Tire wear emission (Exposure & Toxicity CoRs)

Christof Asbach

Institute of Environment & Energy, Technology & Analytics (IUTA)

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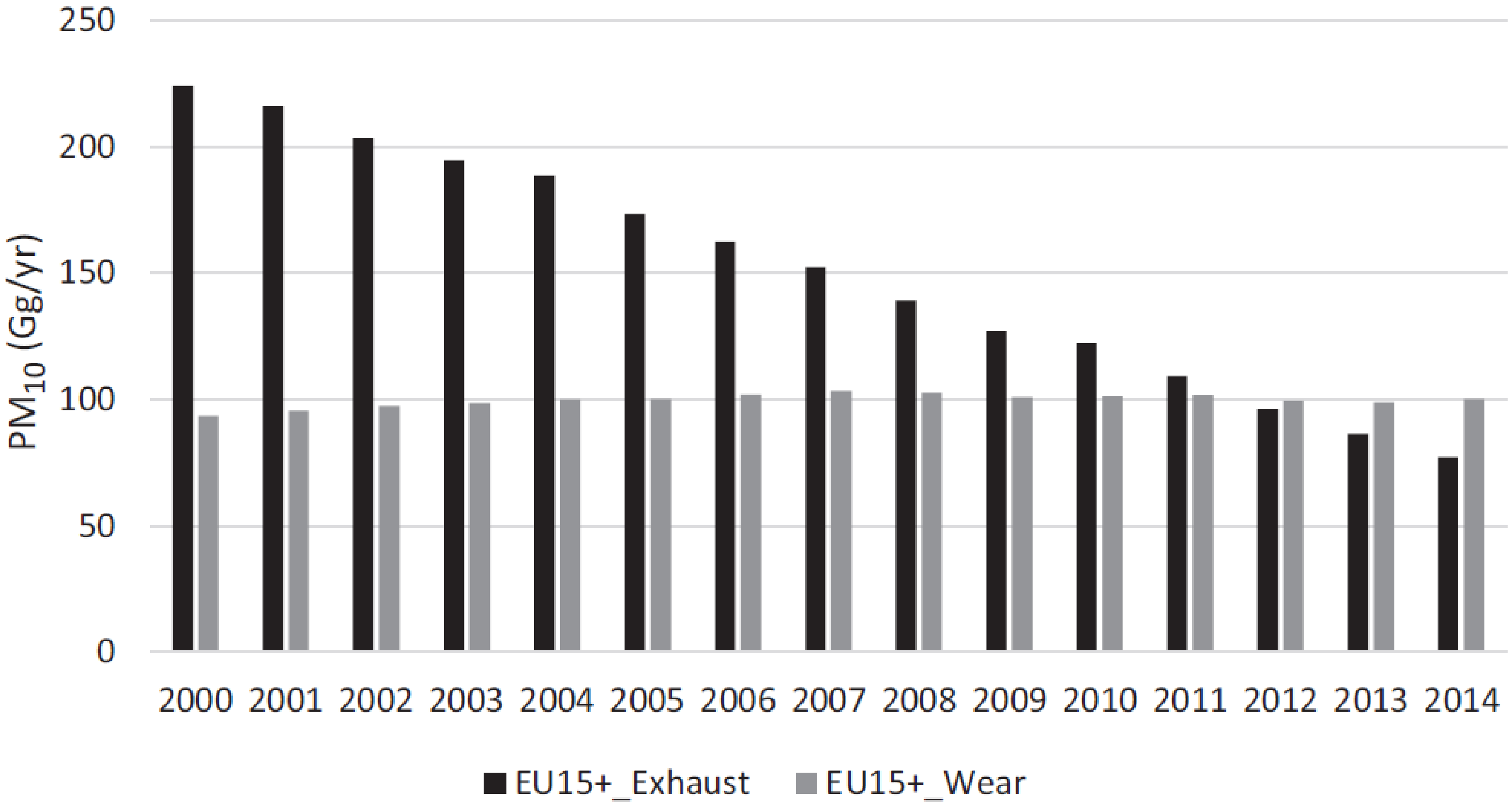
Exhaust vs. wear emissions



H. van der Goonet al. "European emission inventories and projections for road transport non-exhaust emissions," in *non-Exhaust Emissions (Ed. F. Amato)*, Elsevier, London, 2018, pp. 101-121

New Euro 7 legislation

EUROPEAN
COMMISSION

Brussels, 10.11.2022
COM(2022) 586 final

2022/0365 (COD)

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on type-approval of motor vehicles and engines and of systems, components and separate technical units intended for such vehicles, with respect to their emissions and battery durability (Euro 7) and repealing Regulations (EC) No 715/2007 and (EC) No 595/2009

European Council
Council of the European Union

EN

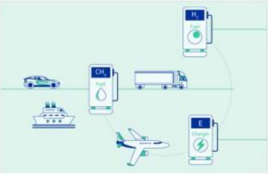
Home › Press › Press releases

Council of the EU | Press release | 12 April 2024 12:30

Euro 7: Council adopts new rules on emission limits for cars, vans and trucks

The Council has today adopted the Euro 7 regulation, which lays down rules on emission limits for road vehicles and battery durability. This is the last step in the decision-making procedure.

The text adopted today covers cars, vans and heavy-duty vehicles in one single legal act and aims to further lower air pollutant emissions from exhaust fumes and brakes. The new regulation also establishes stricter lifetime requirements.



https://www.consilium.europa.eu/en/press/press-releases/2024/04/12/euro-7-council-adopts-new-rules-on-emission-limits-for-cars-vans-and-trucks/

New Euro 7 legislation

Table 2: Euro 7 exhaust emission limits for M_2, M_3, N_2 and N_3 vehicles with internal combustion engine and internal combustion engines used in those vehicles

Pollutant emissions	Cold emissions[2]	Hot emissions[3]	Emission budget for all trips less than 3*WHTC long	Optional idle emission limits[4]
	per kWh	*per kWh*	*per kWh*	*per hour*
NO_x in mg	350	90	150	5000
PM in				
PN_{10} in				
CO in				
NMOG				
NH_3 in				
CH_4 in				
N_2O in				

Table 4: Euro 7 brake particle emission limits in standard driving cycle applying until 31/12/2034

Emission limits in mg/km per vehicle	M_1, N_1 vehicles	M_2, M_3 vehicles	N_2, N_3 vehicles
Brake particle emissions (PM_{10})	7		
Brake particle emissions (PN)			

Table 5: Euro 7 brake particle emission limits in applying from 1/1/2035

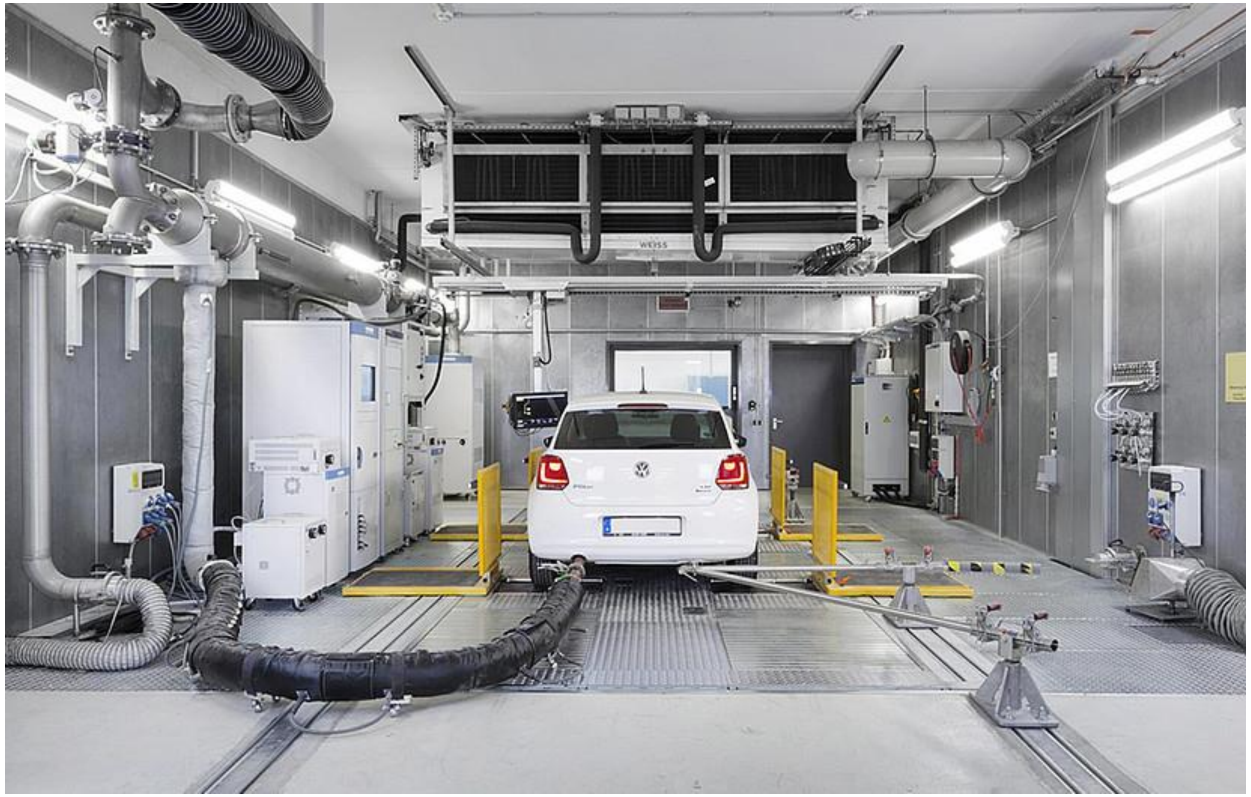
Emiss
Brake
Brake

Table 6: Euro 7 tyre abrasion rate limits

Tyre mass lost in g/1000 km	C1 tyres	C2 tyres	C3 tyres
Normal tyres			
Snow tyres			
Special use tyres			

