Experiences of measuring airborne wear particles from braking materials and wheel-rail contact

Saeed Abbasi
(sabbasi@kth.se)

Ulf Olofsson

Ulf Sellgren

Outline

- Short review
  - Terminology
  - Negative effect on human health
  - Current condition
- Experimental works
  - On-board measurement
  - Sub-scaled test

Terminology

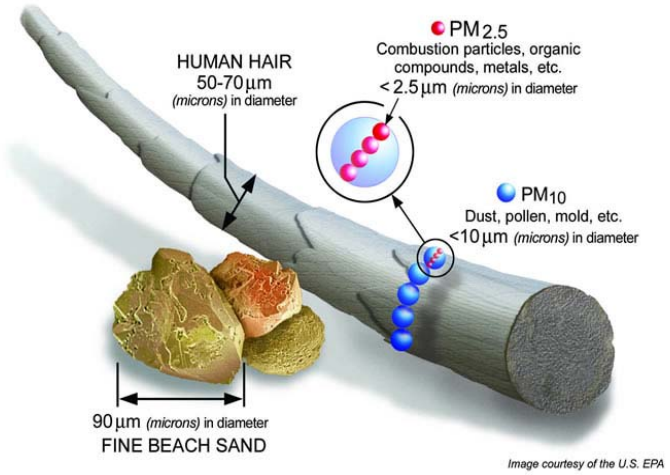
- Particulate matter (PM10, 2.5, 1)

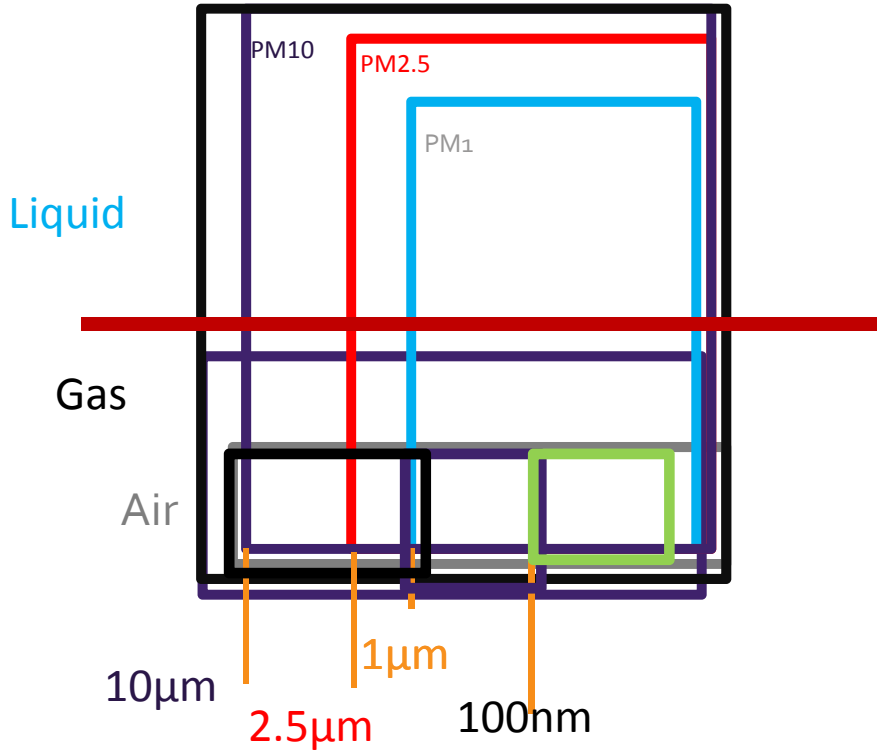
The Suspension of fine solids particles or liquid droplets or mixture of them in the gas or liquid

-Coarse region (2.5μm < dp <10μm)

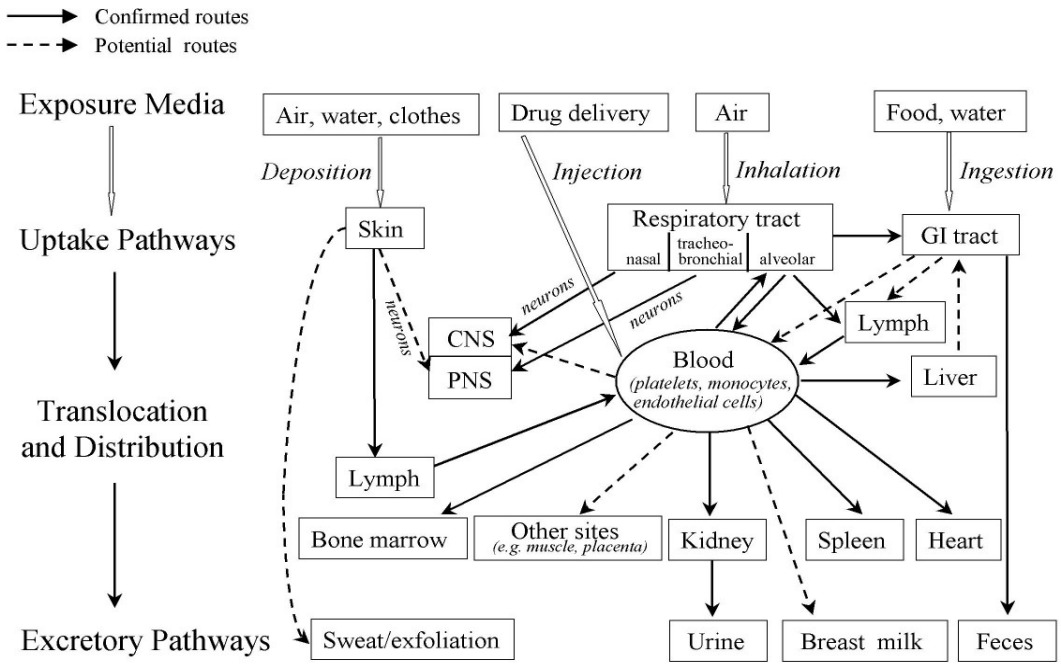
-Fine region (100 nm< dp <2.5μm)

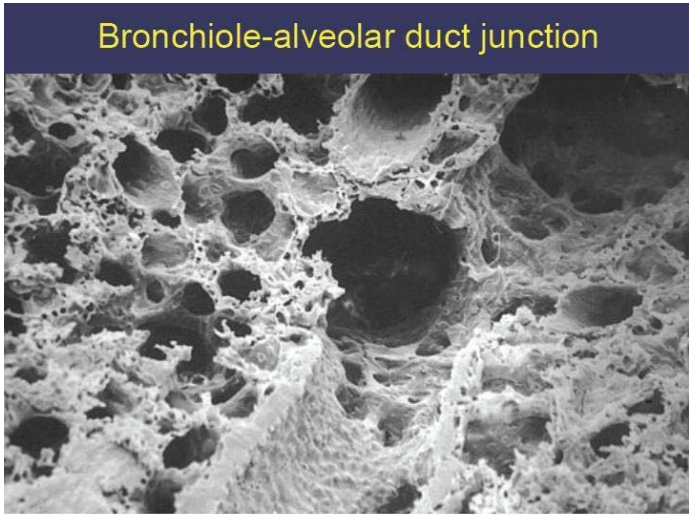
-Ultrafine region (dp <100nm)

