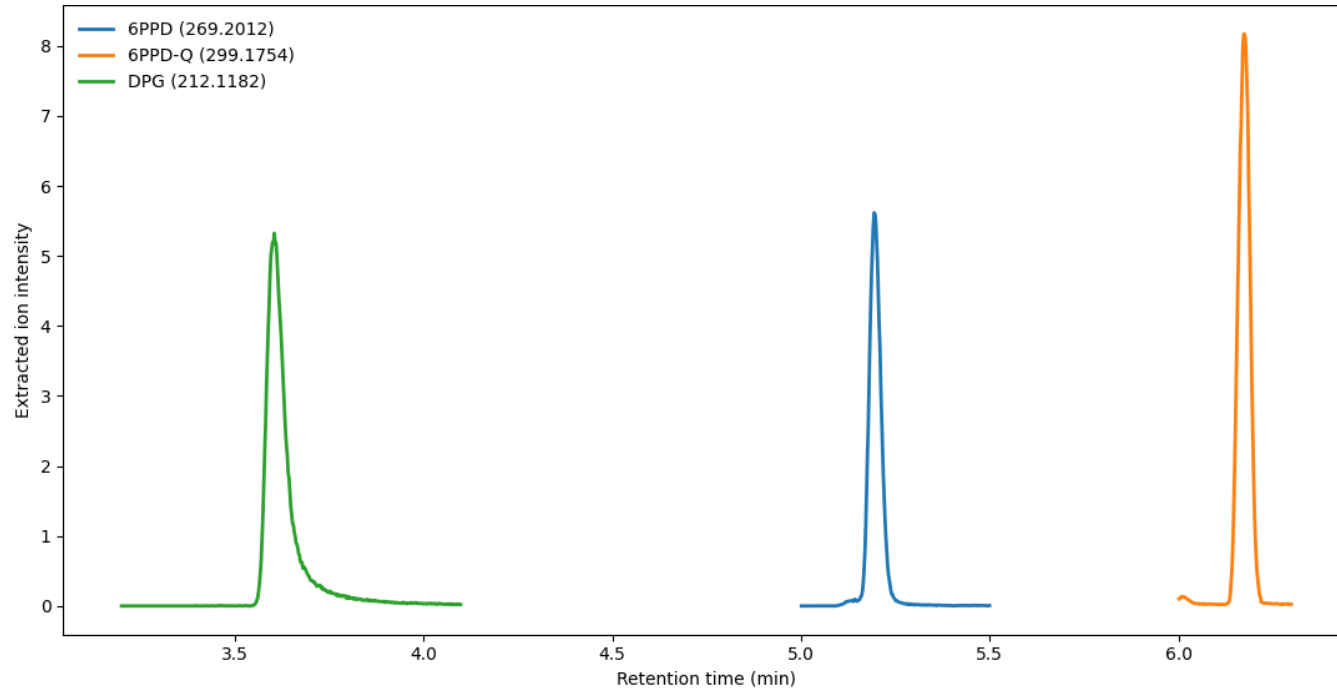
Temperature dependent degradation of 6PPD



Drawbacks of Pyr-GC-MS

- Relatively poor sensitivity
(we've achieved so far about 10 ng/m³ – LOQ)
- Restricted amount of sample
- Thermal degradation of the compounds of interest
- Possible matrix effects

UHPLC-Orbitrap MS



Total analysis time – 13 minutes

LOQ: 0.025 ppb – DPG, 0.1 ppb – 6PPD and 6PPDq

ESI+, H₂O-MeOH 0,1% FA,

Luna Omega Polar C18 1.6 um, 40 °C, 5 uL

Real sample analysis

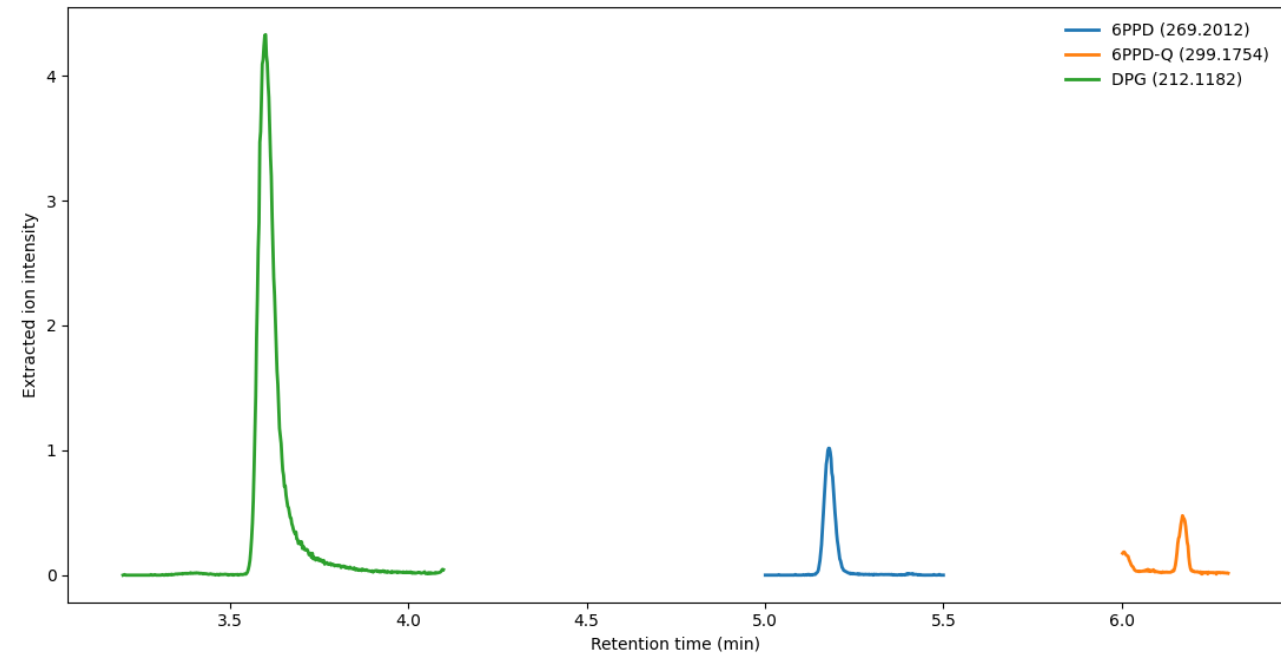
Samples were collected at the
Department of Chemistry, UiO

48 m³ of air were collected on a quartz membrane filter

Filter and blank was extracted using ultrasonic bath at
40°C for 30 minutes in MeOH

Extract was then concentrated using gentle N₂ flow and
analyzed by UHPLC-Orbitrap

Analyte	Detected	LOQ
6PPD	0.3 ± 0.1 ng/m ³	0.01 ng/m ³
6PPDq	0.046 ± 0.01 ng/m ³	0.01 ng/m ³
DPG	0.86 ± 0.01 ng/m ³	0.003 ng/m ³



Additional Full Mass Scan Allowed us to identify:
5-Methyl-1H-benzotriazole
N,N'-di-2-naphthyl-p-phenylenediamine (DNPD)

Thank You for Your Attention

- This work was funded by the Research Council of Norway (NFR; Project No.: 334086; Airborne Microplastic Detection, Origin, Transport and Global Radiative Impact)