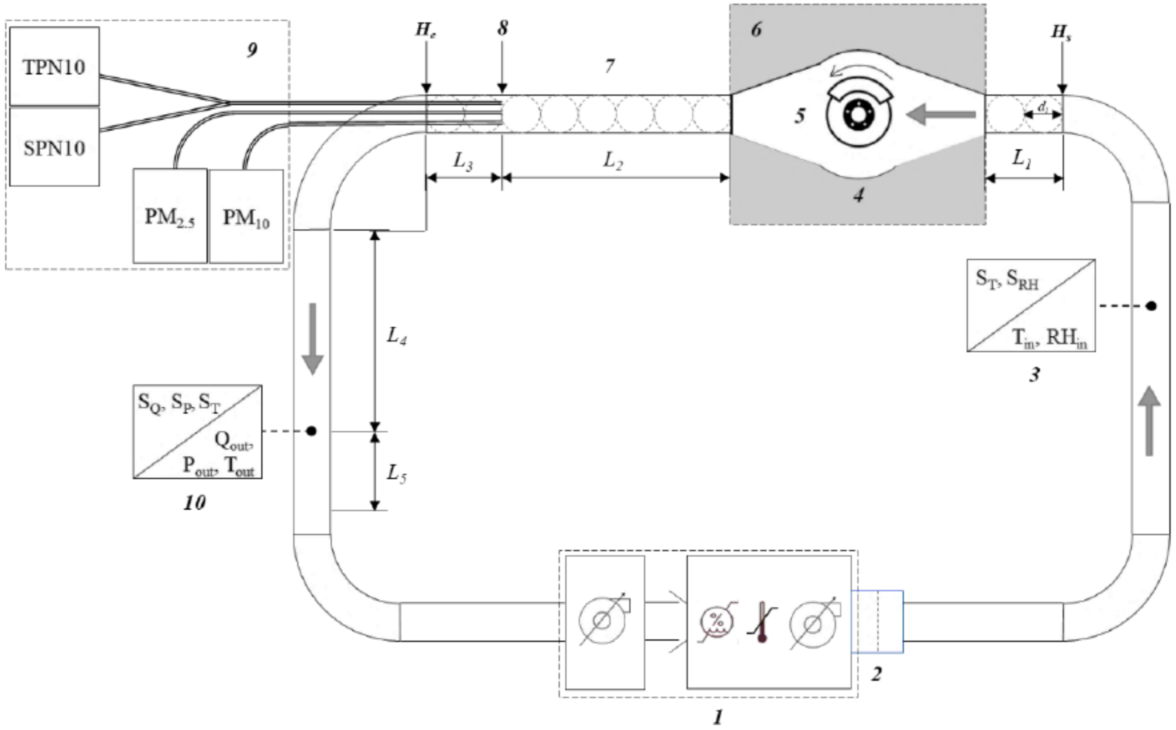
Exhaust emissions

Laboratory

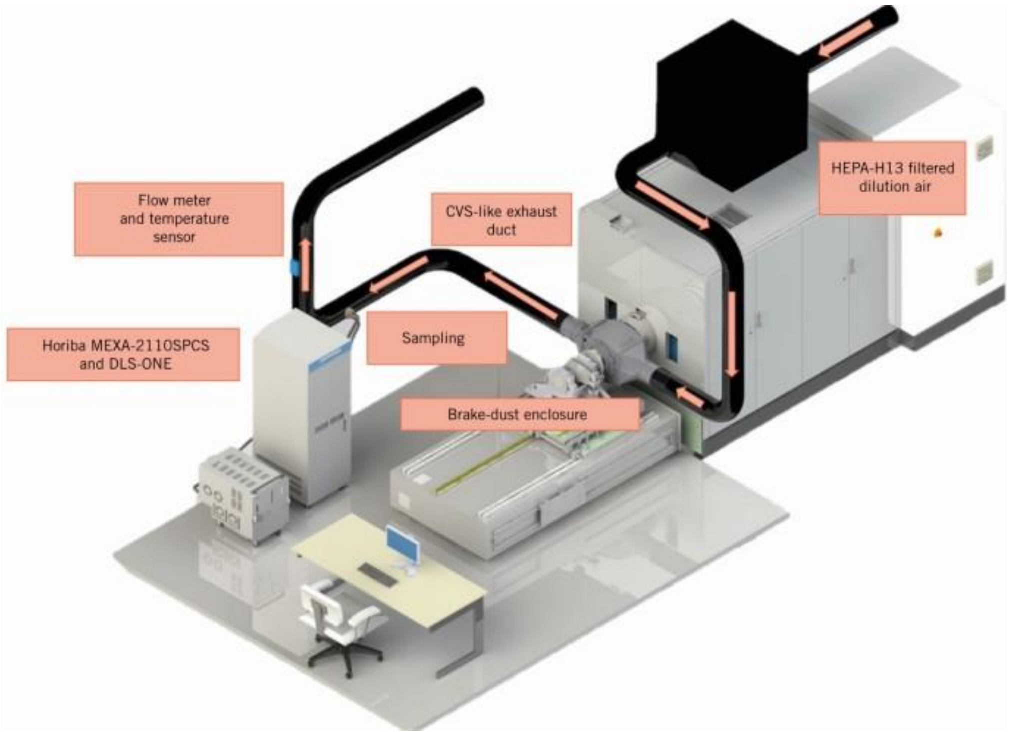


Real Drive Emissions

Brake wear emissions



From UN GTR No. 24



Tire wear emissions

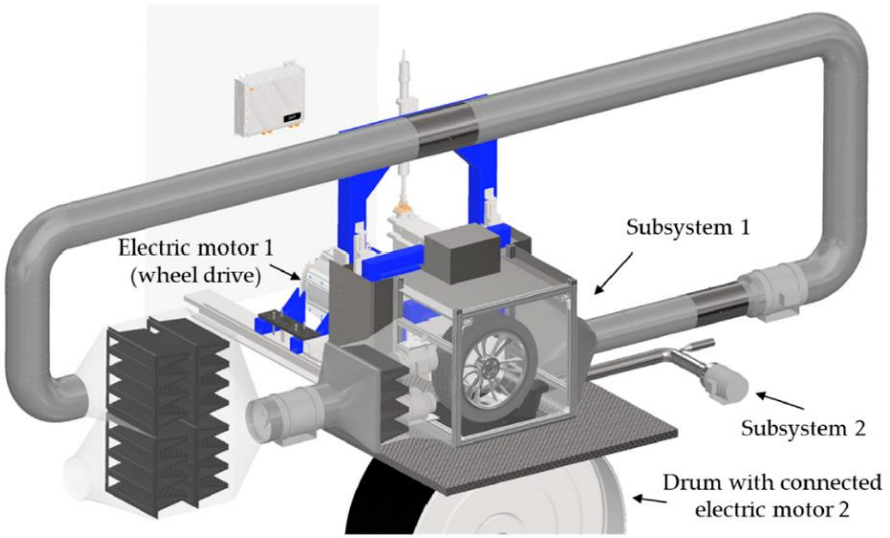
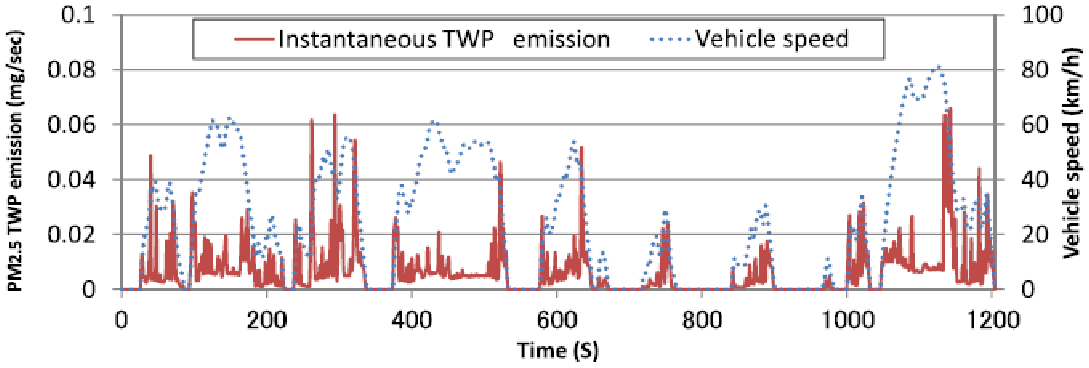
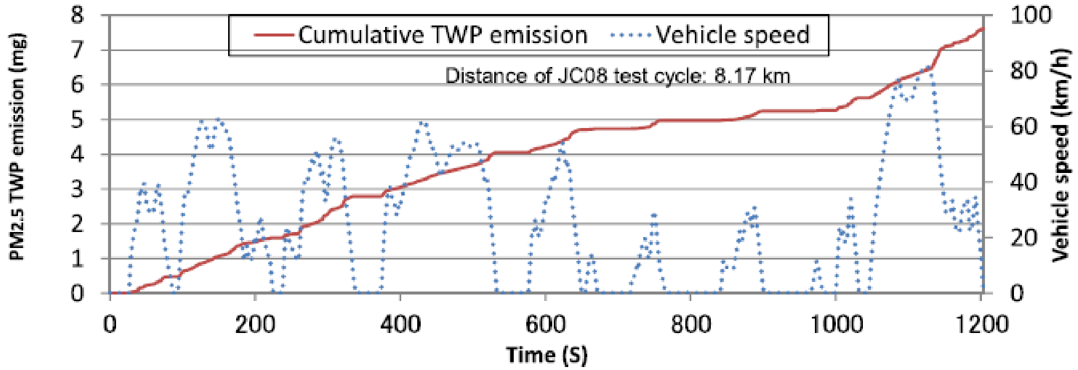


Figure 11. Test setup for the analysis of abrasion rate and PM emission factors on the single-roller test bench.

D. Hesse et al., *Atmosphere* **13**: 1262, 2022





Tonegawa and Sasaki, *Emission Contr. Sci. Technol.* **7**: 56-62, 2021

Tire wear emission factors

Baensch-Batruschat et al.
Sci. Total Environ. **763**: 137823

Table 1
Emission factors of tyre wear for different vehicle types (mg/vehicle km).

Vehicle type	Urban roads	Rural roads	Highways	Reference
Light duty vehicles[a]	5			EPA (1995)
Heavy duty vehicle[a]	7.5			
Motorcycle[a]	1.72			Reference year 1995
Passenger car[a]	3.45			CEPMEIP (2020)
Light duty vehicle[a]	4.5			
Heavy duty vehicle[a]	18.56			
Passenger car	53			Gebbe and Hartung (1997)
Van	107			
Bus	344			
Lorry	539			
Truck	1092			
Passenger car[a]	6.1			Rauterberg-Wulff (1998)
Lorry[a]	≤32			
Passenger car	Mean: 100; range: 40–360[c] 74[d]			Luhana et al. (2004)
Passenger car	Mean: 90; range: 53–200			Hillenbrand et al. (2005)
Van/Lorry	Mean: 700; range: 107–1500			
Bus	700 (like [illegible]			
Truck	Mean: 12[illegible] 1000–150[illegible]			
Not specified[a]	9			
Car	50			
Bus	700			
Motorized 2-wheeler	7			
Not specified[a]	2.2			
Passenger car	33			
Light commercial	51			
Heavy commercial	178			
Not specified[a]	2.4–7			Panko et al. (2013a)
Passenger car[a]	8.8	6.8	5.8	NAEI (2017)
Motorcycle[a]	3.8	2.9	2.5	
Moped[a]	3.8	–	–	
Light duty vehicle[a]	14	11	9.1	
Heavy duty vehicle[a]	47	27	31	
Bus/coach[a]	21	17	14	
Passenger car[b]	132	85	104	DELTARES and TNO (2016)
Motorcycle[b]	60	39	47	
Moped[b]	13	9	10	
Van[b]	159	102	125	
Lorry[b]	850	546	668	
Truck[b]	658	423	517	
Bus[b]	415	267	326	
Light special vehicle[b]	159	102	125	
Heavy special vehicle[b]	850	546	668	

Unit: mg/vehicle km includes the vehicle-specific number of tyres.
[a] Emission factors exclusively for fine airborne particulates (PM10).
[b] Emission factors exclusively for coarse particulates.
[c] Compiled by Luhana et al. (2004) from literature.
[d] Measured by Luhana et al. (2004).

Average emissions per car per year approximately 50 g
(assuming 4 mg/km, 12,500 km/year)

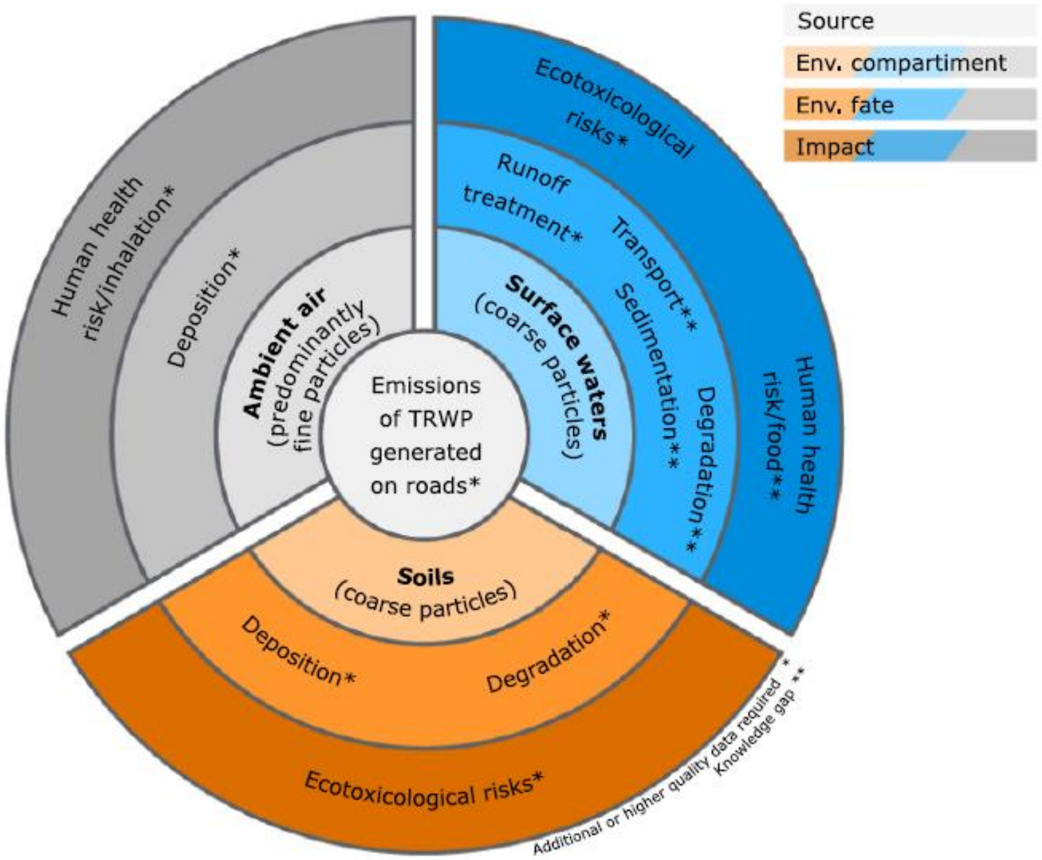
Table 3. Calculated tire wear emission factors for the summer and winter samples with uncertainty. Values calculated from method detection limits are shown in bold font.

Sample	Surface	Tire Wear Emission Factor (mg km^{-1} veh^{-1})
2.1	DG	$1.3 \pm 0.3 \times 10^{-1}$
2.2	DG	$2.0 \pm 0.5 \times 10^{-1}$
3.1	AR	$4 \pm 1 \times 10^{-2}$
3.2	AR	$2 \pm 0.5 \times 10^{-2}$
4.1	AR	$2.2 \pm 0.5 \times 10^{-1}$
4.2	AR	$1.6 \pm 0.4 \times 10^{-1}$
5.1	DG	$4 \pm 1 \times 10^{-2}$
5.2	DG	$6 \pm 1 \times 10^{-2}$
[illegible]	[illegible]	$2 \pm 0.5 \times 10^{-2}$
[illegible]	[illegible]	$2 \pm 0.5 \times 10^{-2}$
[illegible]	[illegible]	$4 \pm 1 \times 10^{-2}$
[illegible]	[illegible]	$3 \pm 0.8 \times 10^{-2}$
[illegible]	[illegible]	$1.2 \pm 0.3 \times 10^{-1}$
[illegible]	[illegible]	$1.8 \pm 0.4 \times 10^{-1}$
[illegible]	[illegible]	$4 \pm 1 \times 10^{-2}$
11.1	AR	$3 \pm 0.6 \times 10^{-2}$
11.2	AR	$5 \pm 1 \times 10^{-2}$
12.1	DG	$4 \pm 0.9 \times 10^{-2}$
12.2	DG	$5 \pm 1 \times 10^{-2}$
W1	DG	$3 \pm 0.6 \times 10^{-2}$
W2	AR	$1 \pm 0.2 \times 10^{-2}$
W3	DG	$5 \pm 1 \times 10^{-3}$
W4	DG	$6 \pm 1 \times 10^{-3}$
W5	AR	$3 \pm 0.6 \times 10^{-2}$
W6	AR	$3 \pm 0.7 \times 10^{-2}$

DG – Diamond ground concrete, AR – Asphalt rubber

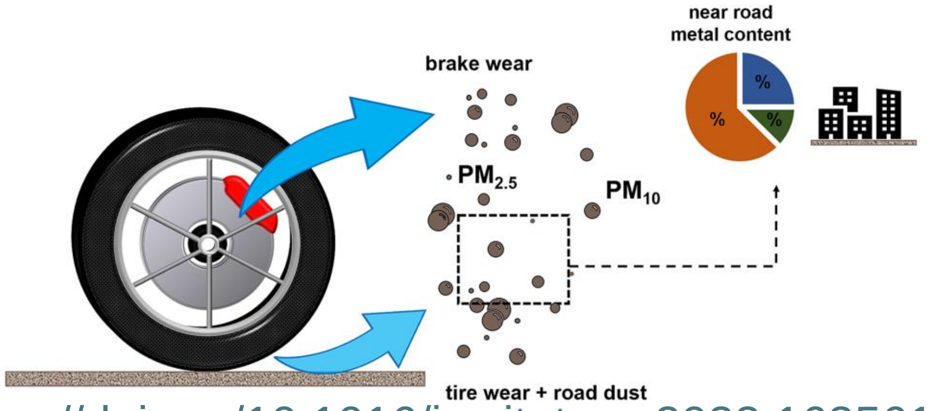
Miech et al. *Atmosphere* **15**: 1122

Relevance of wear particles from traffic



Baensch-Batruschat et al., *Sci. Total Environ.* **763:** 137823

Detection of Tire & Brake Wear Incidental nano/micro Particles



https://doi.org/10.1016/j.scitotenv.2023.163561

Paul Westerhoff

Regents Professor & Fulton Chair of Environmental Engineering

Arizona State University (Tempe) - USA

Field studies can quantify mg Tire Wear released per vehicle-km

- No significant difference in tire wear PM for **different surface types** (asphalt vs. diamond grind concrete)

