



IAS – Società Italiana di Aerosol  
PM2024 – Torino, 28-21 maggio

## Valutazione chimico-fisica del rilascio di PM10 e PM2.5 dalle pastiglie dei freni con test dinamometrico WLTP-Euro7

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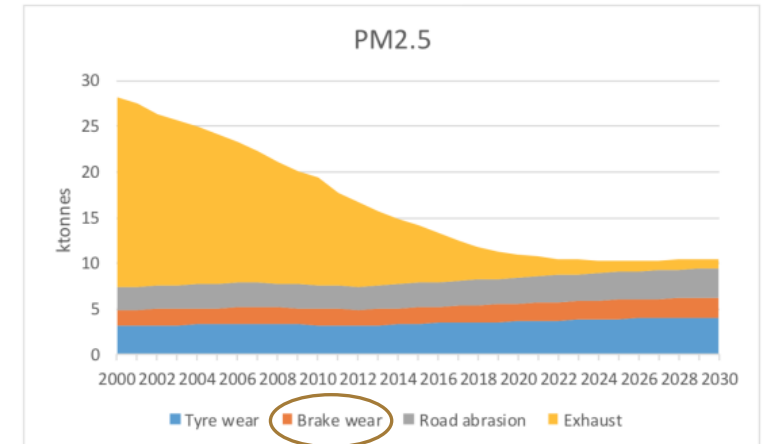
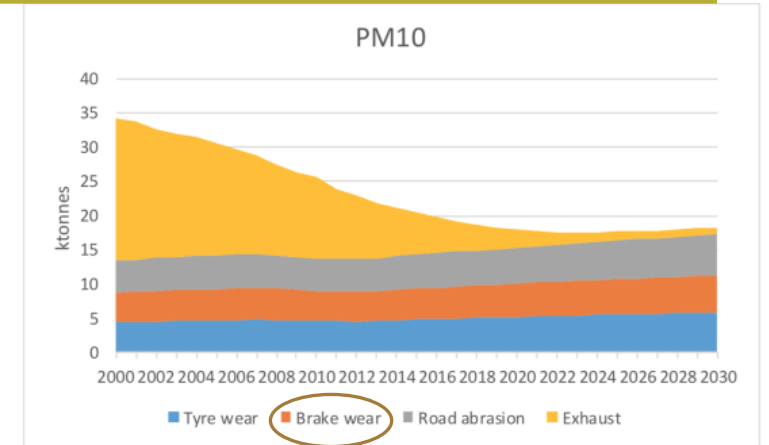
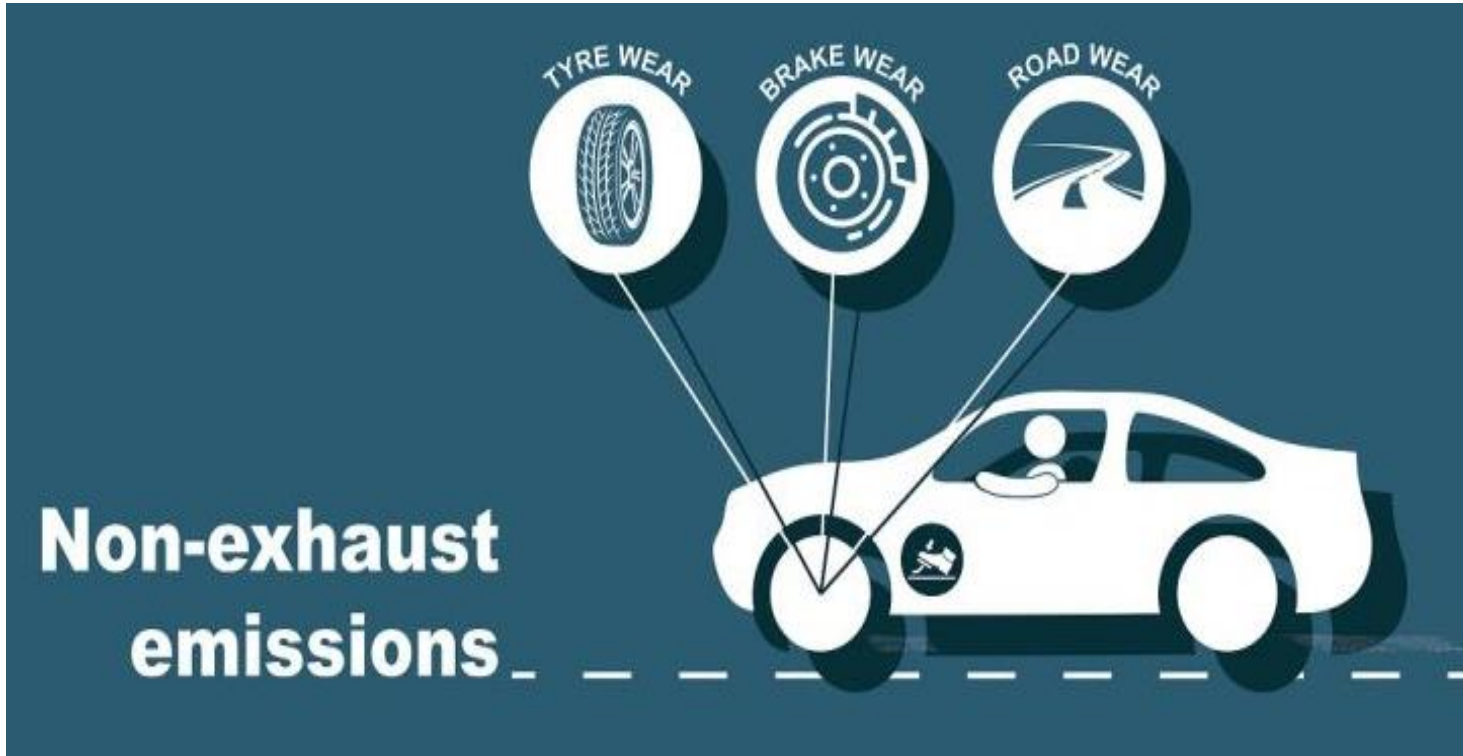


