

*CEECEH 2016 - Central and Eastern European
Conference on Health and the Environment*

Lessons learned from diesel nanoparticles in urban air

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**Particulate matter and ground-level ozone are responsible for over 400 thousands premature deaths in the EU
(traffic accidents for „only“ 39 thousands)**



Particulate matter and ground-level ozone are responsible for over 400 thousands premature deaths in the EU (traffic accidents for „only“ 39 thousands)

European Commission DG ENV: 406 thousands annually in the EU mostly due to particulate matter and ground-level ozone

WHO: 7 milions annually worldwide (25.3.2014)

<http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/>

European Environment Agency: 350 thousands annually in the EU

<http://www.eea.europa.eu/media/newsreleases/reducing-the-20ac-45-billion>

European Environmental Bureau: 455 thousands annually in the EU – just particles

<http://www.eeb.org/EEB/index.cfm/news-events/news/air-pollution-threat-highlighted-at-launch-of-2013-year-of-air/>

Czech National Inst. Of Health 2013 – 7-8 thousands annually in CZ

<http://apps.szu.cz/svi/hygiena/archiv/h2013-1-02-full.pdf>

Sion Elementary School instrumented walking tour: Where are the particles that we breath?

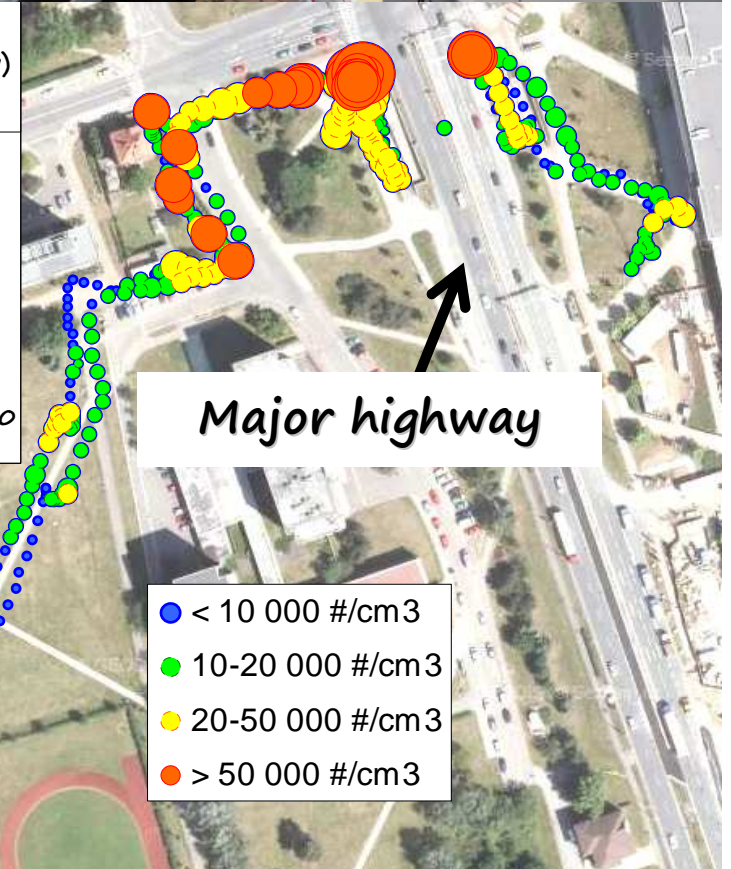
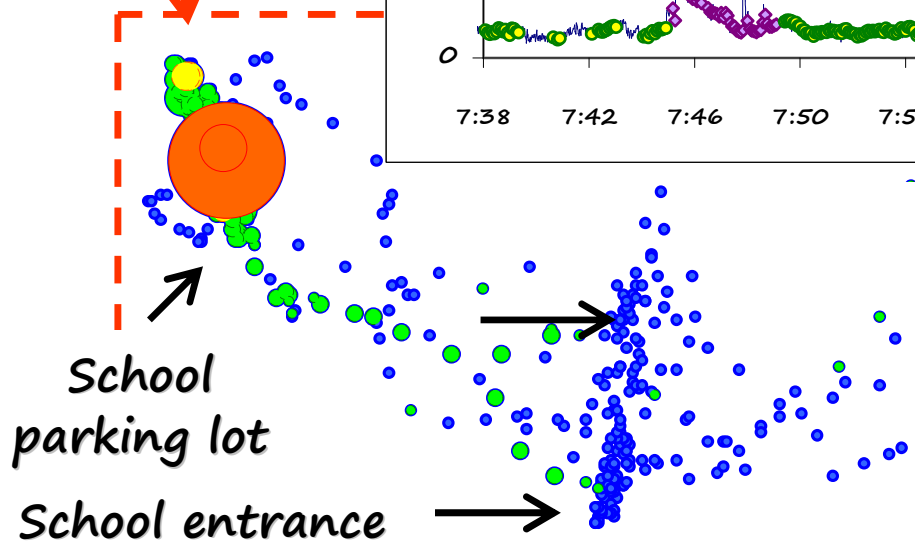
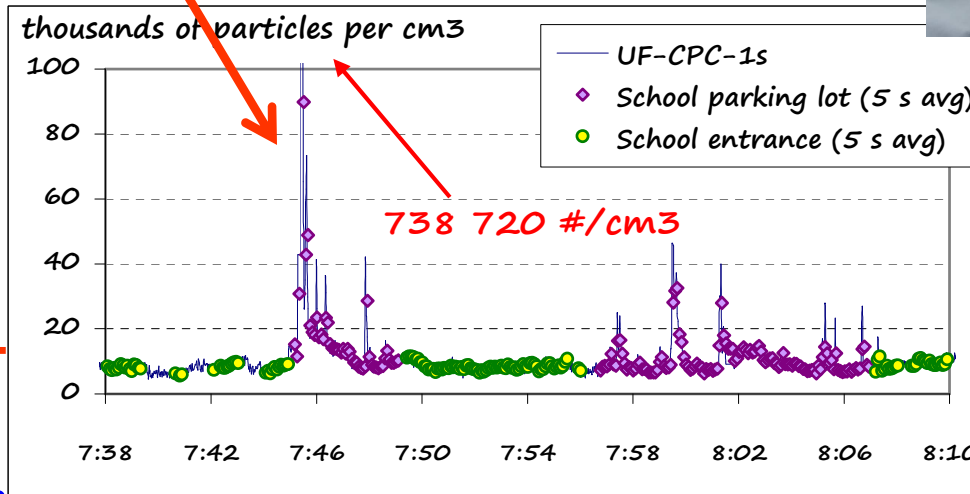


*“Participation of ... junior scientists is critical to the CEECHE mission.”
(William Suk on Monday)*

“Children may be more susceptible to exposures.” (Nina T. Holland on Monday)

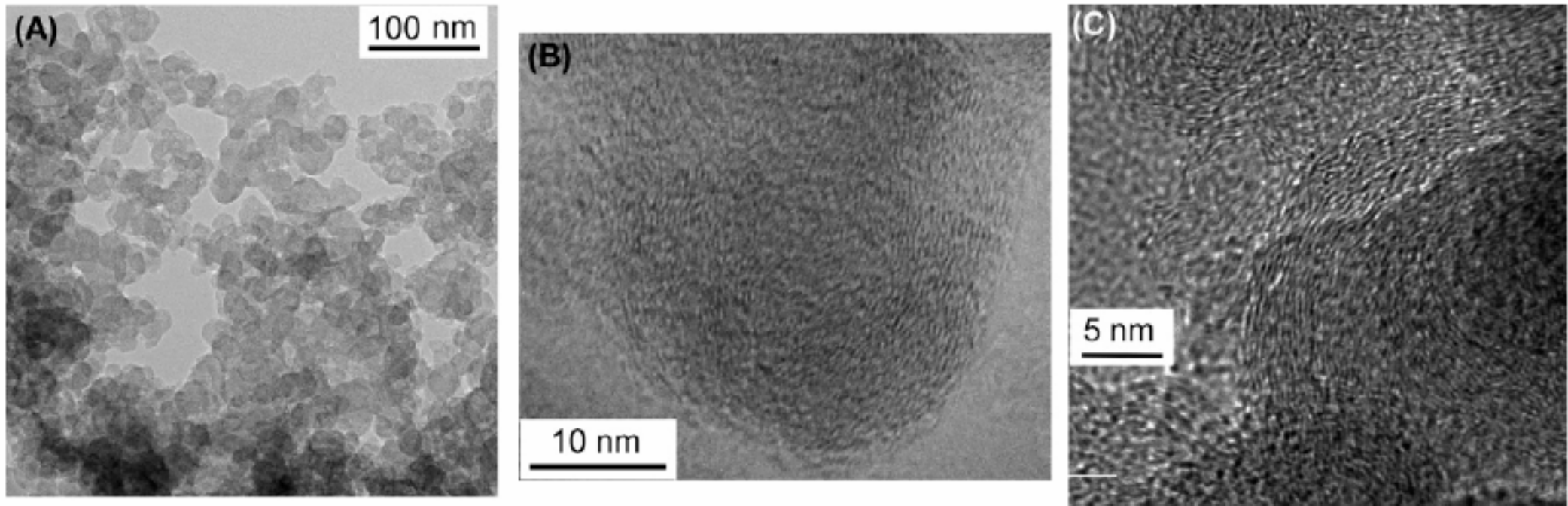
Sion Elementary School instrumented walking tour: Where are the particles that we breath?

The particles are mostly along the roads!
 Hey, they are in the parking lot!
 Lots of them!
 It is all cars!!!



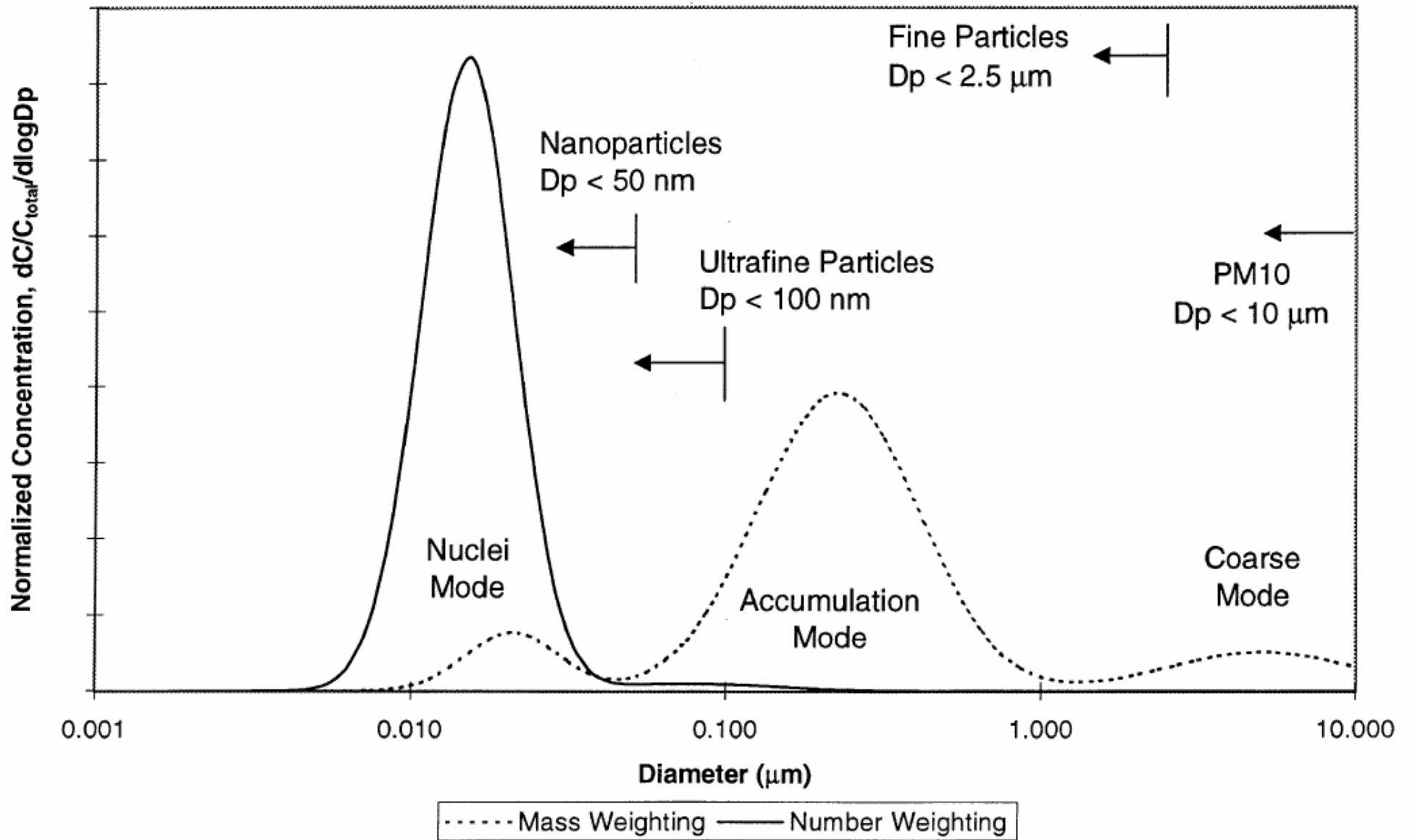
(Diesel) ICE exhaust particulate matter

- Small particles (units to hundreds of nm) formed by incomplete combustion of fuel and engine lubricating oil and wear metals
- Complex mixture of compounds, many known to be carcinogenic
- More premature deaths (> 400 K per year in EU) than traffic accidents (< 40 K per year)
- One of the most pressing urban environmental problems