- But higher emission rates in **summer than winter**

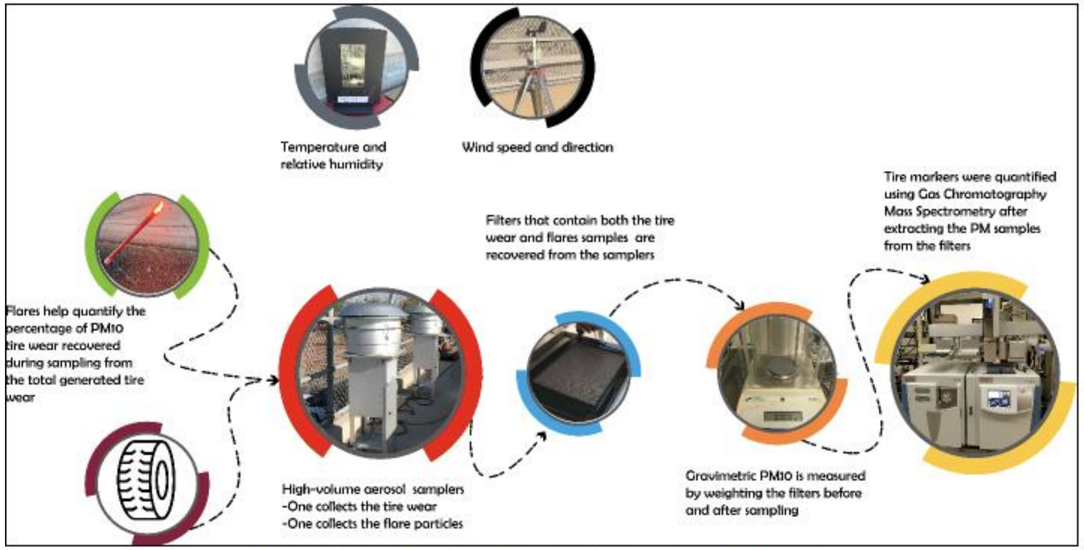


Figure 30. TW Emissions Measurement Methodology

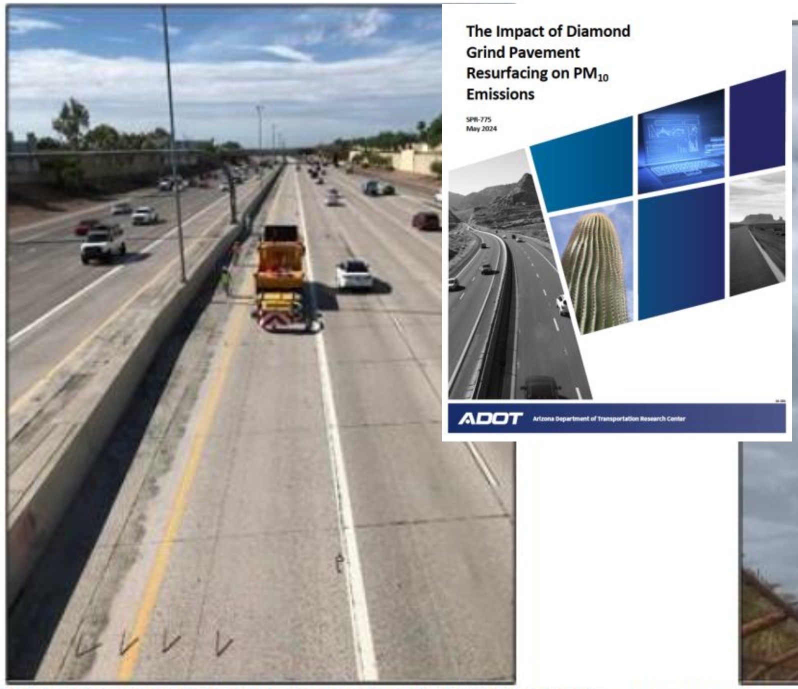
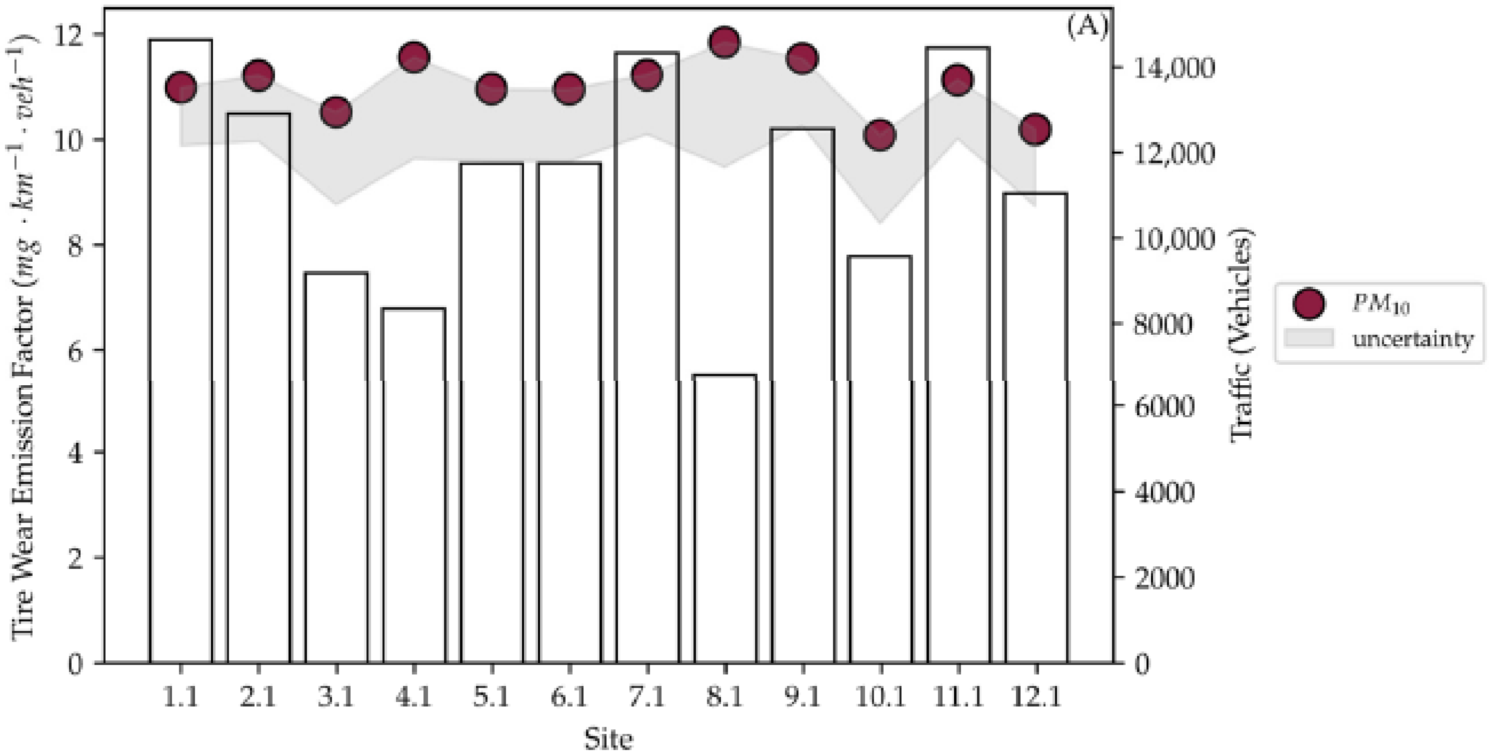


Figure 31. Setting Up Traffic Control at the Victory Drive Site and Traffic Counters Installed on a Pole

Figure 32. Setting Up Traffic Control at the Victory Drive Site and Traffic Counters Installed on a Pole

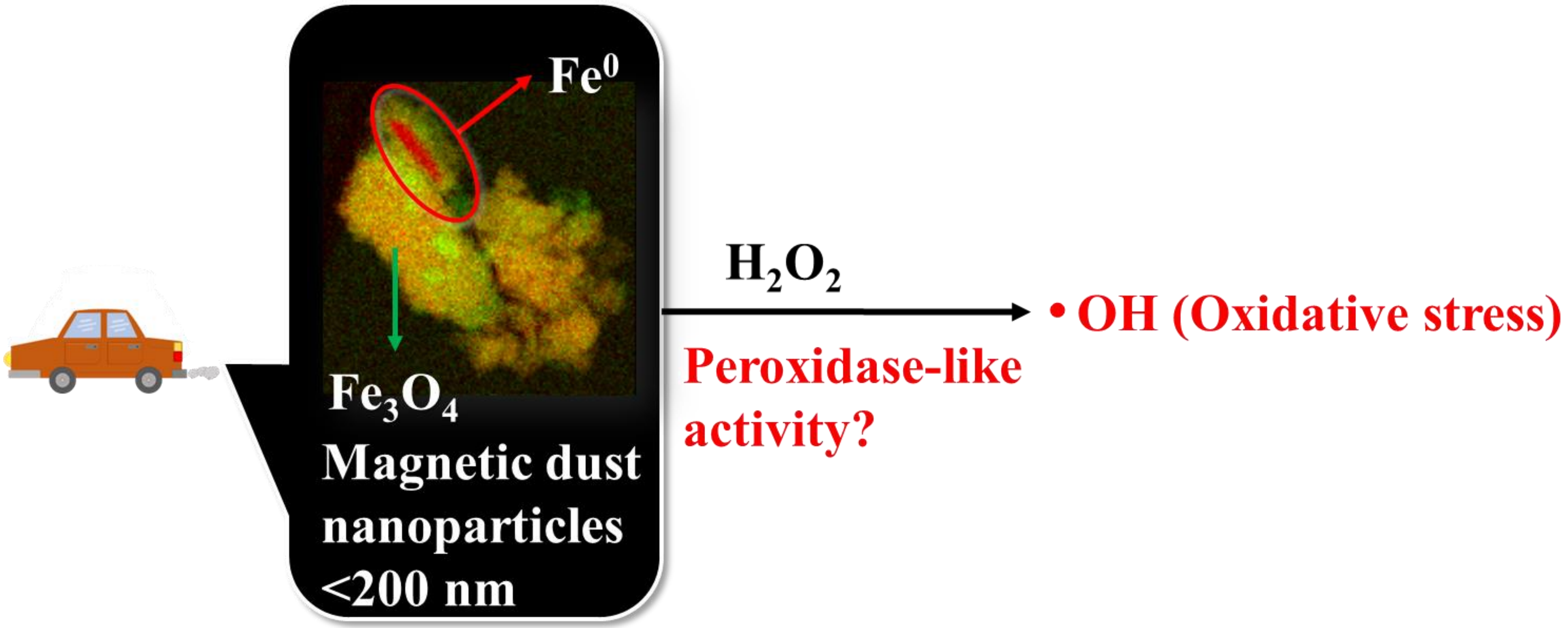
Tire wear quantified in sampled PM10 using benzothiazoles (vulcanization accelerators) as tire markers

The measured tire emission factors had a range of 0.005 to 0.22 mg km^{-1} veh^{-1}



Miech, J.A.; Aker, S.; Zhang, Z.; Ozer, H.; Fraser, M.P.; Herckes, P. TireWear Emissions by Highways: Impact of Season and Surface Type. *Atmosphere* 2024, 15, 1122.

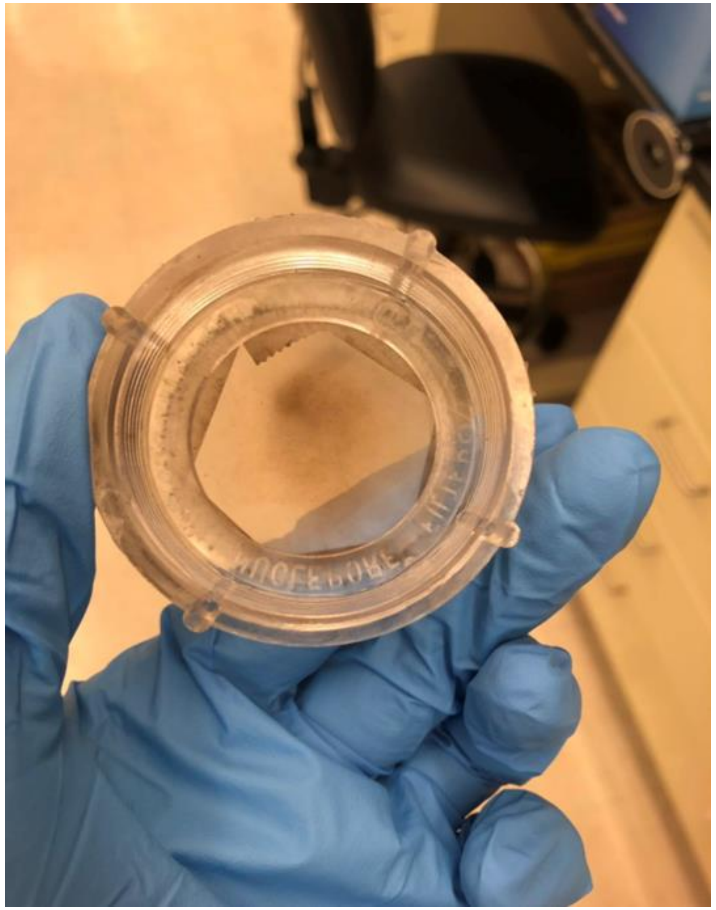
Brakes & other vehicle components produce "magnetic dust" & is of rising global concerns