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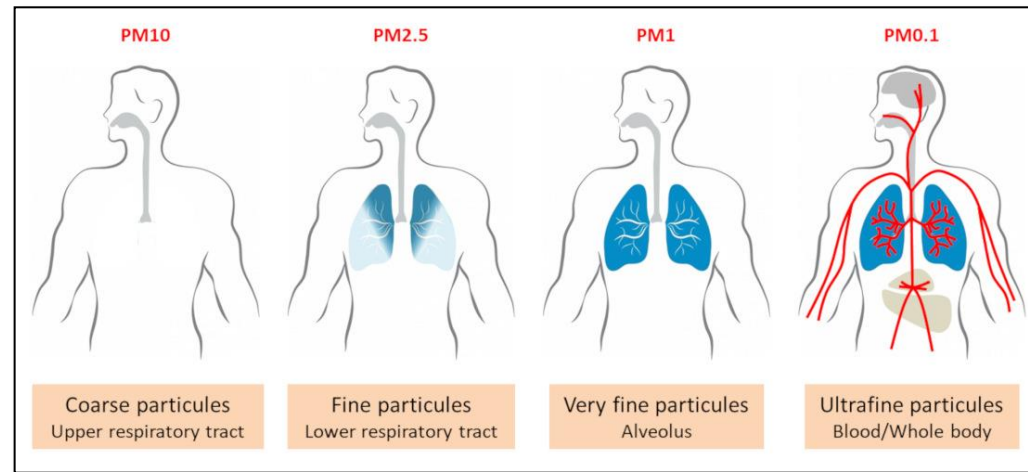
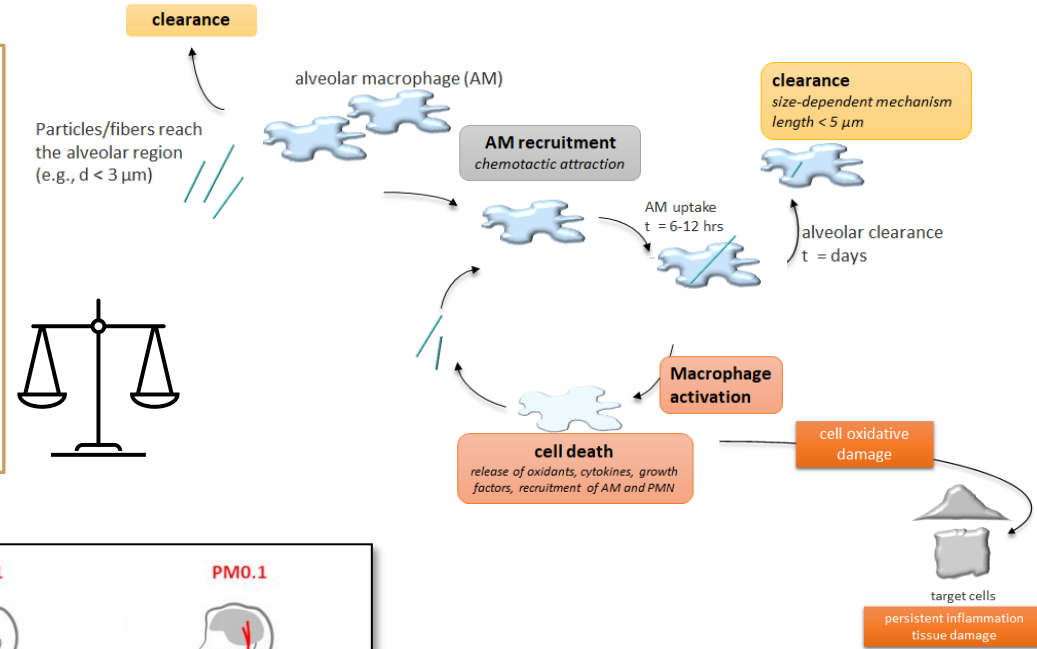
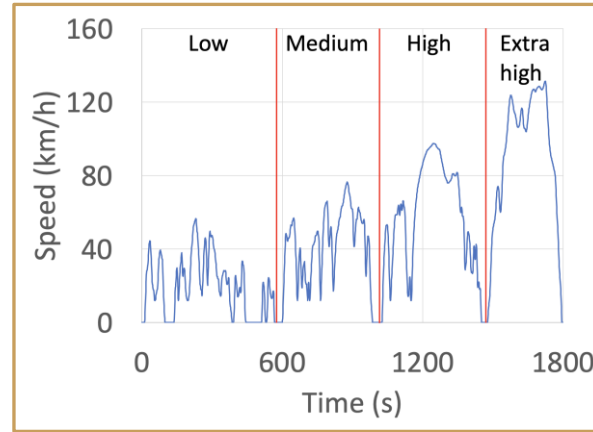
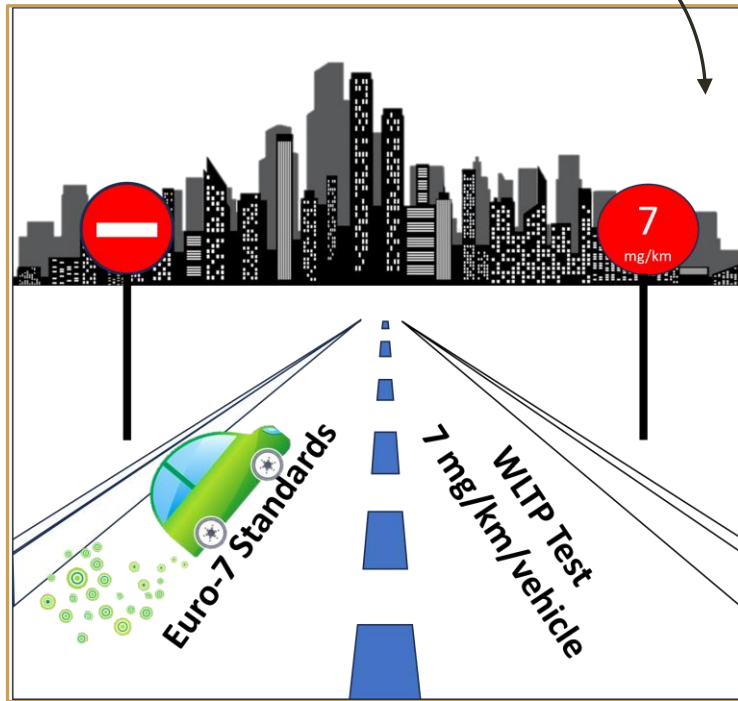


# BACKGROUND: NON-EXHAUST EMISSIONS

UK emissions of PM<sub>10</sub> (top) and PM<sub>2.5</sub> (bottom) from road transport.

# Background

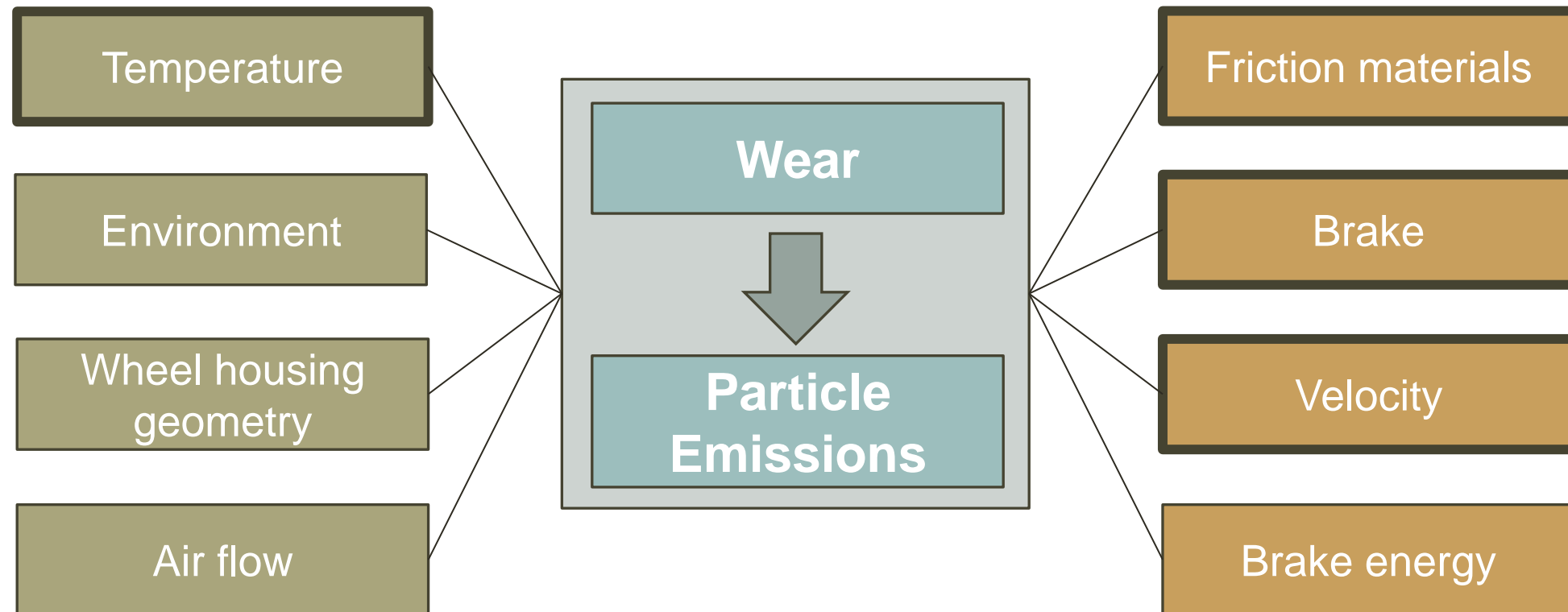
## WLTP-Brake Test



- PM Count
- Size and shape
- Chemical composition

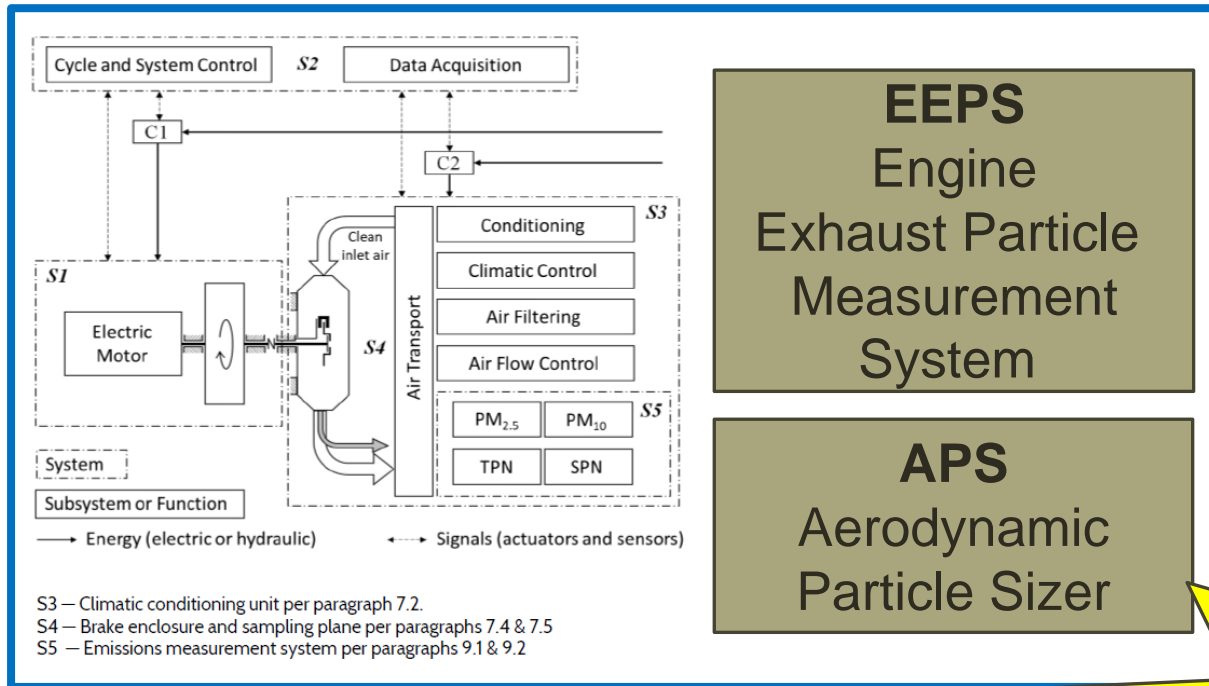
# Background

Analysis of influencing factors on brake wear and non-exhaust emission with reference to applied materials in brake pads



