EMISSIONS ANALYTICS

Tyre emissions from battery electric vehicles

Effects on wear rates and toxicity

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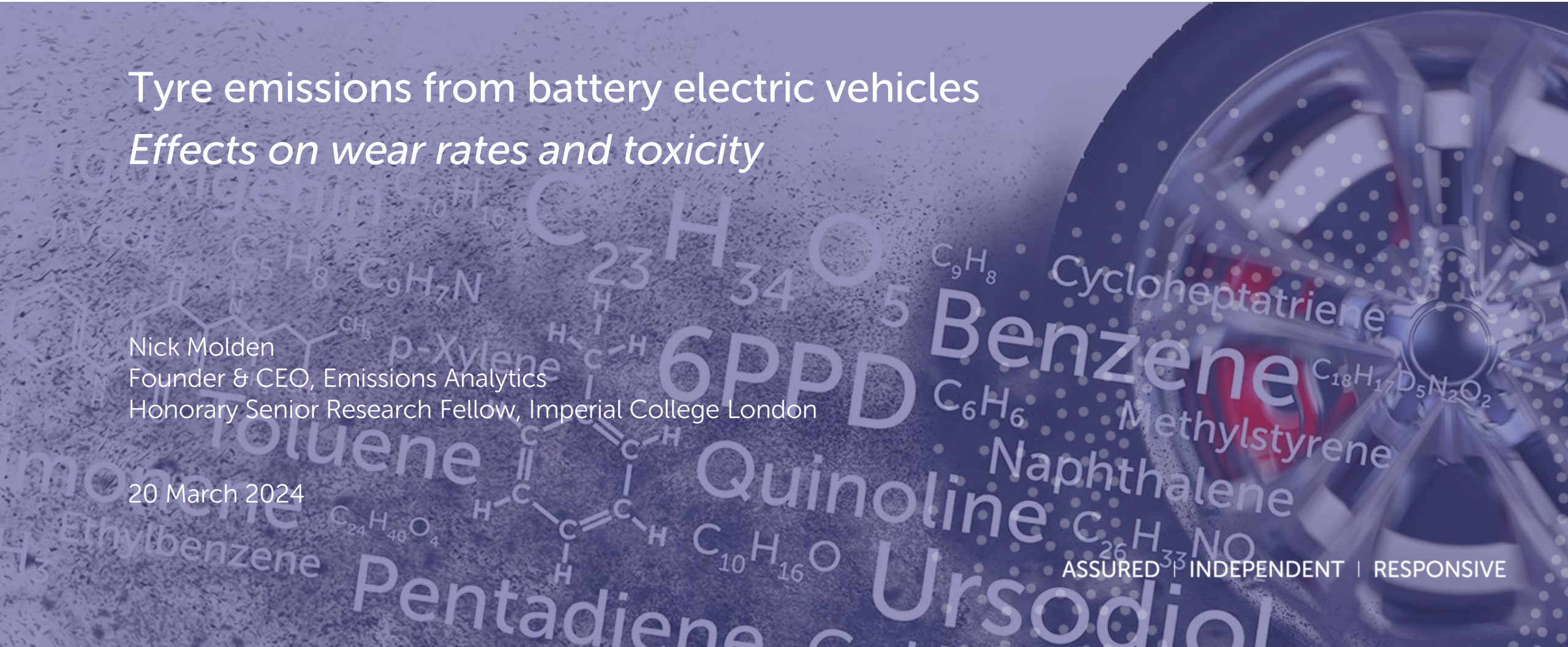
20 March 2024



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Agenda

- Defining tyre emissions
- Regulatory trends
- Experimental approach
- Are BEVs worse for tyre emissions?
- Understanding the complexities

Defining tyre emissions

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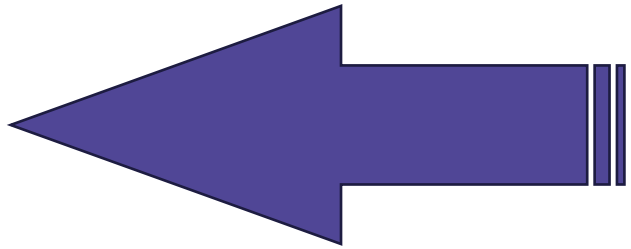
EQUA real-world test database

What are tyre emissions?

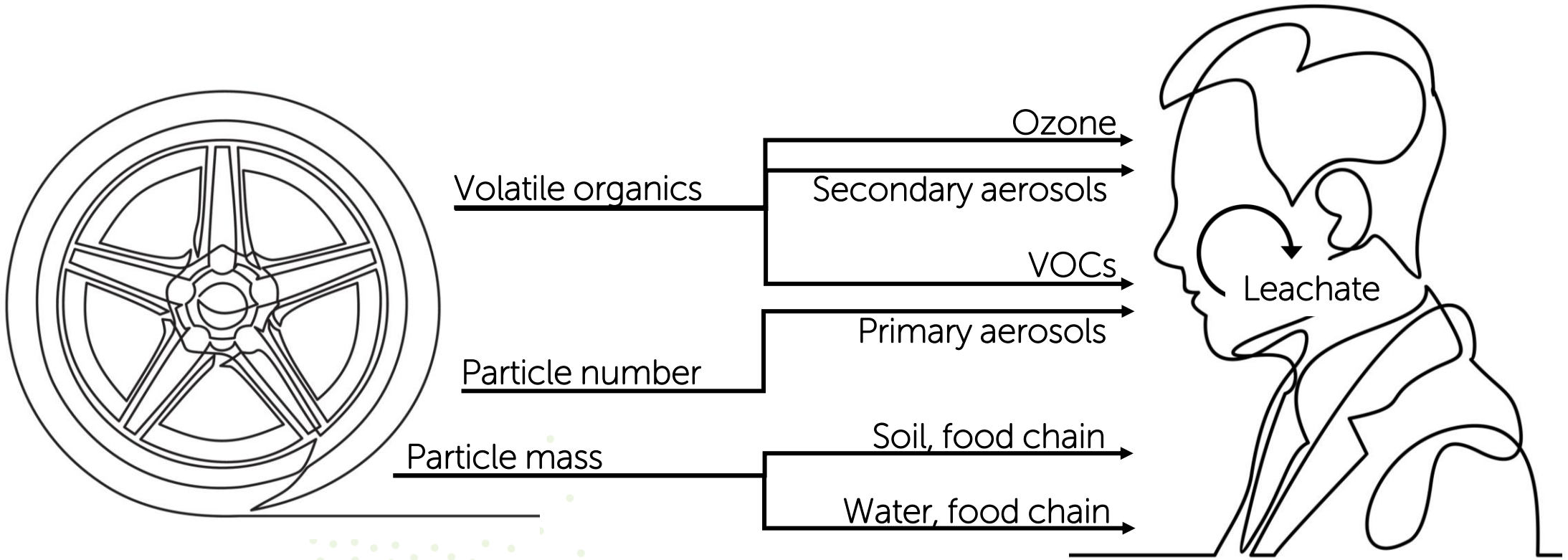
- “Sustainability”: reducing carbon emissions during production
- Alternative materials