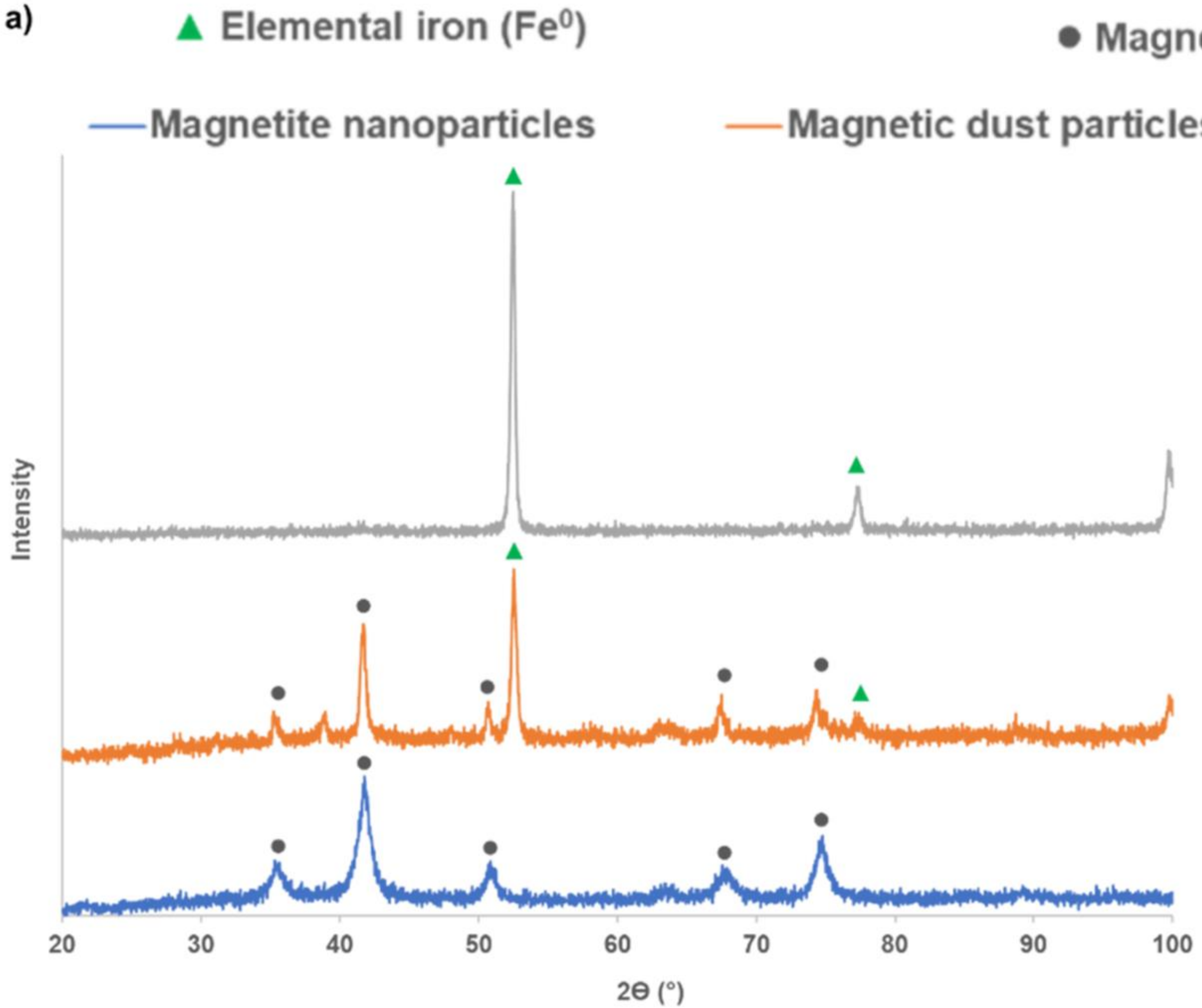
Long, X., Luo, Y. H., Zhang, Z., Zheng, C., Zeng, C., Bi, Y., ... & Westerhoff, P. (2020). The nature and oxidative reactivity of urban magnetic nanoparticle dust provide new insights into potential neurotoxicity studies. Environmental Science & Technology, 54(17), 10599-10609.

Collection of magnetic dust

- Collect dust from the ground of the Rural Road Parking Structure.
- Gently grind the dust and sieve the dust using a 53-μm nylon mesh sieve.



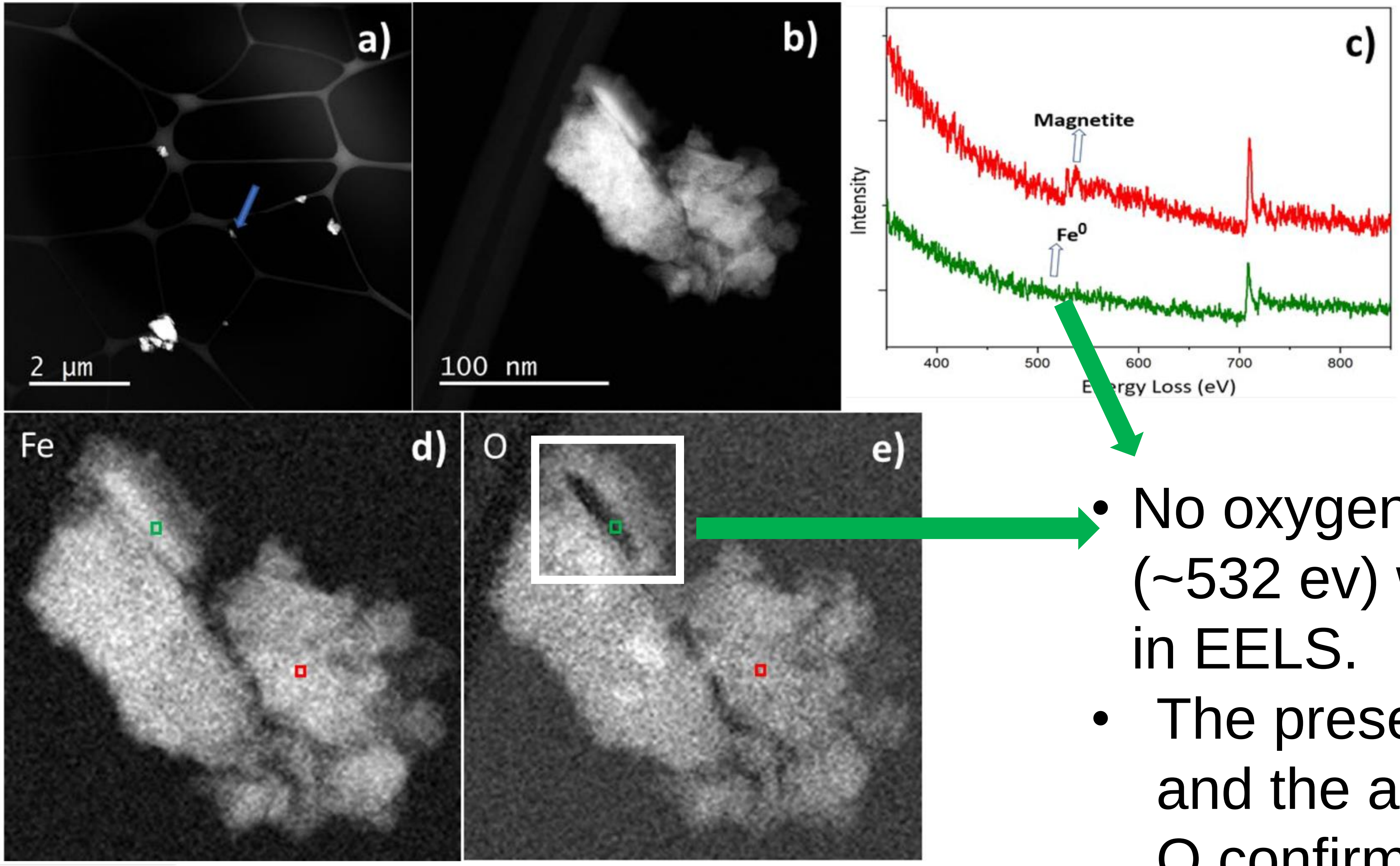
Heterogeneous crystallinity



XRD confirms the presence of ~40% metallic iron (Fe^0) and 60% of magnetite (Fe_3O_4).

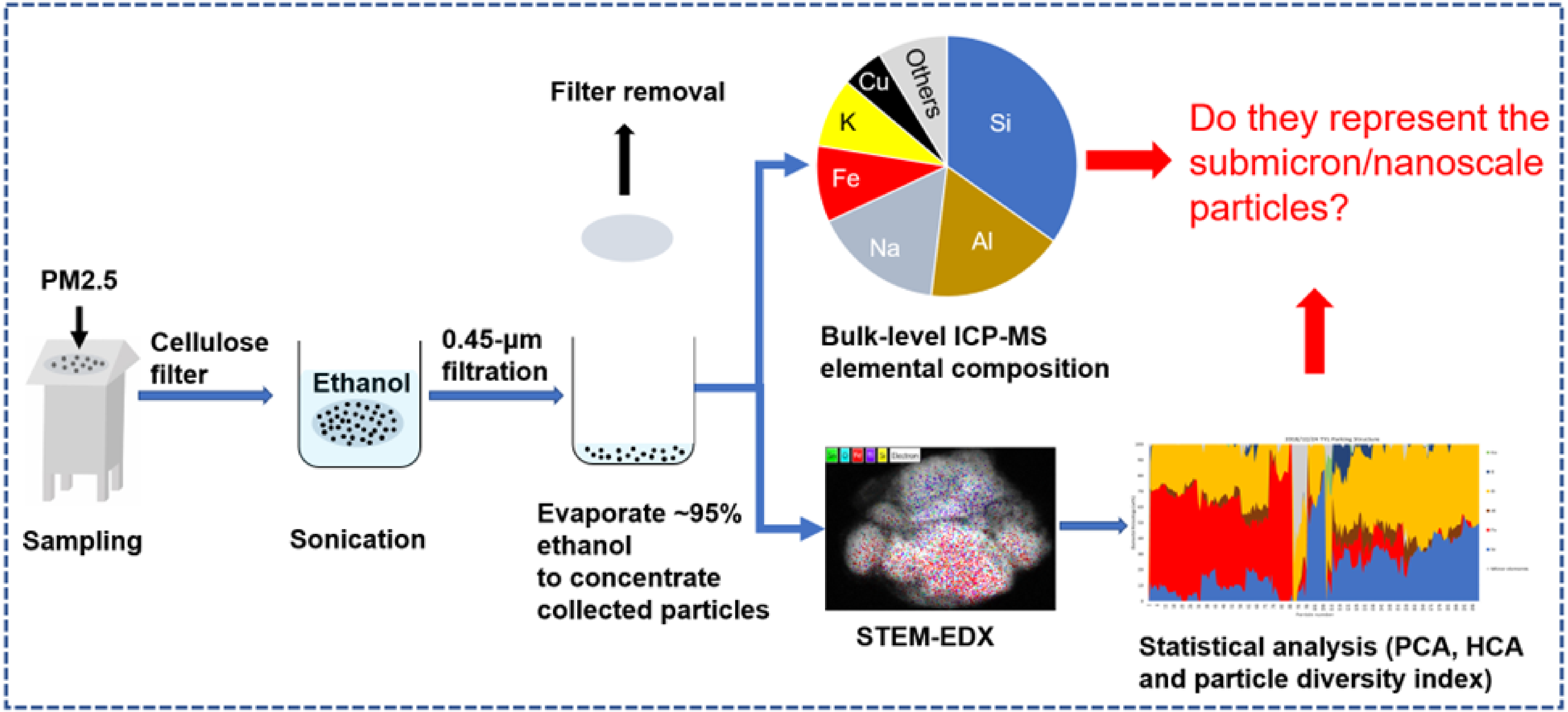
Not exclusively Fe_3O_4

Heterogeneity in single-particle level



- No oxygen signal (~532 ev) was found in EELS.
- The presence of Fe and the absence of O confirm **Fe^0**

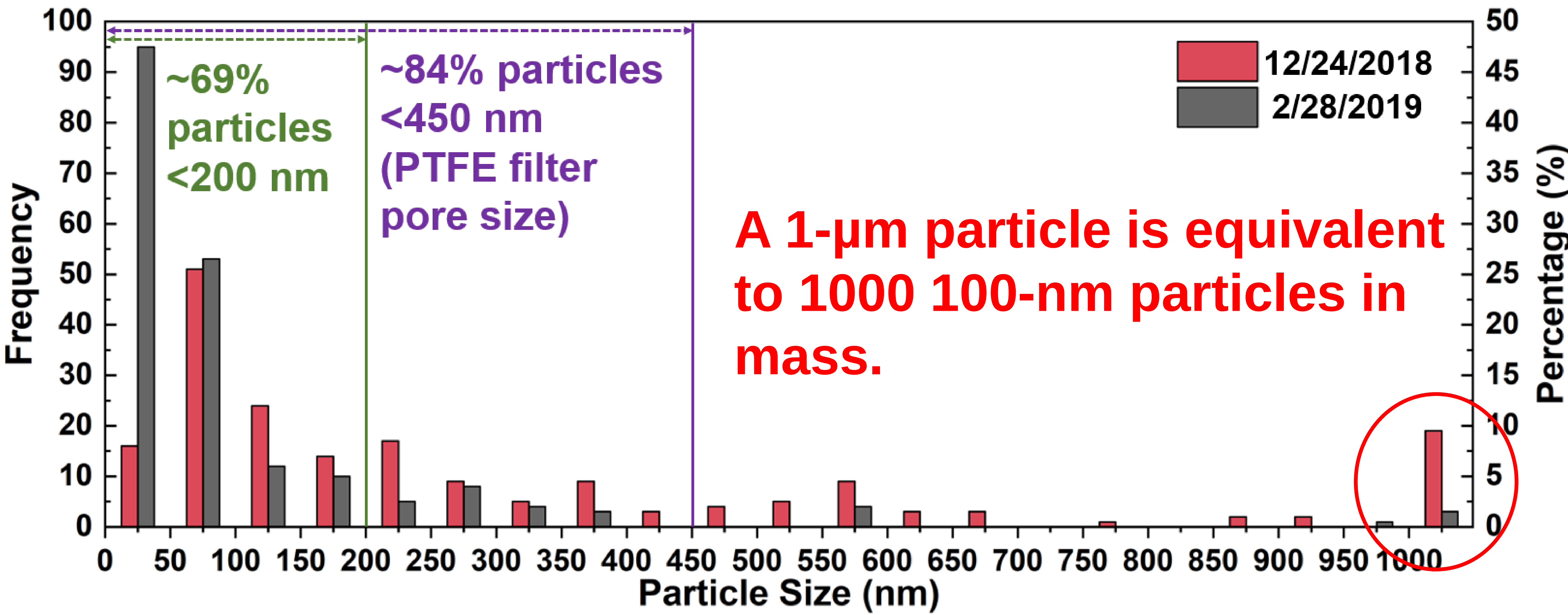
Also collected "airborne" Particles



- PM2.5 sample was collected onto a cellulose filter at Tyler Street Parking Garage
- Extract particles from the cellulose filter by sonication in pure ethanol
- Pass the extract solution through a 0.45-µm PTFE filter
- The filtrate solution was used for STEM-EDX and bulk-level ICP-MS analysis

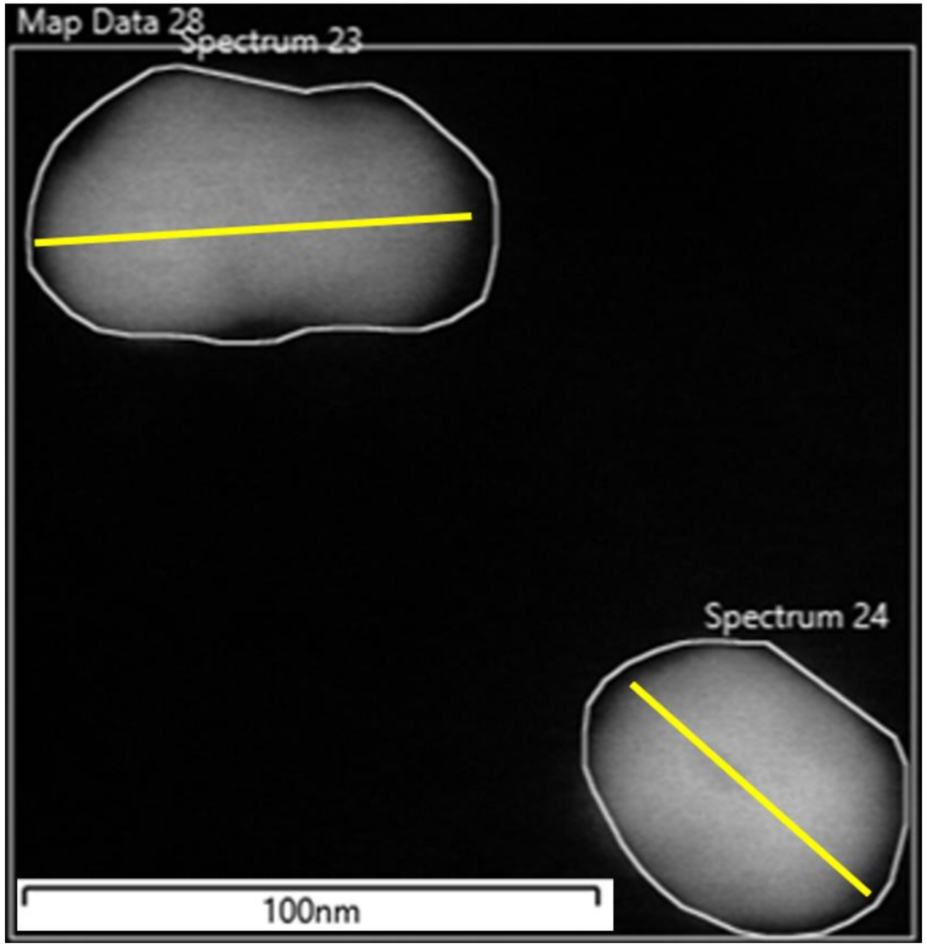
Particle size after passing a 0.45-μm filter

How does the particle size enhance our understanding of the bulk-level ICP-MS?