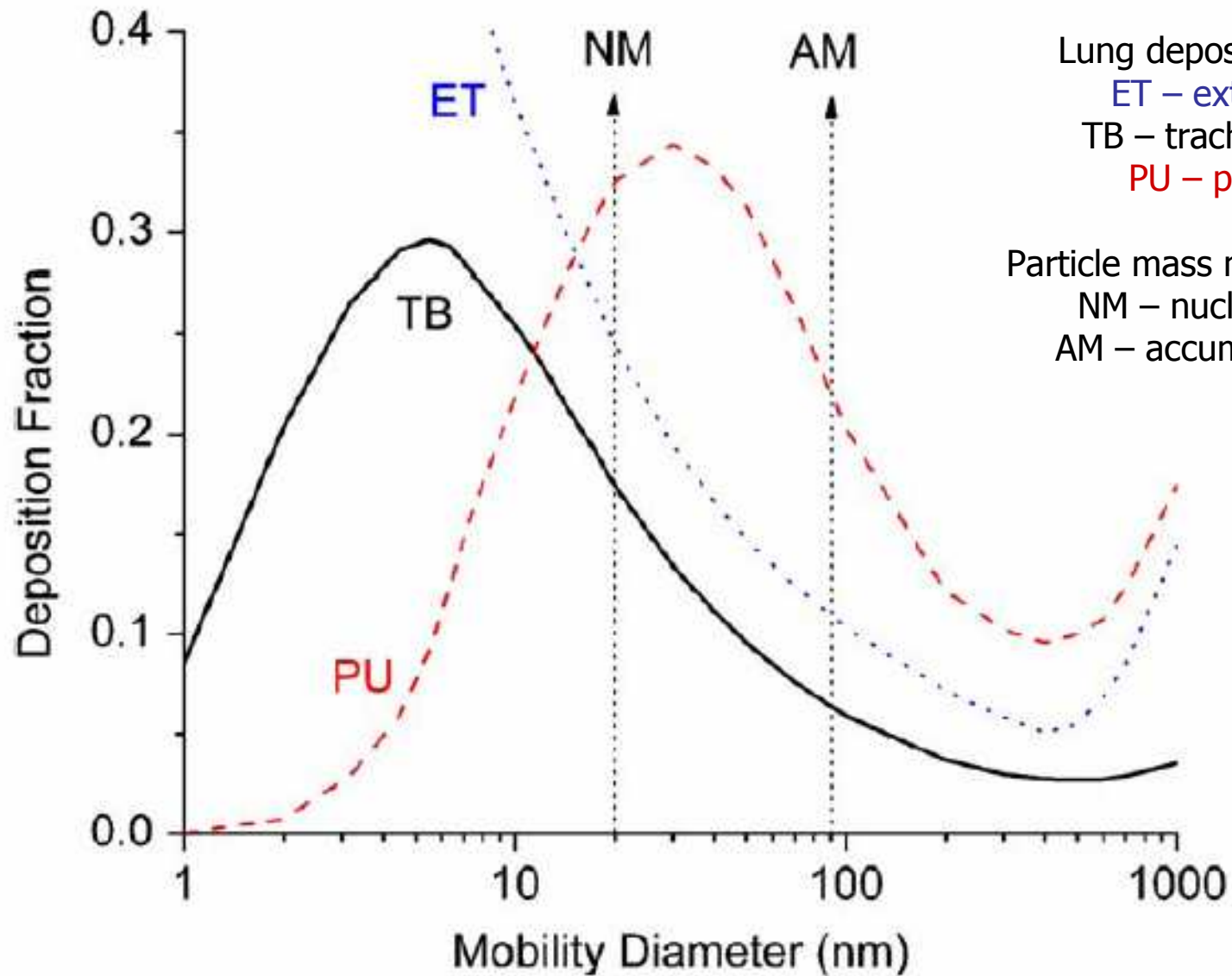
Liati A., Dimopoulos P.E., Combustion and Flame 157 (2010) 1658–1670.

Typical diesel exhaust PM size distribution



Kittelson, *J. Aerosol Sci.* Vol. 29, No. 5/6, pp. 575-588, 1998

Lung particle capture efficiency



B. Alföldy et al., Aerosol Science 40 (2009) 652–663.

Lung particle capture efficiency

Fractional Deposition of Inhaled Particles (Oberdörster)

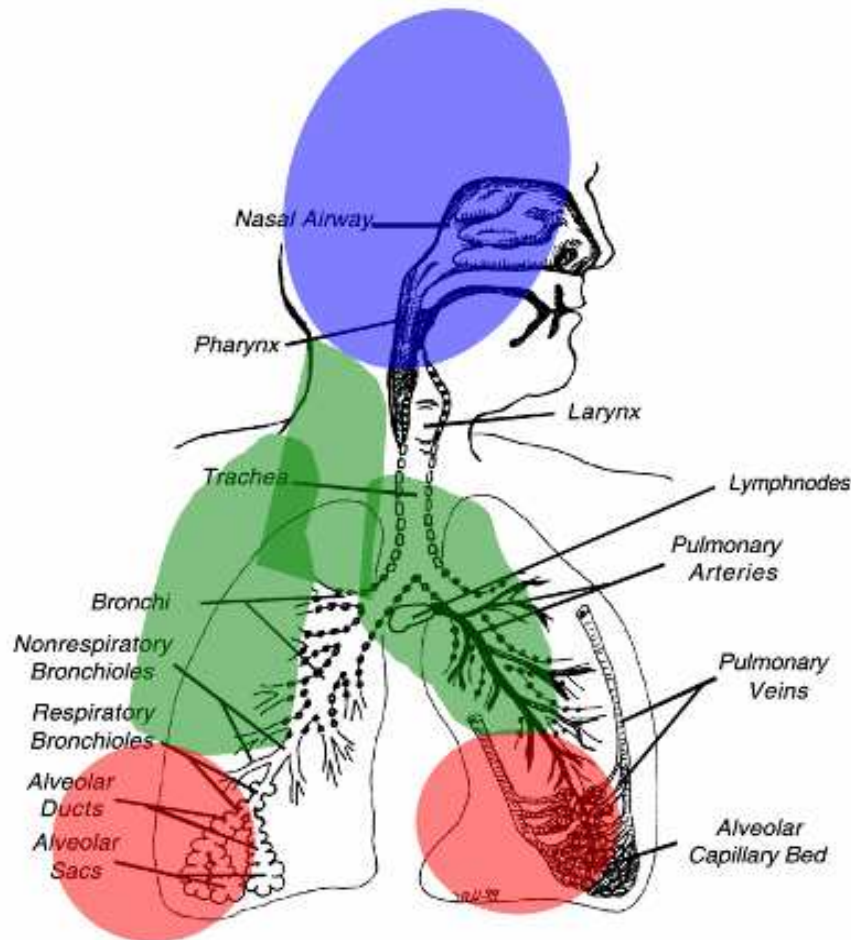
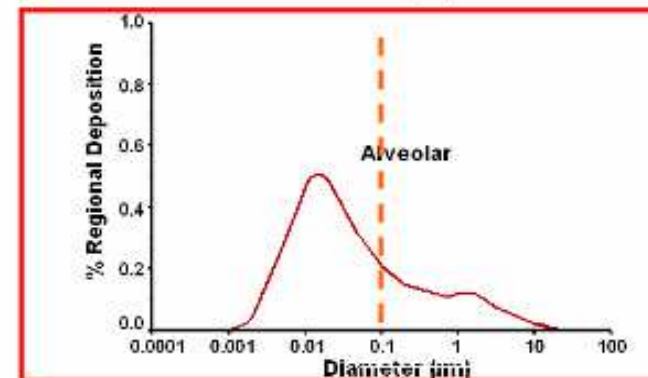
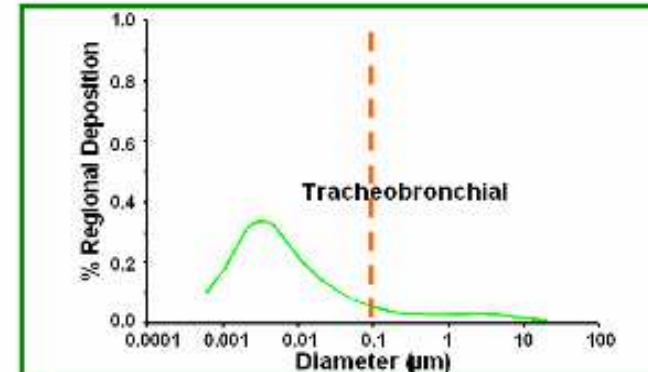
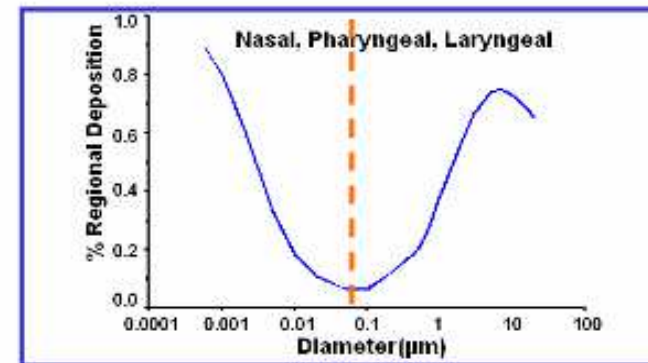
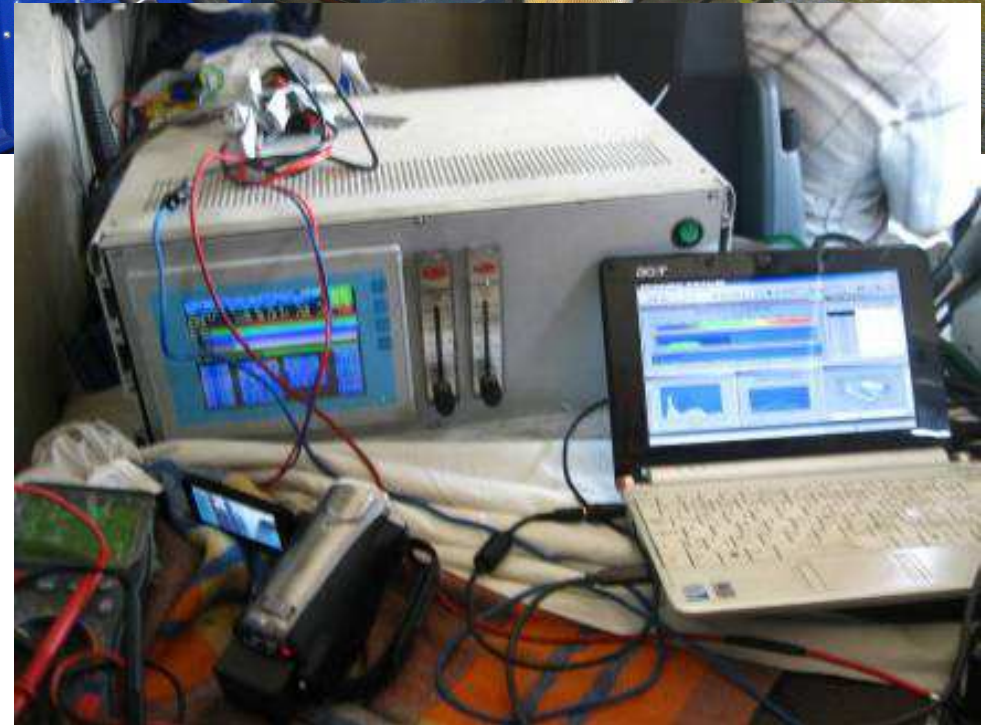
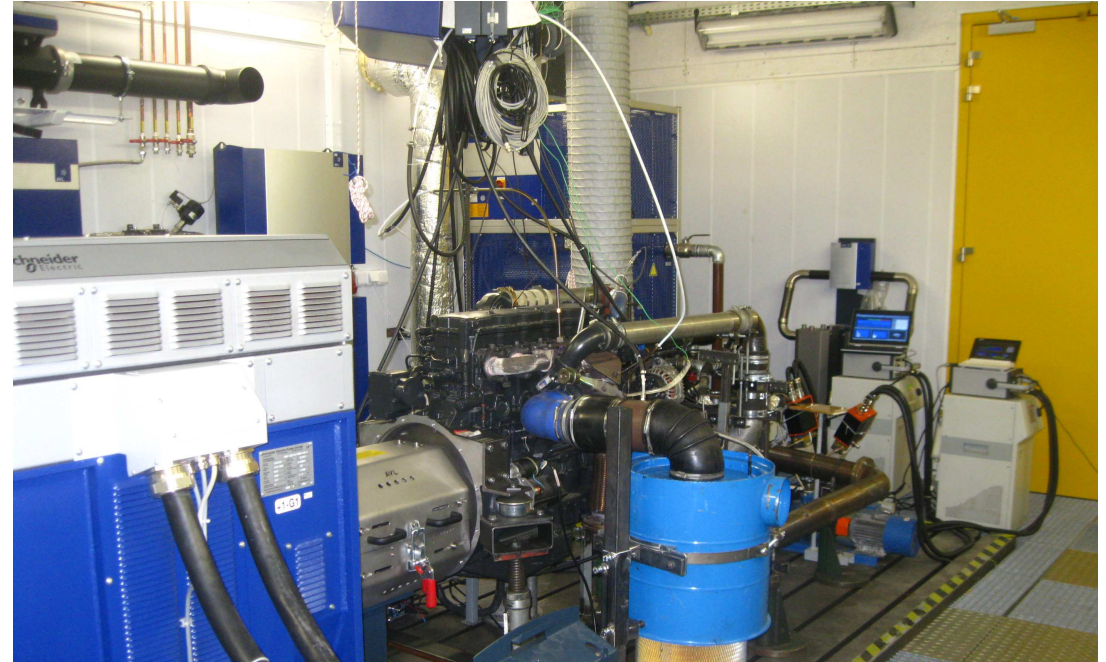