- In-use pollution
- Larger and nano-particles
- Off-gassing volatile organics

- End-of-life tyres and recycling
- Rubber crumb
- Fuel source



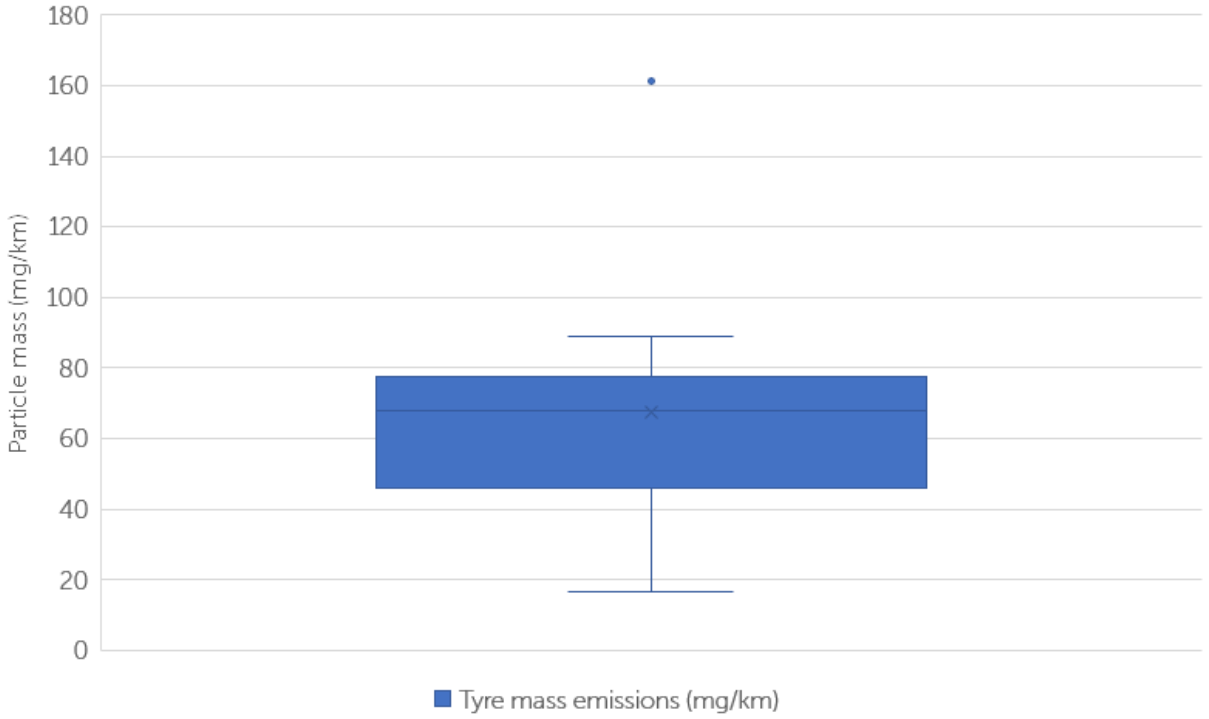
Vectors



Tyre mass emissions

- 18 different models of tyre
- Tested from new
- Public highway
- Majority motorway by distance
- Average total distance ~5,000 km

- 67 mg/km mean
- Inter-quartile range: 46-77 mg/km
- Outliers
- Suggests limit value ~80 mg/km

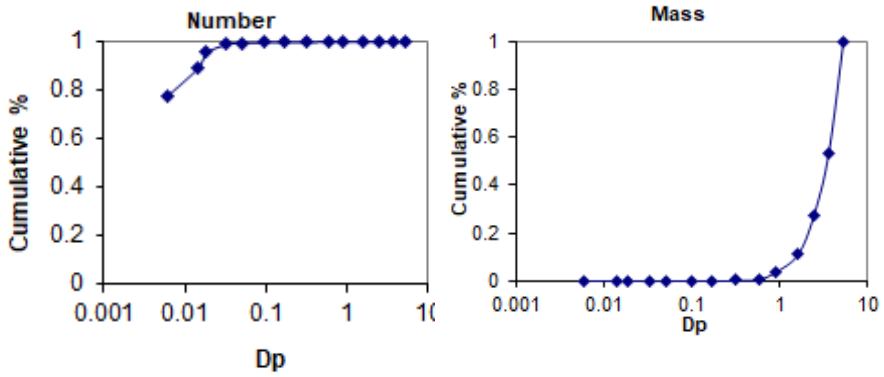


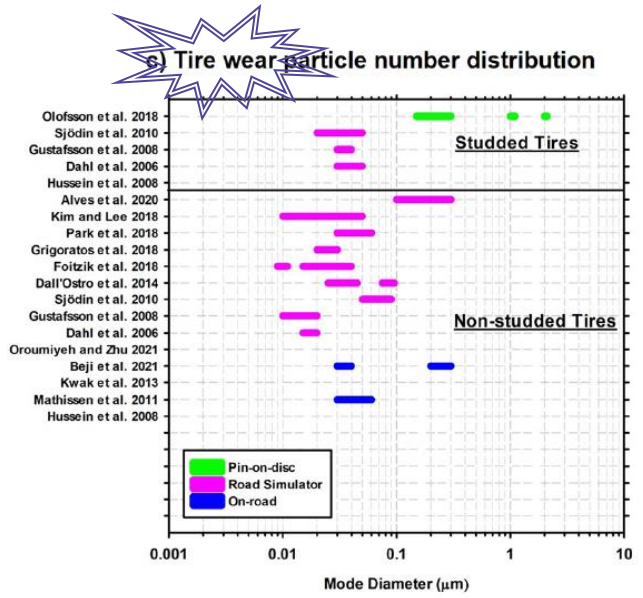
BTAS brake and tyres analysis system

Ultrafine particles from tyres

- On-road test with ‘normal’ dynamics
- 11% of PM10 is below 2.5 µm diameter
- Ultrafines account for 92% by number
- But what interference from road wear, resuspended material and brake wear? Currently unknown in real-world testing
- Then add in secondary organic aerosols
- Absolute PM10 and PM2.5 emissions factors have high uncertainty

