EMISSIONS ANALYTICS

Chemical fingerprinting tires to understand tire wear emissions

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Our Belief

When it comes to the pursuit for improved air quality, we believe in the power of clarity, transparency and integrity. With real-world data we can meet emissions challenges – instilling trust and confidence in our industry partners and public.

It's with our commitment and independence we are able to make a significant contribution toward positive change and to achieve enduring results.

EMISSIONS ANALYTICS

Introduction

- Founded in 2011
- Headquartered in the UK
- Operations in UK, Germany, USA and South Korea
- Independent testing house specialising in real-world emissions testing
- Over 2,500 vehicles/machines tested across passenger, commercial and off-road
- Largest commercially available database of real-world emissions data
- We work with regulators, OEMs, Tier 1/2 suppliers, fuel and chemical companies, fleets, consumer media
- Chair of EU CEN Workshops 90 and 103
- Honorary Research Fellow, Imperial College London

Overview

- Real-world tire emissions are poorly understood separate from other non-tailpipe emissions
- Both for wear rates and chemical make-up
- Bigger and heavier vehicles may lead to increased tire emissions
- Rapidly declining exhaust emissions mean that non-tailpipe makes up a growing share of total automotive emissions

Tire wear testing

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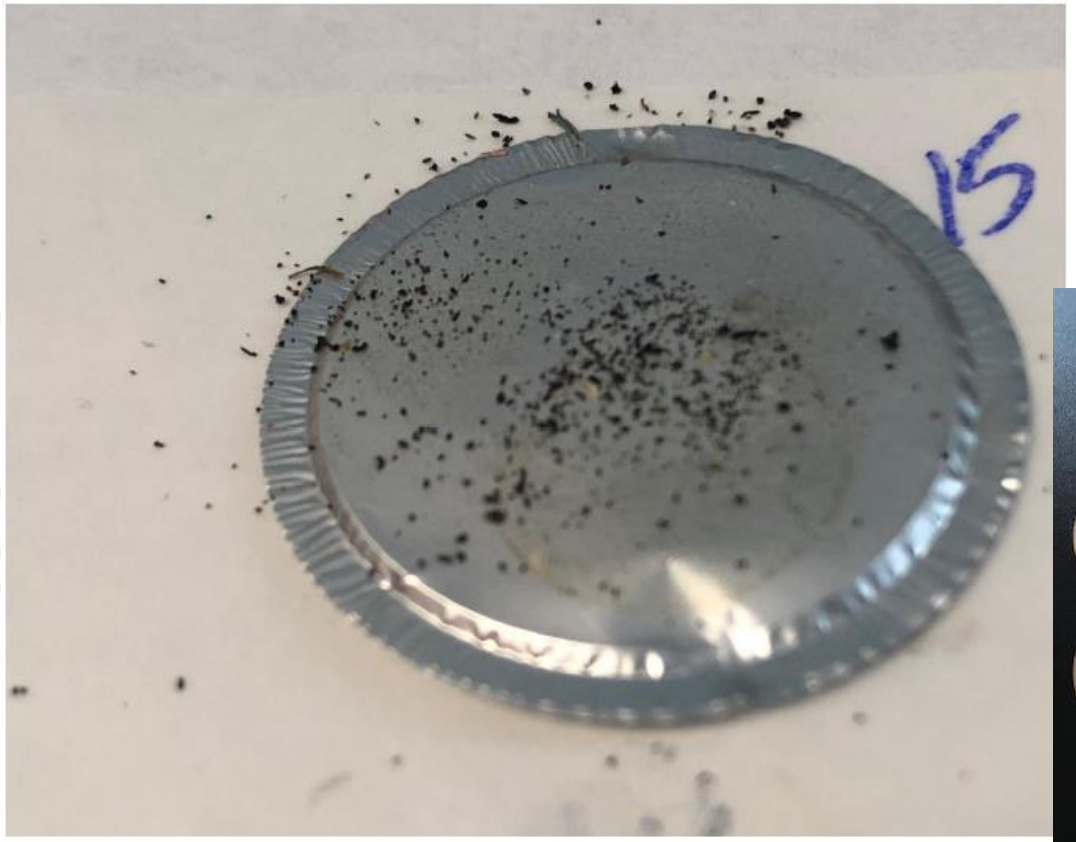
Tire wear testing