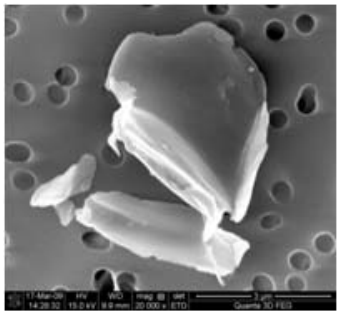


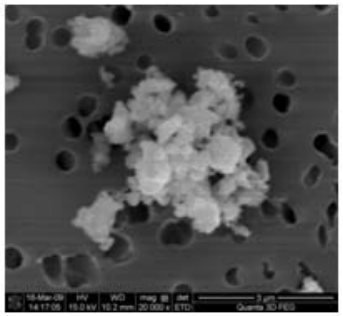


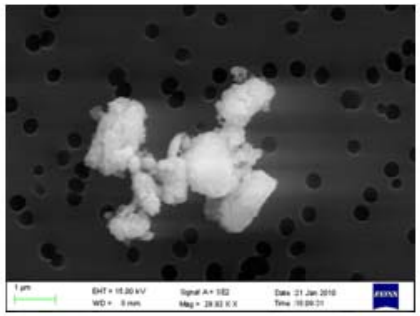
Particles & health problems

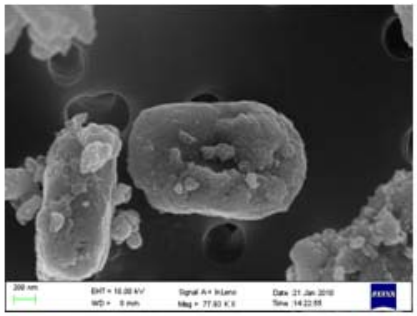












PM & outdoor air quality

Outdoor air quality legislation

		PM_{10} (μg m^{-3})	$PM_{2.5}$ (μg m^{-3})
US EPA[2] website	Daily (24 h)	150	35
	Annual	–	15
EU directive 2008/50/EC	Daily (24 h)	–	50
	Annual	25	40

Typical PMC value in subway stations

Typical PMC results in subways (Different cities)		PM_{10} (μg m^{-3})	$PM_{2.5}$ (μg m^{-3})
Cairo	Daily (24 h)	938	
London	Daily (24 h)	1000-1500	270-480
Paris	Daily (24 h)	320	91
Stockholm	Daily (24 h)	357-500	199

PMC: particle mass concentration

Typical PMC value in road transport

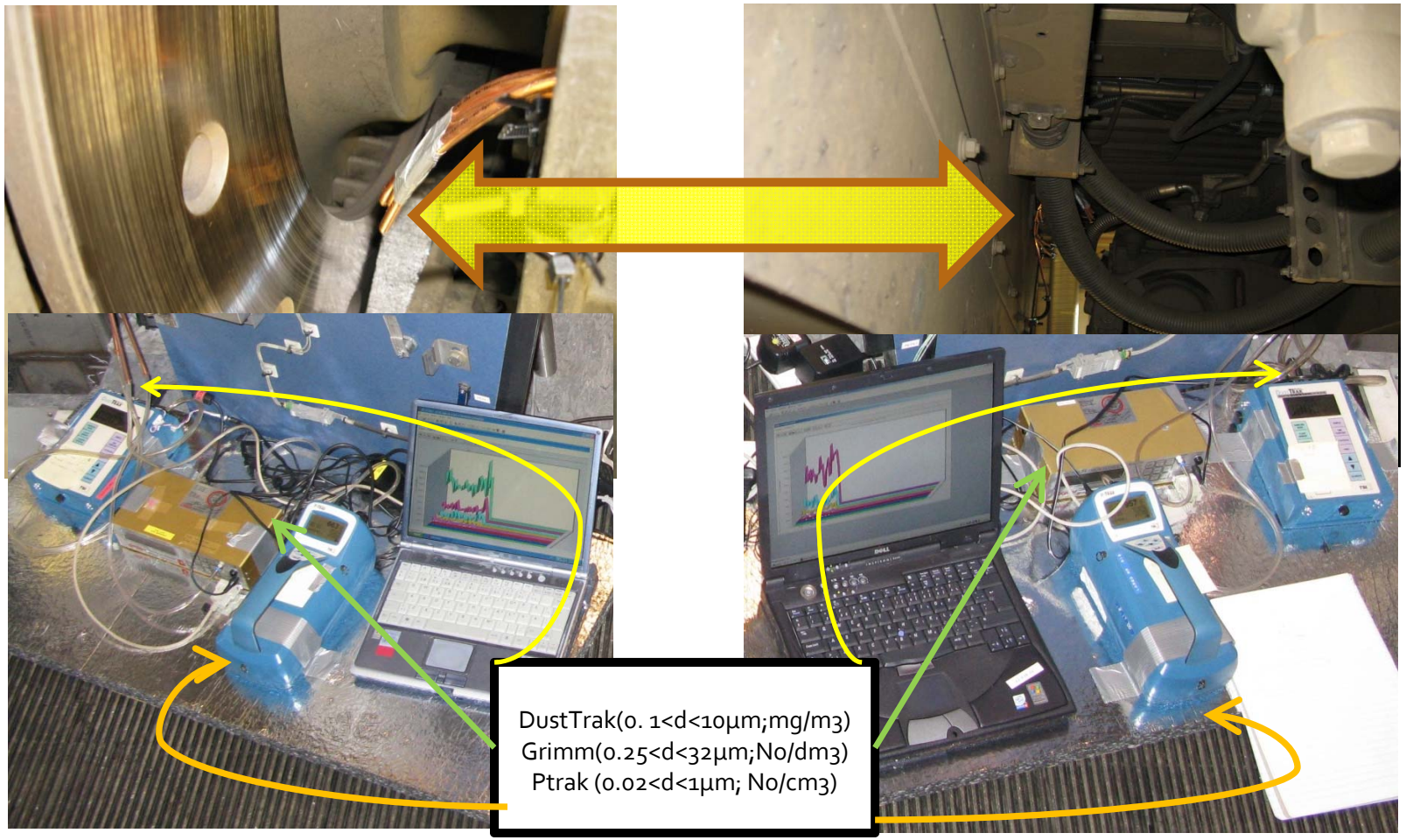
Source	$PM_{2.5}$	$PM_{10-2.5}$ (Coarse)
Exhaust	73%	15%
Tyre	6%	11%
Brake	5%	31%
Road	5%	16%
Resuspnsion	N.A	27%

Abbasi *et al*. Particle emissions from rail traffic: A literature review, ***Critical Reviews in Environmental Science and Technology***, In press.