Figure courtesy of J.Harkema



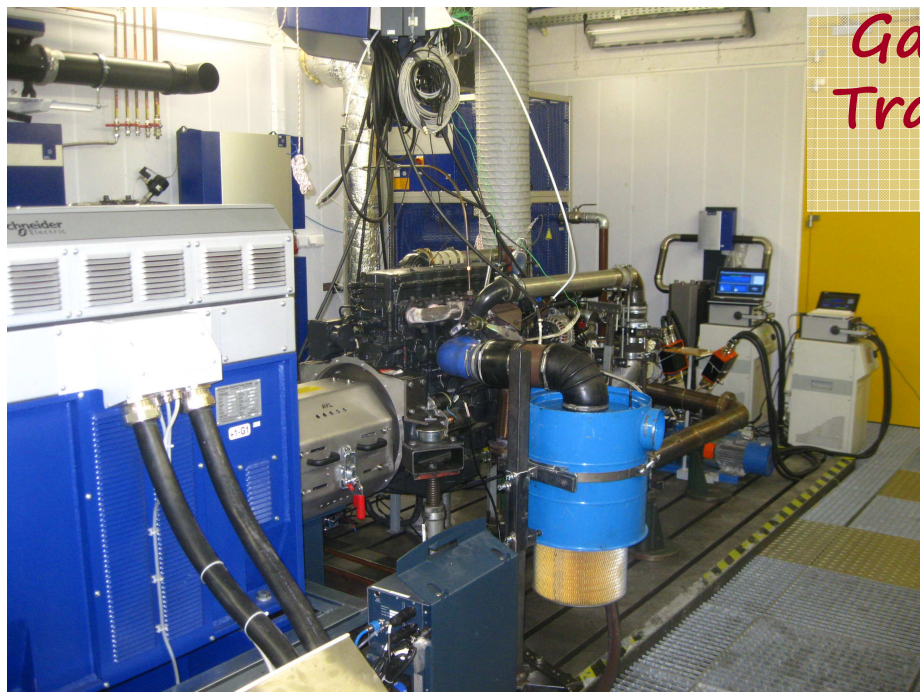
A. Mayer, 12th ETH Conference on Combustion Generated Nanoparticles, Zurich, 2008

Online PM measurement at Czech Technical Univ. in Prague



Project BIOTOX – Mechanisms of Toxicity of Particles from Biofuels

PM measurement and sampling using high-volume samplers



Gasoline MPI and direct injection, diesel, Traditional and alternative fuels (ethanol, butanol, biodiesel, NExBTL, blends)



Real driving emissions measurement Portable on-board monitoring systems (PEMS)



Cars, buses, trucks, tractors, loaders, mowers, small airplanes, mopeds, ferries, locomotives, construction machinery

Lessons learned from diesel nanoparticles in urban air
Michal Vojtisek et al., CEECHE 2016, Prague, 13.4.2016

Real driving emissions measurement Portable on-board monitoring systems (PEMS)



First PEMS used for CNG bus studies
Pittsburgh, USA, 1996-1999

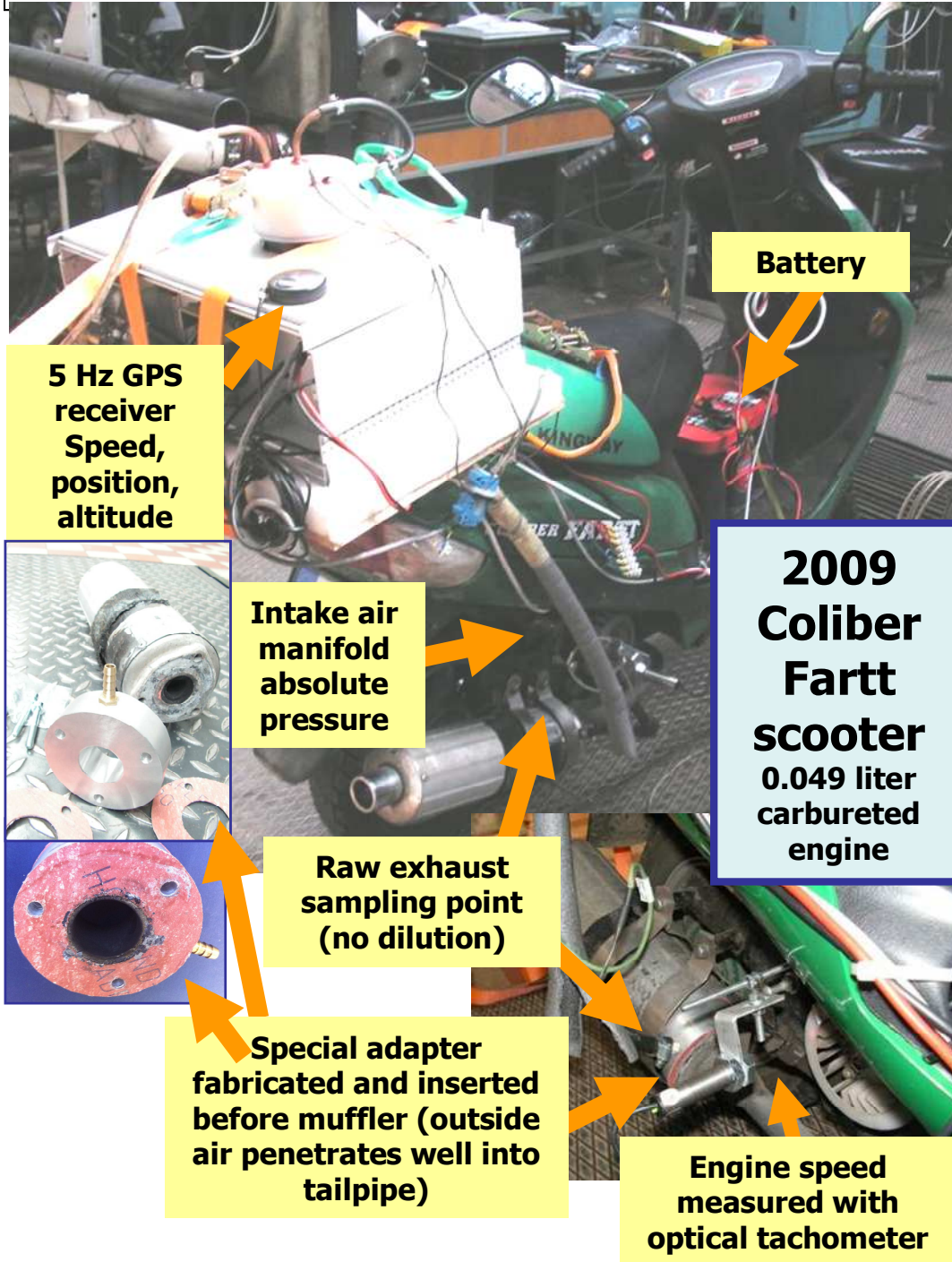


First commercially sold PEMS
(OEM-2100, 1999-2002)



Dimethyl ether (DME) bus testing
Pennsylvania State University, 2001-2003

On-board system versatility: Motorcycle to locomotive



Portable on-board emissions monitoring systems (PEMS)

“Research PEMS”: On-board FTIR (gaseous compounds),
EEPS (size distributions), CPC (particle count)



Student projects: E85, n-butanol, isobutanol in unmodified gasoline engines in Škoda cars

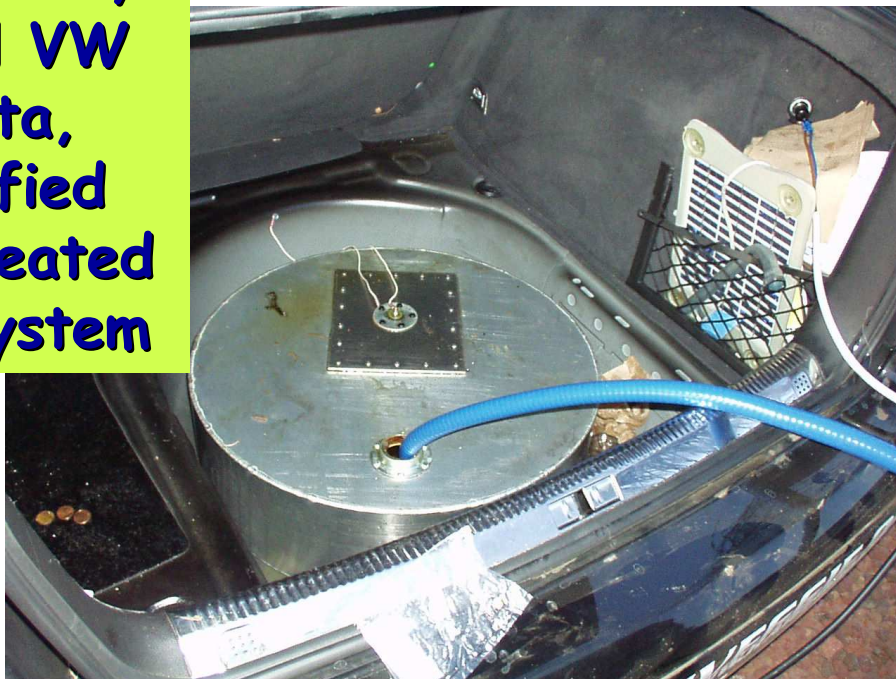


On-board FTIR
~ 30 kg
~ 300-400 W
3 hours on
26 kg of batteries

Used frying oil as vehicle fuel (effects on PM)