# How to do that...

## WLTP-brake dynamometric test + PM collection

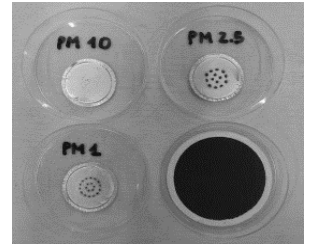


**EEPS**  
Engine Exhaust Particle Measurement System

**APS**  
Aerodynamic Particle Sizer

1

Analysis on PM  
Collection and characterisation of PM10 & PM2.5



2

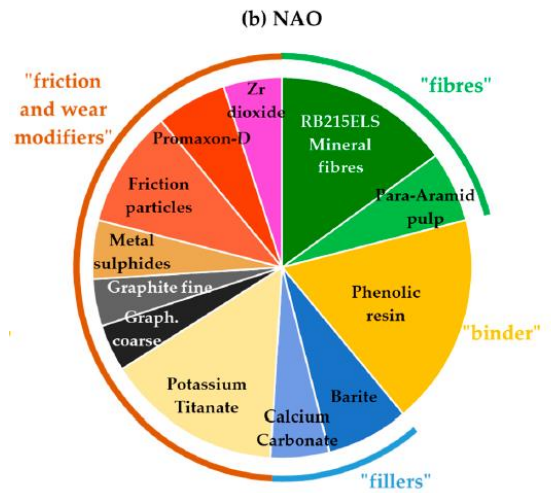
Analysis on powders

Scratch the surface after dyno test

Pad surface characterisation through chemical analysis

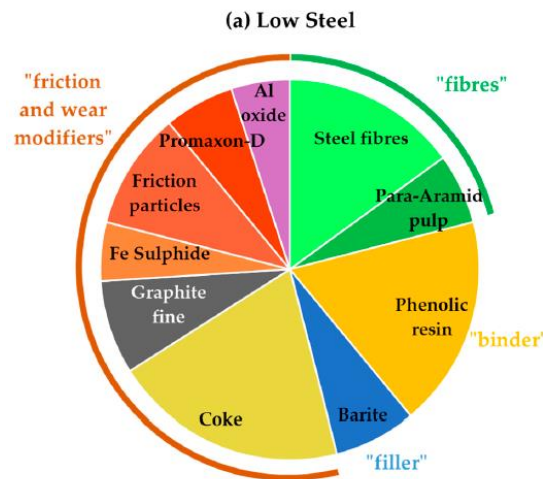
Scanning electron microscope  
**SEM-EDS**