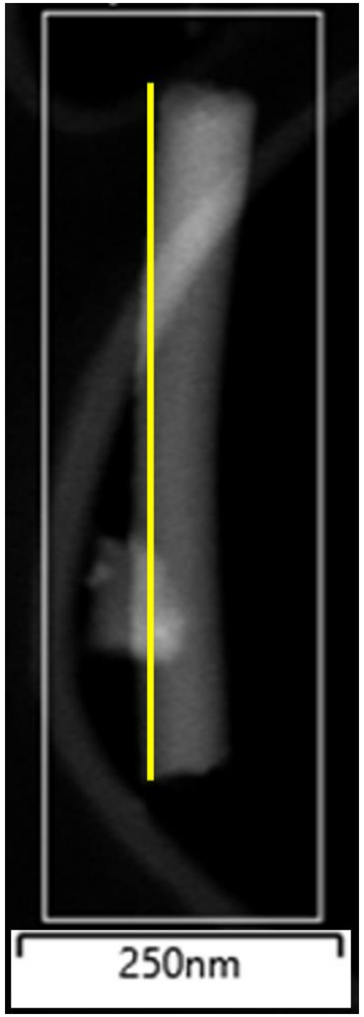


Heterogenous particle morphology

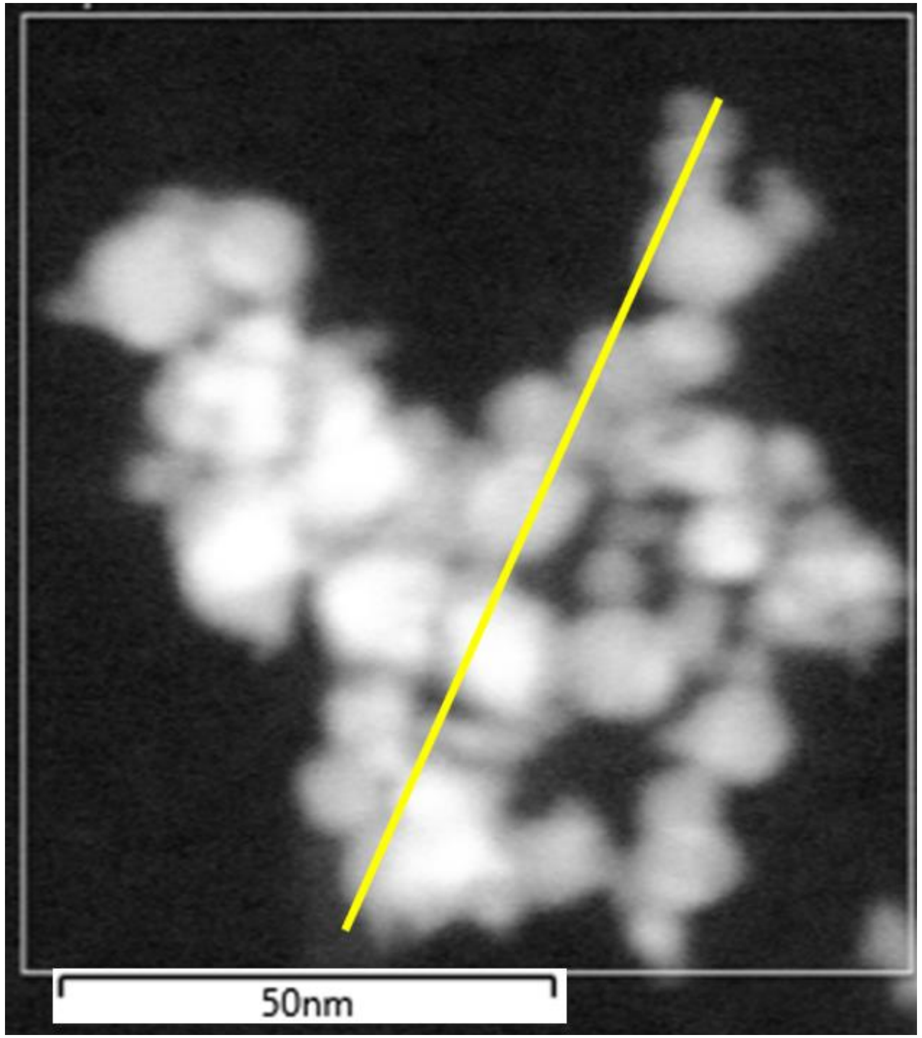
Aspect ratio (AR) for a particle = longest length/smallest length



Near-round shape: AR 1~1.5



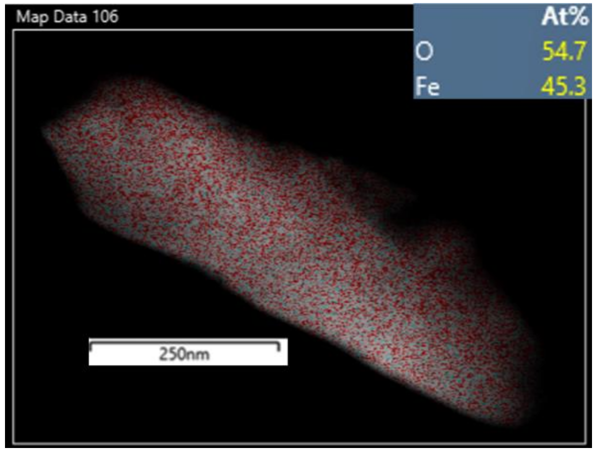
Rod shape: AR > 5



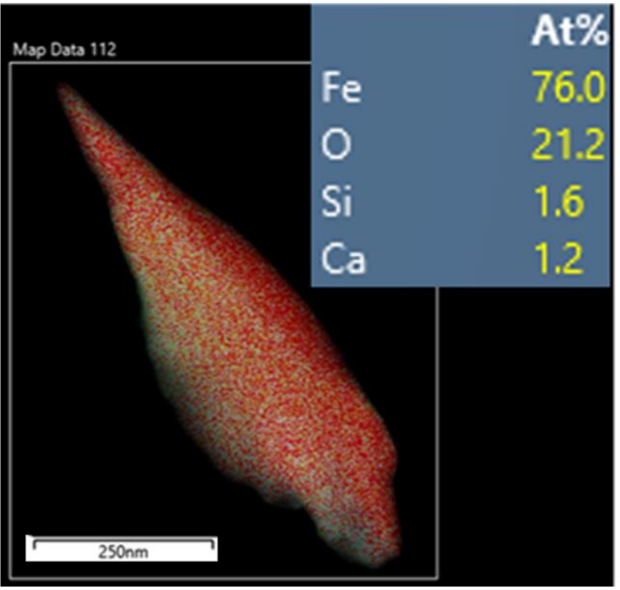
Agglomerate: AR 1~2

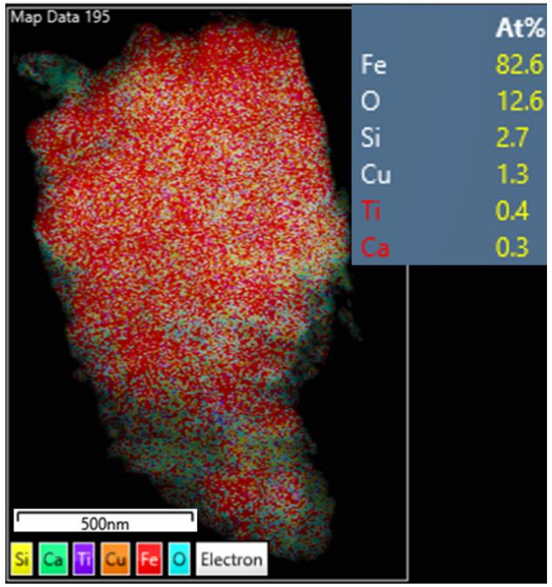
Heterogeneous Fe speciation of magnetic dust identified by EDX

- Iron and oxygen quantified by EDX in atomic percentage to study the **heterogeneity in Fe speciation**



- 481 magnetic dust particles were classified into 4 groups (Method presented in RQ2)





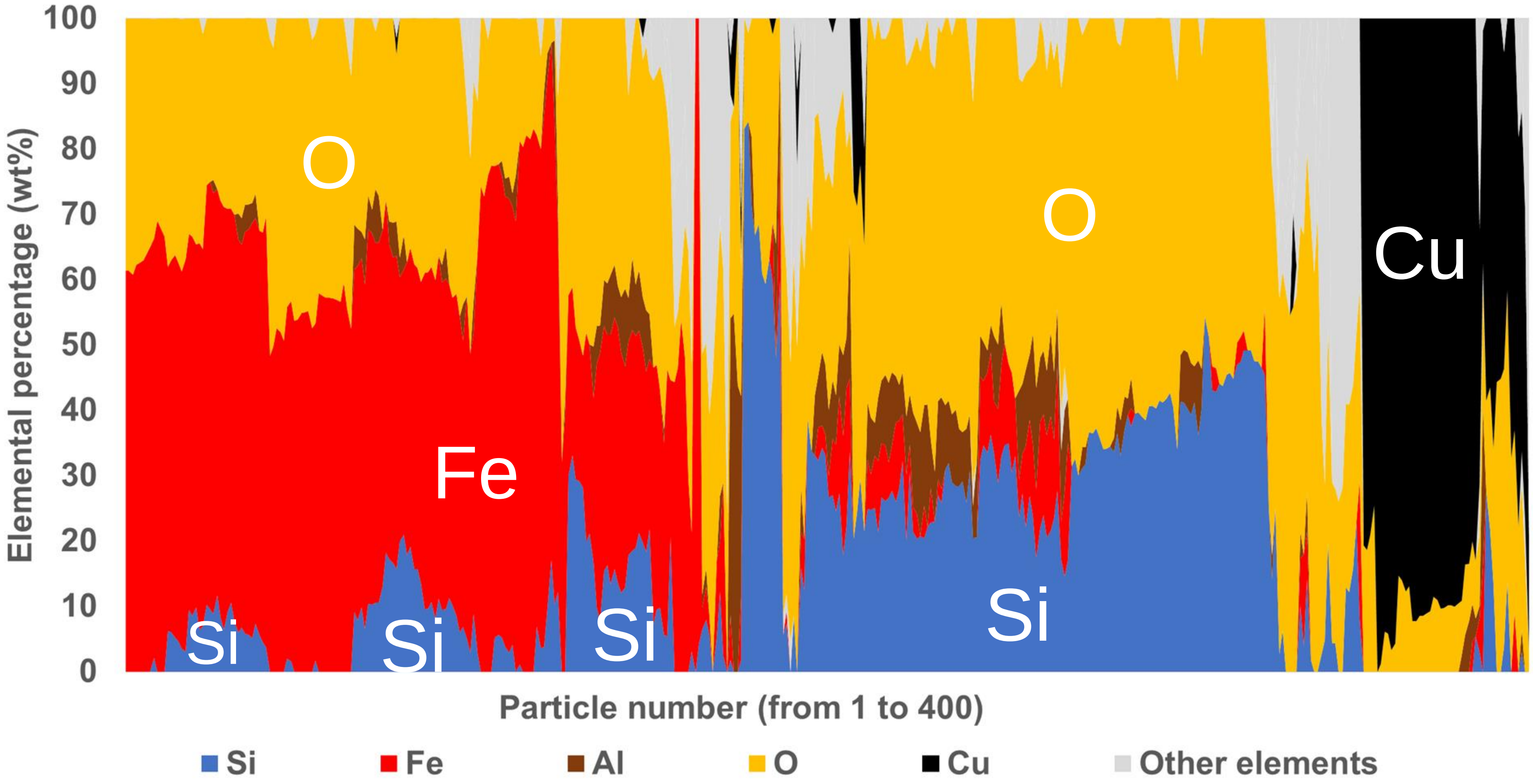
Operative name of particle group	Major elements in the group (up to 5), at%	Particle Relative abundance (%)	Aspect ratio
Fe-O-Si-Ca-Al	73.4 Fe, 23.7 O, 1.9 Si, 0.6 Ca and 0.2 Al	3.1	3 ± 2*
O-Fe-Si-Ca-Al	61.9 O, 22.0 Fe, 8.2 Si, 3.4 Ca and 2.3 Al	96.5	1.6 ± 0.8*
O-Sb-S-Si-Fe	37.4 O, 28.3 Sb, 17.9 S, 10.5 Si and 6.0 Fe	0.2	1.6
O-Al-Fe-Si-Ca	54.8 O, 36.0 Al, 4.0 Fe, 3.6 Si and 0.8 Ca	0.2	1.4

- Metallic iron (Fe^0) and iron oxides are separated into different groups.