San Diego,
California,
diesel VW
Jetta,
modified
with heated
fuel system



Lessons learned from diesel nanoparticles in urban air
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DOC+DPF efficiency

(Pilot project, World trade center, New York, 2003)



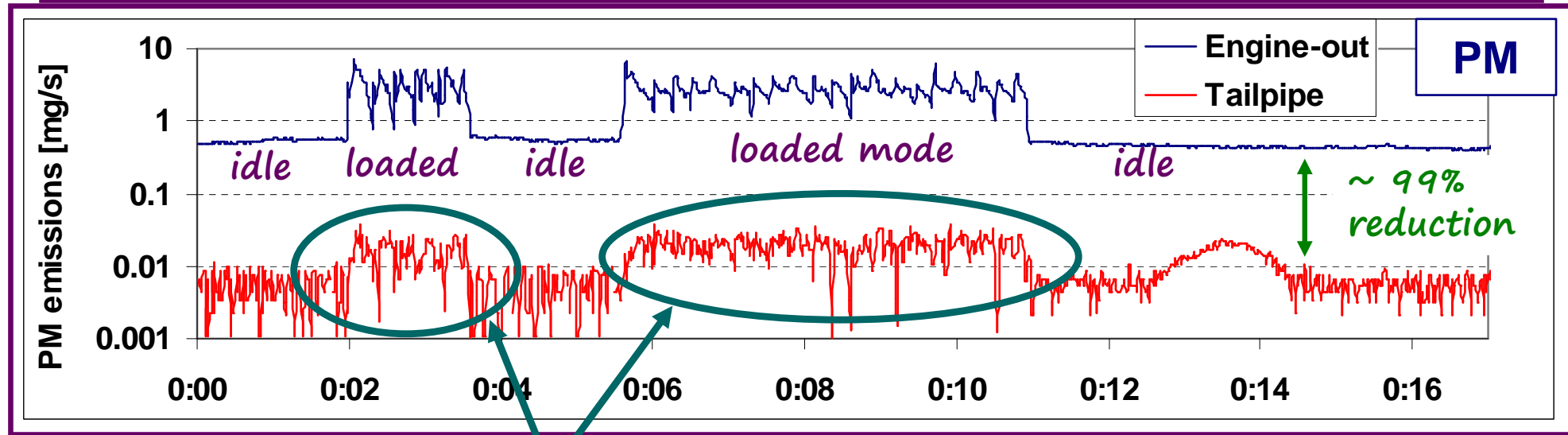
Online
measurements
before & after
catalysts with
two PEMS



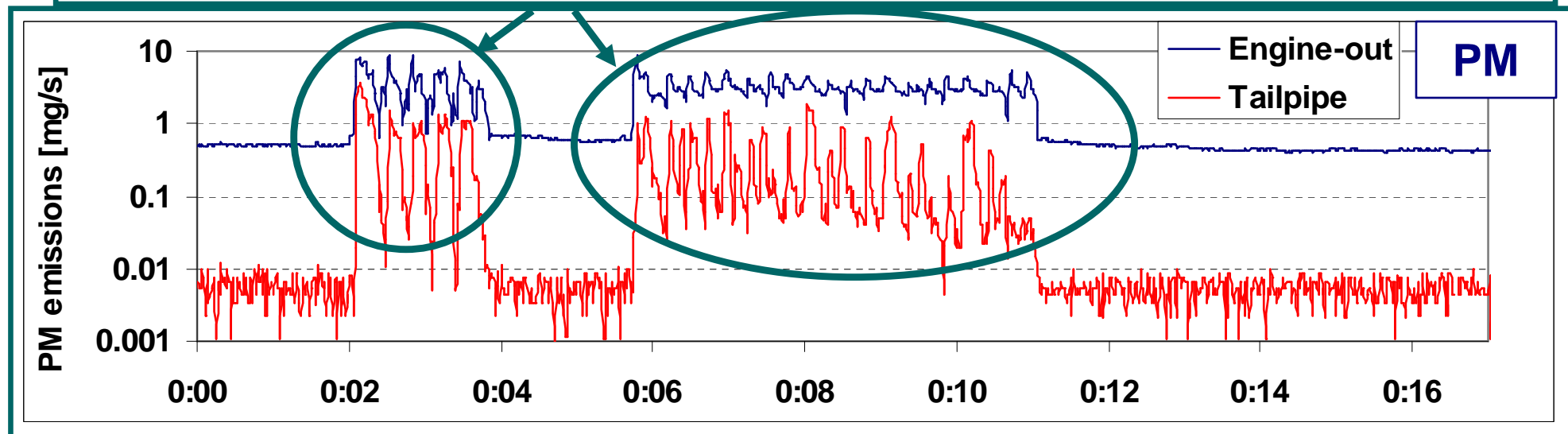
Field test – excavator with diesel particulate filter

Emissions measured simultaneously upstream & downstream of DPF

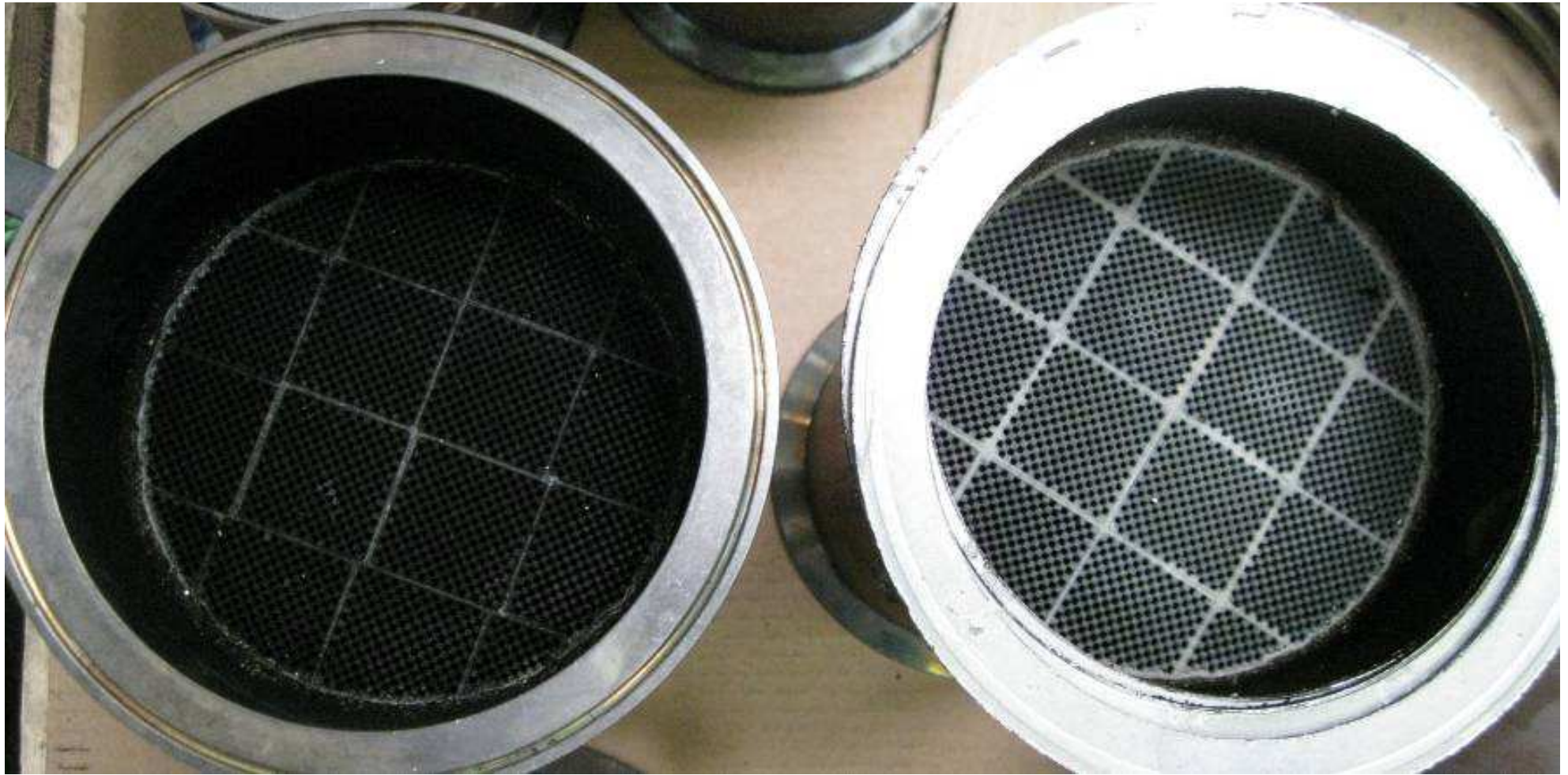
Typical test run, construction equipment with diesel particulate trap