# Brake Pads Samples



**NAO**  
Non-Asbestos Organic

→ Metal free



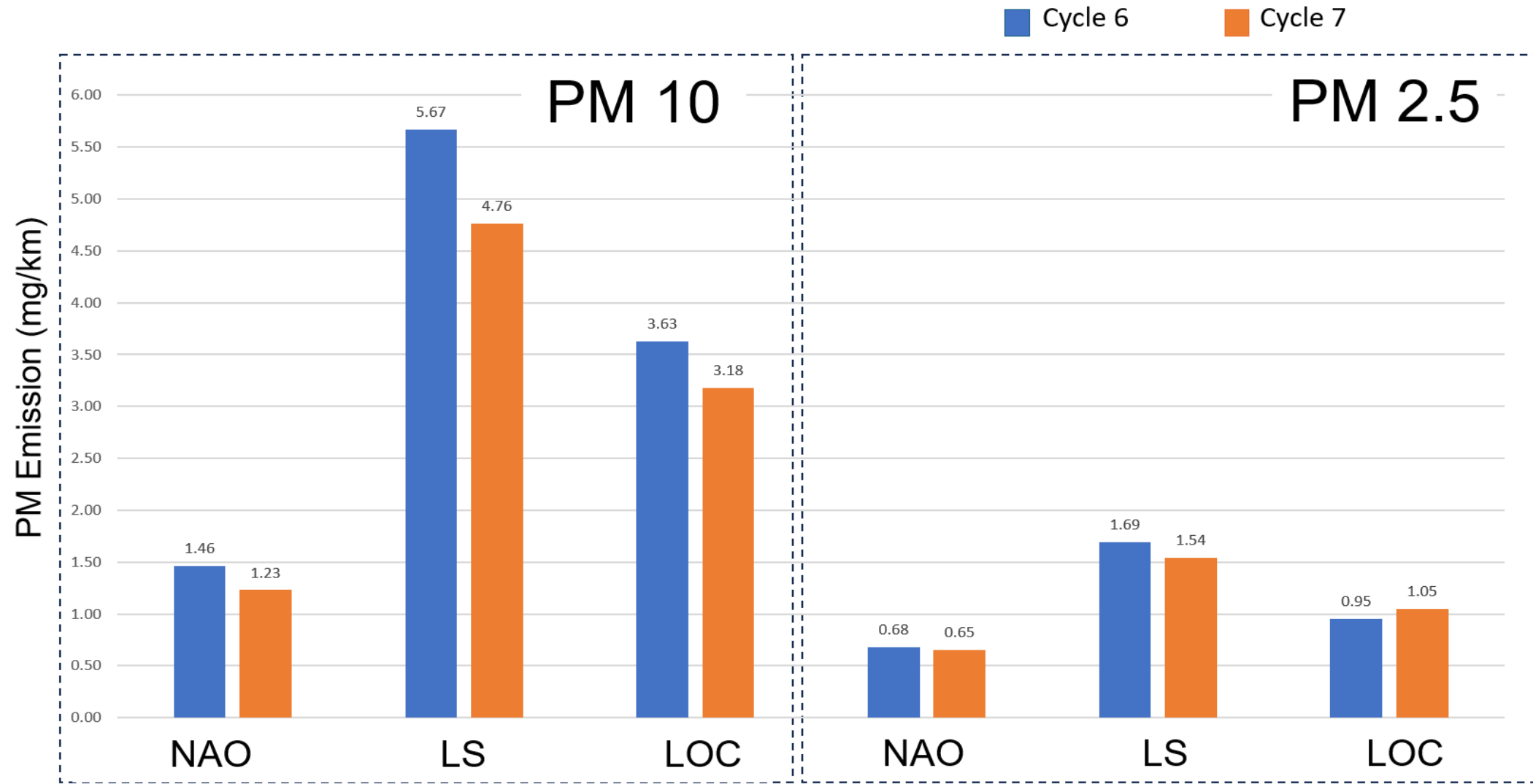
**LS**  
Low Steel

**LOC**  
LS with low organic content

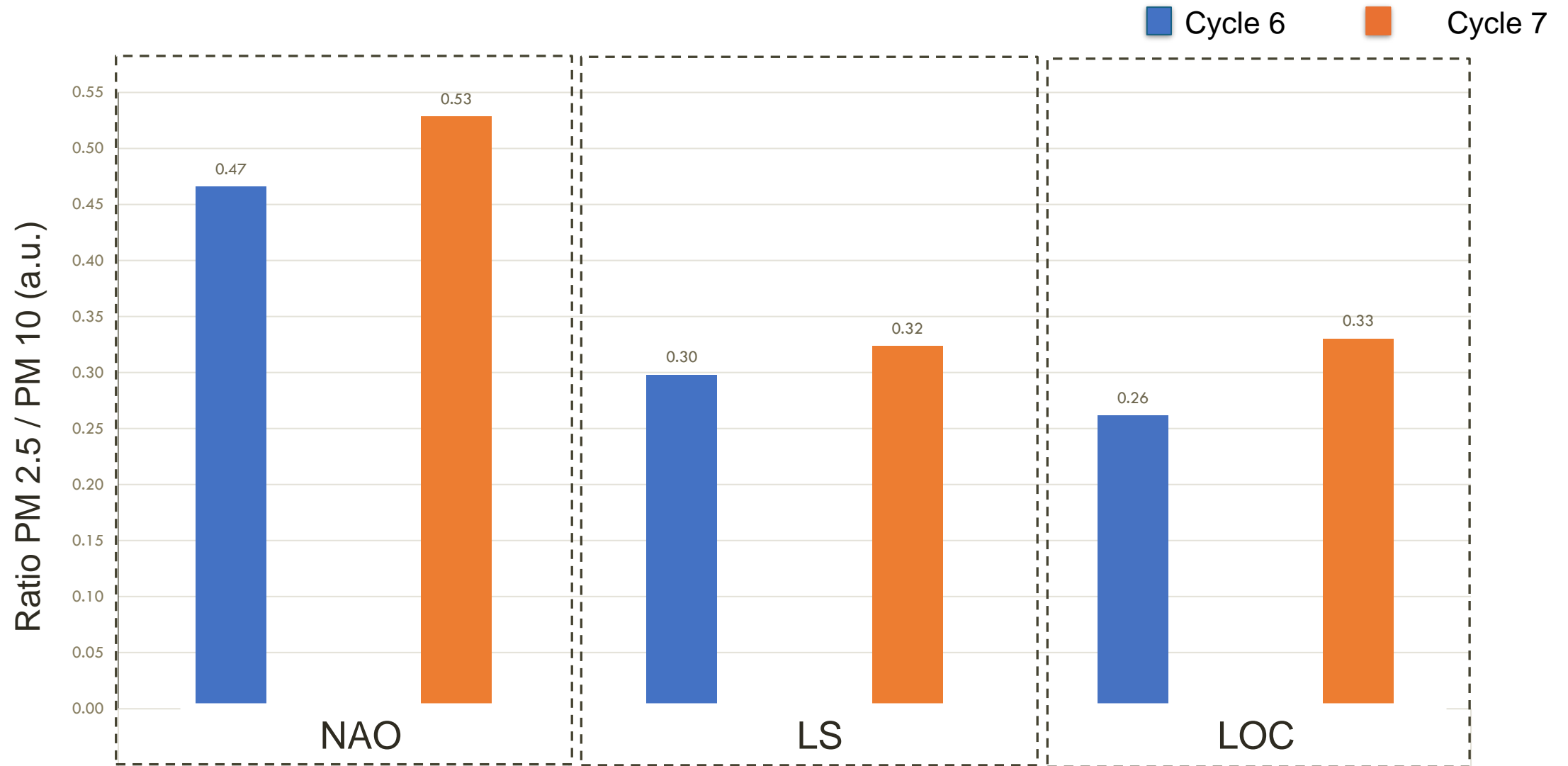


Prototype

# PM Emission (mg/km)



# PM Emission: PM2.5 / PM10

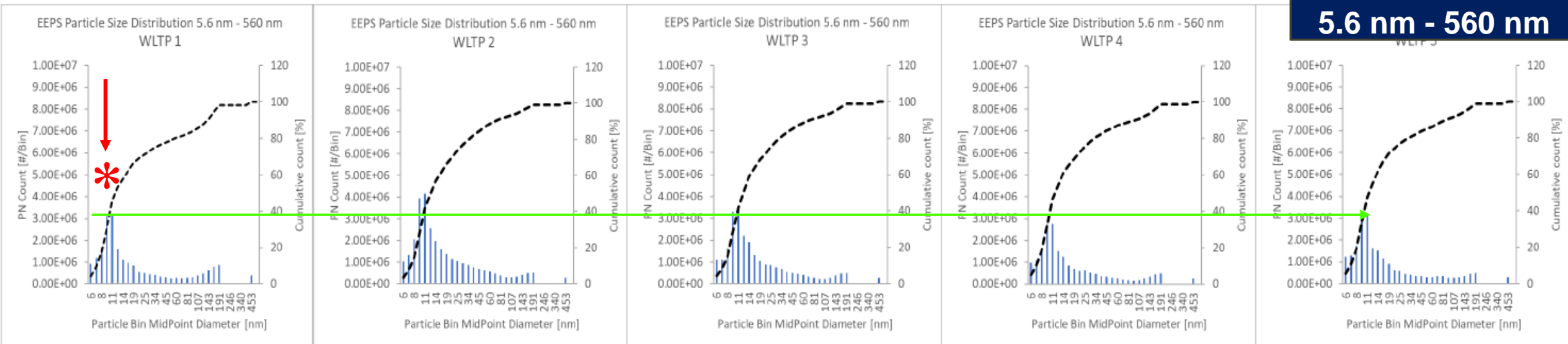




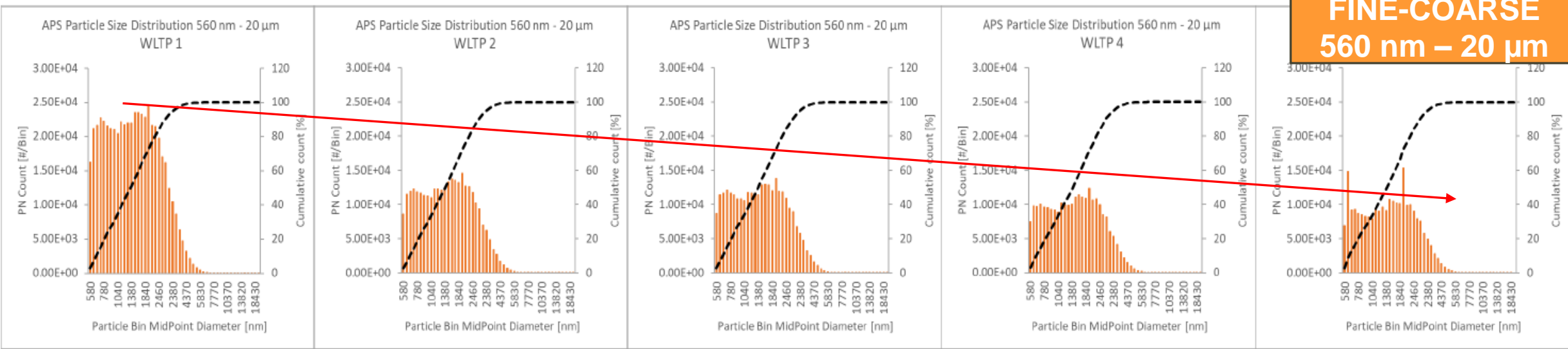
# WLTP Results: PM Emissions Fine Particles

PN Count (n°. Particles / diameter Bin)

**ULTRAFINE**  
5.6 nm - 560 nm



**FINE-COARSE**  
560 nm - 20 µm

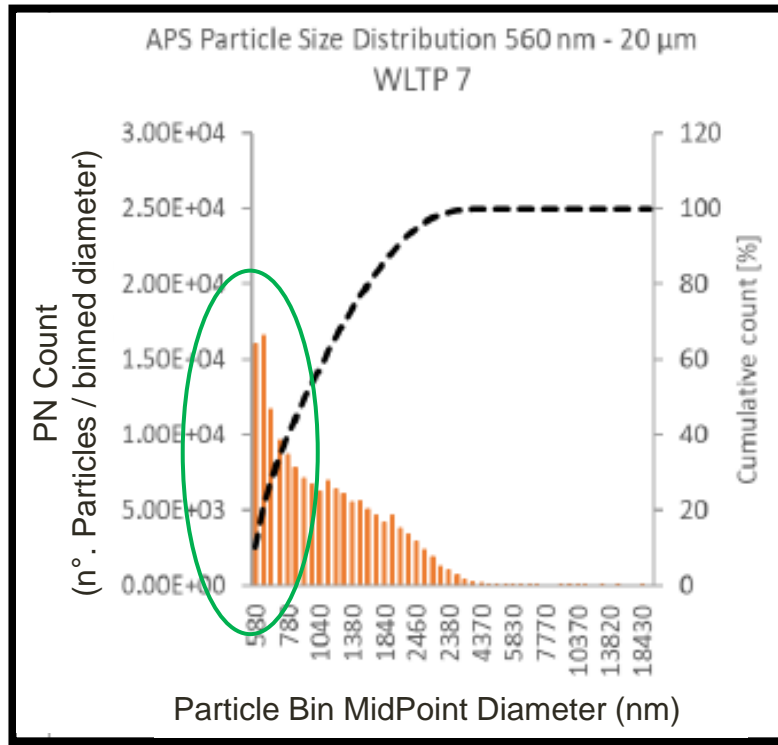


Particle Bin MidPoint diameter (nm)

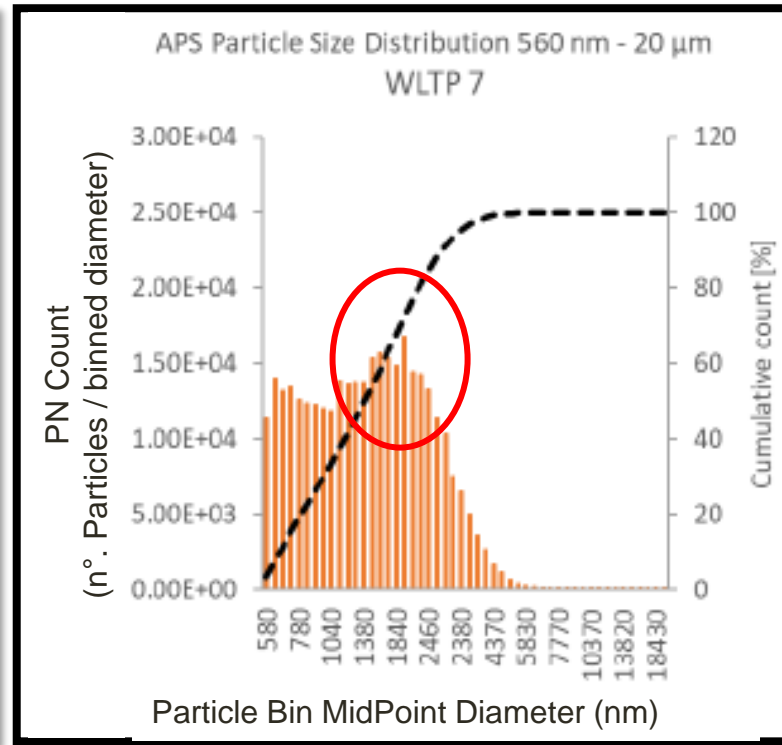
# WLTP Results: PM Emissions Fine Particles