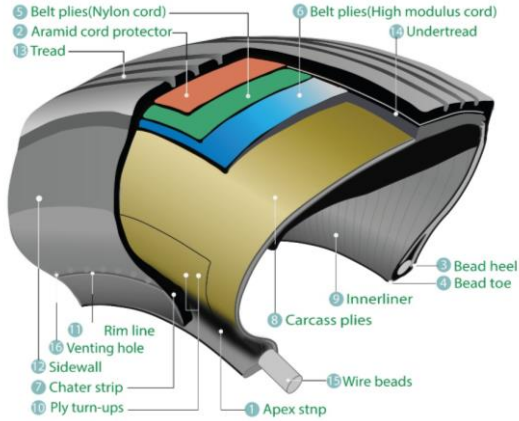
➢ Tyres are simultaneously a problem for air, soil and water

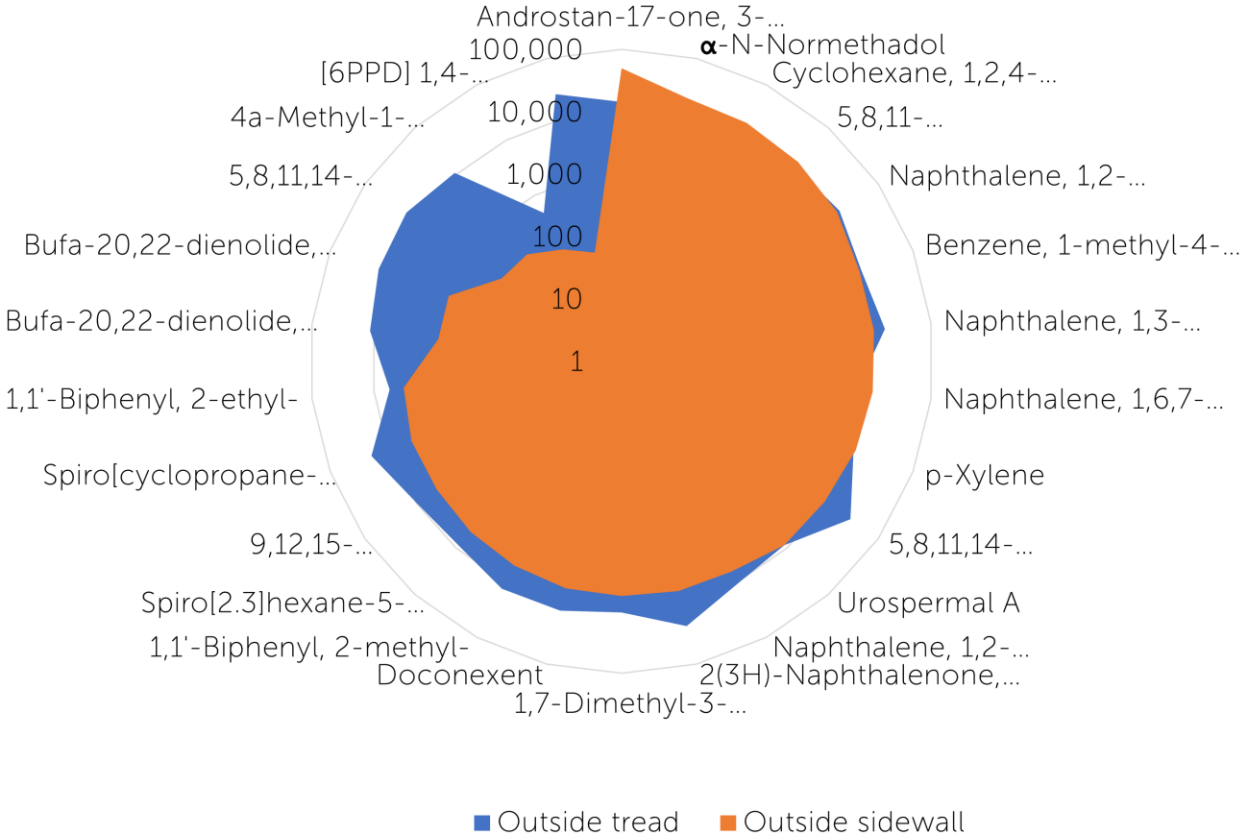




Secondary pollutants

- Secondary organic aerosol formation from off-gassed VOCs reacting in air
- Mainly from tyre sidewall, which can be different chemical composition from tread
- SOA Yield of 4.01 µg/m^3 from toluene in recent research in Shanghai
- Plus ozone formation potential of around x3





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Regulatory trends

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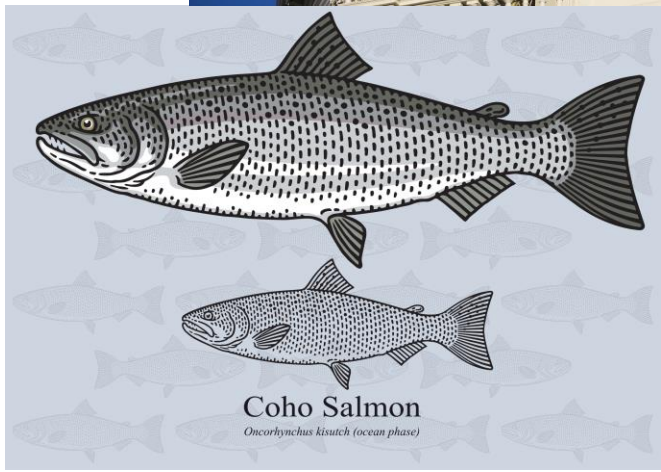
Emerging regulation – EU

- “Euro 7” proposes to set limit values for distance-specific mass emissions
- More details required on how this would be enforced for replacement tyres
- Test method being developed by Task Force on Tyre Abrasion at UNECE
- Likely introduction in 2028/9
- Not fully approved yet, but passed trialogue
- Conceptual issues such as inclusion of ice tyres
- Major potential loophole if limit value set on mg/km per tonne basis