Test run after prolonged idling: Elevated PM during high load operation



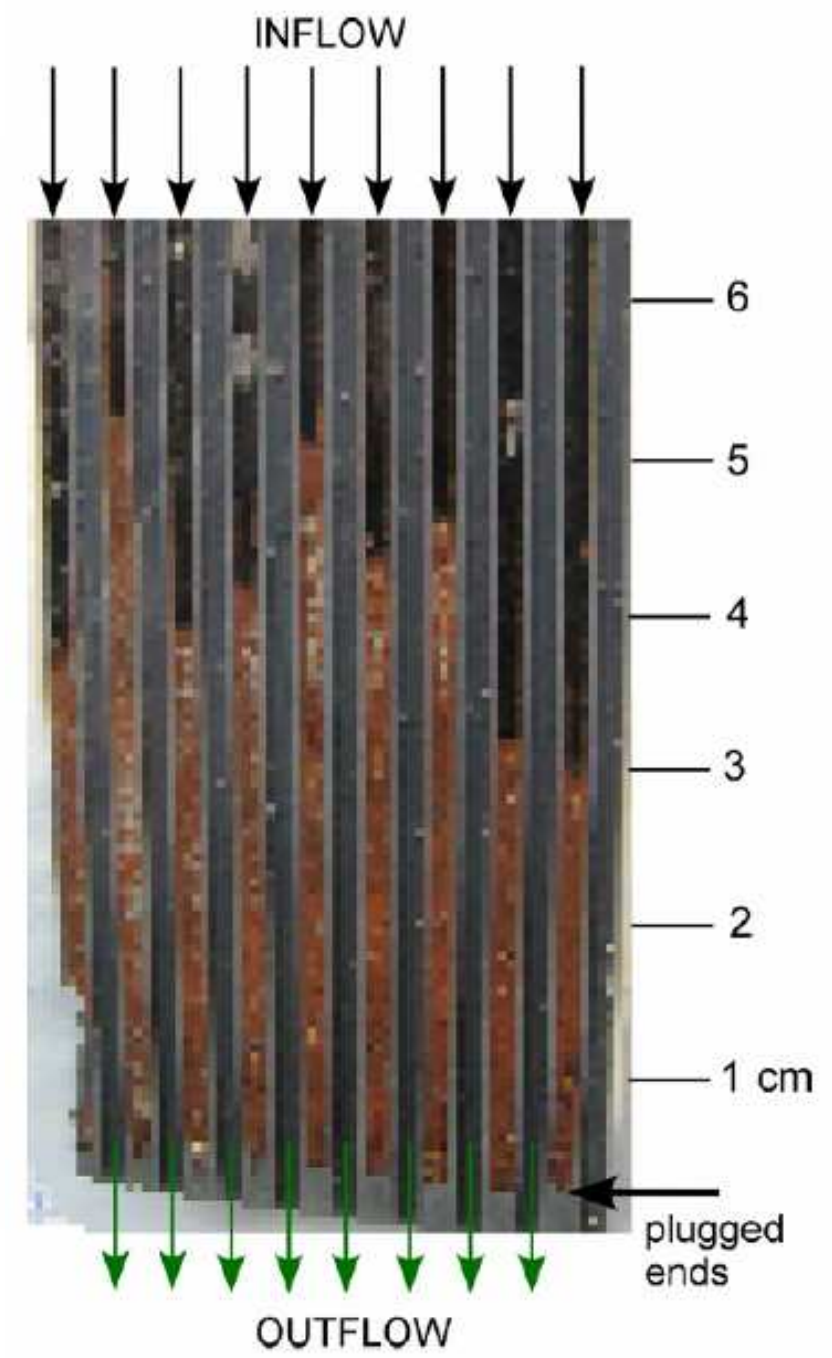
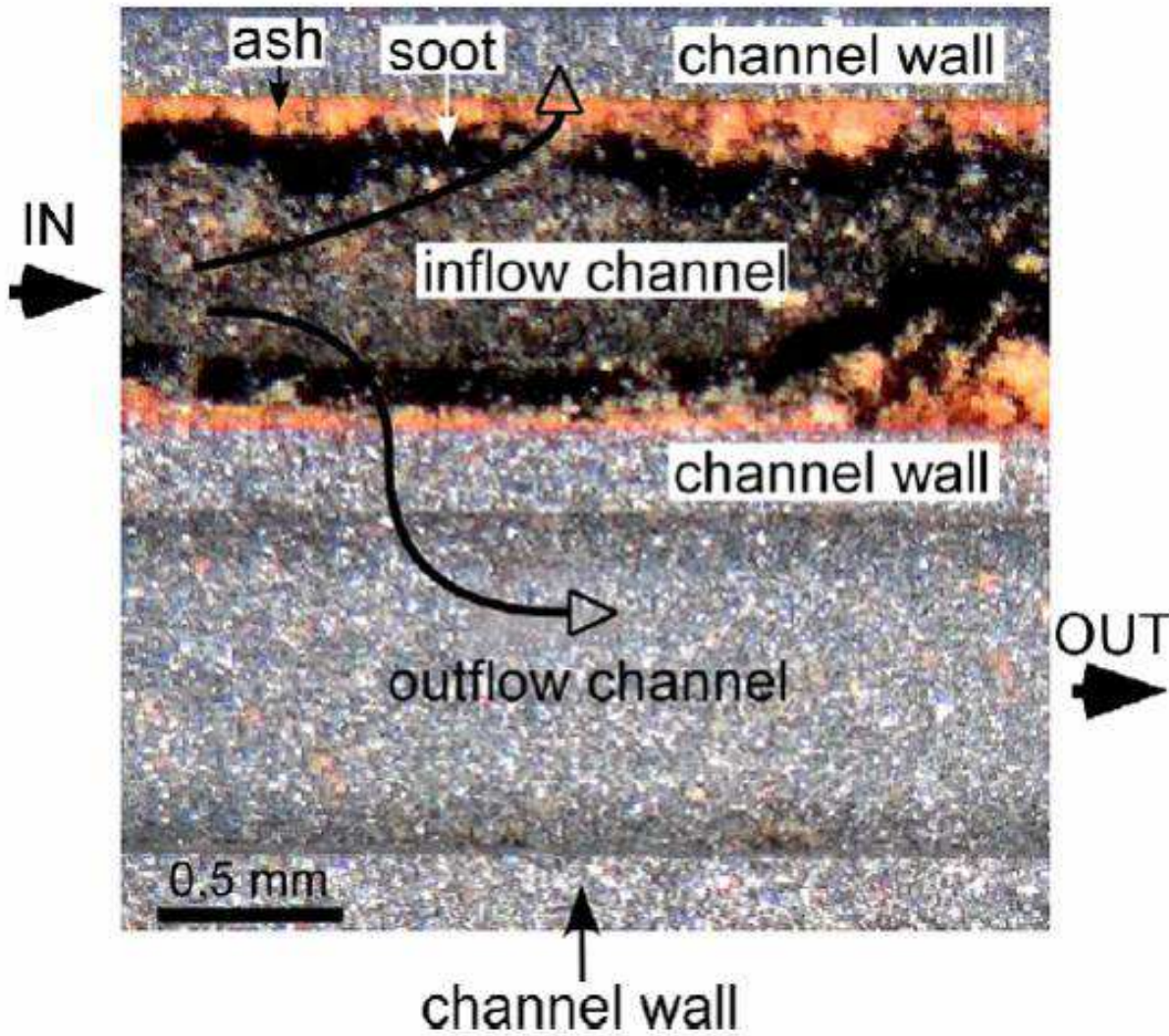
Diesel particle filters (90 to 99,99% efficiency)



Inlet side

Outlet side

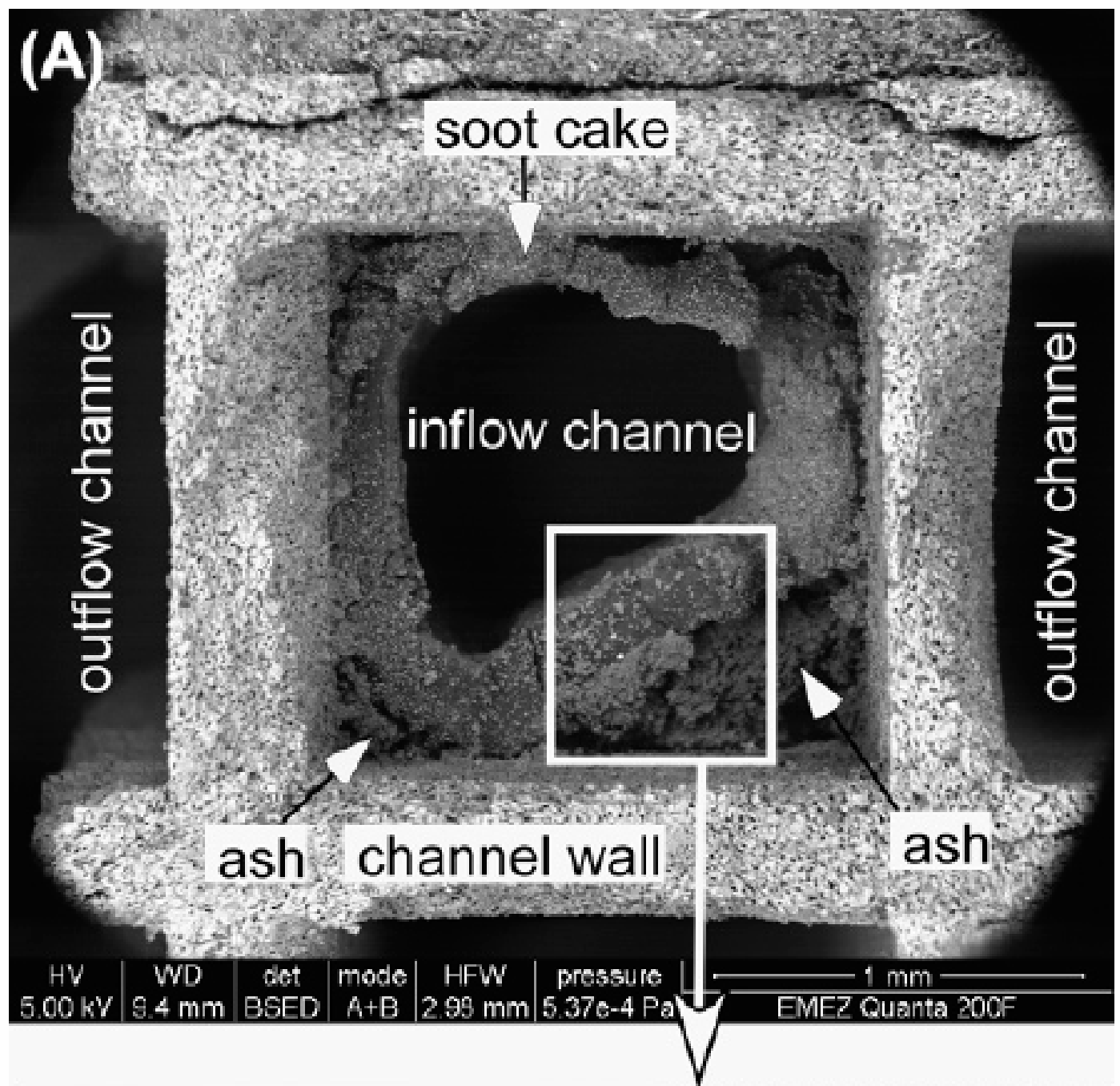
Diesel particle filters



A. Liati, P. Dimopoulos Eggenschwiler / Combustion and Flame 157 (2010) 1658–1670

Diesel particle filters

A. Liati, P. Dimopoulos
Eggenchwiler / Combustion and
Flame 157 (2010) 1658–1670



Modern diesel engine technology: 10^{11} particles / kWh to meet 6×10^{11} p/kWh Euro 6 limit – at $5-10 \text{ m}^3/\text{kWh}$, this corresponds to 10–20 thousands p/cm^3 .

European „urban background“ is 7–8 thousands p/cm^3 .



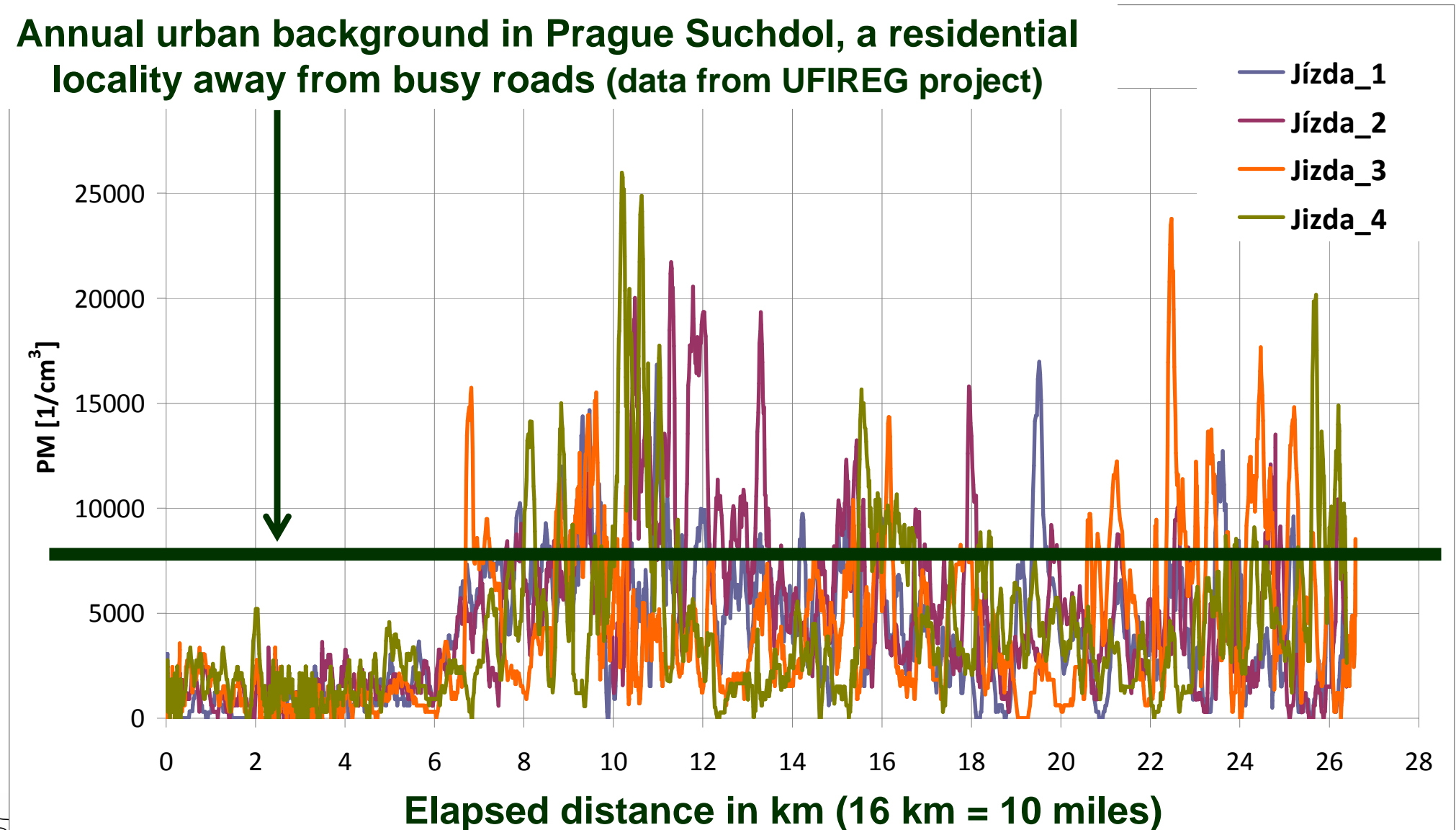
**EURO 5 – DOC, DPF (particle filter), no SCR
2012 Iveco Daily, 3.0-liter Iveco engine**