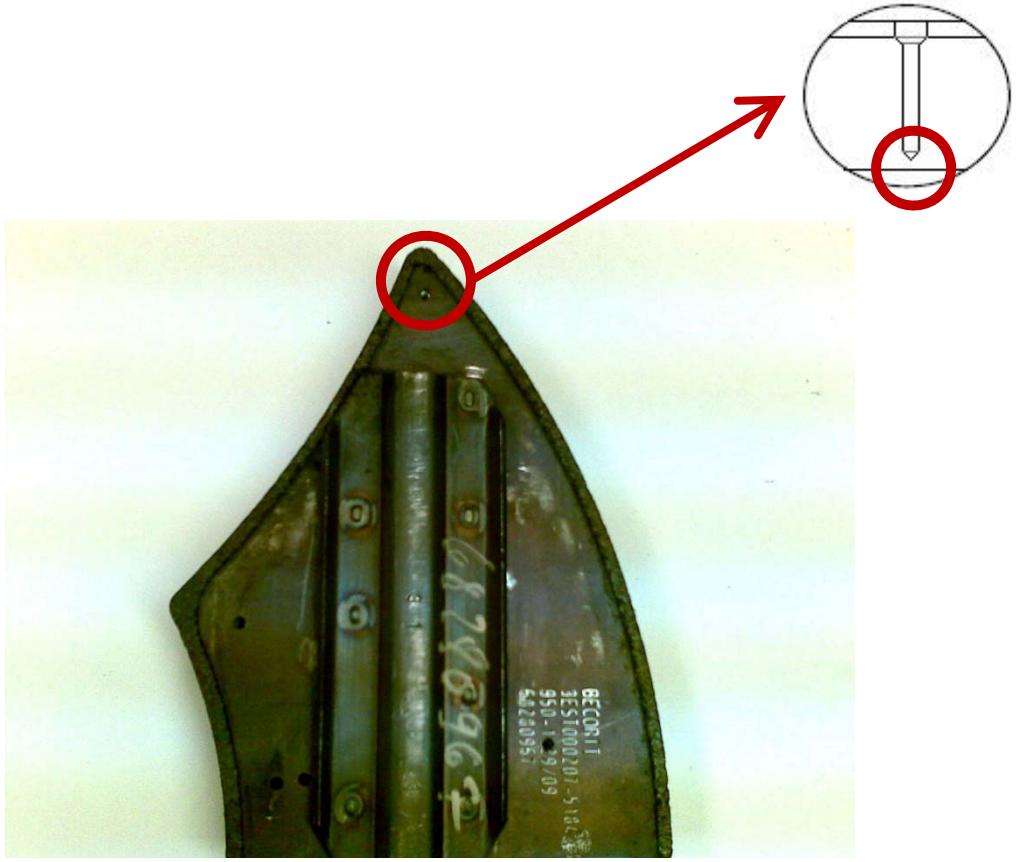
Particle measurement devices arrangement in an on-board experiment

Sampling point 'Brake pad'

Sampling point 'Global '

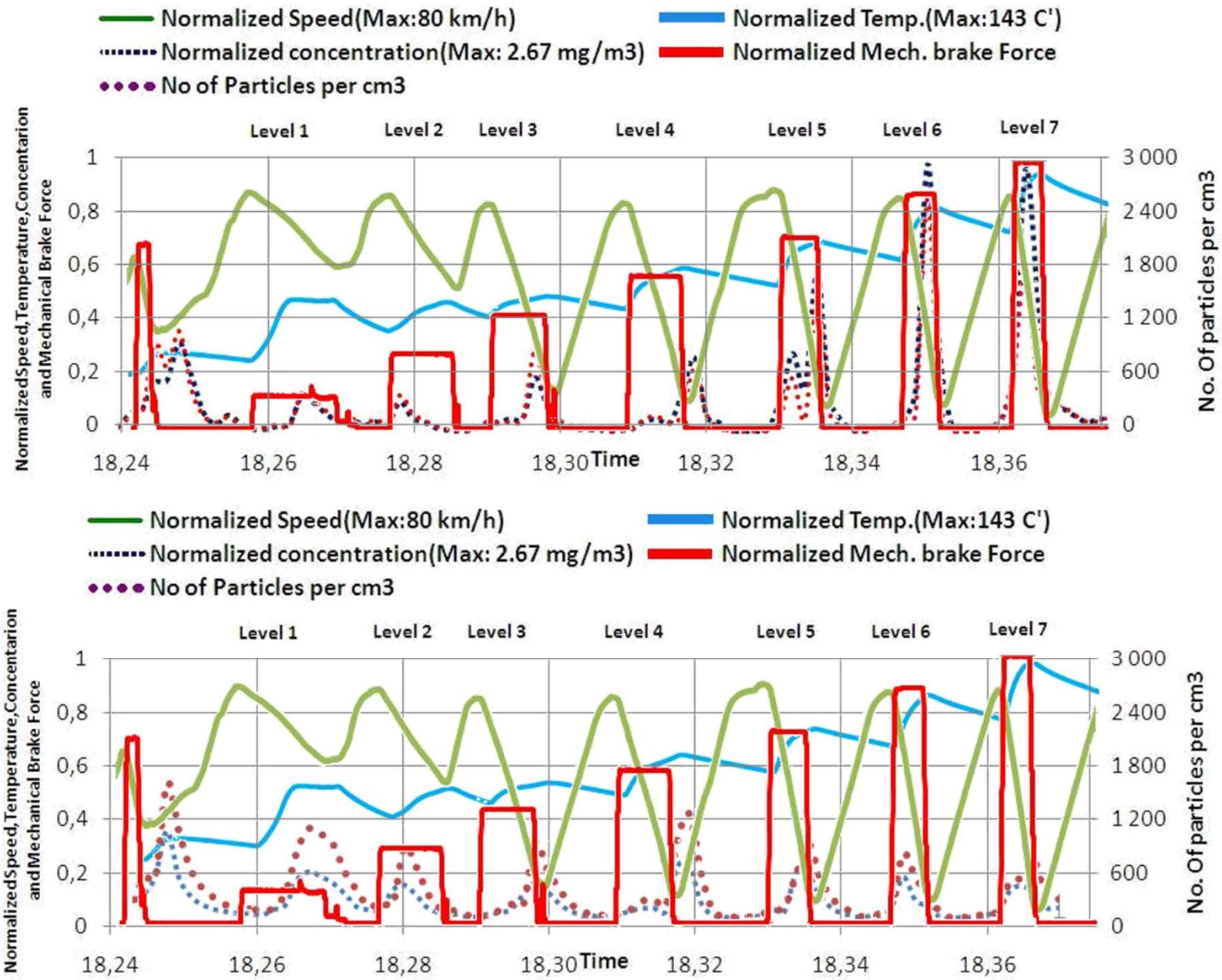


Temperature Measurement in brake pad:

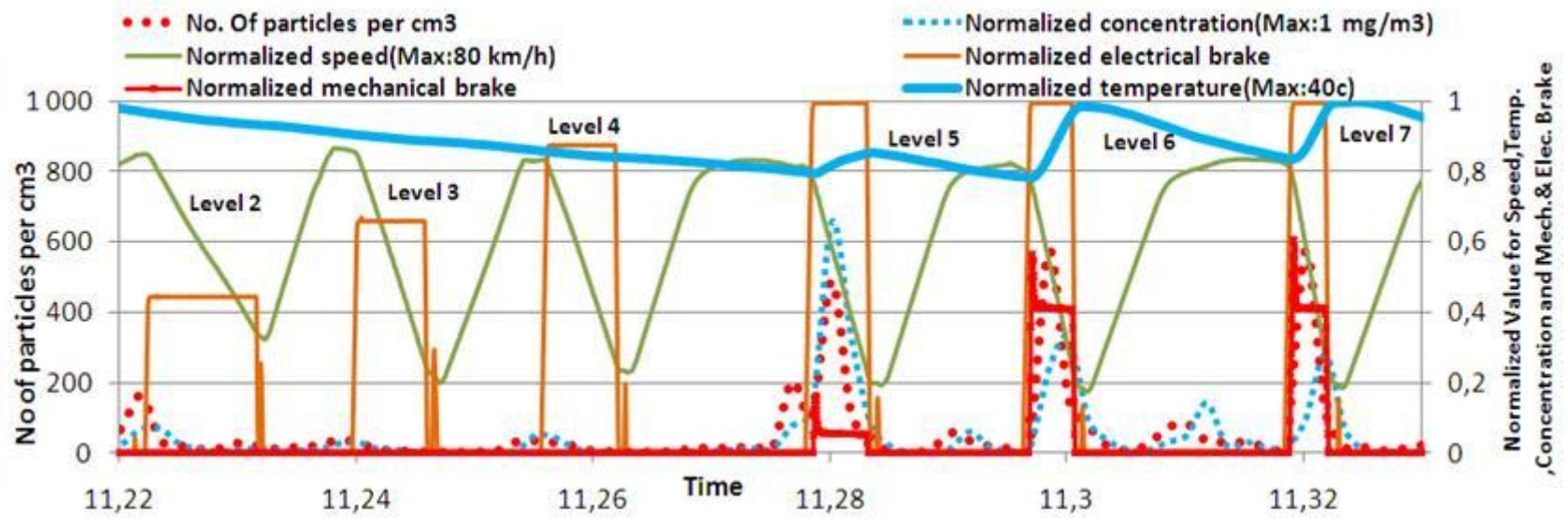


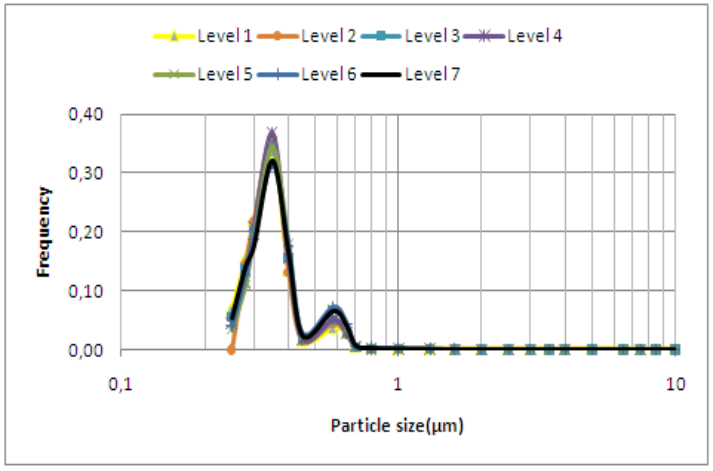
The distance between hole bottom and contact zone was 1 mm

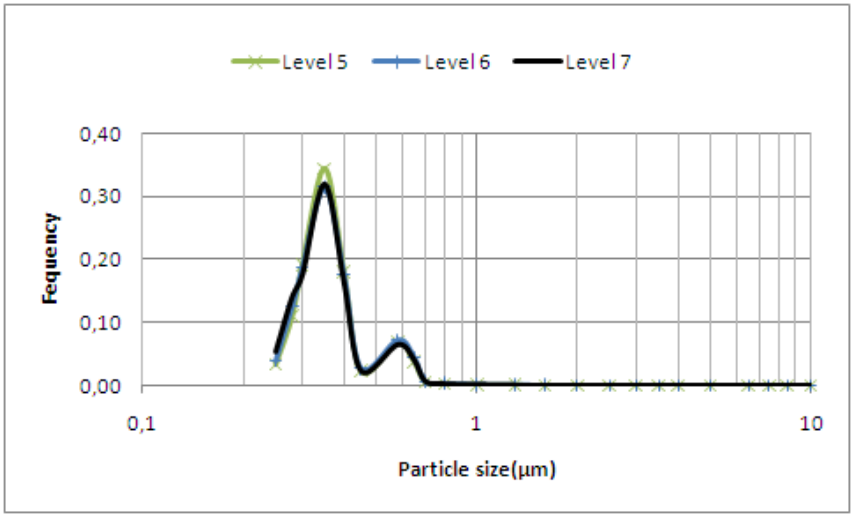
Recording particles in different brake levels:



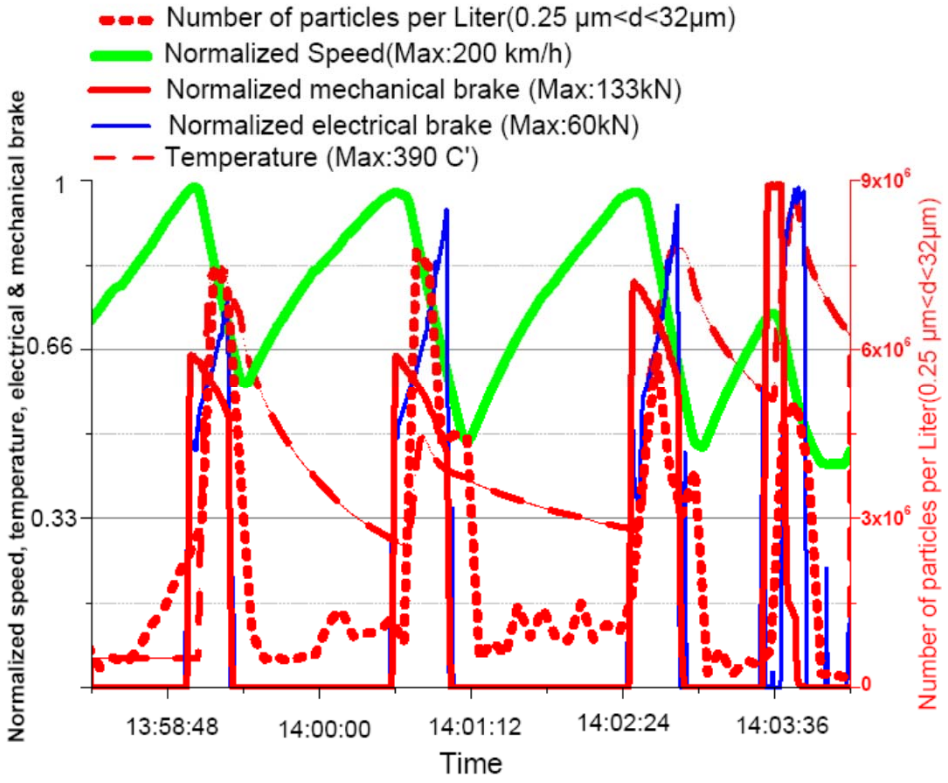
Recording particles in different brake levels:
(Electro-magnetic brake activated)