- REACH already limits 8 polycyclic aromatic hydrocarbons

Emerging regulation – US (1)

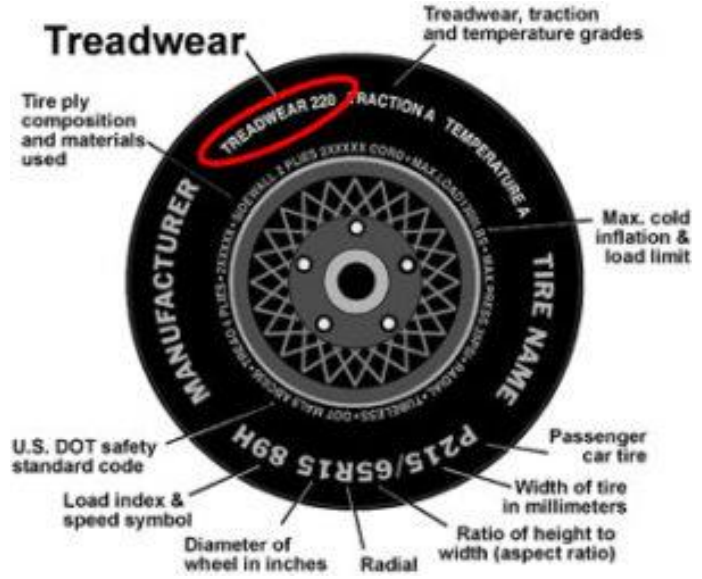
- California 6PPD rule introduced in 2023
- To address mass die-off of coho salmon (https://www.emissionsanalytics.com/news/fishy)
- Forces tyre manufacturers to investigate alternatives to 6PPD
- Or remove from sale
- Accelerated timeline – November 2023
- One-off review only



- Other West Coast states planning to follow, with more prescriptive direction

Emerging regulation – US (2)

- California replacement tyre rule is…
- "…designed to ensure that tires sold in the state are at least as energy efficient, on average, as tires sold in the state as original equipment on new passenger cars and light-duty trucks."
- Replacement tyres currently have 21% greater rolling resistance than new, original tyres
- 5* rating system – by manufacturers, for use at point of sale
- Must not affect safety, durability and end-of-life
- Maximum rolling resistance coefficient of 9.0 from 2026
- Falling to 7.0 from 2028



Experimental approach

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Concept

Tyre wear rate

x

Chemical speciation

x

Compound hazard

=

Potential environmental impact

On-vehicle sampling – principles

- Universal fitment across vehicles
- Fits to any and all wheels on a vehicle
- No vehicle modification required
- Articulates as the vehicle steers
- Safe and road-legal
- Can be coupled with any detector
- And collecting plates/receptacle
- Published patent PCT/GB2023/051826

➢ Mass, number and physical collection

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Chemical fingerprinting

- Two-dimensional gas chromatography with mass spectrometry
- INSIGHT flow modulator from SepSolve Analytical for separation
- BENCH-TOF time-of flight mass spectrometer
- Multi-stage pyrolysis method

Hazards

Hazard code	Description
H300	Fatal if swallowed
H301	Toxic if swallowed
H302	Harmful if swallowed
H303	May be harmful if swallowed
H304	May be fatal if swallowed and enters airways
H305	May be harmful if swallowed and enters airways

- Globally Harmonized System of Classification and Labelling of Chemicals (GHS) – United Nations' standardised system
- Compounds identified CAS Registry Number, unique identifier assigned by US Chemical Abstracts Service
- European Chemicals Agency database of manufacturer disclosures
- 'Hazard codes' describe different effects, from irritants to carcinogens
- Each compound can have multiple hazard codes
- Which can be weighted together using a severity index

$$\text{Overall toxicity factor} = \sum_{i=1}^{n} \text{Number of hazard codes}_i \times \text{Compound concentration in sample } (\mu g/mg)_i$$

BEVs and trade-offs

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EQUA real-world test database

No consensus…

nokian TYRES | TYRES | INNOVATION | CONSUMER PROMISES | COMPANY

Previous page

THU NOVEMBER 21 09:33 AM 2019 IN CATEGORIES PRODUCT NEWS, COMPANY NEWS

THERE IS A COMMON MISCONCEPTION RELATED TO ELECTRIC CARS – IN REALITY, TIRES WILL LAST FOR A LONG TIME

FleetLogistics

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Electric cars heavier on tyres than ICE equivalents

Sustainability

23.02.2023

There is now a wealth of empirical evidence that e
ICE equivalents due to the extra weight, a factor th
when assessing SMR budgets.

Compared to internal combustion cars, electric ve
emissions, and better maintenance and running c
switching to an EV is a significant increase in weigh
places additional strain on electric car tyres.

Electric cars accelerate quicker than petrol or dies
additional strain on tyres - so the advice is to acce

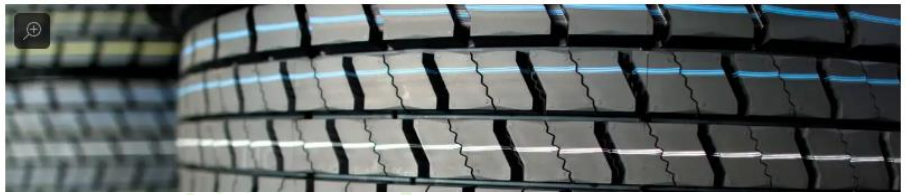
So, what's the verdict?

It seems, then, that electric vehicle tyres do actually last longer on paper. But this result comes with a caveat. Not only are electric vehicle tyres much more expensive, but the actual rate of tyre wear has a lot more to do with the driver than the tyre itself.

Florida Drivers Discover Hard Truth About EVs: They Eat Tires

Some EV owners in the Sunshine State are reporting having to buy tires after just 5,000 to 7,000 miles of driving.