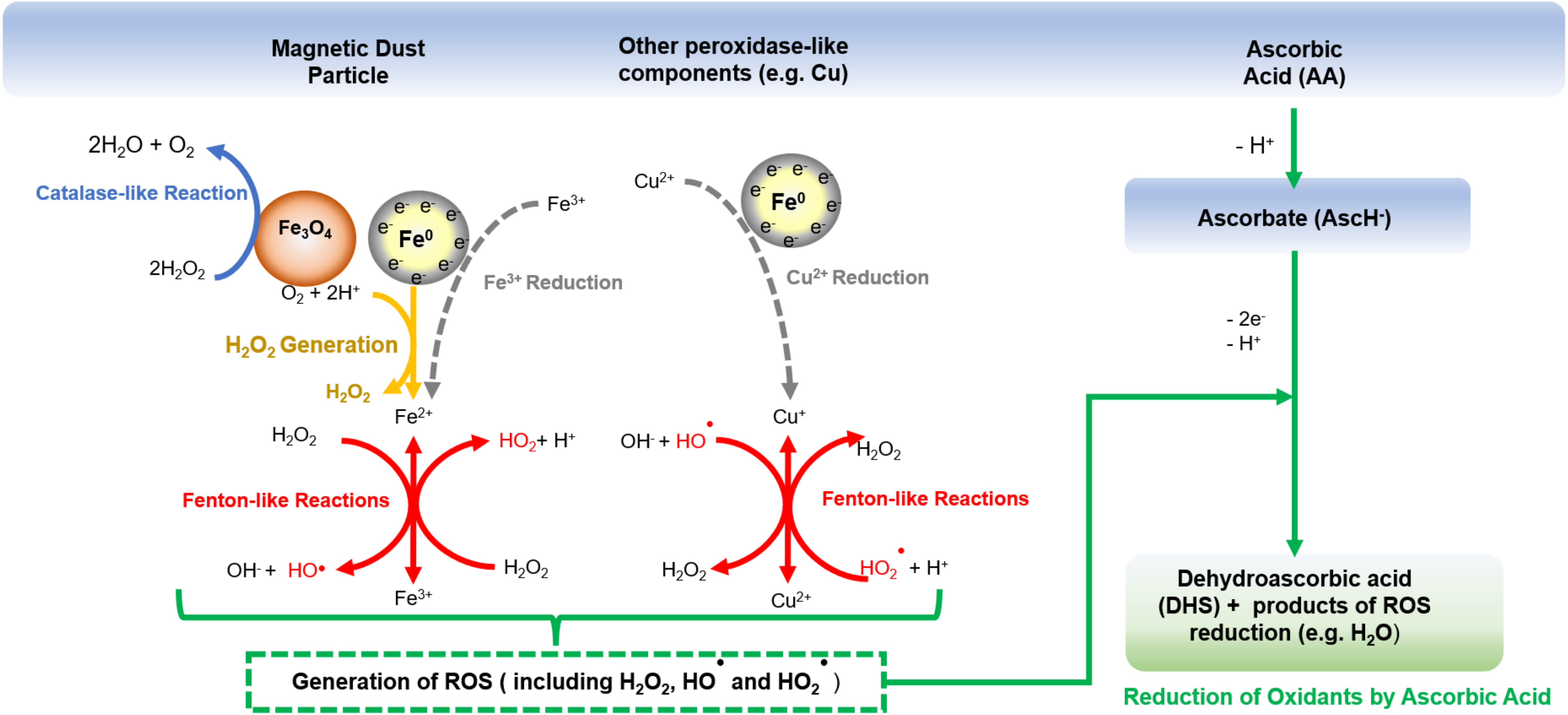
Heterogeneous elemental composition at single-particle level

Match all particles to the dendrogram

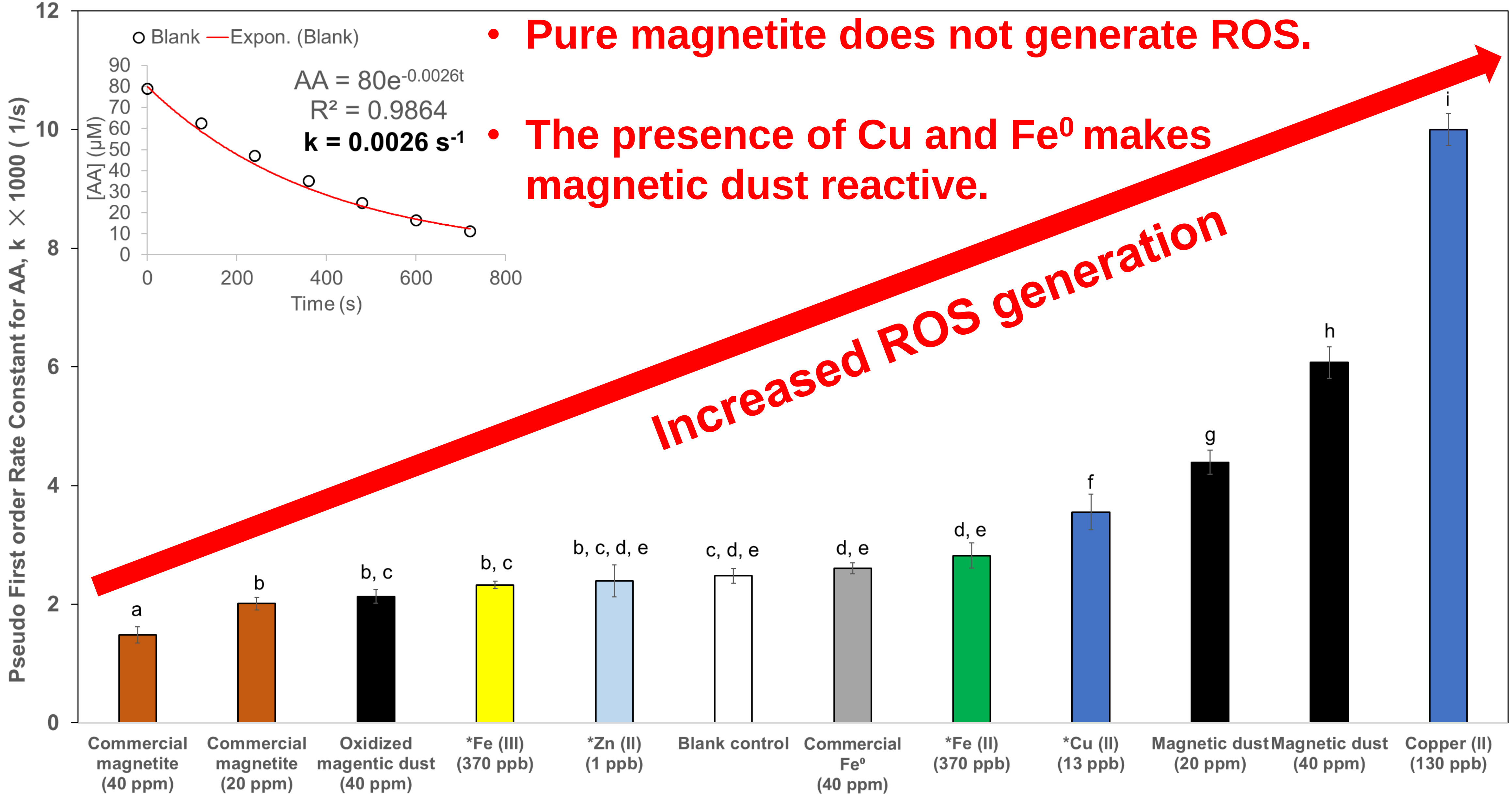
- Particles of similar elemental composition are clustered together
- Enable the study of heterogeneity in elemental composition for each particle group.



How can this heterogeneity affect ROS generation?



ROS generated by the heterogeneous magnetic dust

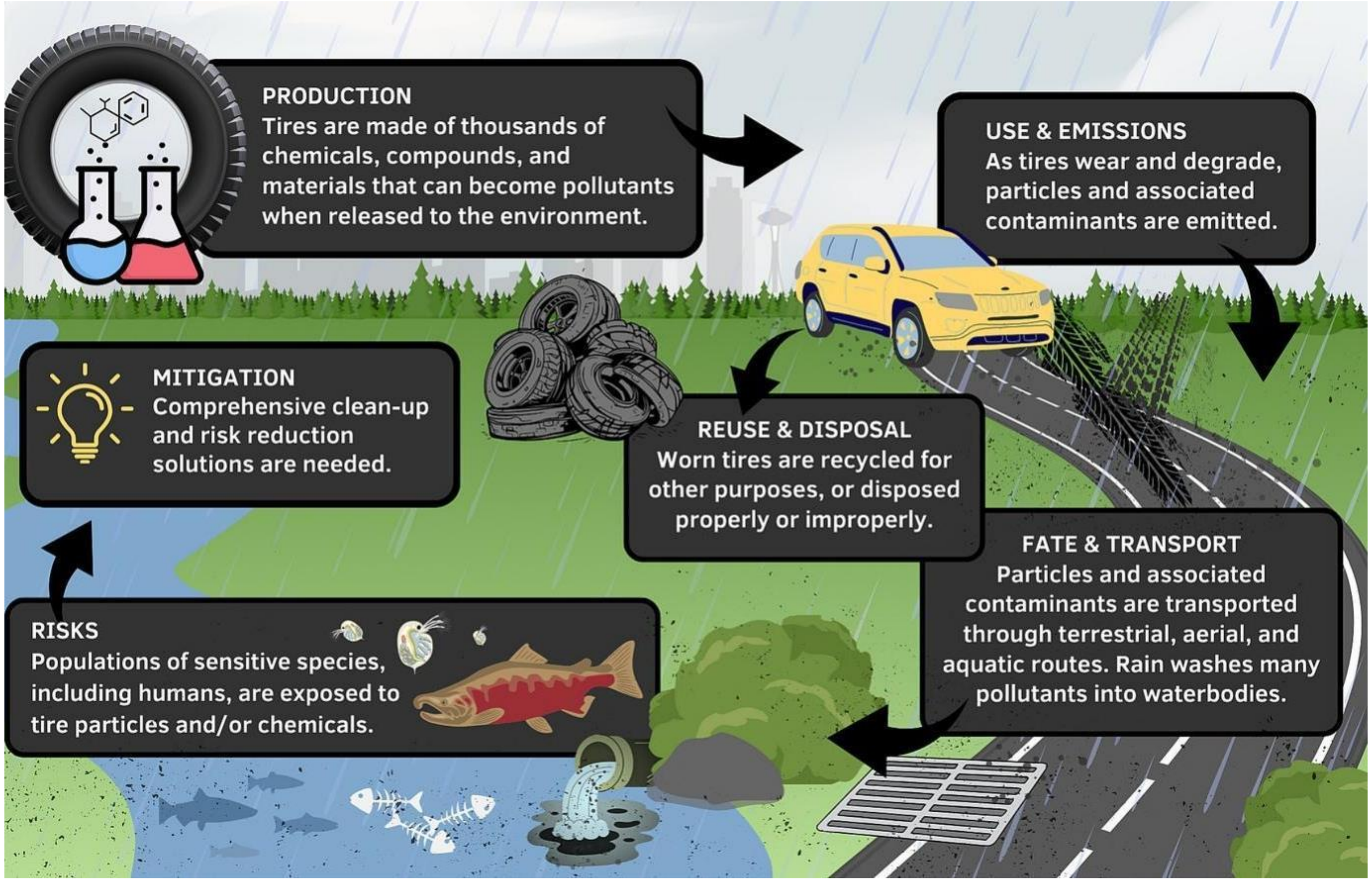


Ecotoxicity of tire- and break-wear particles

Ecotoxicity

CoR

Olga Tsyusko
University of Kentucky
Lexington, KY,



https://doi.org/10.1016/j.scitotenv.2024.171153

ELSEVIER

Journal of Hazardous Materials
Volume 429, 5 May 2022, 128319

Toxicity of micro and nano tire particles and leachate for model freshwater organisms

Brittany Cunningham [a], Bryan Harper [a], Susanne Brander [b], Stacey Harper [a c]

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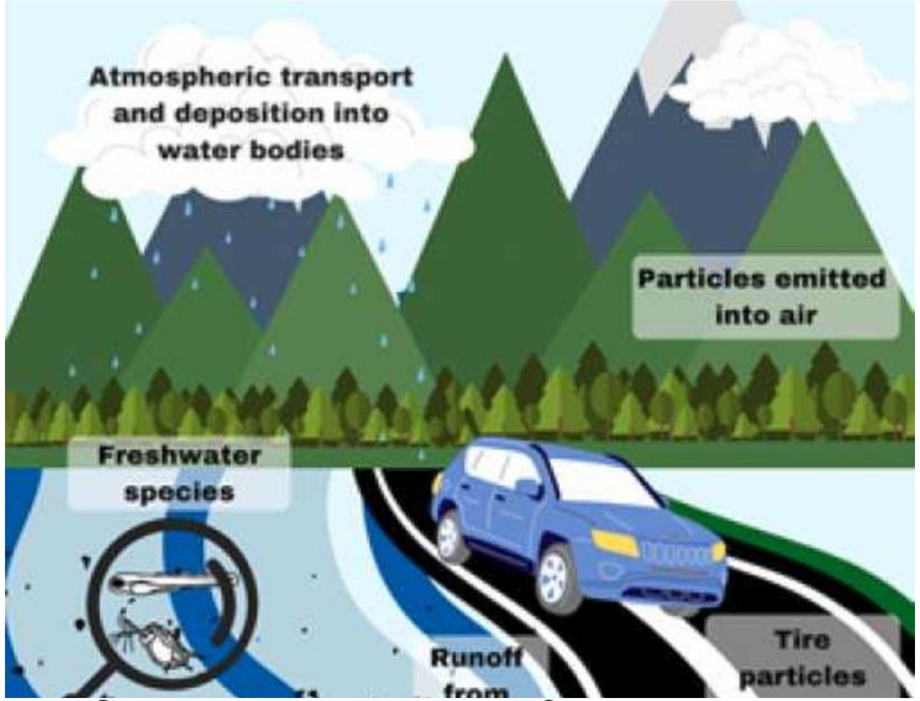