Lower PN count for NAO and LOC

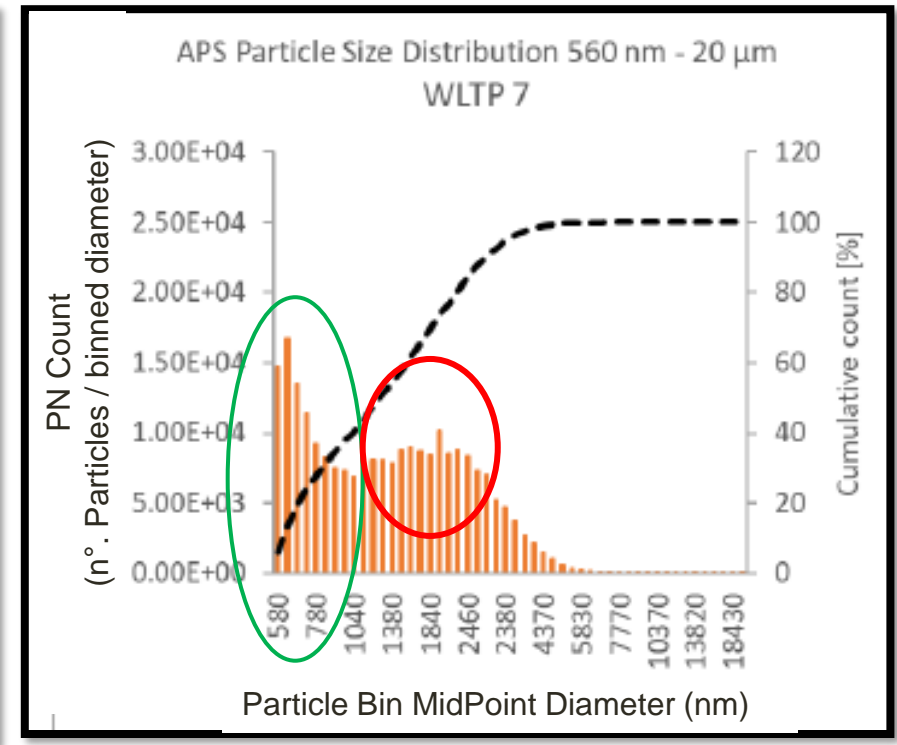
FINE-COARSE  
560 nm – 20 μm



NAO

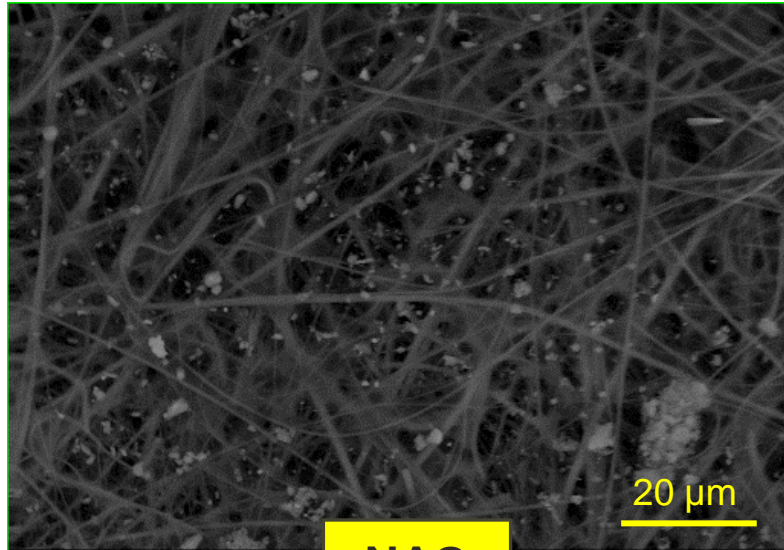


LS

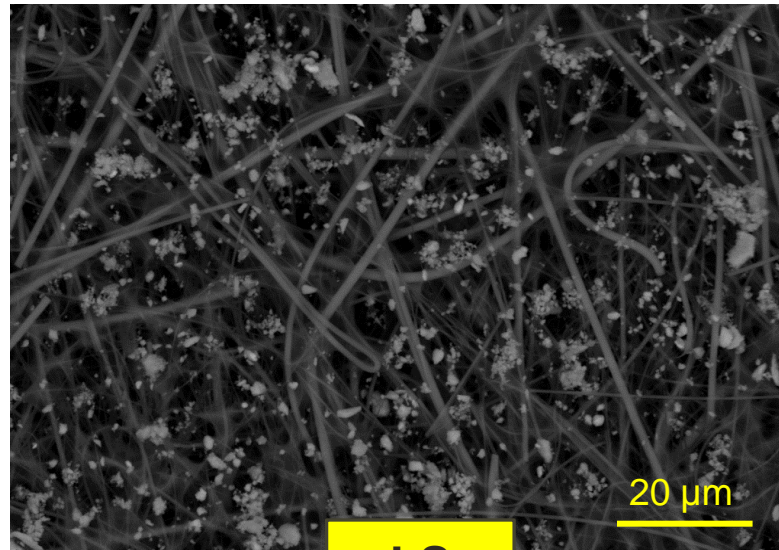


LOC

# Morphological Characterisation



NAO

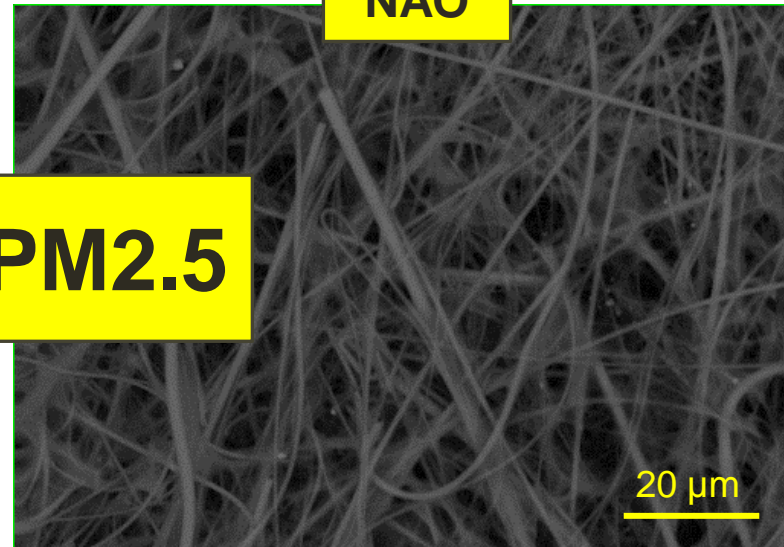