Sample collection and analysis



Tire wear rates

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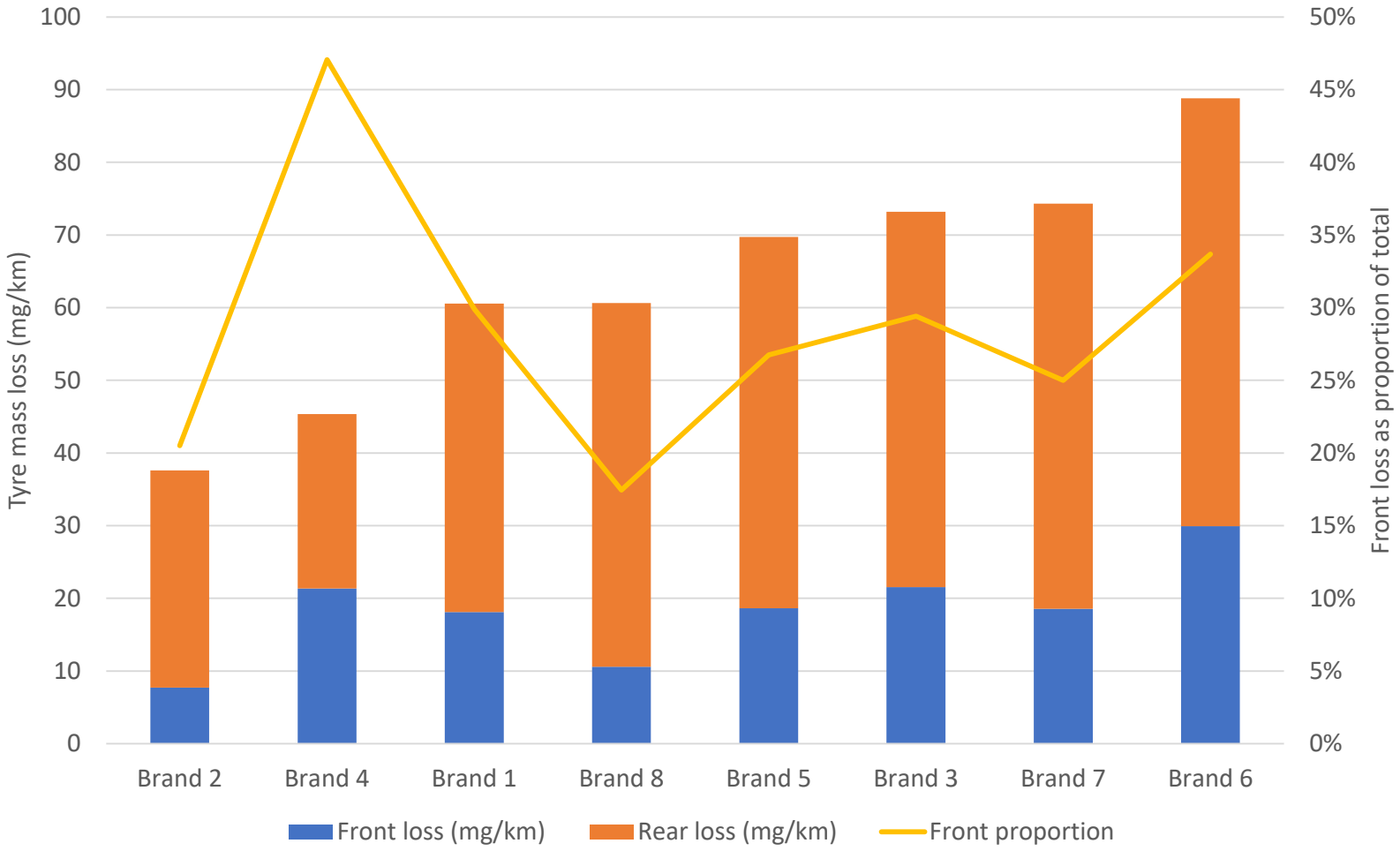