By **Lawrence Hodge** Published January 25, 2024 | Comments (295)



TIRE AND ROAD WEAR PARTICLES – NOVEMBER 19, 2021

MICHELIN

ELECTRICAL VEHICLES IMPACT

- We will see an acceleration of the transition from ICE to electrical vehicles
- An electrical vehicle could generate 10 to 20% more tire and road wear particles due to its weight

BTAS brake and tyres analysis system

Do BEVs have higher tyre wear? (1)

- Add more weight to the same car and drive it in the same, normal way
- +30% vehicle mass ⇒ +21% wear
- Due to very low tailpipe pollution on modern cars, tyre emissions could be x1,850 higher
- https://www.emissionsanalytics.com/news/gaining-traction-losing-tread

Do BEVs have higher tyre wear? (2)

- With the extra payload, drive as aggressively as possible within the law
- Wear x160
- Tyre emissions could be x1,000 the maximum permissible at the tailpipe
- https://www.emissionsanalytics.com/news/2020/1/28/tyres-not-tailpipe

Do BEVs have higher tyre wear? (3)

- Choose a pair of equivalent vehicles and drive in convoy
- +32% vehicle mass ⇒ +26% wear
- https://www.emissionsanalytics.com/news/do-no-harm
- But, should the equivalence be on payload, power, maximum speed, cost, or something else? Factor in regenerative braking or not? Torque control?

How can this all be true?

- Real-world observations of tyre wear do have a large spread
- BEVs do not systematically have the highest emissions

➢ Emissions are more sensitive to driving style differences than on ICE vehicles
➢ Choosing the right comparators is challenging and subjective
➢ Regenerative braking and torque limitation technology can reduce the gap
➢ BEV tyre choice can offset additional wear through design and composition

- Even so, BEV tyres have to withstand higher loads and are bigger

Trade-offs: higher loads require bigger tyres

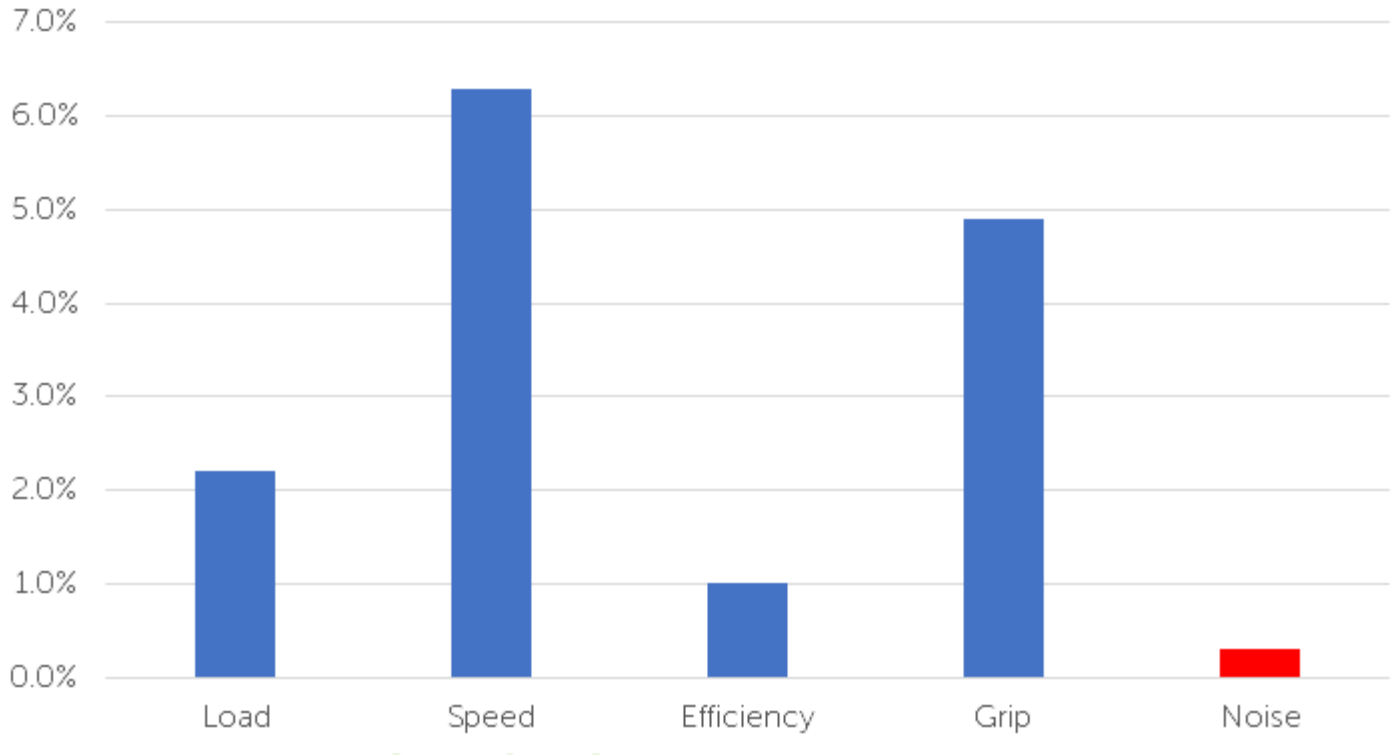
Each extra 100 kg of passenger car kerb weight leads on average to…

- 4.8mm extra width (+2%)
- 0.27″ extra rim size (+2%)
- Slightly lower profile – aspect ratio
- 0.032 m^2 surface area (+4%)

Leading to extra tyre emissions…

- 2.2 mg/km mass wear (+3%)
- 2.8 µg/hour off-gassing VOCs (+4%)

Trade-offs: bigger tyres have better performance...