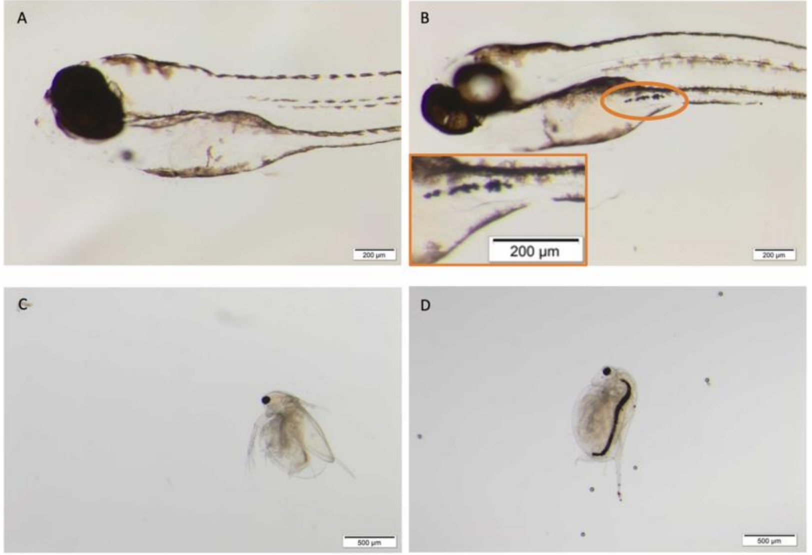

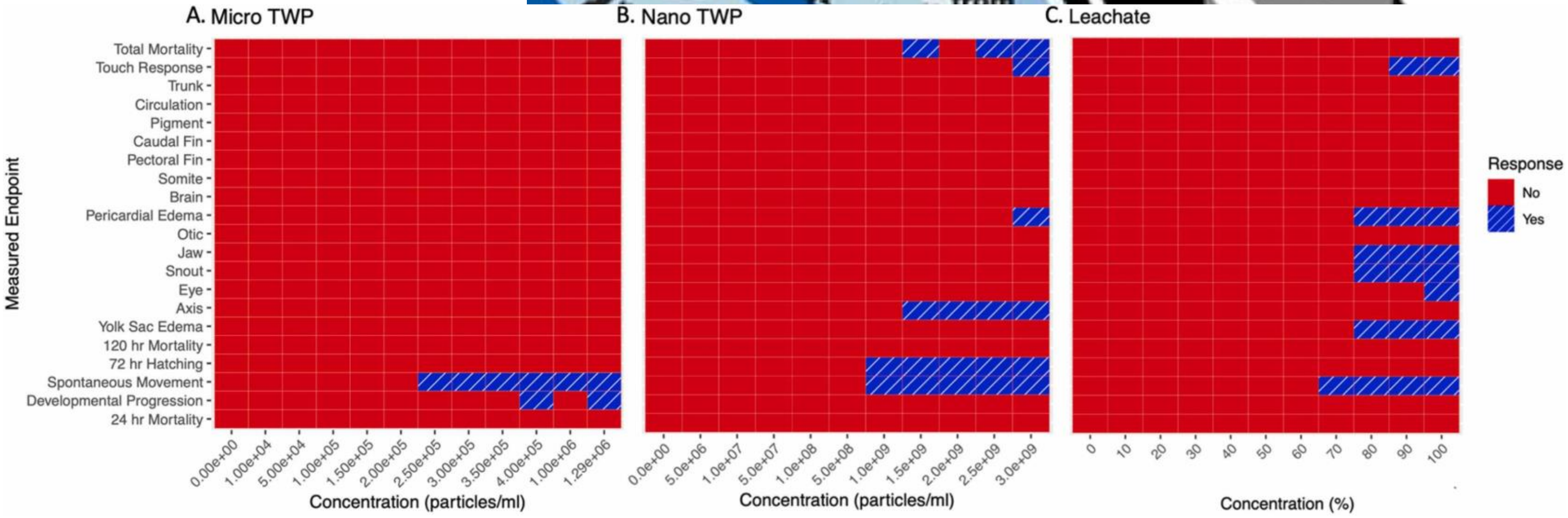

https://doi.org/10.1016/j.jhazmat.2022.128319

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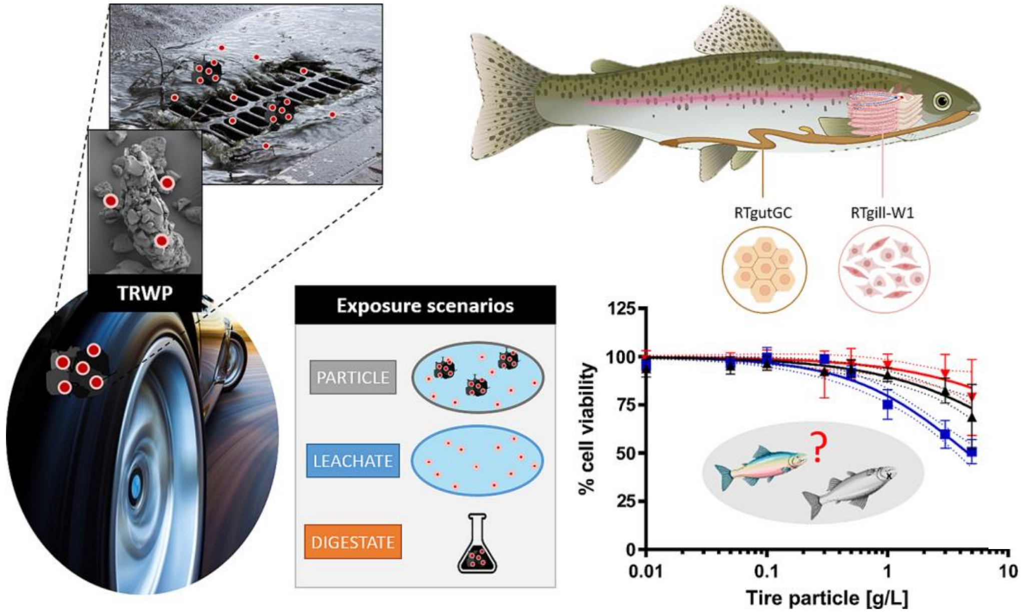
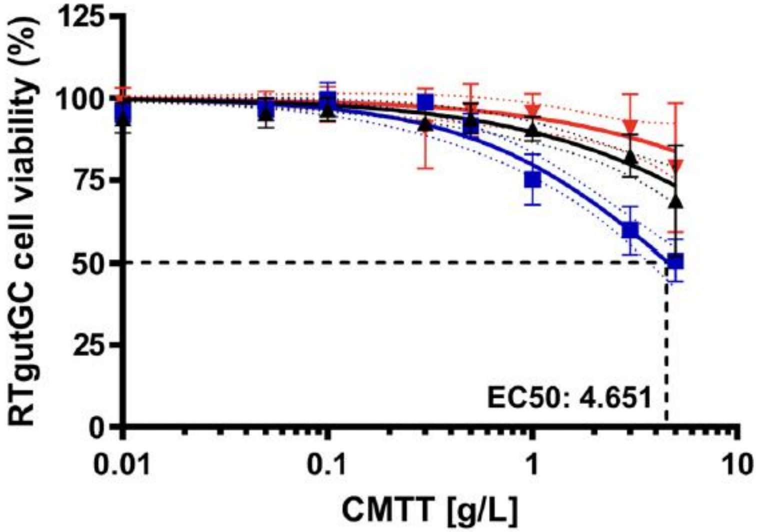
aquatic research

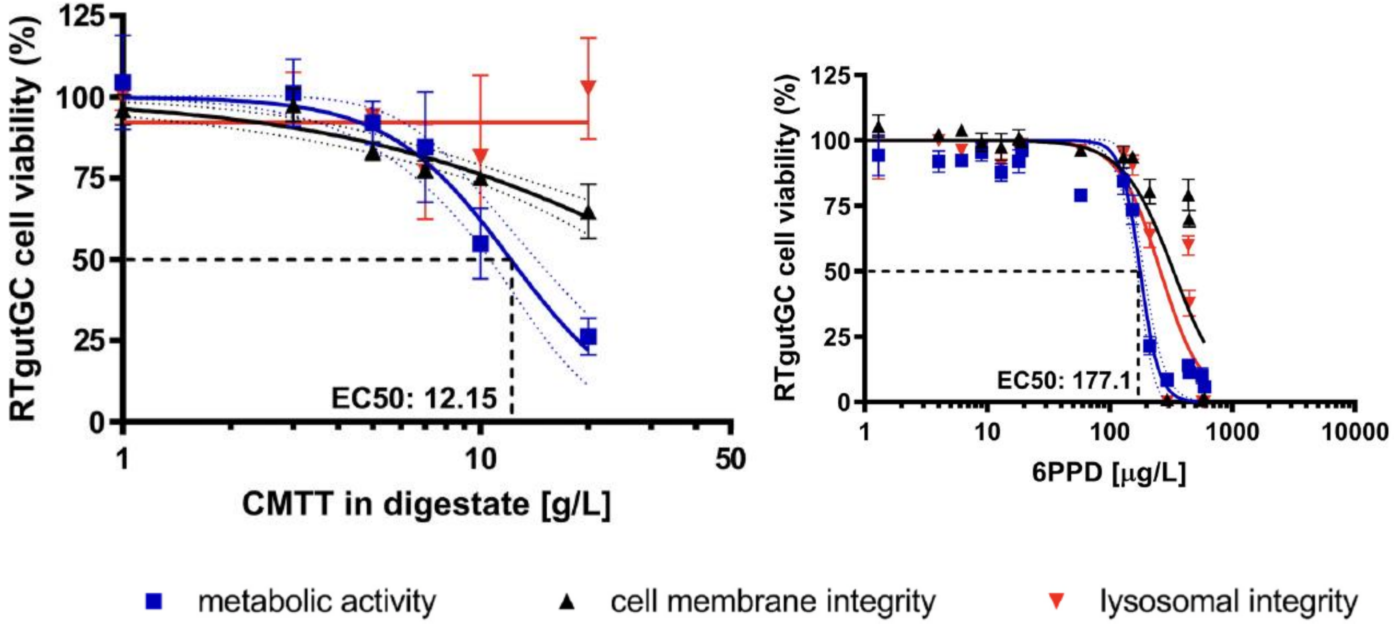
Science of The Total Environment
Volume 912, 20 February 2024, 168933

Evaluation of tire tread particle toxicity to fish using rainbow trout cell lines

W. Dudefoi [a], B.J.D. Ferrari [b c], F. Breider [d], T. Masset [d], G. Leger [d], E. Vermeirssen [c], A.J. Bergmann [c], K. Schirmer [a e f]







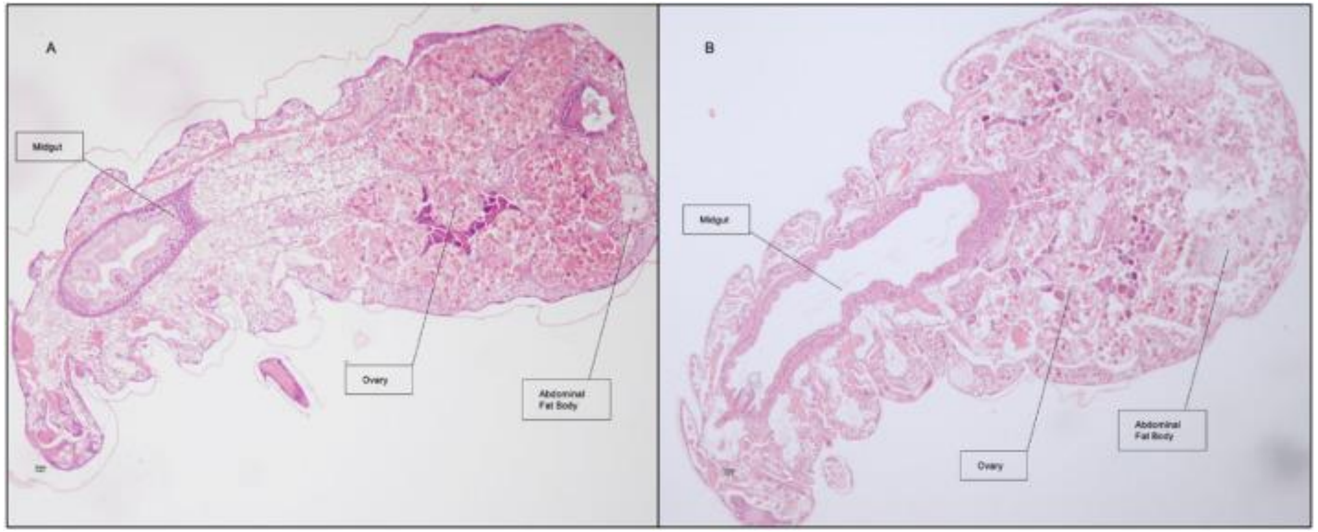
https://doi.org/10.1016/j.scitotenv.2023.168933

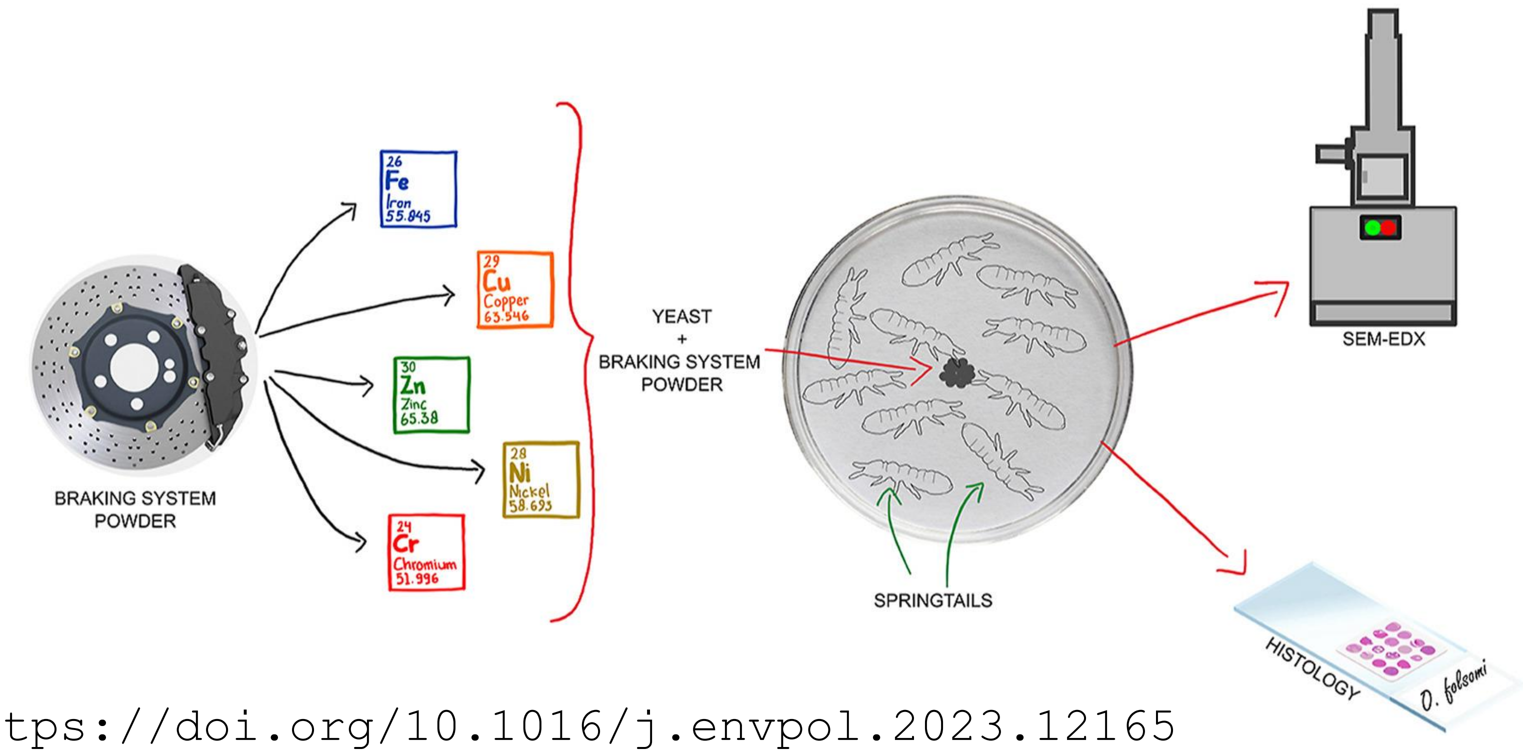
Main drivers of CMTT toxicity were Zn (22.5%)
68% - by other degradation products