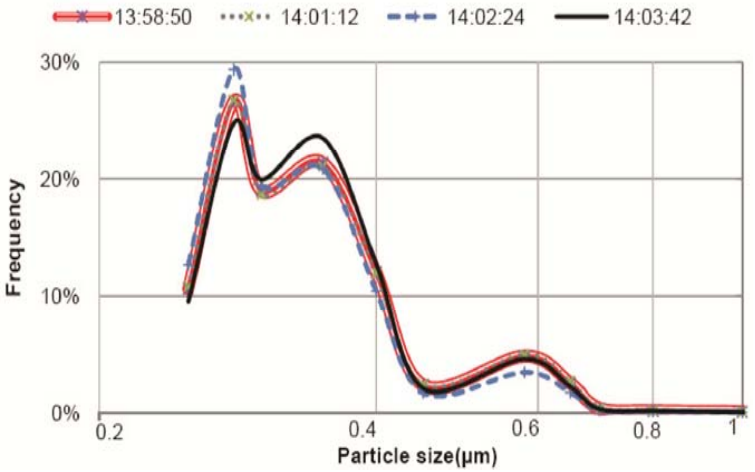






Recording particles in high temp. of brake pad :





The comparative percentile weights of elements:

	Run	Fe	Cu	Zn	Ca	Mg	Al	Sb	Na	Ni	Mn	Ba	Cr
Brake Pad	1	65	10.1	4.4	2.9	2.2	1.8	1.4	0.5	7.1	0.6	2.6	0.8
Global	1	60.2	9.7	3.9	5	4	5.7	1.8	3.2	1.1	0.6	0.2	1.2
Brake Pad	2	66.2	10.7	4.5	3.5	3.7	1.6	2.8	0.5	3.6	0.7	0.8	0.6
Global	2	63.9	7.4	3.1	5.3	4.8	5.3	2.3	3.4	0.6	0.7	0.3	0.6
Brake Pad	3	65.8	9.5	3.8	4.2	3.4	3.7	2.4	1.2	1.3	0.7	0.8	0.5
Global	3	62.8	8.5	3.3	5.4	4.1	6	2.6	2.2	1	0.7	0.3	0.7
Brake Pad	4	64.7	9.9	3.9	4.9	4	2.6	2.9	1.6	0.7	0.7	0.4	0.7
Global	4	59	8.1	3	6	4.9	6	2.6	3.7	0.5	0.7	0.2	0.5

Notes:

a. The amounts of K, Si, As, and U were above the detection limit only in the global filters.

b. The amounts of B, Be, Se, Cd, P, S, Th, and Tl were under the detection limit in all filters in both locations.

c. The percentile weights of Li, Ag, As, U, Bi, Co, Rb, Pb, V, Sn, Sr, Ti, and Mo were under 0.5%.

d. Regarding limitations of the ICP-MS method, C, F, O, H, and N were not investigated, so all presented percentile weights were comparative values.

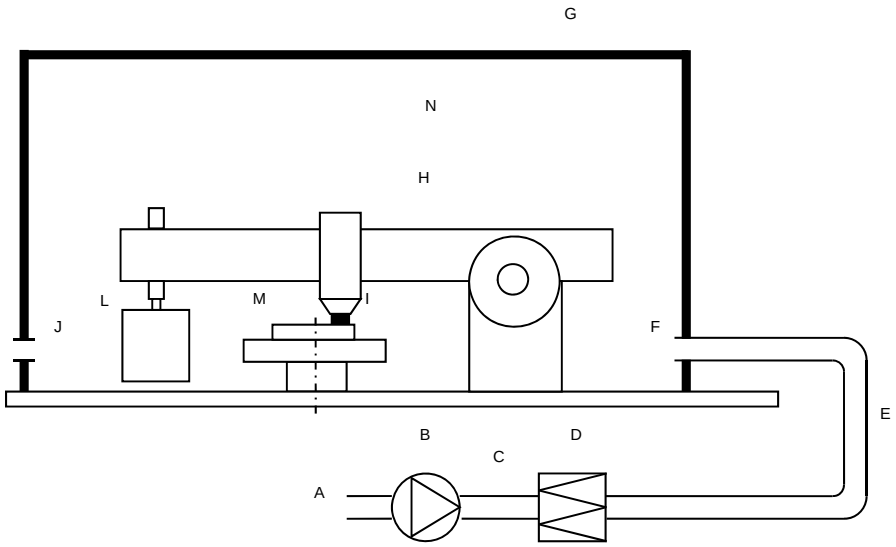
e. The unused Millipore filters contain Ca in addition to C, H, F, and O; the amounts of other elements in the filters were negligible. The filter composition has no effect on the results as the relative comparative weights were discussed.

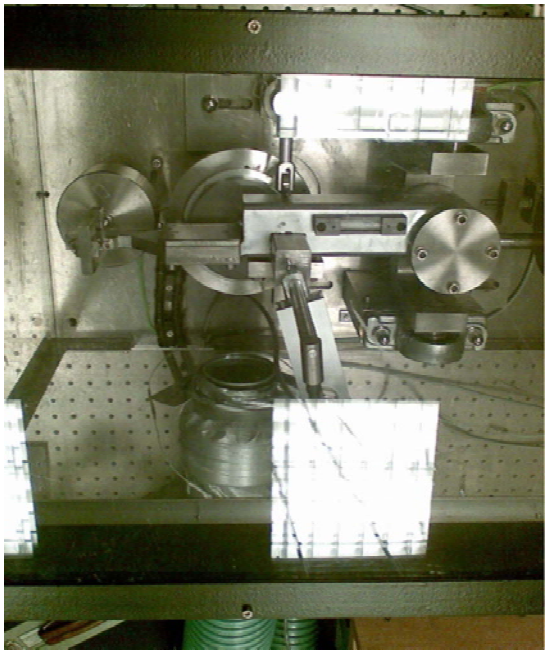
f. The amounts of Ti and Sn were above the detection limit in the global filters when whole filters from the fourth run were digested.

g. Hydrofluoric and nitric acids were applied to all filters in the digestion process.

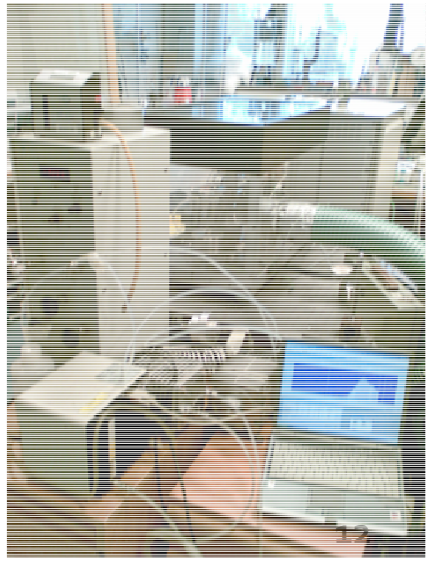
Abbasi *et al.* A field test study of airborne wear particles from a running regional train. ***Journal of Rail and Rapid Transit***, *226*(1), 95-109, 2012

Sub-scaled laboratory test:

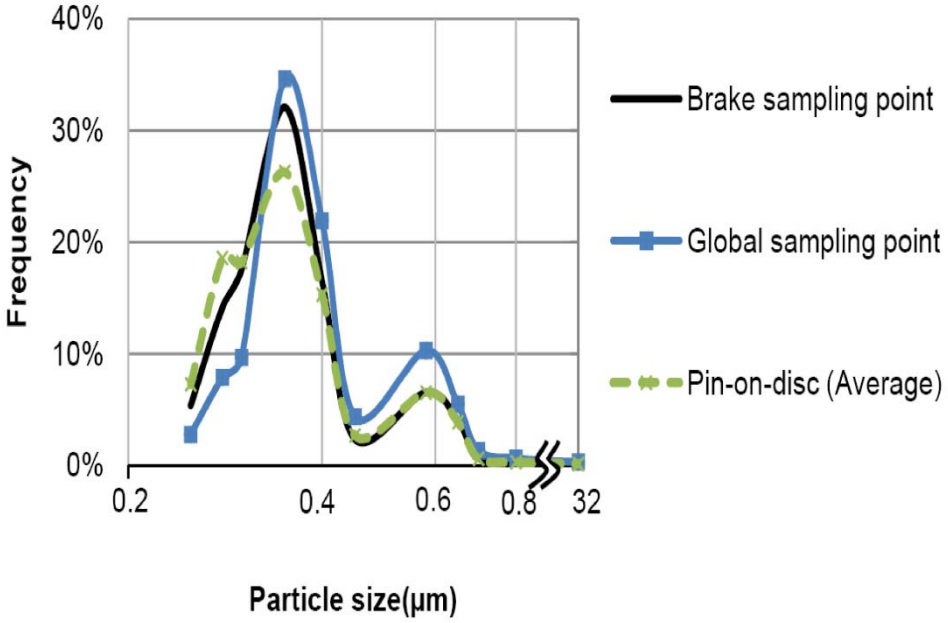




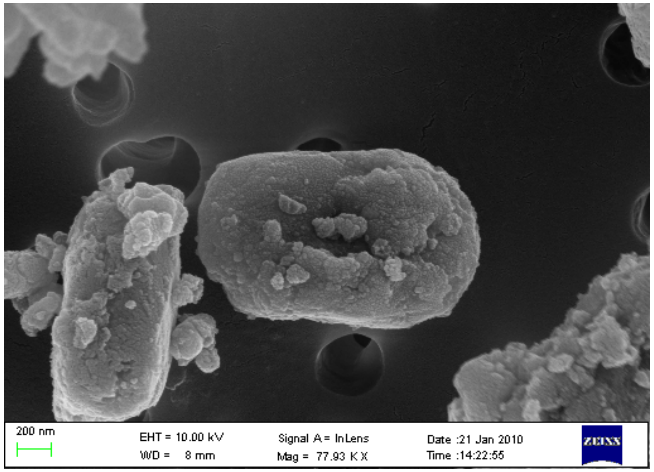
A: Room air; B: Fan; C: Flow rate measurement; D: Filter; E: Flexible tube; F: Inlet for clean air, measurement point; G: Closed box (Chamber); H: Pin-on-disc machine; I: Pin sample along with thermocouple; J: Air outlet, measurement points; L: Dead weight; M: Rotating disc sample, N: Air inside box, well-mixed;



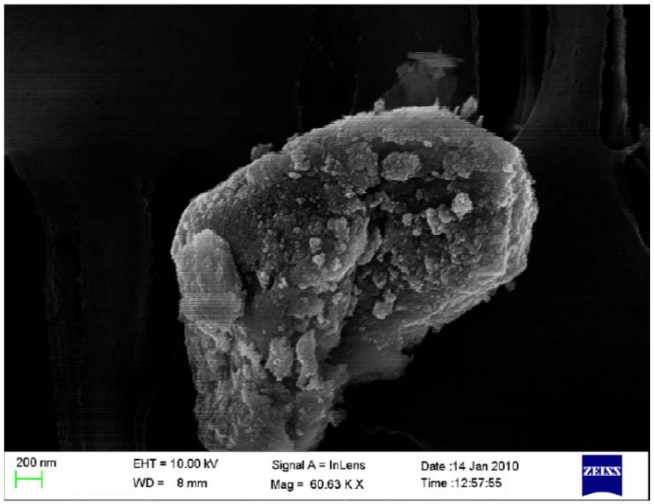
A Comparison between results:



Abbasi *et al.* A study of airborne wear particles generated from organic railway brake pads and brake discs. ***Wear,*** *273*(1), 93-99, 2011.



An image from a particle of pin-on-disc simulation.

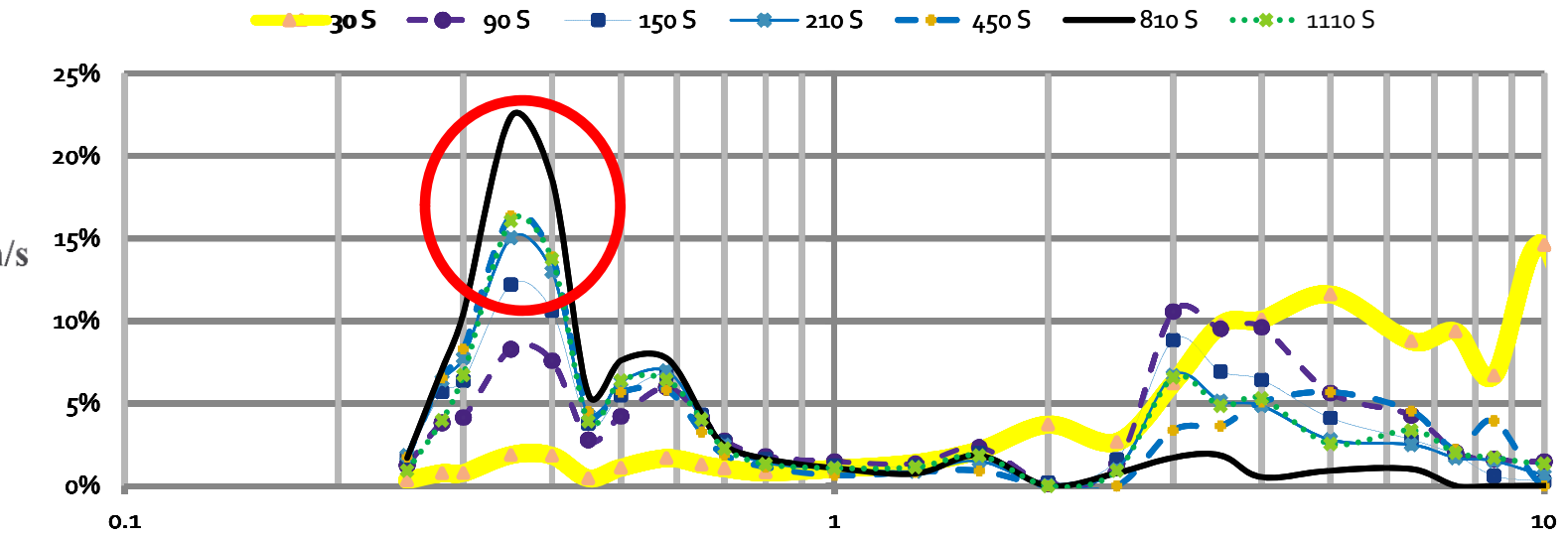


An image from a particle of brake pad sampling point filter.