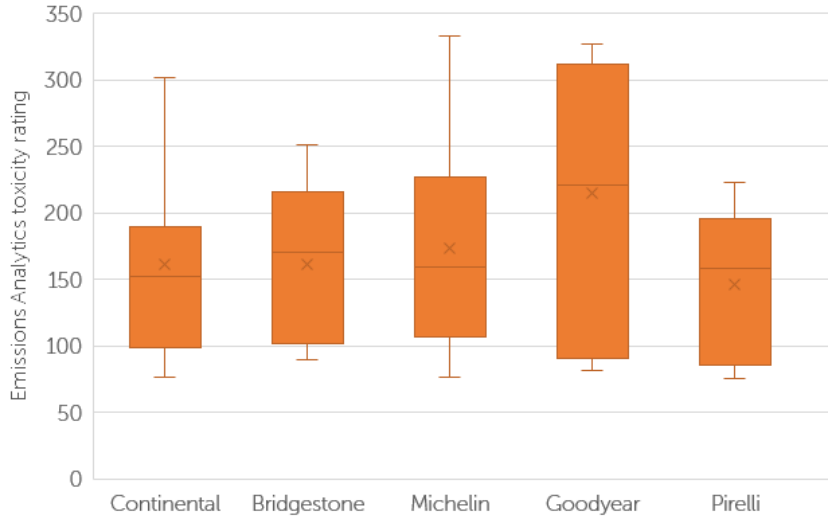


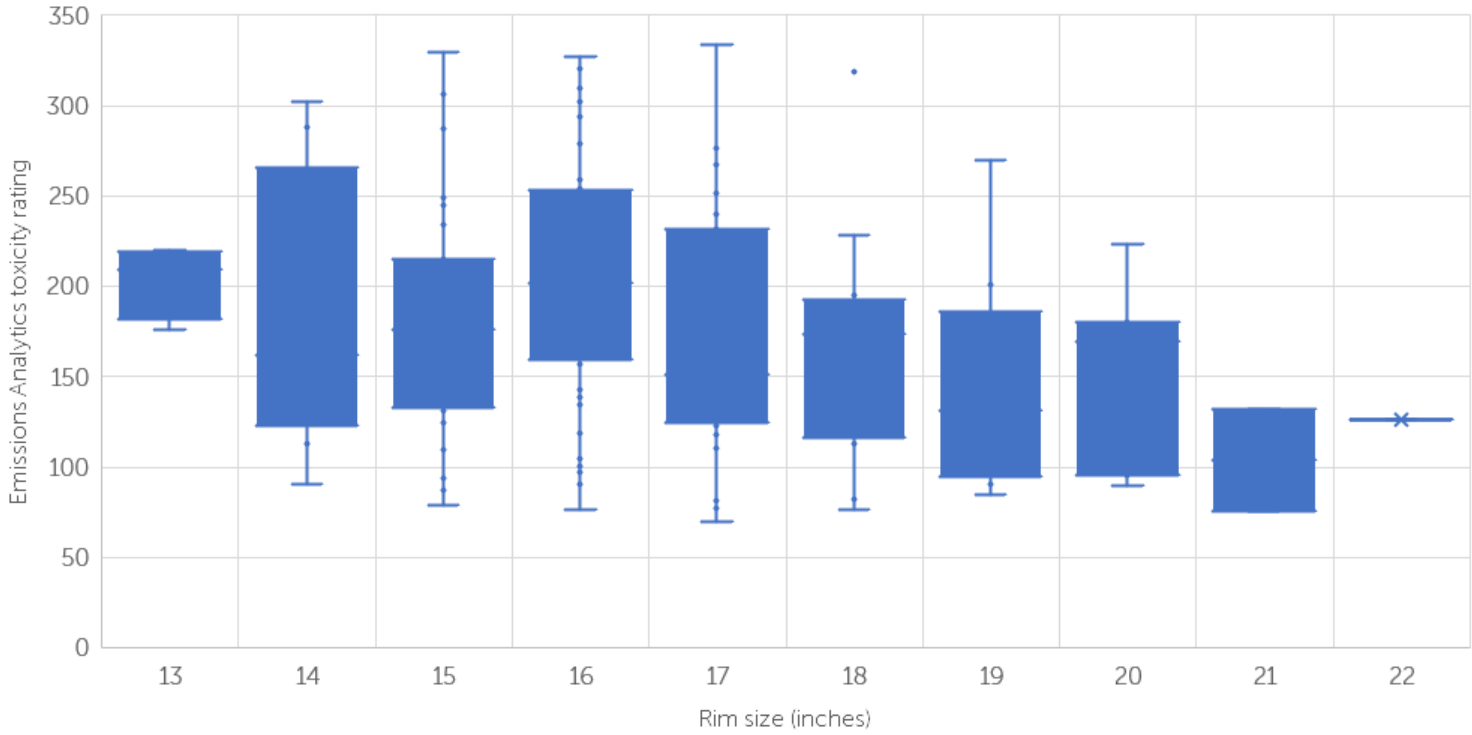
Almost a Pareto improvement, but...

- Slightly worse noise
- Cost premium
- Toxicity?

Trade-offs: ...and reduce toxicity

- 4.3% lower potential toxicity, on Emissions Analytics' normalised scale
- 9.5% lower aromatics concentrations
- But significant variation between makes and models