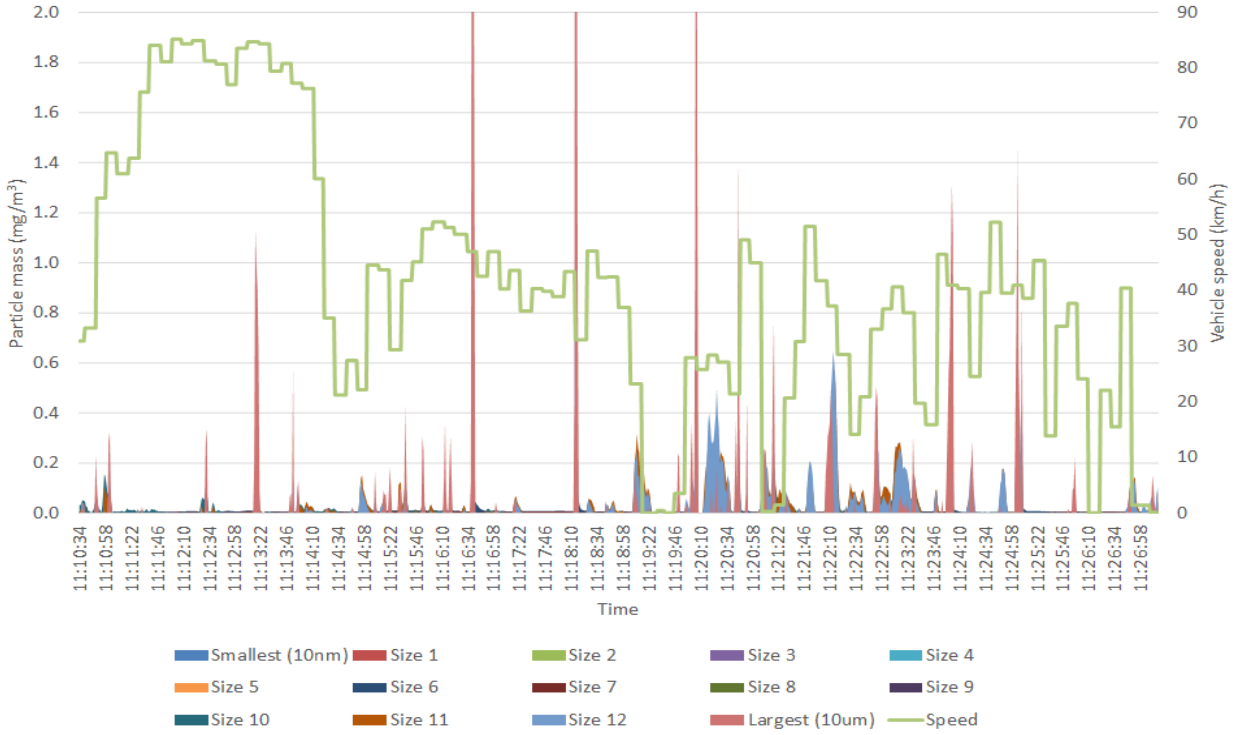
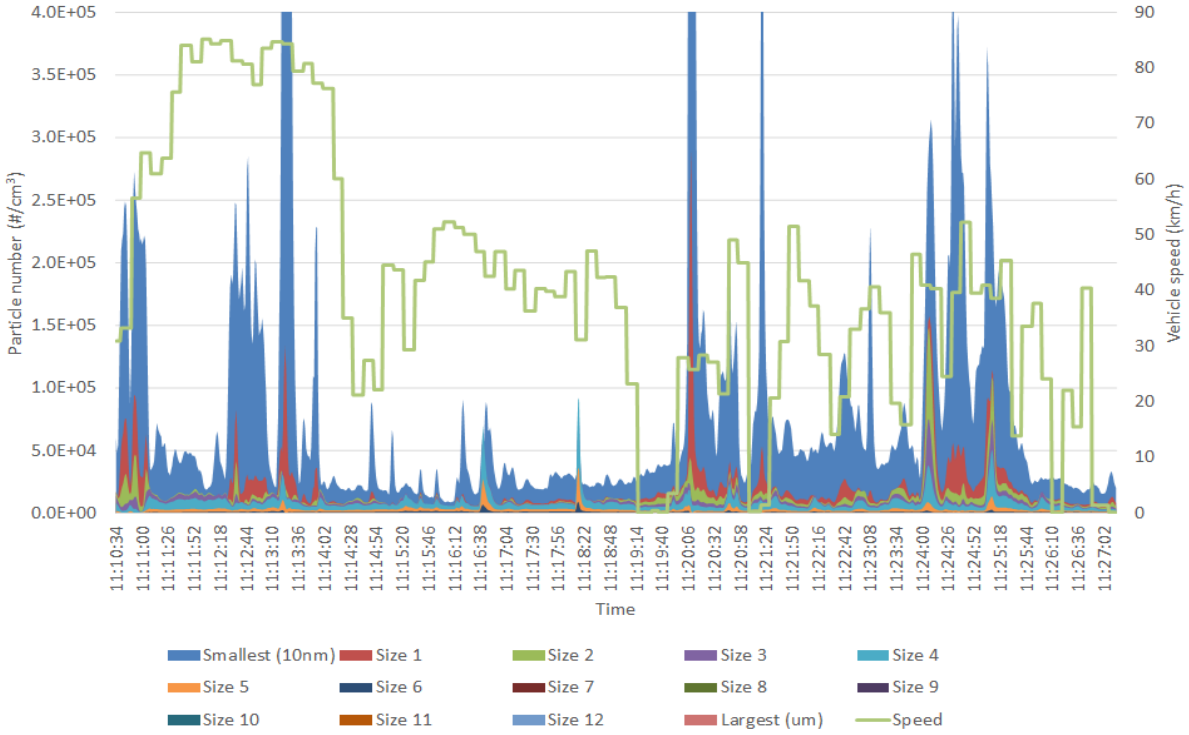
Comparative mass loss between brands