Time effects on the volume size distribution of the particles from organic brake pad & sintered brake pad

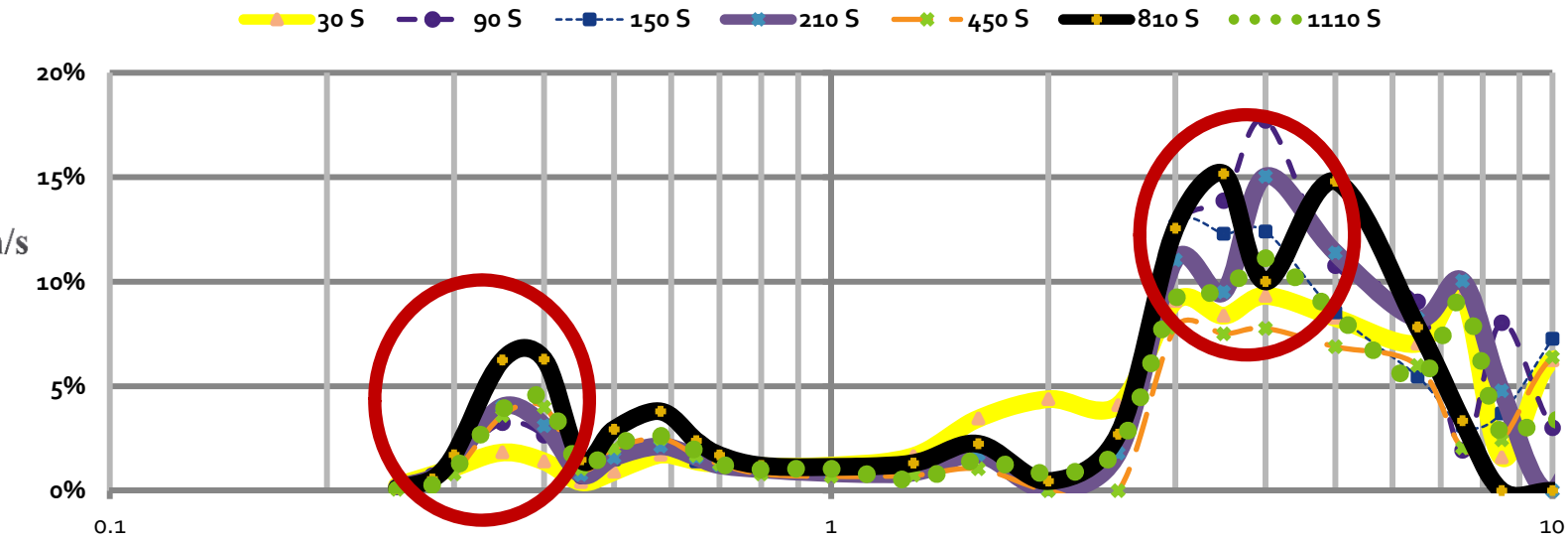
F=60 N

V=12.4 m/s

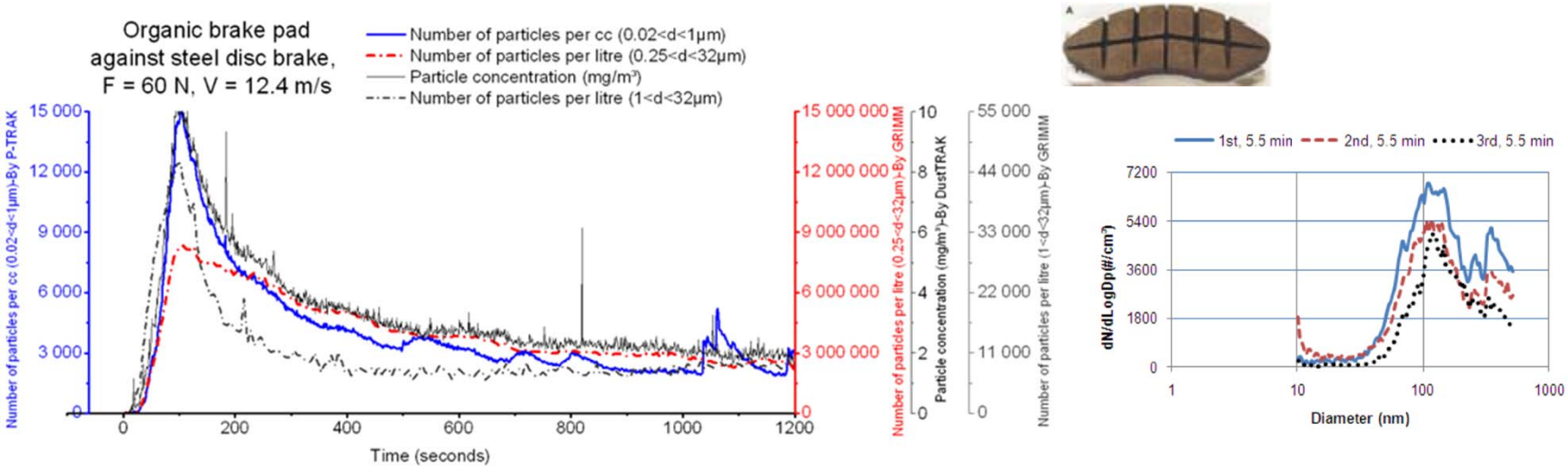


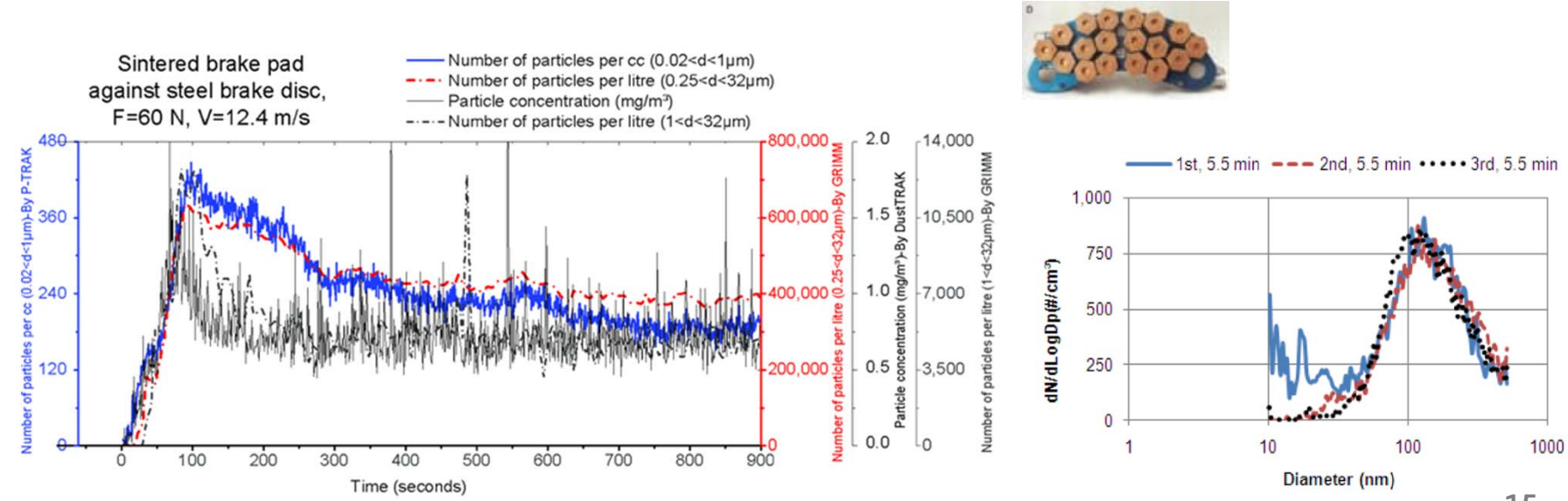
F=60 N

V=12.4 m/s



Organic brake pad & Sintered brake pad

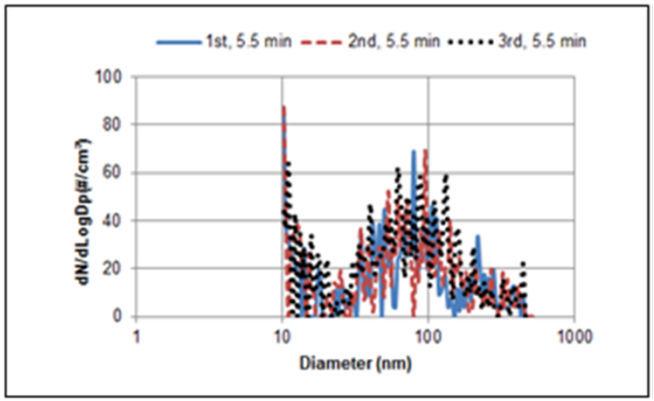




Abbasi *et al.* A pin-on-disc study of the rate of airborne wear particle emissions from railway braking materials. ***Wear,*** *284-285*, 18-29, 2012

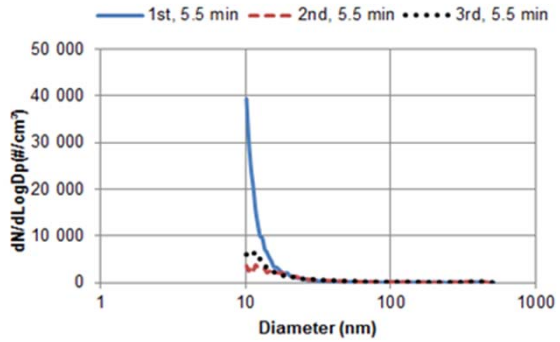
Effect of lubrication on fine & ultra fine particles in wheel-rail contact

Dry contact

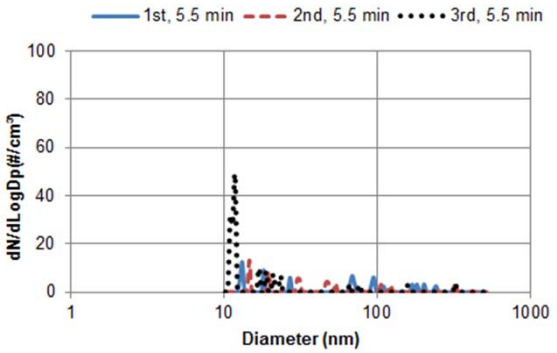


Typical particle measurement for a Dry/lubricated wheel–rail contact : the load applied on the round-head pin is 40 N and the sliding velocity is 0.1 m/s. (Data from SMPS 10 < dp < 540 nm diameter

Water-based lubricant



Oil-based lubricant



Abbasi *et al*. Pin-on-disc study of the effects of railway friction modifiers on airborne wear particles from wheel–rail contact, ***Tribology International***, In press