Environmental Pollution
Volume 329, 15 July 2023, 121659

Effects of oral exposure to brake wear particulate matter on the springtail Orthonychiurus folsomi ☆

Giulia Papa [a,b,1], Karen Power [c,1], Bartolo Forestieri [a], Giancarlo Capitani [d], Paola Maiolino [c], Ilaria Negri [a]





- Alterations in the midgut and ovaries
- Fat body in HiC-treated samples -necrosis in ovaries
- No significant tissue modifications in LoC-treated samples

https://doi.org/10.1016/j.envpol.2023.121659

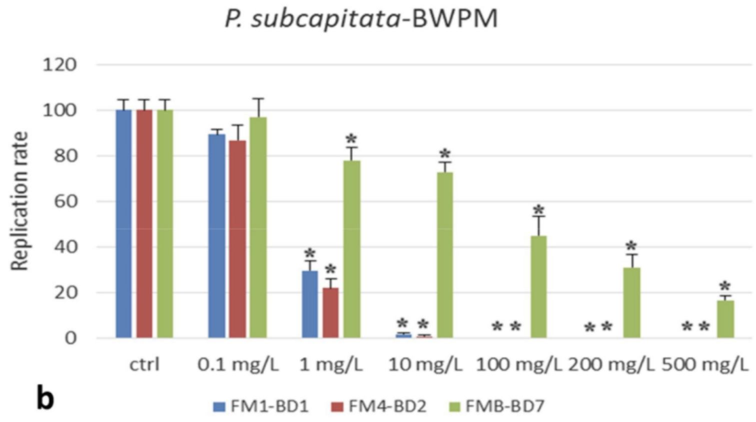
ELSEVIER

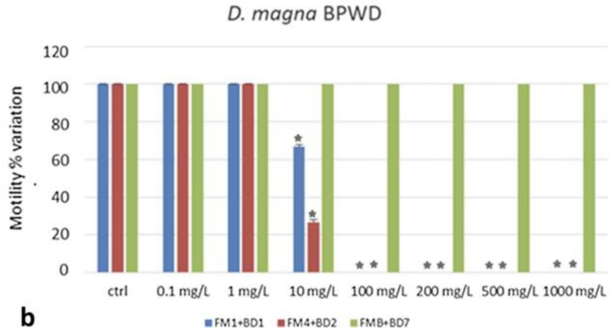
Environment International

Volume 137, April 2020, 105564

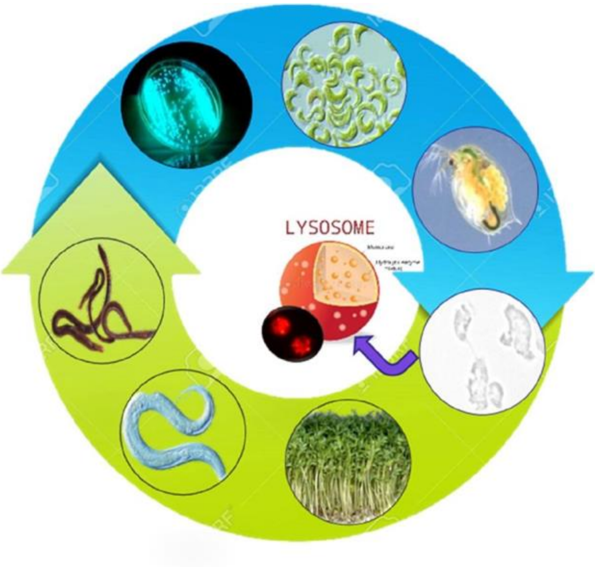
Ecotoxicological effects of atmospheric particulate produced by braking systems on aquatic and edaphic organisms

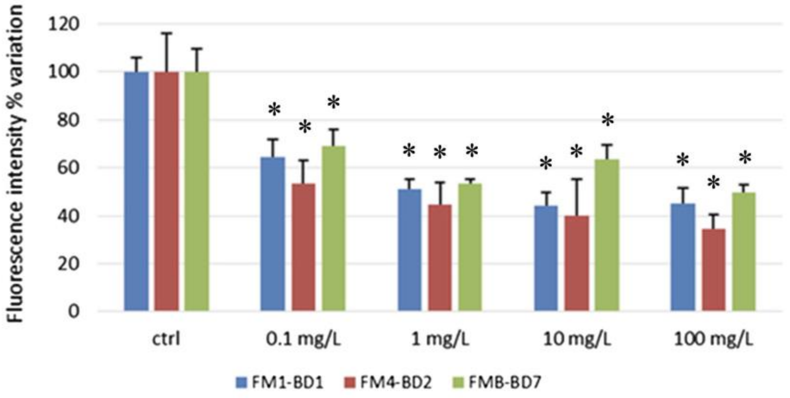
Anna Volta [a b], Susanna Sforzini [a b], Corrado Camurati [a b], Federico Teoldi [b], Simone Maiorana [b], Alessandro Croce [a], Emilio Benfenati [b], Guido Perricone [c], Marco Lodi [b], Aldo Viarengo [b d]

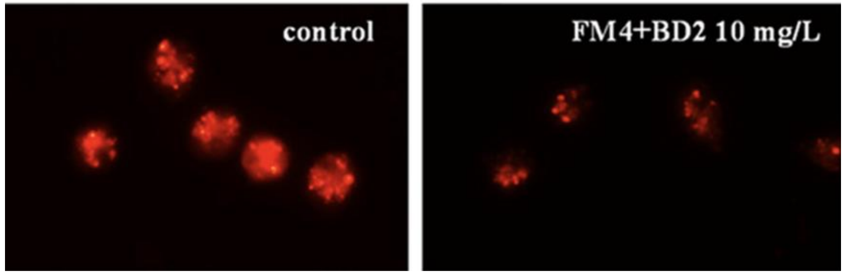




LOW BRA SYS







https://doi.org/10.1016/j.envint.2020.105564

Lysosomal membrane stability of *D. discoideum amoebae* after exposure to the three brake-system particulate

frontiers in Environmental Science

ORIGINAL RESEARCH
published: 20 September 2021
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Check for updates

Time-Dependent Toxicity of Tire Particles on Soil Nematodes

Shin Woong Kim[1,2]*, *Eva F. Leifheit*[1,2], *Stefanie Maaß*[2,3] and *Matthias C. Rillig*[1,2]

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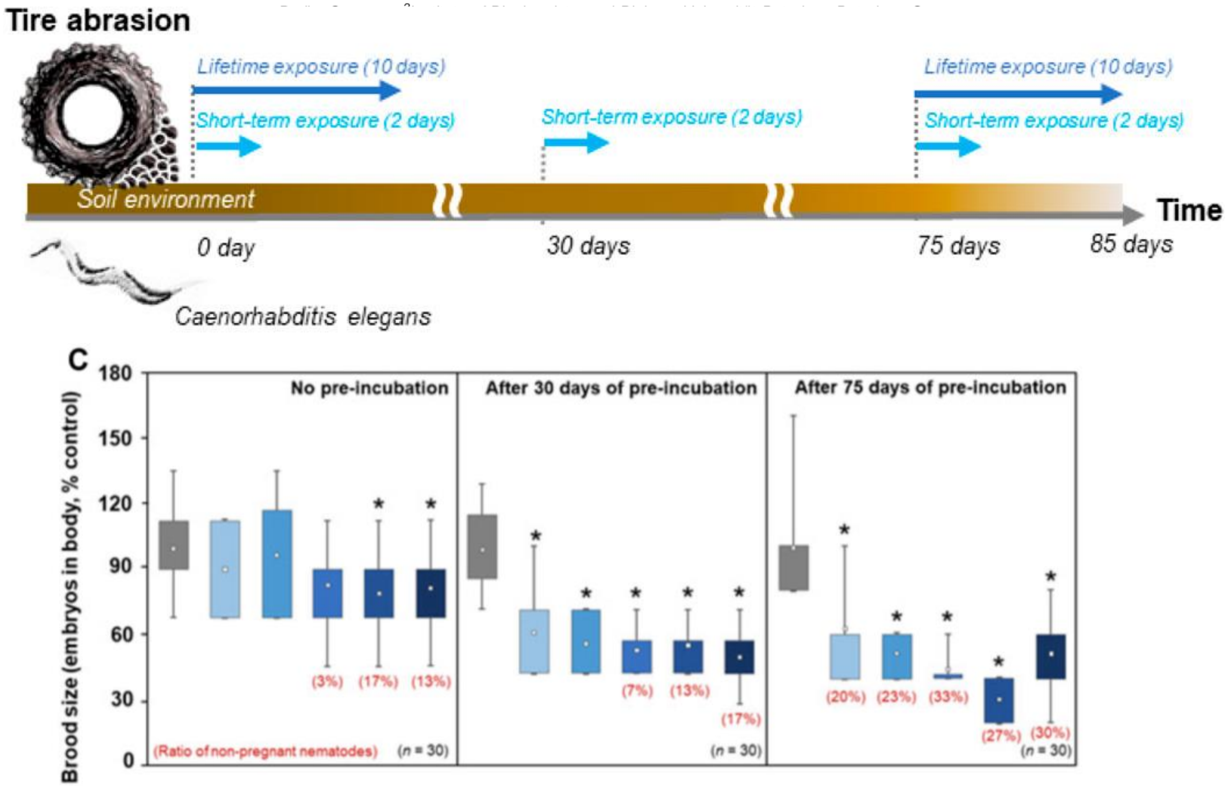

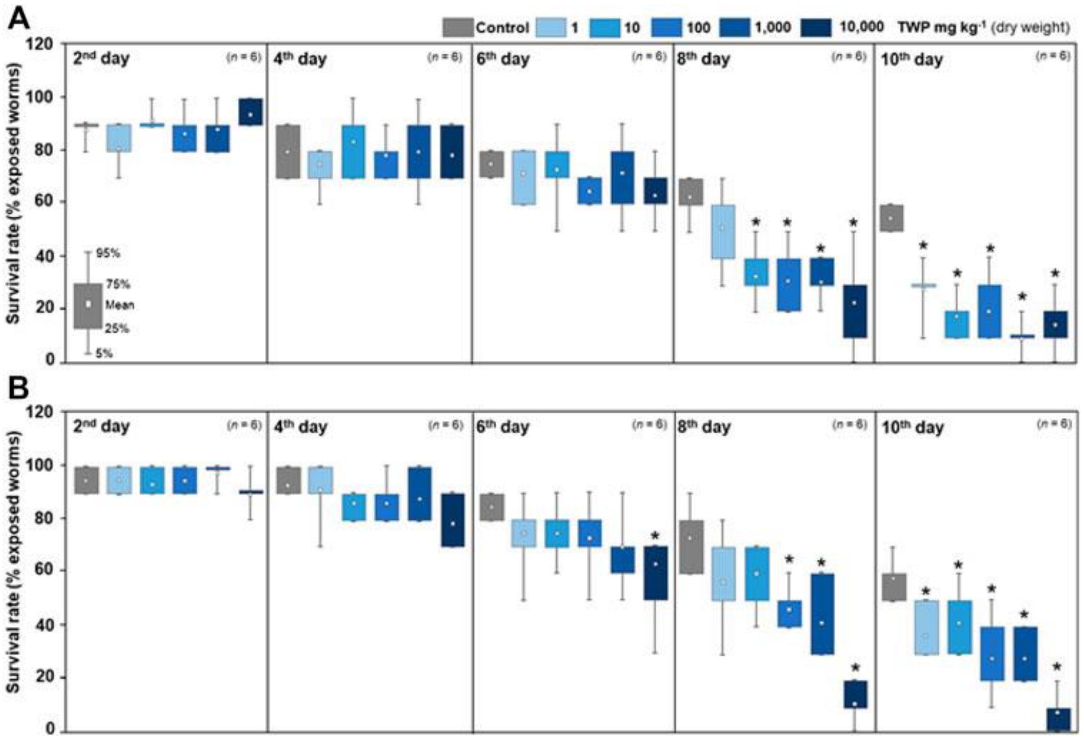

Top – no pre-incubation of TPW
Below –75-days of pre-incubation

- Soil pre-incubation increased toxicity
- Lifetime survival is more sensitive compared to short-time exposure

https://doi.org/10.3389/fenvs.2021.744668

Interactive Exercise

- *Drawing on our unique strengths and expertise in engineered and incidental nanomaterials, what actions do you think would be worth pursuing in order to scale-up research on the tire-wear and break-wear to more complex systems?*

- Solo (5 min): Please identify 1-2 key action(s) and write it down on a sticky note
- Share with the partner next to you – 10 min
- Share several with the group

Prompt Question #2

CONGRATULATIONS

Your team was awarded 1 Million (USD or EU) to split between US and EU research

What would you be able to do to advance our understanding of brake/tire wear incidental nanomaterials

Interactive Exercise (can start with this one)

- *Where are the most critical challenges and research gaps in mesocosm research?*

1. *Solo: Please identify 1-2 main gap(s) and write it down on a sticky note -5 min*
2. *Share with the partner next to you – 10 min*
3. *Share with the group -10 min*

Potential questions for discussion (optional)

- *Given the research gaps identified, what new research would be truly novel and valuable?*
- *Do you think research in mesocosms can predict ecosystem effects?*