LS

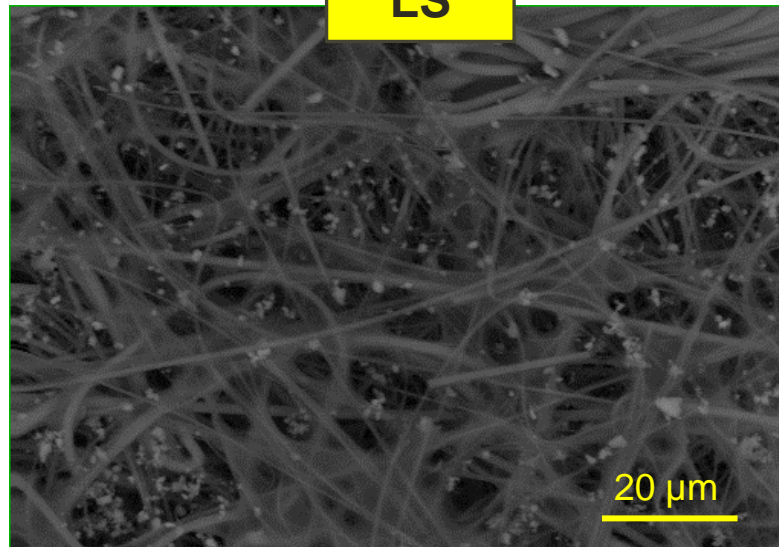


LOC

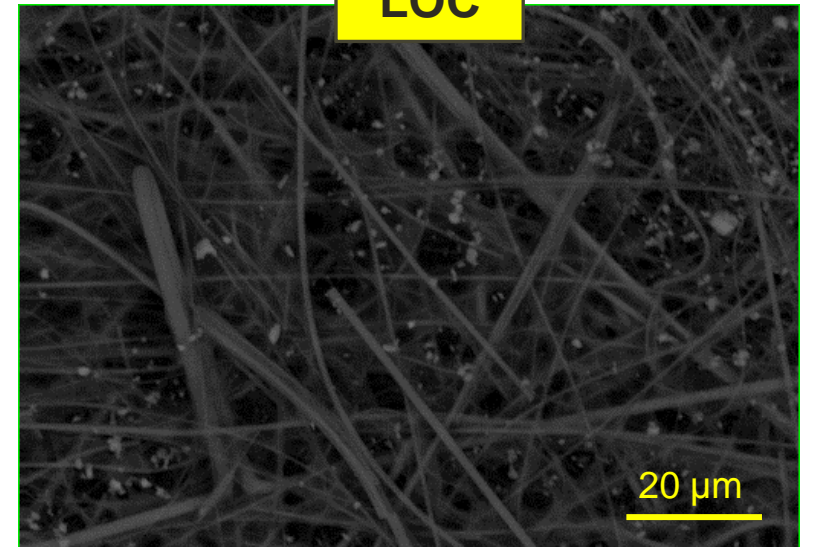
PM10



PM2.5

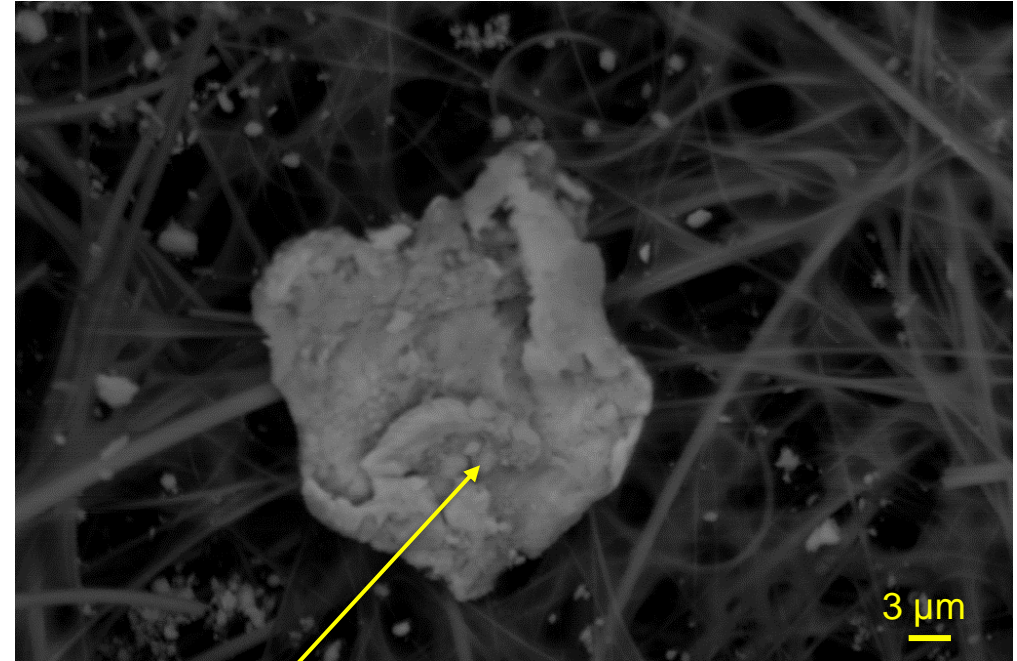


20 μm



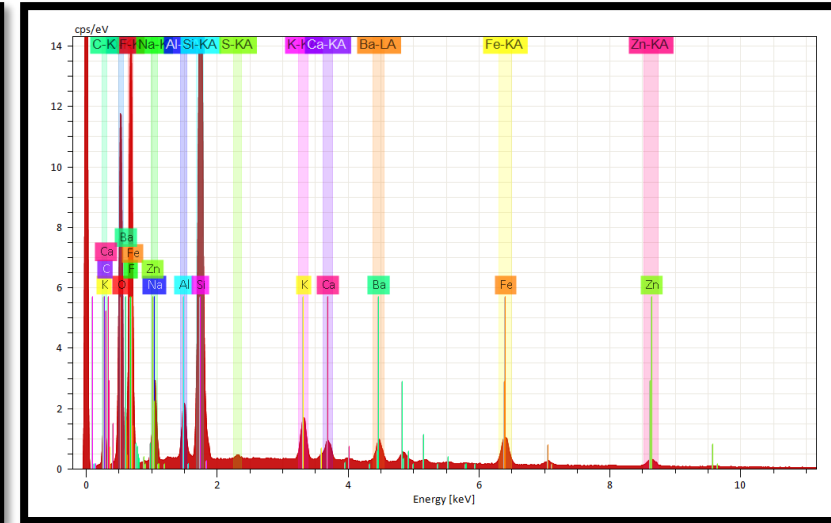
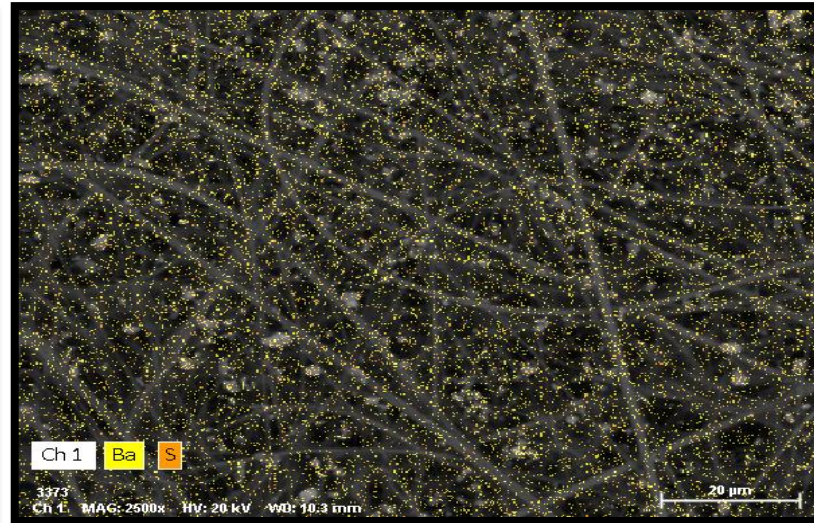
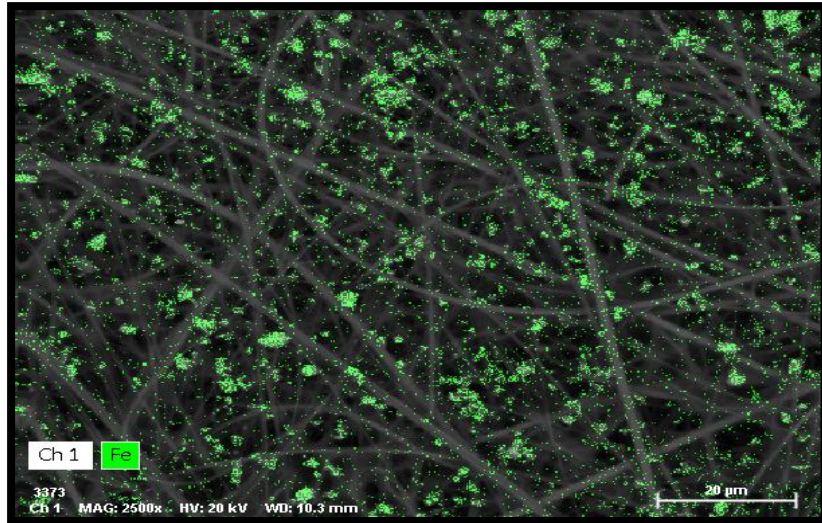
20 μm