- Same Mercedes C-Class
- Total mass loss of all four tires
- 64 mg/km average wear rate across 8 different brands – premium to budget
- Front wear more consistent – average 29%
- 21% added wear with 500 kg payload

Size distribution





Chemical fingerprinting

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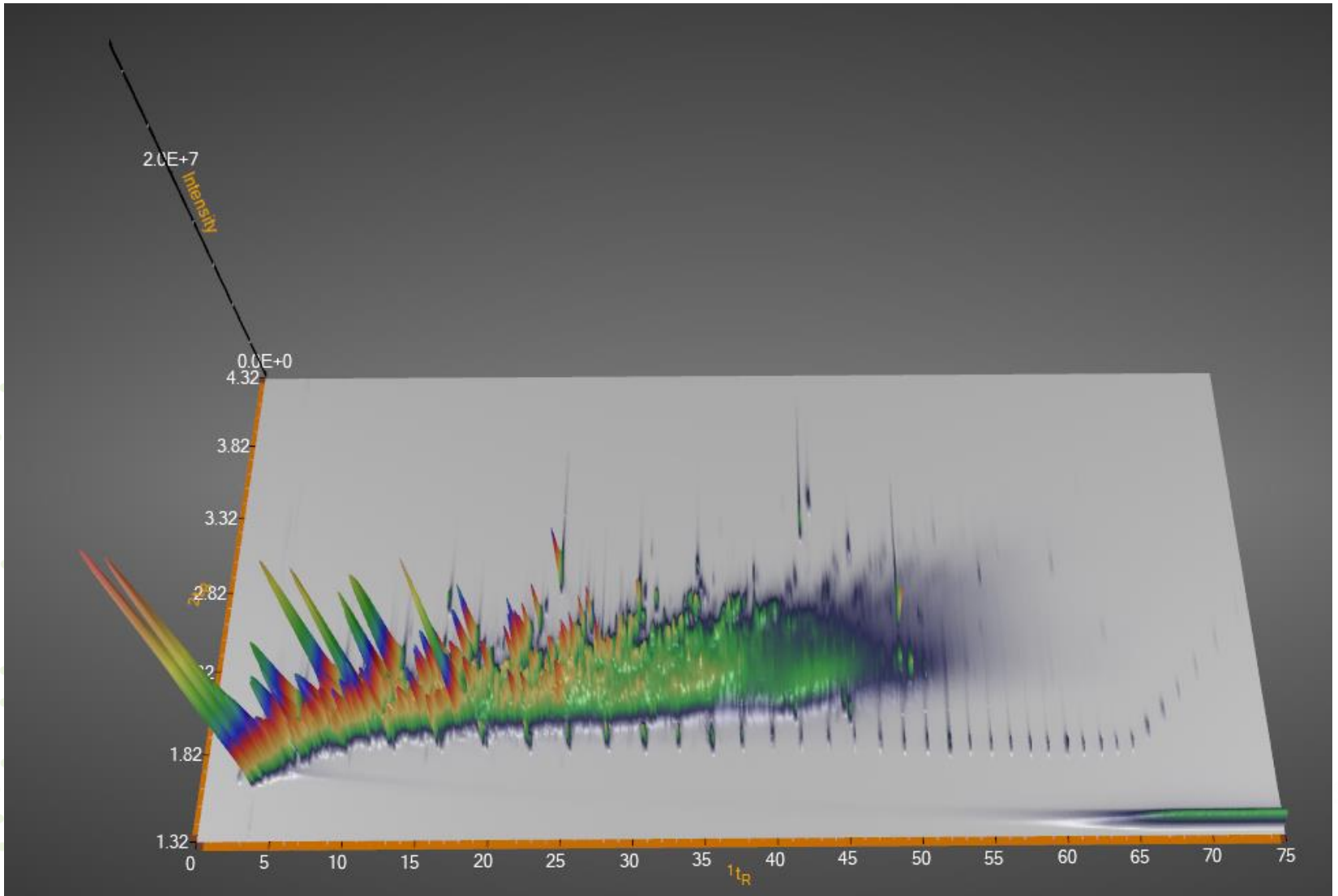
Measurements – volatile organic compounds

- Two-dimensional gas chromatography with mass spectrometry from
- INSIGHT flow modulator from SepSolve Analytical for separation
- BENCH-TOF time-of flight mass spectrometer
- OPTIC-4 sample introduction