**Emissions of particulate matter very low even during
1-hour idle and generally well below $1 \text{ mg}/\text{m}^3$**



Euro 6 diesel truck, November 2015,
Říčany – Kostelec nad Černými Lesy (east of Prague)
Particle concentrations in the exhaust (p/cm³)

Annual urban background in Prague Suchdol, a residential locality away from busy roads (data from UFIREG project)

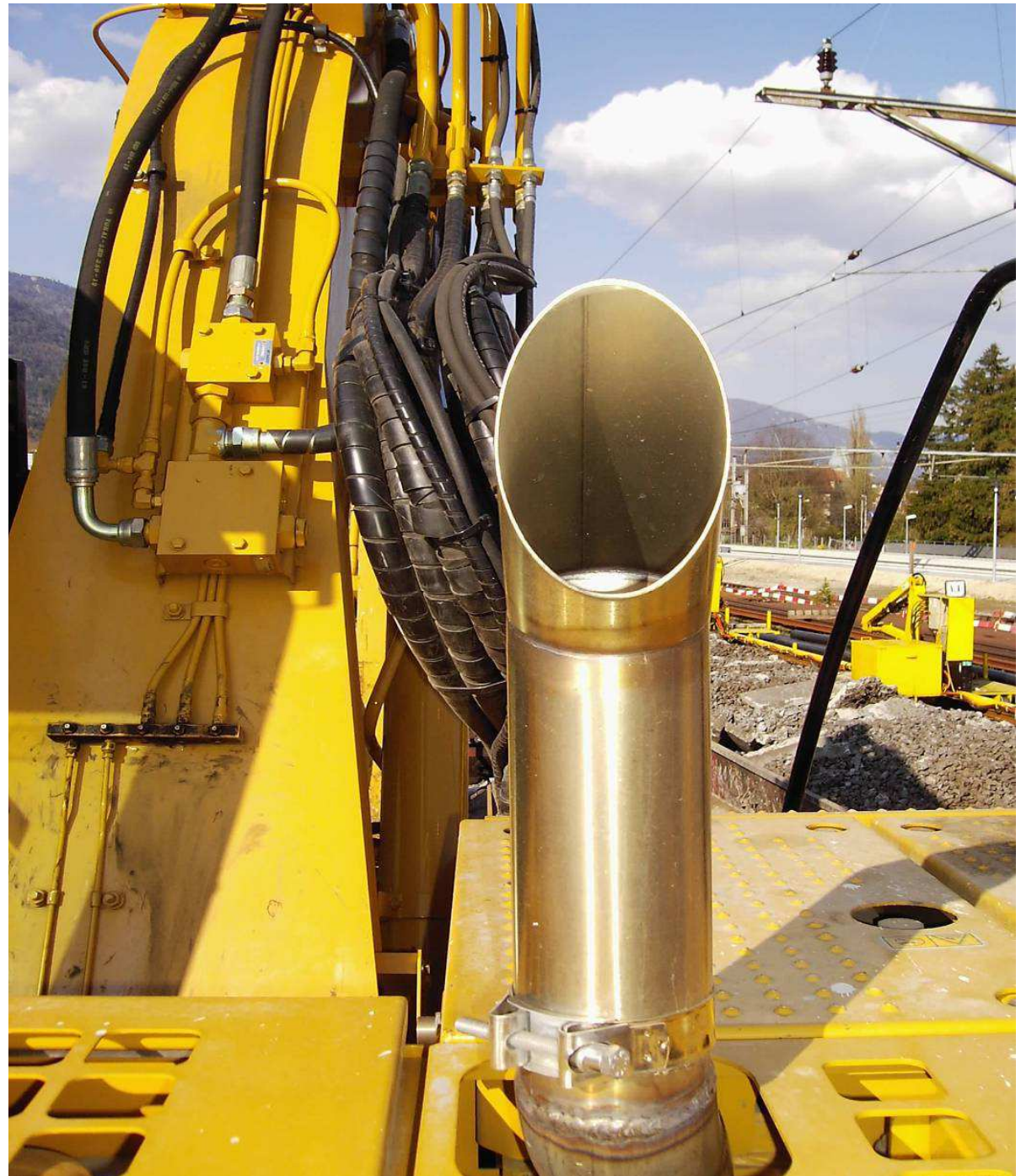


Internal combustion engines produce very small particles which are harmful to human health and released in the immediate vicinity of people.

We have diesel particle filters (DPF) and other technology to take care of this. But does it help?

Is the situation improving sufficiently?

Are air quality improvement actions in central Europe based on educated decisions supported by facts?



Challenges of EU automobile diesel engines

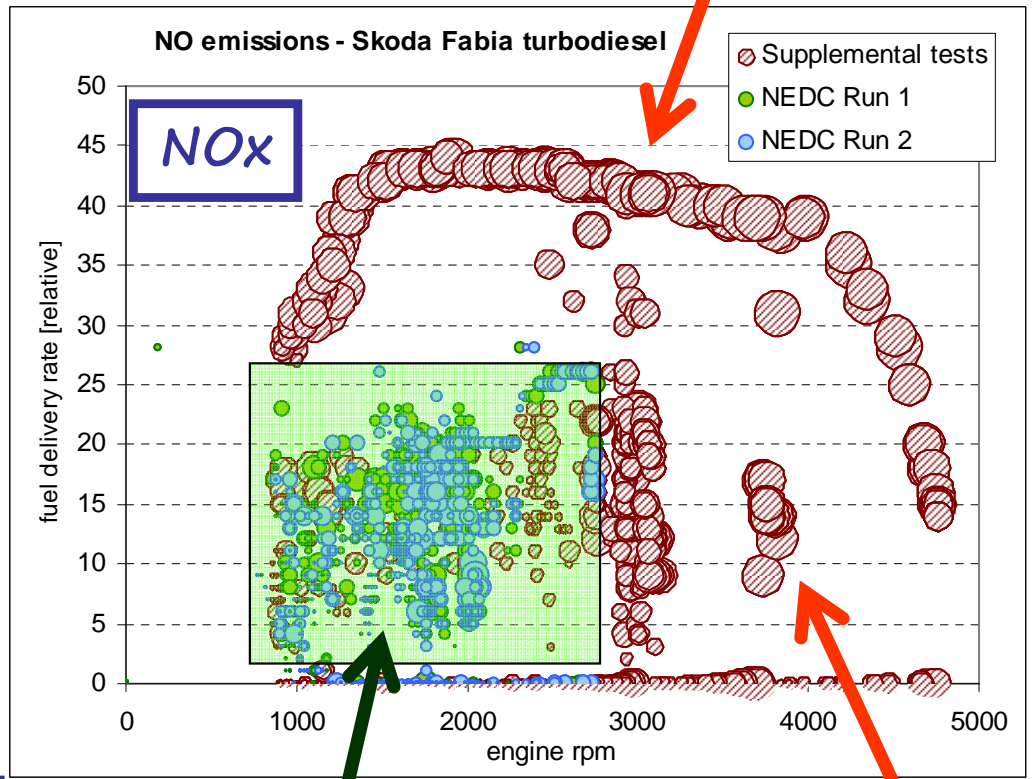
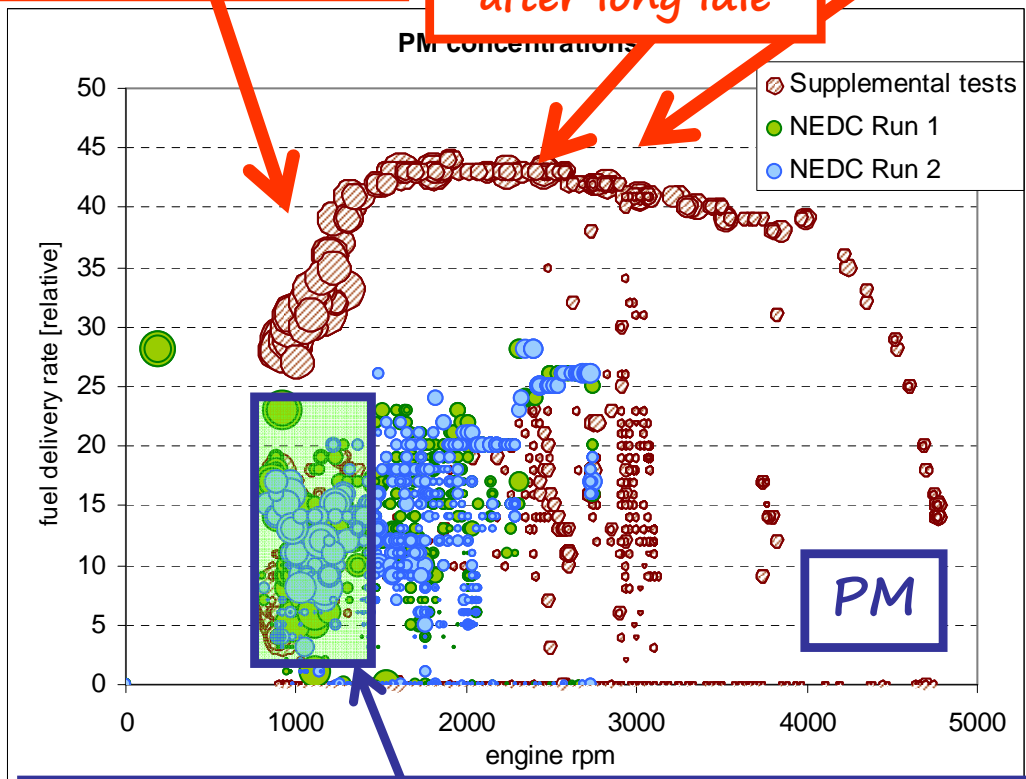
Euro 4 Skoda Fabia – chassis dynamometer runs NEDC vs. full-power loaded accelerations

Problem compounded by downsizing & turbocharging: Relatively low torque at idle.