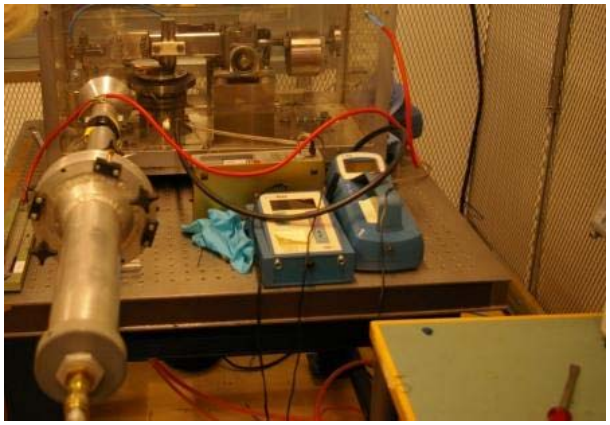
Cooperation toward Toxicological studies:

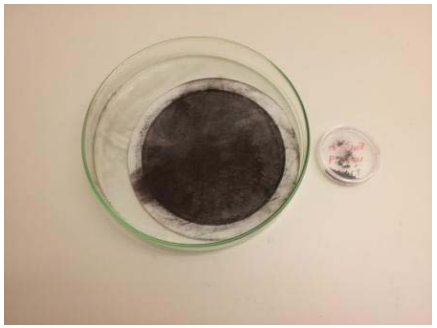
FOI

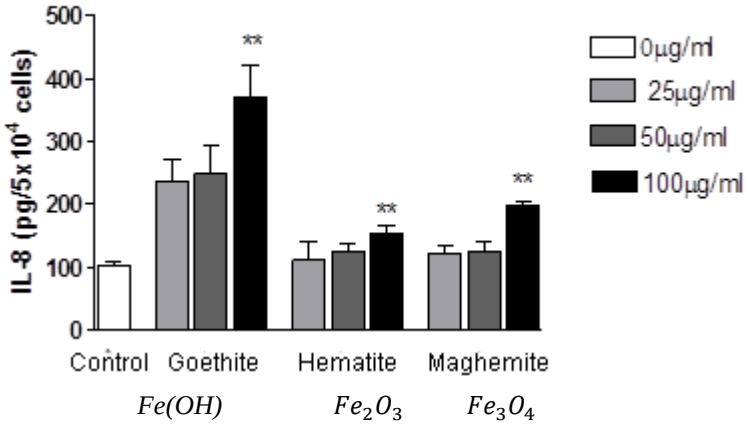
Swedish research defence agency

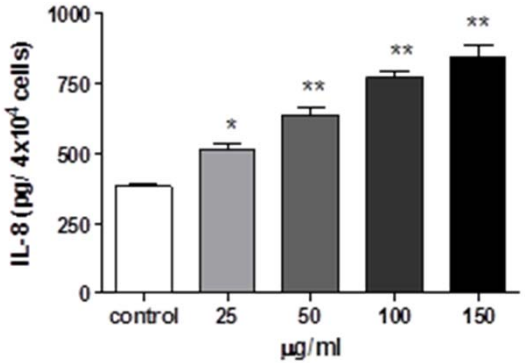
Stockholm University

Department of applied environmental science at SU









Car brake dust

References:

- Abbasi et al. A study of airborne wear particles generated from organic railway brake pads and brake discs. *Wear, 273*(1), 93-99, 2011.

- Abbasi *et al*. Particle emissions from rail traffic: A literature review, *Critical Reviews in Environmental Science and Technology*, http://dx.doi.org/10.1080/10643389.2012.685348

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- Abbasi *et al*. Pin-on-disc study of the effects of railway friction modifiers on airborne wear particles from wheel–rail contact, *Tribology International*, http://dx.doi.org/10.1016/j.triboint.2012.11.013