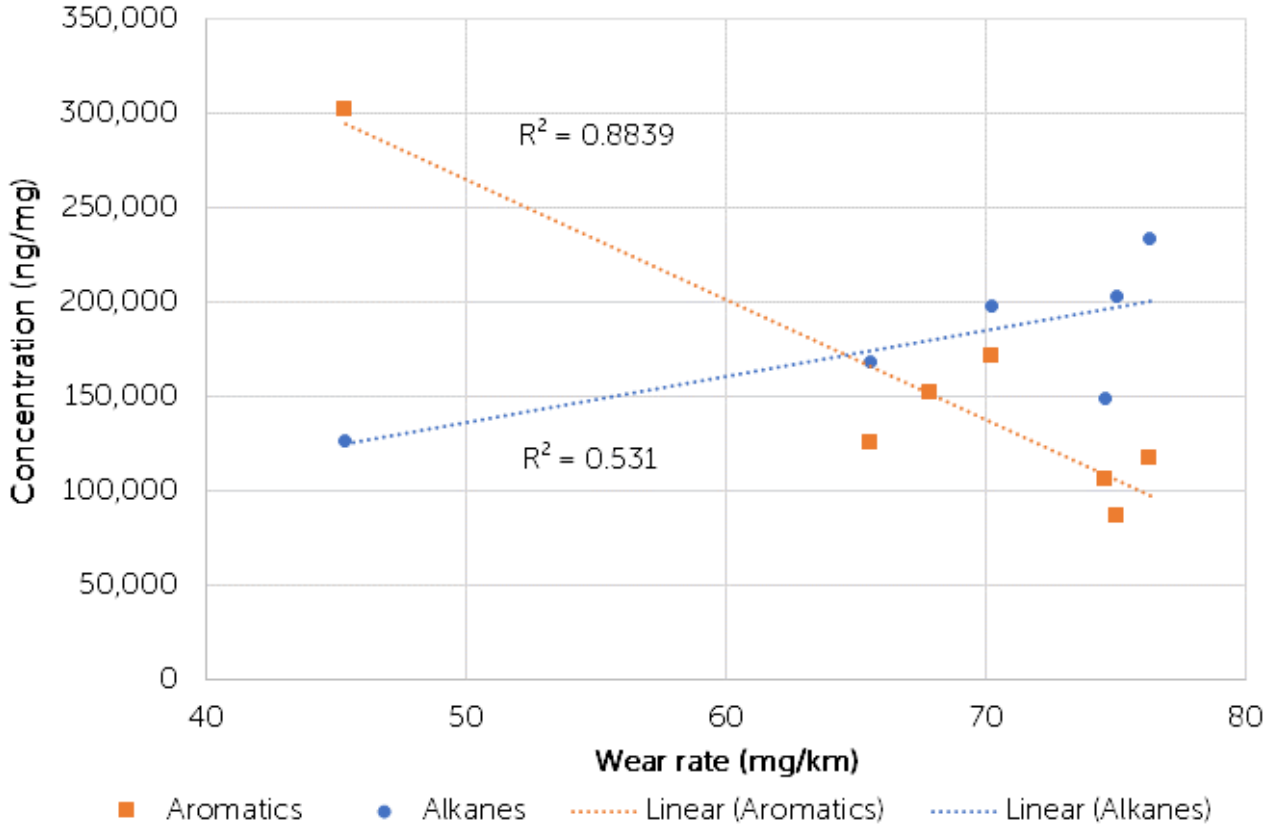




BTAS brake and tyres analysis system

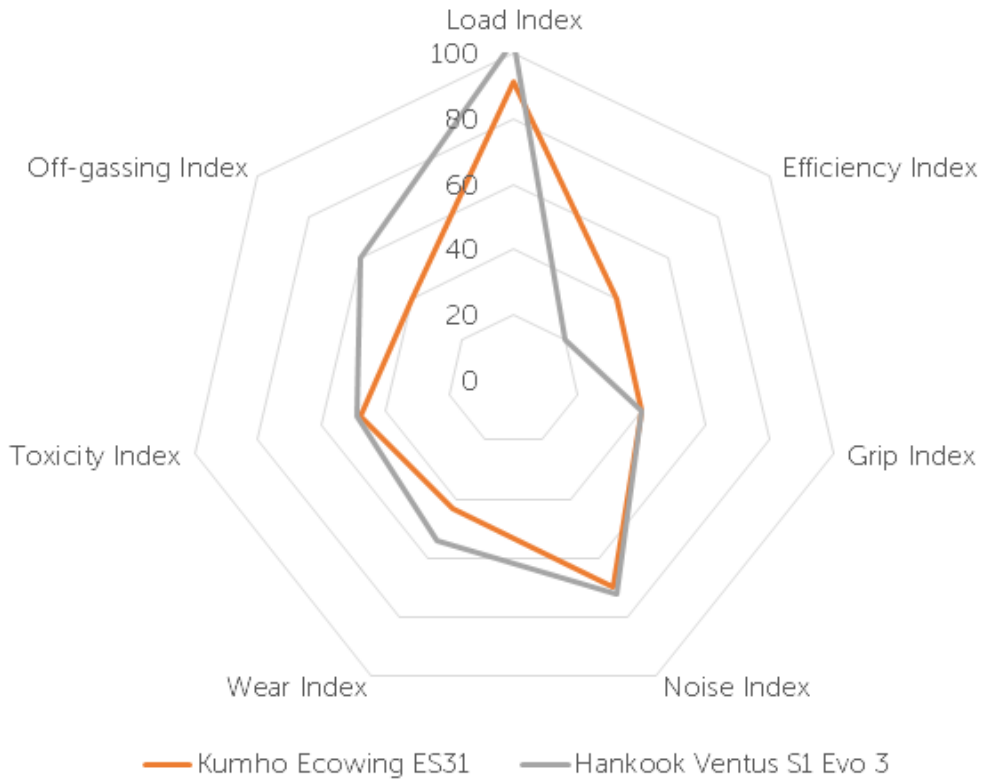
Complexities of chemical formulations

- Aromatics facilitate the processing of rubber compounds
- Add to grip performance
- Regulated PAHs are a subset of this group
- Evidence that higher wear rates are correlated with lower aromatics and higher alkane concentrations



Ratings

- 7 dimensions
- Load index, related to…
- 3 performance criteria
- 3 pollutants
- Smaller values are better



- ➢ Added load required for Hankook on Tesla Y leads to worse emissions in all dimensions
- ➢ And noisier, but more efficient

Conclusion and the future

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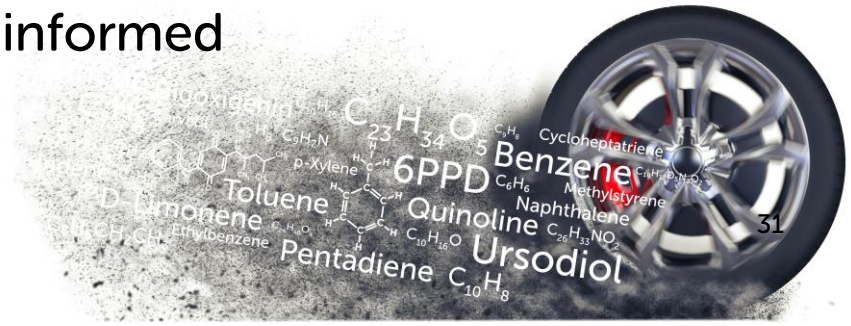
Omnipresence of tyre wear emissions

- 6 million tonnes of tyre wear globally per year
- Or 1-4 kg per car per year
- Excluding 1-2 billion end-of-life tyres per year
- Larger particles wash into the drainage system
- Fine particles settle on soil close to roadway
- Ultrafine particles are airborne before eventually settling
- Multiple vectors for human inhalation or ingestion
- 135 ng of 6PPD and 6PPD-quinone in urine of average adult per day

Key messages

- Tyre emissions problem is more complex and significant than previously thought
- It affects vehicles of all types, not just BEVs
- But BEVs do have higher emissions on average on a like-for-like basis, but the real world is rarely like-for-like
- High variability in chemical composition between brands and models of tyre
- Current BEV tyres tend to be higher wearing but less toxic – and at a price
- While US regulations are targeting certain chemicals, Euro 7 may incentivise heavy vehicles and compounds with higher aromatics