Two-dimensional pyrolysis chromatogram



TEMS tyre emissions measurement system

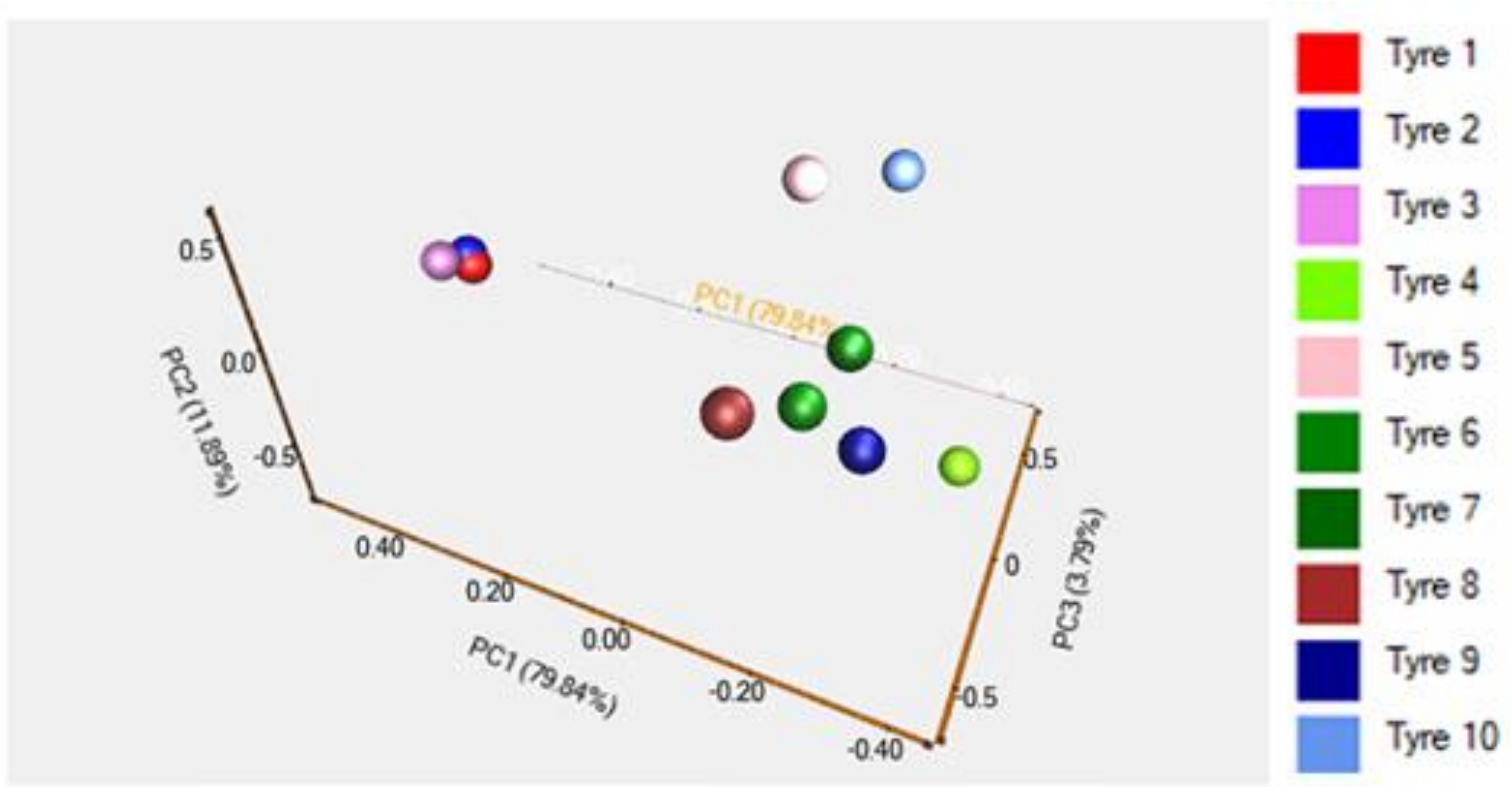
Common, prevalent compounds in tires

Compound; peak area %	Androstan-17-one, 3-ethyl-3-hydroxy-, (5α)-	Limonene	β-Guaiene	Longifolene	Ursodeoxycholic acid	Cyclohexane, 1,2,4-triethenyl-	Desogestrel	2-[4-methyl-6-(2,6,6-trimethylcyclohex-1-enyl)hexa-1,3,5-trienyl]cyclohex-1-en-1-carboxaldehyde	Doconexent
	$C_{21}H_{34}O_2$	$C_{10}H_{16}$	$C_{15}H_{24}$	$C_{15}H_{24}$	$C_{24}H_{40}O_4$	$C_{12}H_{18}$	$C_{22}H_{30}O$	$C_{23}H_{32}O$	$C_{22}H_{32}O_2$
Tyre 1	16.8	3.8	5.8	2.7	5.4	3.1	1.4	1.9	3.0
Tyre 2	17.2	5.2	4.9	2.4	5.3	2.6	0.5	2.8	4.1
Tyre 3	8.0	5.6	5.4	4.0	10.5	2.0	1.1	3.0	2.4
Tyre 4	7.7	4.9	4.3	4.4	6.7	1.4		2.3	0.6
Tyre 5	6.3	2.7	3.9	1.6		3.3	3.4		
Tyre 6	10.1	3.9	4.3	6.2	0.6	1.8	2.5	1.5	
Tyre 7	10.9	4.9	5.2	5.6		2.7	3.7	1.5	
Tyre 8	10.9	4.3	4.7	5.1	2.8	2.4	2.4	1.8	
Tyre 9	7.9	3.8	4.9	6.3	0.7	1.6	2.5	1.4	
Tyre 10		6.3				4.3			4.1
Total	95.7	45.4	43.3	38.3	32.0	25.1	17.6	16.1	14.3
Description	Unknown	terpenic pine herbal peppery	sweet woody dry guaiacwood spicy powdery	sweet woody rose medical fir needle; irritant to skin and eyes	Drug to dissolve cholesterol; irritant to skin and eyes	Eye, skin, respiratory irritant	Hormone	Unknown	Fatty acid