# Morphological Characterisation



Aggregates

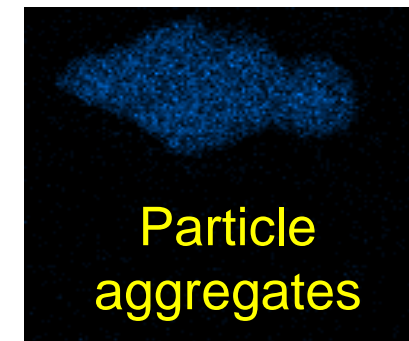
# Chemical Characterisation



## MAIN ELEMENTS

- Fe and Fe-oxides
- Ba → BaSO<sub>4</sub>

## OTHER ELEMENTS

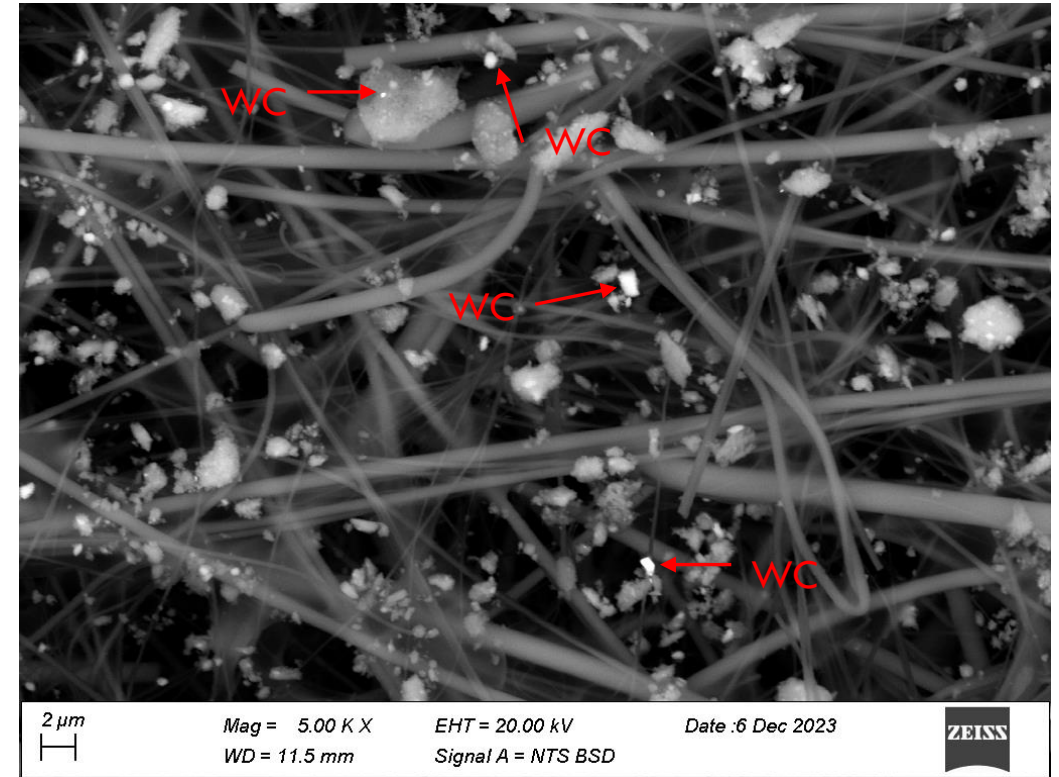
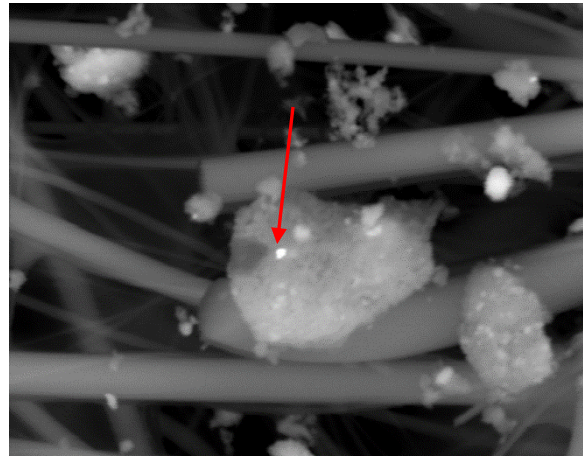
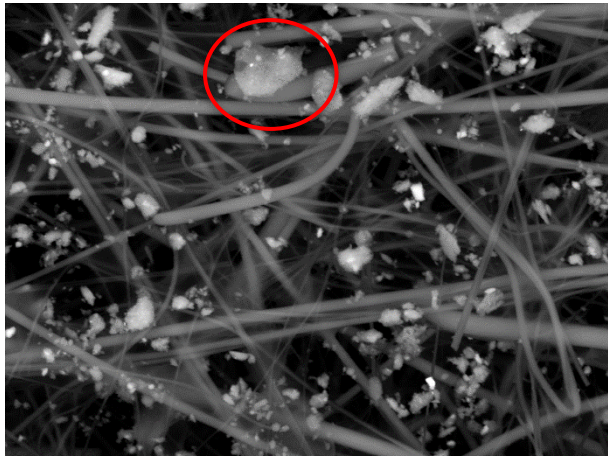


- Si
- K
- Ca
- Zn

# Chemical Characterisation

WHAT'S NEW...

NAO formula (metal free) against Coated (WC)



Element	At. No.	Line s.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] a
Silicon	14	K-Serie	35715	12.16	18.80	22.78	0.55
Fluorine	9	K-Serie	8680	12.01	18.56	33.24	1.74
Zirconium	40	L-Serie	11820	9.35	14.46	5.39	0.40
Tungsten	74	L-Serie	2318	4.68	7.23	1.34	0.19
Barium	56	L-Serie	5610	4.65	7.19	1.78	0.17
Magnesium	12	K-Serie	6850	3.85	5.95	8.34	0.25
Titanium	22	K-Serie	5922	3.70	5.71	4.06	0.14
Sodium	11	K-Serie	4562	3.48	5.39	7.97	0.27
Potassium	19	K-Serie	5643	2.64	4.09	3.56	0.12
Calcium	20	K-Serie	4932	2.56	3.96	3.36	0.11
Aluminium	13	K-Serie	4476	2.10	3.25	4.10	0.14
Sulfur	16	K-Serie	2762	1.30	2.01	2.13	0.08
Iron	26	K-Serie	1517	1.23	1.89	1.15	0.07
Zinc	30	K-Serie	722	0.98	1.51	0.79	0.07

Element	At. No.	Line s.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)
Tungsten	74	L-Serie	6497	15.17	26.99	5.65	0.49
Silicon	14	K-Serie	41283	12.45	22.15	30.34	0.56
Fluorine	9	K-Serie	8696	10.04	17.87	36.19	1.46
Barium	56	L-Serie	6082	4.93	8.77	2.46	0.18
Zinc	30	K-Serie	2000	3.17	5.84	3.32	0.14
Potassium	19	K-Serie	6341	2.77	4.94	4.85	0.12
Sodium	11	K-Serie	3197	2.26	4.02	6.72	0.19
Calcium	20	K-Serie	3715	1.84	3.27	3.14	0.09
Aluminium	13	K-Serie	3647	1.52	2.71	3.86	0.11
Titanium	22	K-Serie	1005	0.61	1.09	0.87	0.05
Iron	26	K-Serie	552	0.46	0.82	0.56	0.05
Phosphorus	15	K-Serie	766	0.41	0.73	0.91	0.05
Magnesium	12	K-Serie	647	0.35	0.62	0.98	0.05
Molybdenum	42	L-Serie	278	0.22	0.39	0.15	0.04
			Sum	56.19	100.00	100.00	