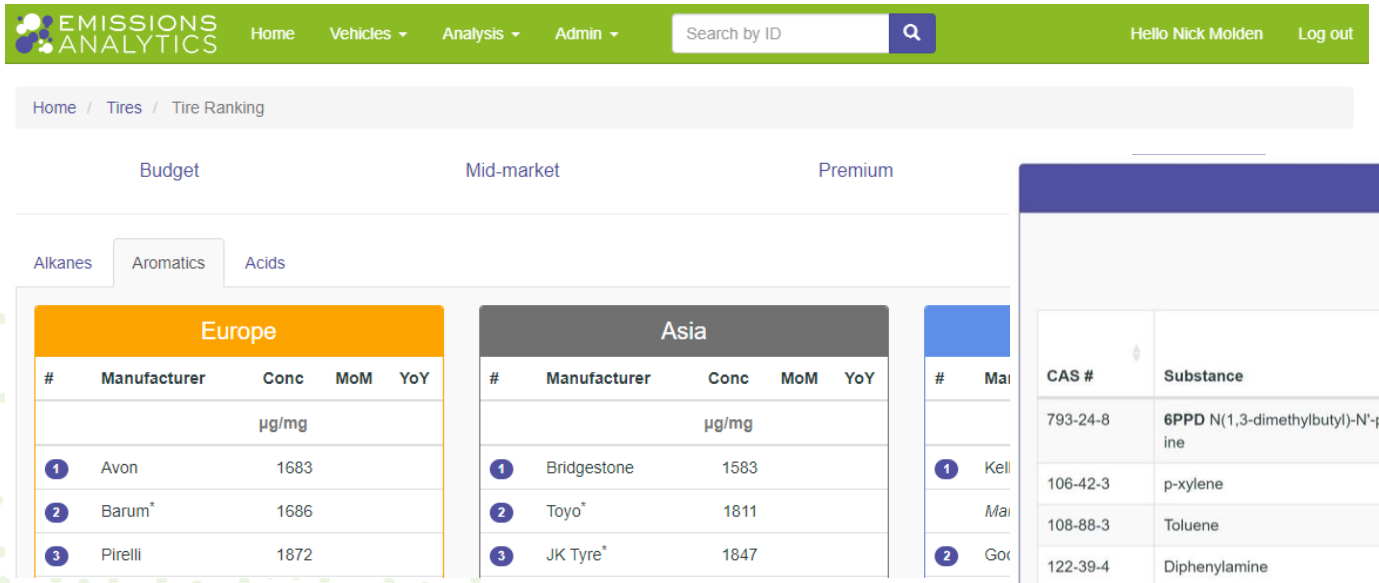
➢ Developing regulation must be holistic, and empirically informed

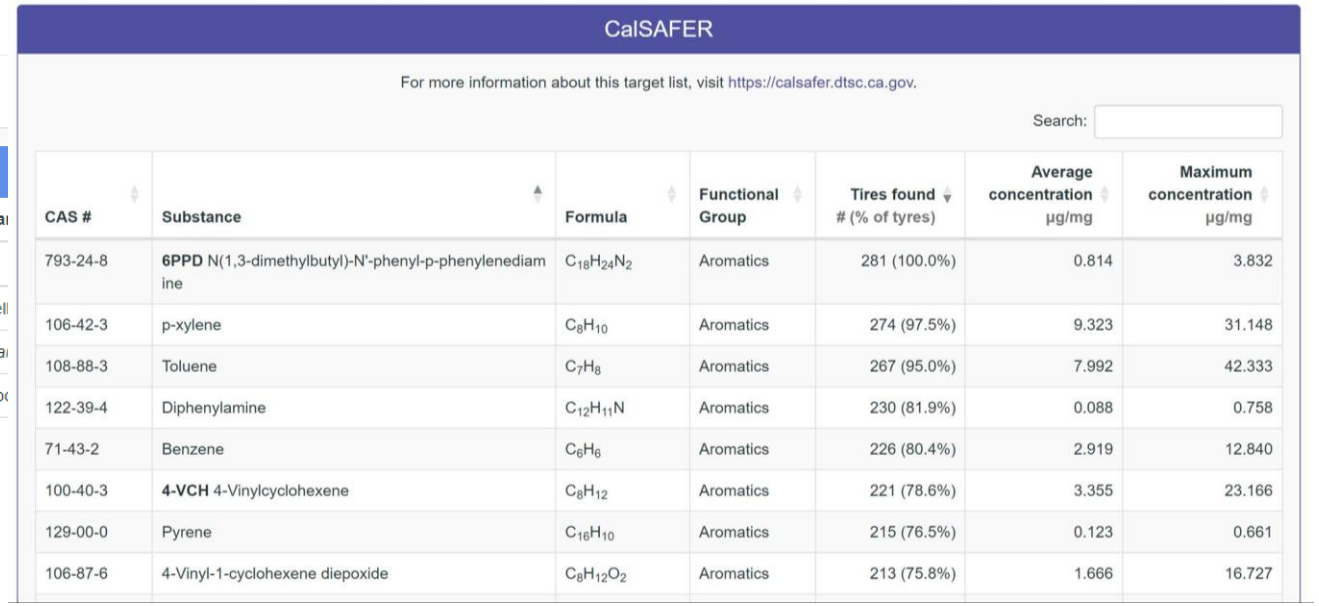


Tyre Emissions Research Consortium

https://www.linkedin.com/company/tyre-emissions-research-consortium

Subscription database





CalSAFER

For more information about this target list, visit https://calsafer.dtsc.ca.gov.

Search:

CAS #	Substance	Formula	Functional Group	Tires found # (% of tyres)	Average concentration µg/mg	Maximum concentration µg/mg
793-24-8	**6PPD** N(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine	$C_{18}H_{24}N_2$	Aromatics	281 (100.0%)	0.814	3.832
106-42-3	p-xylene	C_8H_{10}	Aromatics	274 (97.5%)	9.323	31.148
108-88-3	Toluene	C_7H_8	Aromatics	267 (95.0%)	7.992	42.333
122-39-4	Diphenylamine	$C_{12}H_{11}N$	Aromatics	230 (81.9%)	0.088	0.758
71-43-2	Benzene	C_6H_6	Aromatics	226 (80.4%)	2.919	12.840
100-40-3	**4-VCH** 4-Vinylcyclohexene	C_8H_{12}	Aromatics	221 (78.6%)	3.355	23.166
129-00-0	Pyrene	$C_{16}H_{10}$	Aromatics	215 (76.5%)	0.123	0.661
106-87-6	4-Vinyl-1-cyclohexene diepoxide	$C_8H_{12}O_2$	Aromatics	213 (75.8%)	1.666	16.727

- Substances of concern tracking
- For benchmarking, research and development

Thank you.

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