- Fragrances – citrus, sweet, woody, spicy
- Irritants – eyes, skin
- 2 unknowns

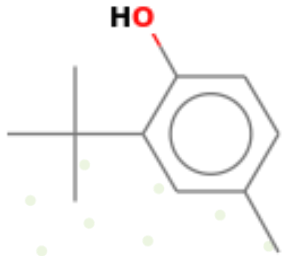
➢ Tire 10 has very different composition

Differentiation between tires



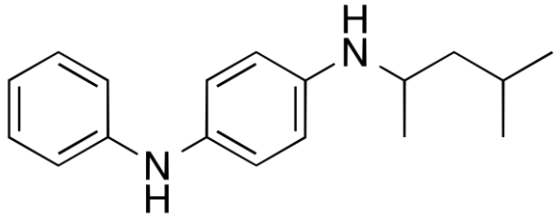
- Principal Component Analysis helps comparison of products with a large number of features
- PC1 explains 80% of differences – toluene and 1,2-pentadiene – toxic if swallowed or inhaled
- PC2 explains 12% - 2-pentene – also toxic
- PC3 explains just 4%

Notable compounds



Prevalent in Tire 8

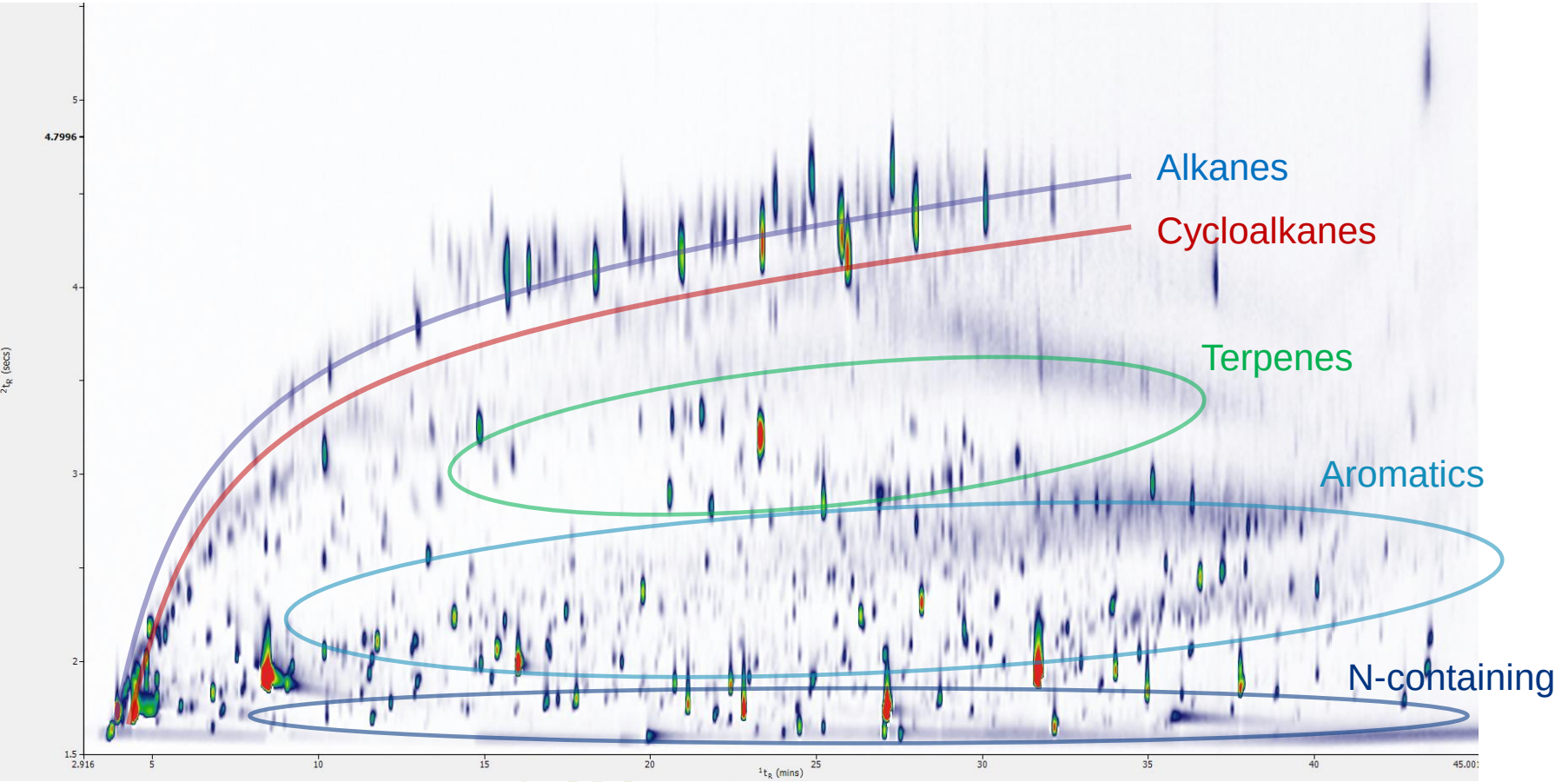
- phenol, 2-(1,1dimethylethyl)-4-methyl-
- Respiratory irritant, leathery smell



Prevalent in Tire 4, absent from Tire 5

- N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, aka 6PPD
- Preservative, reacts with ozone in the air
- 6PPD-quinone killed coho salmon in California

Functional group classification



- Wide-ranging analytes identified

- Alkanes: lungs, liver, kidney, brain
- Cycloalkanes: headaches, dizziness
- Terpenes: aromas
- Aromatics: carcinogens
- N-containing: carcinogens

Profile of functional groups

% of peak area	Alkane, Alkene, Alkyne, Cyclo, Aldehyde, Acid	Aromatics, PAH and Nitro-containing group
Tyre 1	14.8	85.2
Tyre 2	15.3	84.5
Tyre 3	16.1	83.9
Tyre 4	31.8	68.1
Tyre 5	34.8	65.2
Tyre 6	41.1	58.9
Tyre 7	43.3	56.7
Tyre 8	44.6	54.9
Tyre 9	45.2	54.8
Tyre 10	58.0	42.0
Average	**34.5**	**65.4**

- Some compounds are deliberate additions, whereas others come in component mixtures such as carbon black
- Alkanes, etc are often irritants, but toxic in high concentration
- Aromatics, etc are more often carcinogenic and toxic at lower concentrations
- Significant variation in composition between brands

Conclusion

- 64mg/km average tire wear emissions of new tires in normal driving
- Increases with vehicle weight
- Chemical composition can be studied through heating and pyrolysis
- Differentiation can be made within tires and to other non-tailpipe emissions
- Combining wear and chemistry gives speciated emissions
- Tires contains hundreds of compounds
- Wide range of environmental and health effects

Thank you.

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Emissions testing in real-world conditions brings challenges that experience anticipates and expertise overcomes. We deliver.

Independent
Objectivity and candour are the driving forces in all our work, so you know the facts.

Responsive
We're fast on our feet so we can conduct emissions testing when and where we're needed.

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