Problem compounded by cold DOC during accelerations after long idle

Maintaining adequate excess air competes with desire for additional torque

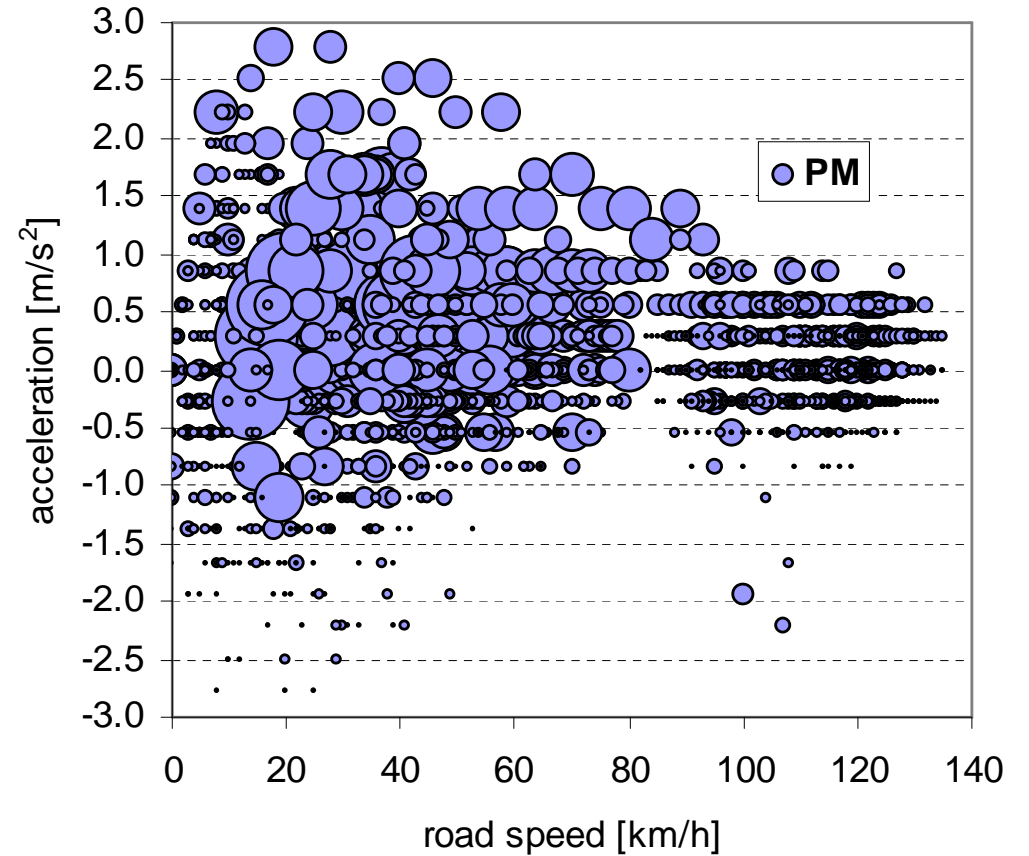
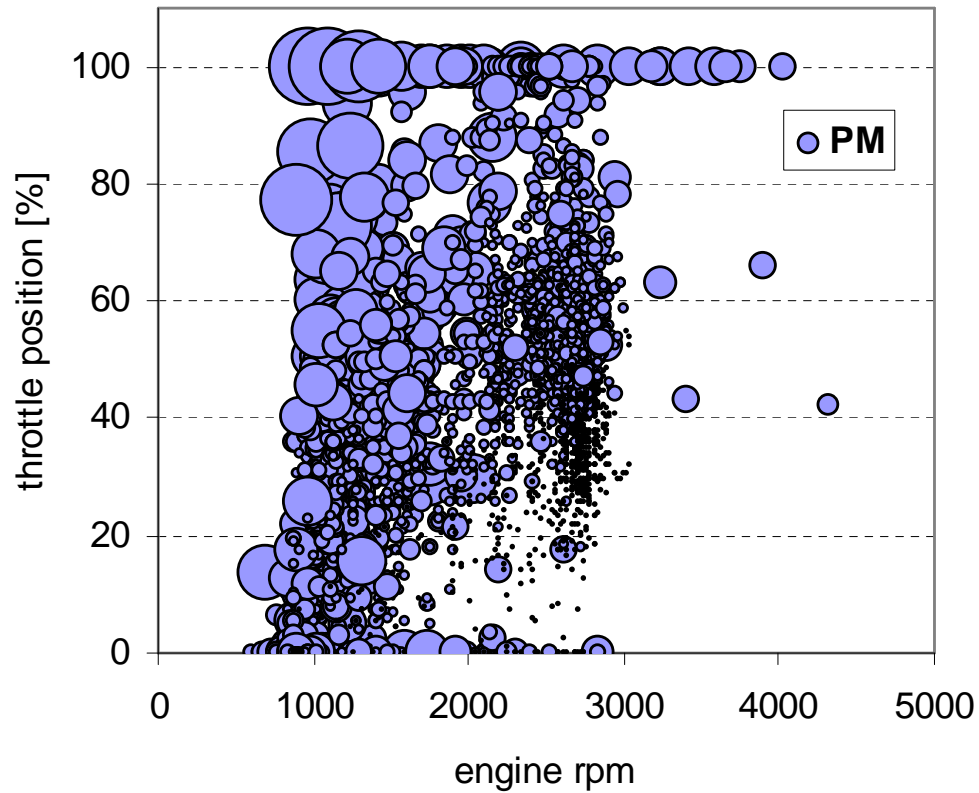
NOx: Use of EGR competes with the desire for additional torque



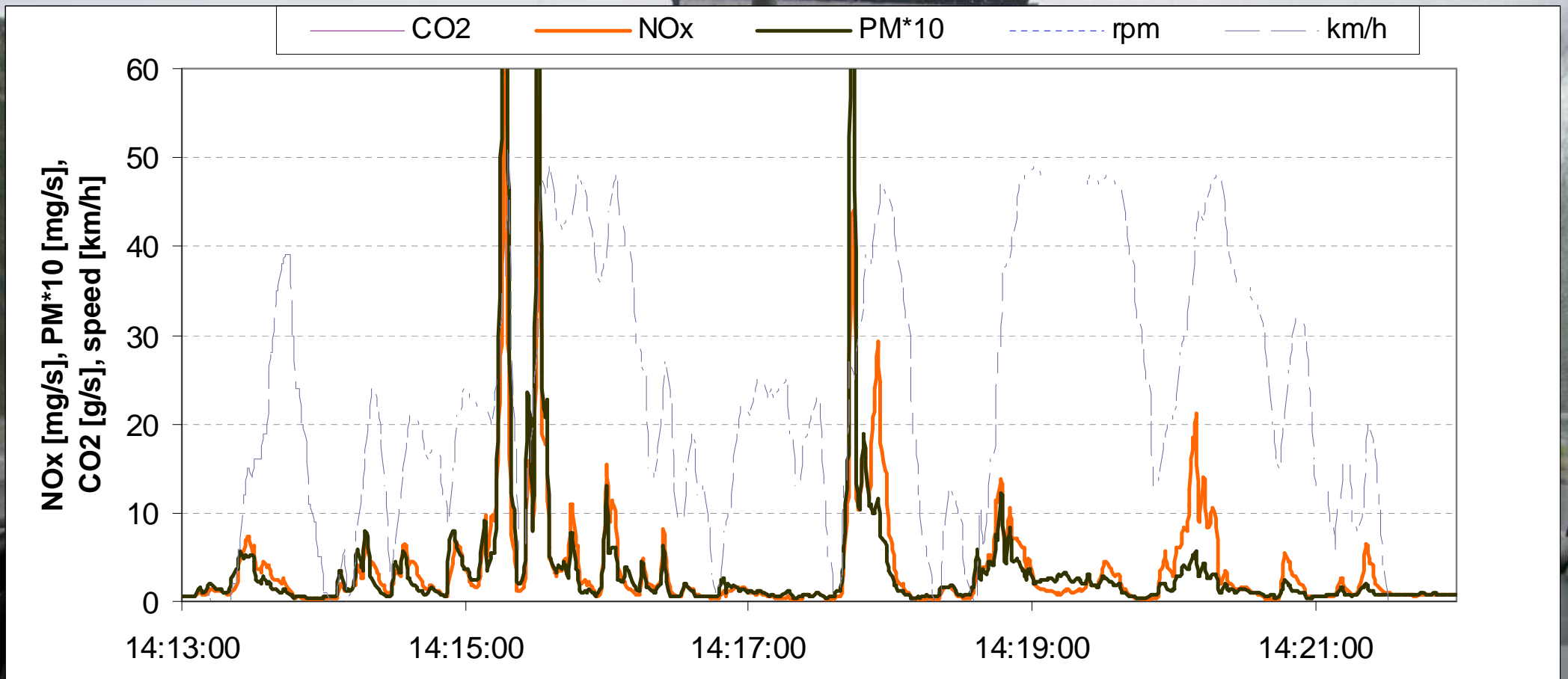
Long idle / low load: DOC cooldown, combustion deterioration, high fraction of OC in PM

NOx reduced by EGR

Euro 4 Skoda Octavia – real-world city driving tests

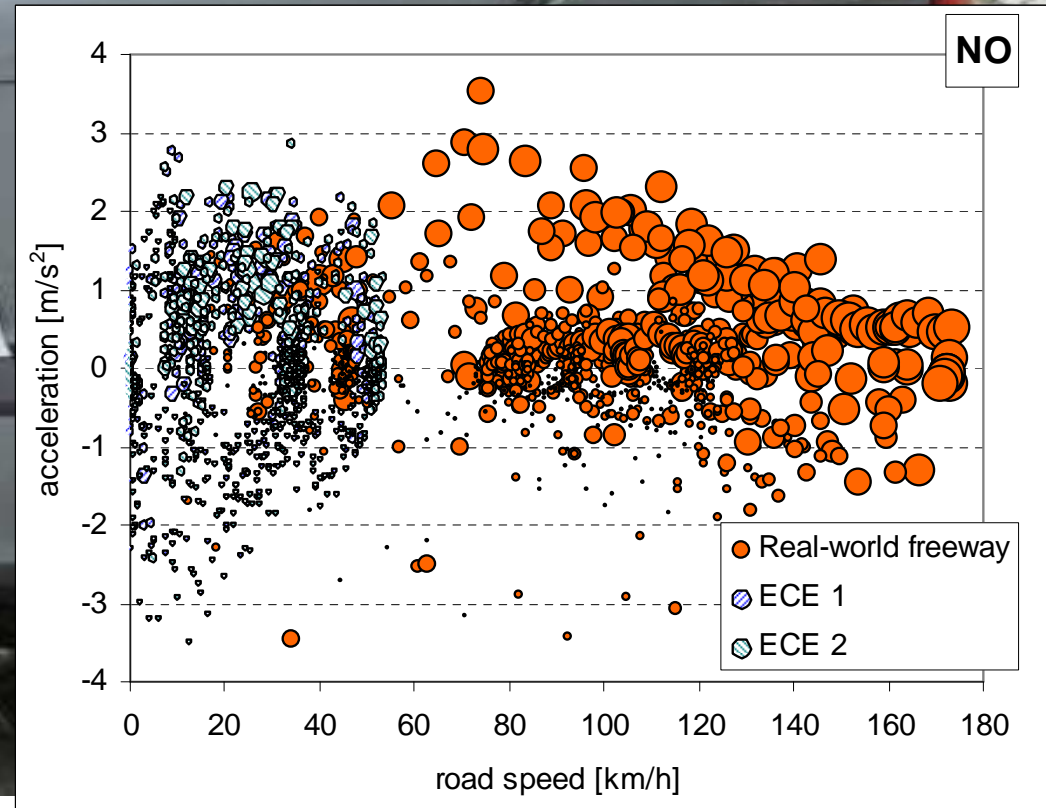
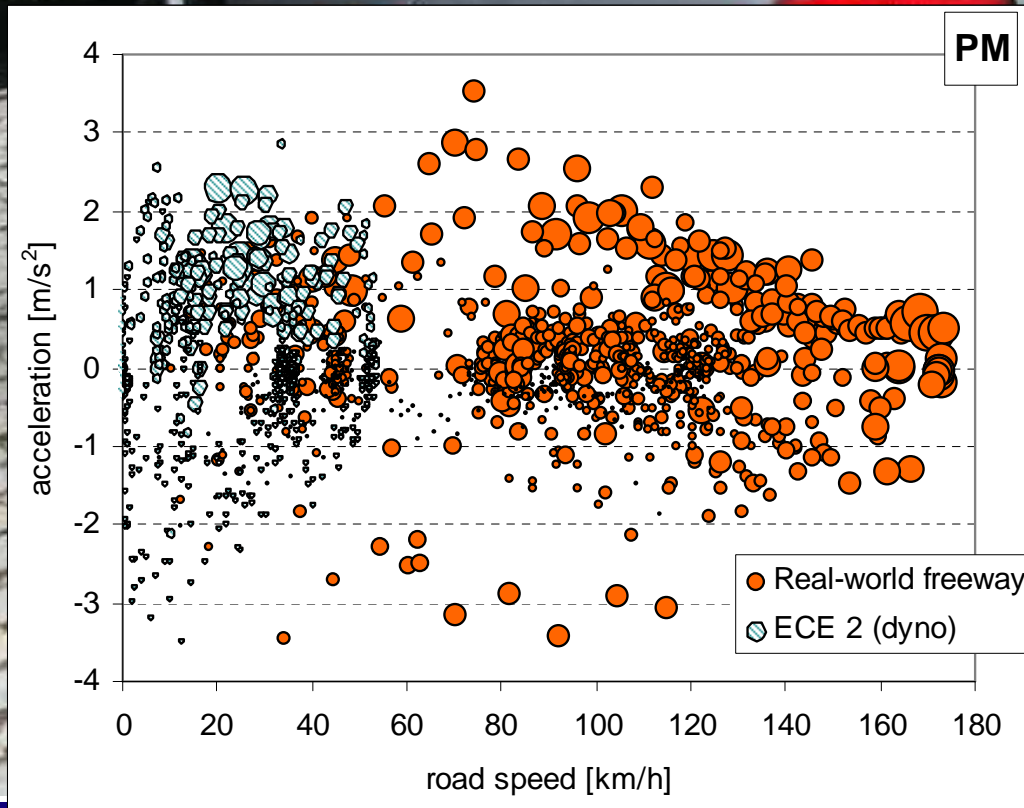