2 μm

Mag = 5.00 K X

EHT = 20.00 kV

Date :6 Dec 2023

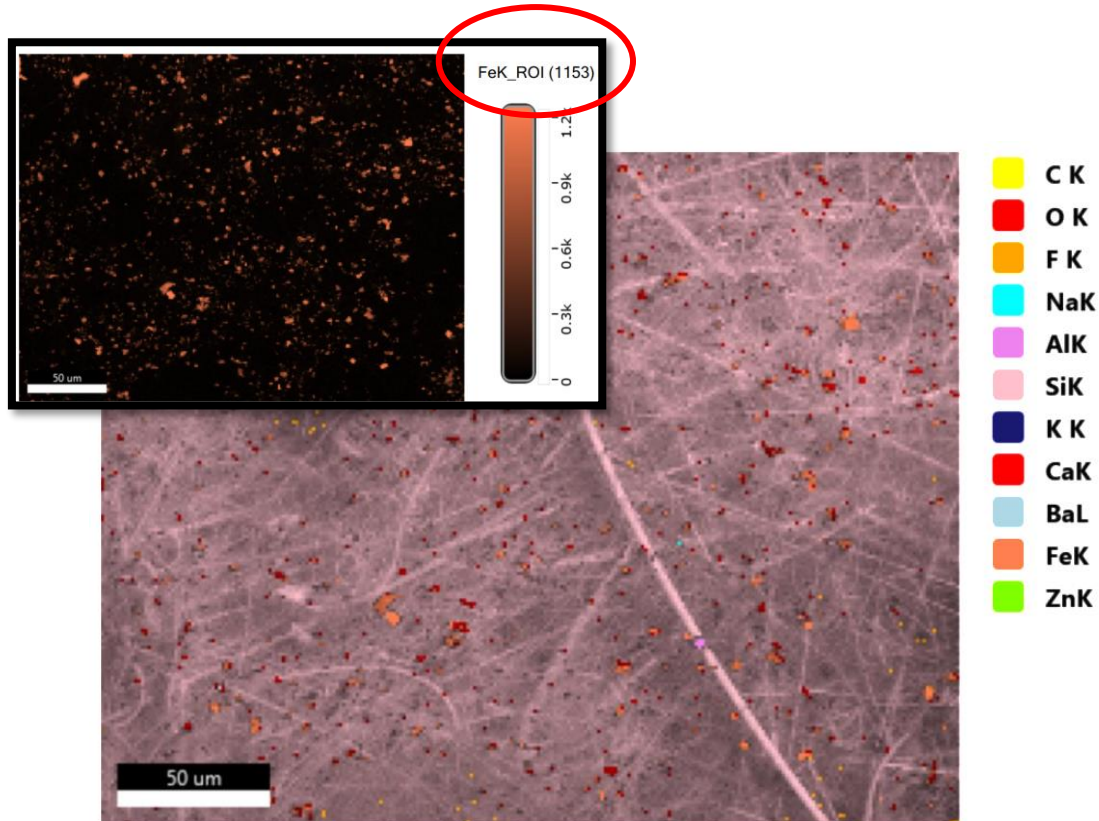
WD = 11.5 mm

Signal A = NTS BSD

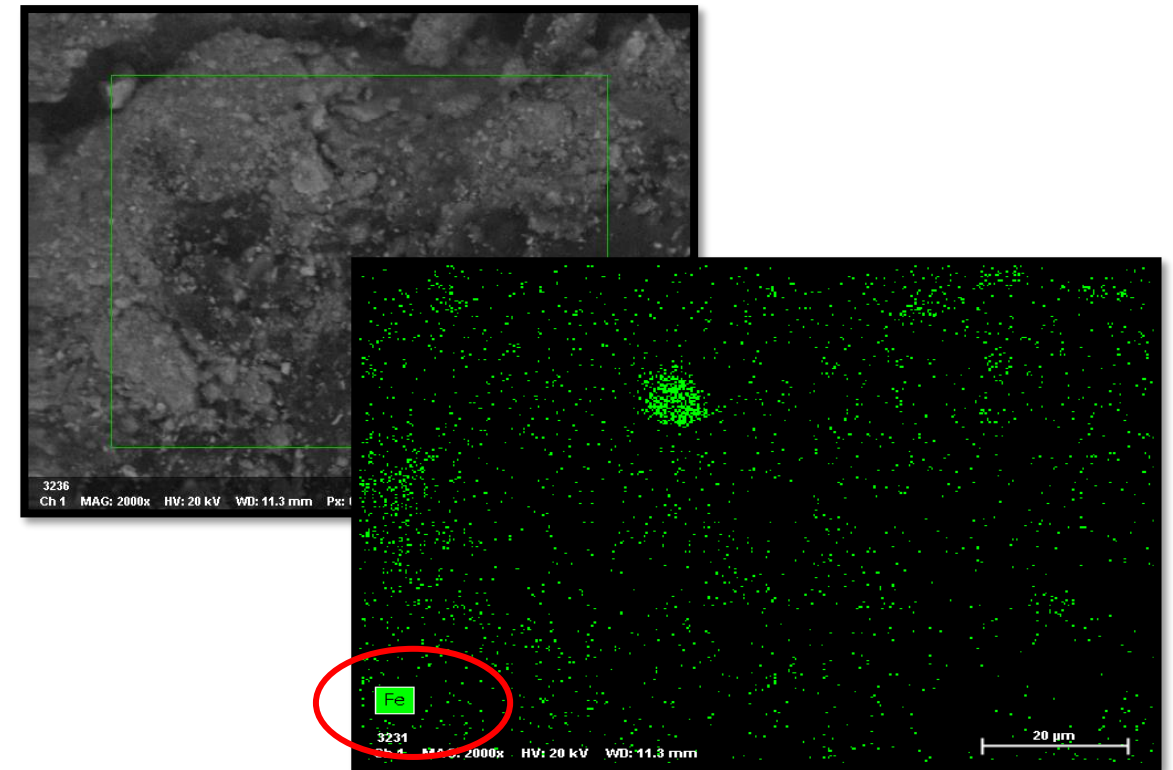


# Chemical Characterisation - NAO

PM on filter



Powders from pad surface



# Conclusions & Future Perspective

- Chemical correspondence between PM and pad surfaces →  
Aggregates and particles
- PM2.5 as a percentage of total (PM10) →  
Change related to material
- Size distribution →  
LOC distribution curve intermediate between LS and NAO
- Iron from disc →  
Disc wear contribution on emissions  
Further studies using coated discs





# THANK YOU

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Enrico Casamassa    *ecasamassa@raicam.com*

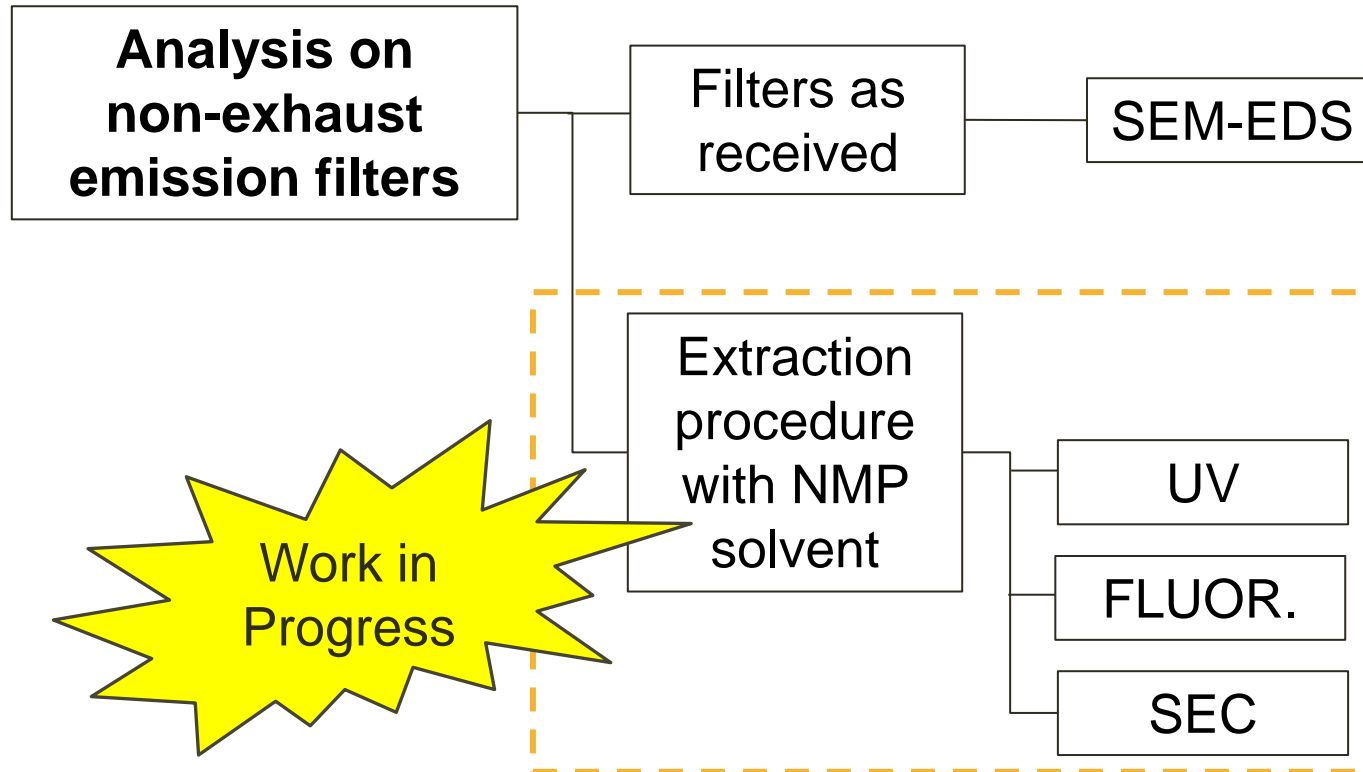
**“Appendix\_ Experimental Set-up” at the following slide**

# Appendix\_ Experimental Set-up

①

## PM Characterisation

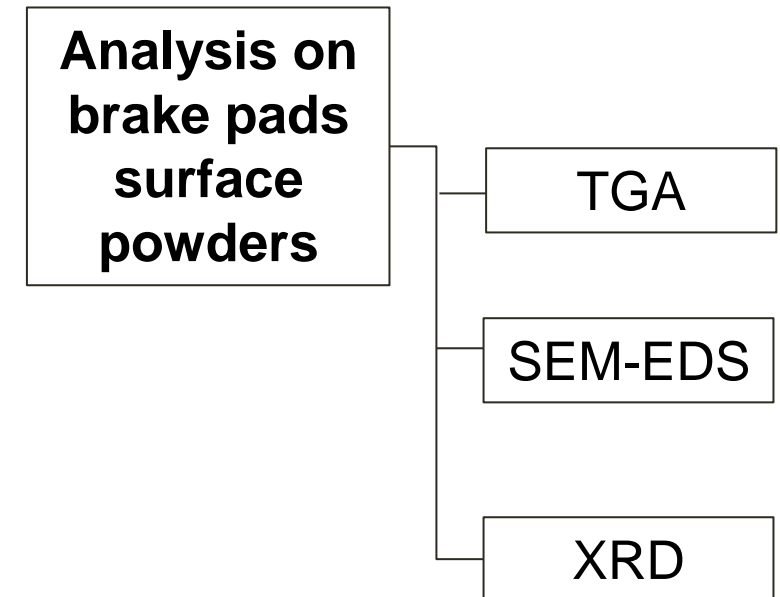
Chemical analysis on PM10 & PM2.5



②

## Surface Method

Chemical analysis on dust scratched from the surface after WLTP test



### Scratched procedure:

Russo, C., di Confiengo, G. G., Magnacca, G., Faga, M. G., & Apicella, B. (2023). *Insights on non-exhaust emissions: An approach for the chemical characterization of debris generated during braking*. *Heliyon*, 9(10).