Euro 4 Skoda Octavia – real-world city driving tests



Euro 4 Škoda Octavia – high-speed freeway tests

Aggressive, high-speed driving on a freeway, not atypical for Czech roads
Results contrasted with ECE cycle test on a chassis dynamometer



Congestion effects: DAF 1505 truck, 2006, Euro 5 Paccar engine, 540 thousands km, with loaded trailer (39 tons total weight)



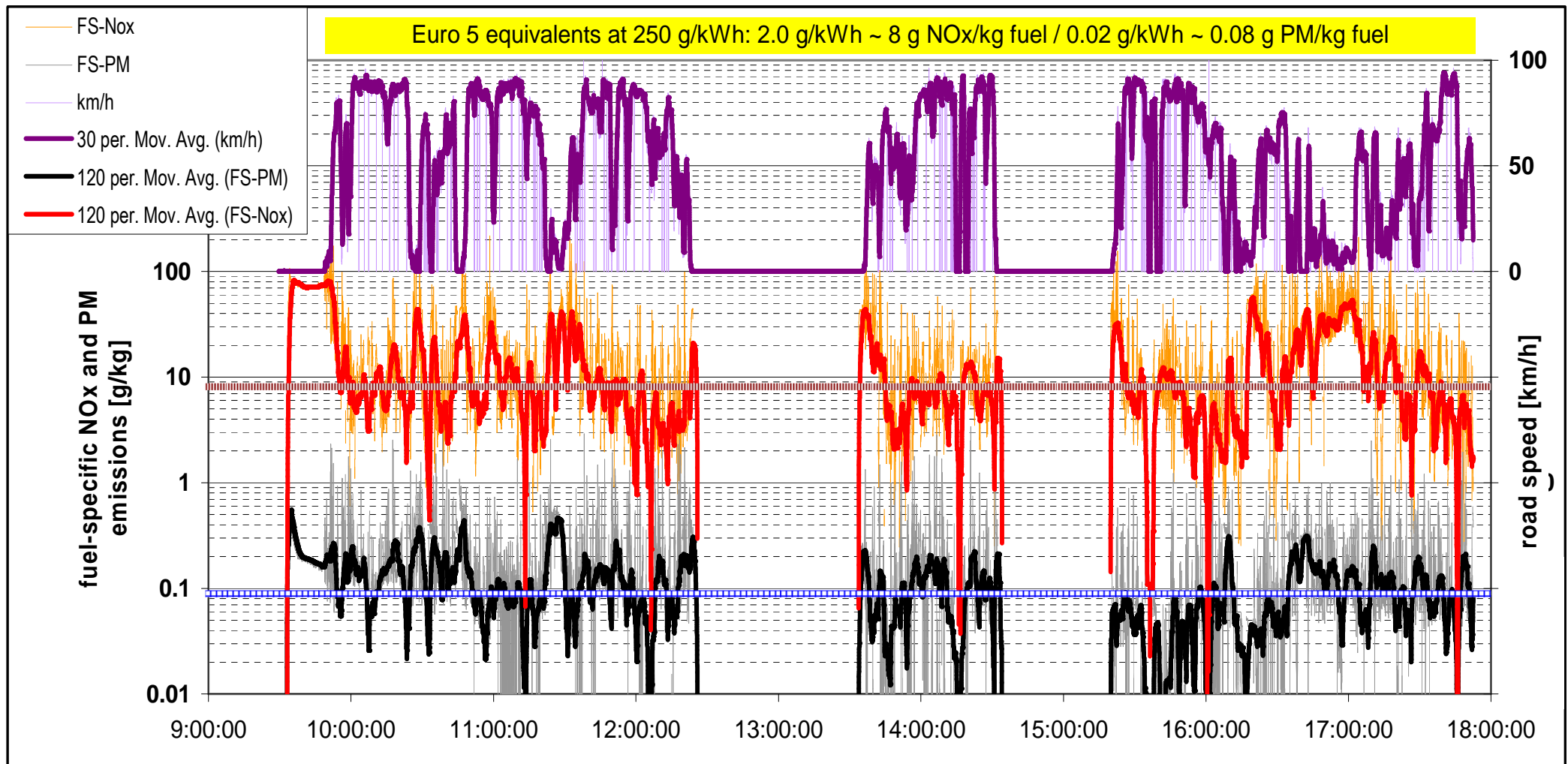
The horror of transit truck traffic

We took a DAF truck with semi-trailer, 39 tons, EURO 5 but no DPF, and circulated the Prague perimeter road waiting for congestion to happen

“Urban creep”:

combustion worsens, DOC cools down, SCR cools down, EGR not feasible

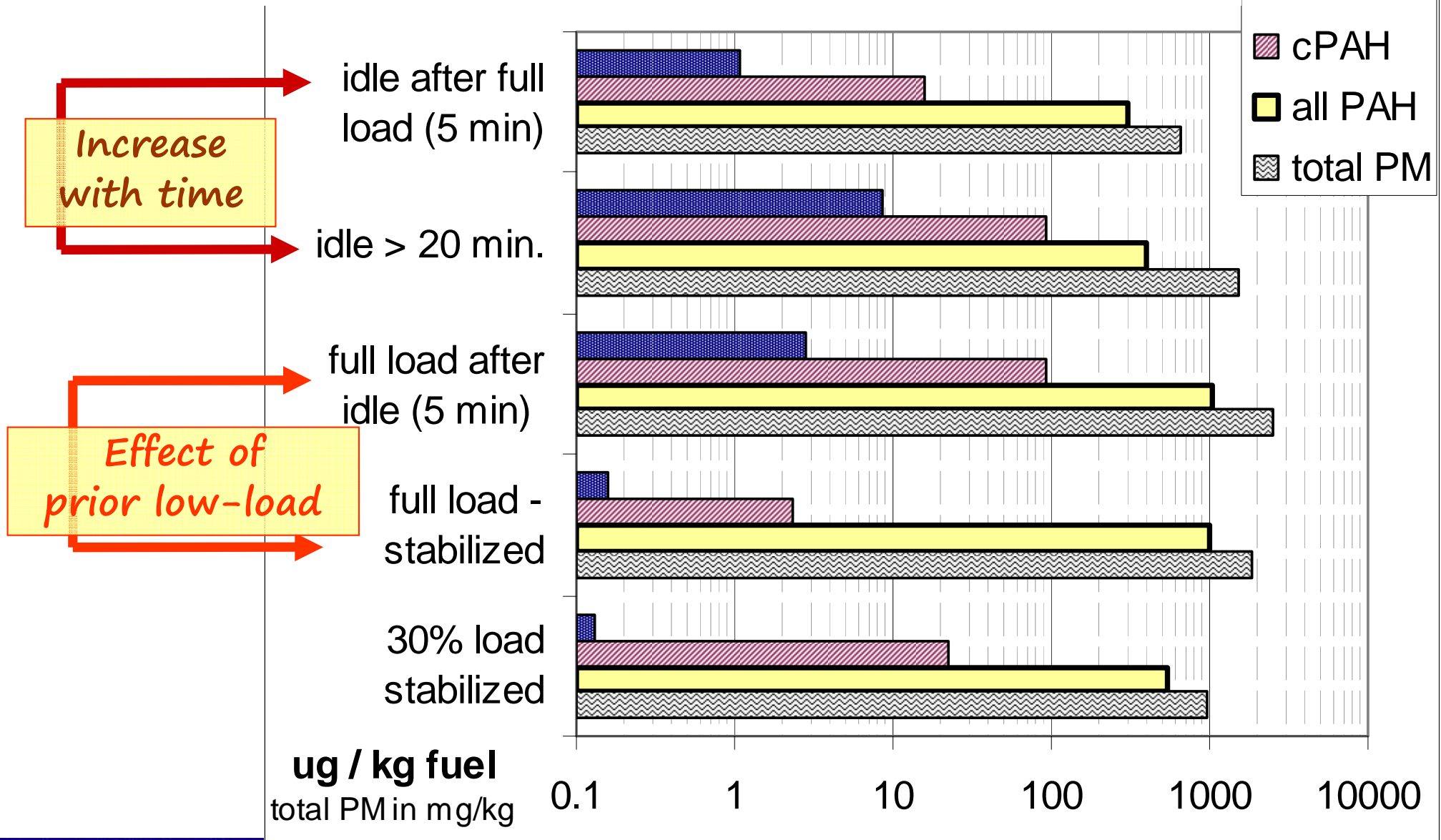
Result: NOx and PM up to one order of magnitude higher



Extended idling effects – diesel fuel – logarithmic scale

An order of magnitude increase during + after extended low-load of emissions of BaP, carcinogenic PAH, all PAH, PM mass

EU Stage III A non-road diesel engine, no aftertreatment



Is diesel PM becoming more of a question of public policy rather than technology?



With DPF



Euro 5 with no DPF
(Prague, CZ)

Warning: This engine emits carcinogenic nanoparticles that are harmful when inhaled.

DPF work, but ... are they the EU norm, or the privilege of wealthy and progressive countries and regions?

Polish advertisement for emulation of (removed) DPF to the ECU

Emulatory FAP-DPF :: O firmie - Mozilla Firefox

File Edit View History Bookmarks Tools Help

dpf removal s... Improve MPG... Emulatory ... x DPF / FAP re... DPF Removal... FAQ's | DPF R... Filtr pevných ... Odstranění fit... Filtry pevných...

fap-dpf.pl/en/?gclid=CLGgs8W74rACFUJL3wodpG_u1A

ADS
ADVANCED DIGITAL SYSTEMS

get rid of the problem of diesel particulate filter... forever!

EMULATORS FAP-DPF

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o firmie

Advanced Digital Systems is dynamically burgeoning company, which operates in the automotive industry, electronics and lighting. Our team is based on highly experienced, ambitious people, graduated of the Silesian Technical University, the Silesian higher education and the Technical University of Cracow, which are caring for the best cooperation with many European and Asian business partners. Main priority of company is satisfaction of our customers. Continuously we improve the quality of our services and products.

emulatory fap-dpf

Do we mandate the installation of DPF through emissions limits, but then tolerate DPF removal?

DPF / FAP removal - Mozilla Firefox

File Edit View History Bookmarks Tools Help

www.ecusafe.com/html/DPF_fap_removal.html

DPF / FAP removal

Removing of FAP / DPF is easy ! All you need is to read original file from car and process it with proper ECUsafe module, designed to find and remove all important DPF structures automatically, without your attendance.

File can be then directly written in ECU, or it can be tuned by you and then - written into car. DPF can be removed from car, sensors left unplugged (no sensors at all) or left in the exhaust. It does not matter.

No more regeneration, no more black smoke behind. No more DPF check light or lamps on the dashboard. Add DPF removal offer to your workshop capabilities !

You can buy selected modules from list above or bundle set of all for discount price.

ECUsafe

Version 3.00

FORD SID206

DPF (FAP) removal

Welcome.

1. Select manufacturer & ecu type & operations.
2. Upload your file (binary, do not use zip, BDMtoGo or so)
3. After a while your file will be processed by server and sent back.

UPLOAD

ECUsafe

UK advertisement for removal of DPF and corresponding adjustments of ECU



ate and Diesel Tuning - Mozilla Firefox

bookmarks Tools Help

MPG... Emulatory FA... DPF / FAP re... DPF Remo... x FAQ's | DPF R... Filtr pevných ... Odstranění fit... Filtry pevných... Filtry pevn

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page are out of date.

FIND OUT BY HOW MUCH PERFORMANCE WILL INCREASE ON YOUR VEHICLE

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DPF Delete And DPF Removal With Viezu

DPF Delete software and tuning is becoming ever more popular and needed. Viezu technologies, the world leading provider of vehicle tuning services offer a full range of DPF removal, DPF delete, and DPF problem solving services

A DPF (Diesel particulate filter) or FAP (Filtre A Particules) is a device designed to remove diesel particles or soot from the exhaust gas of a diesel engine. It basically traps the diesel particles in the filter and at a given condition the vehicles ECU will carry out a "regeneration" cycle when these particles are burnt and blown out of the exhaust.

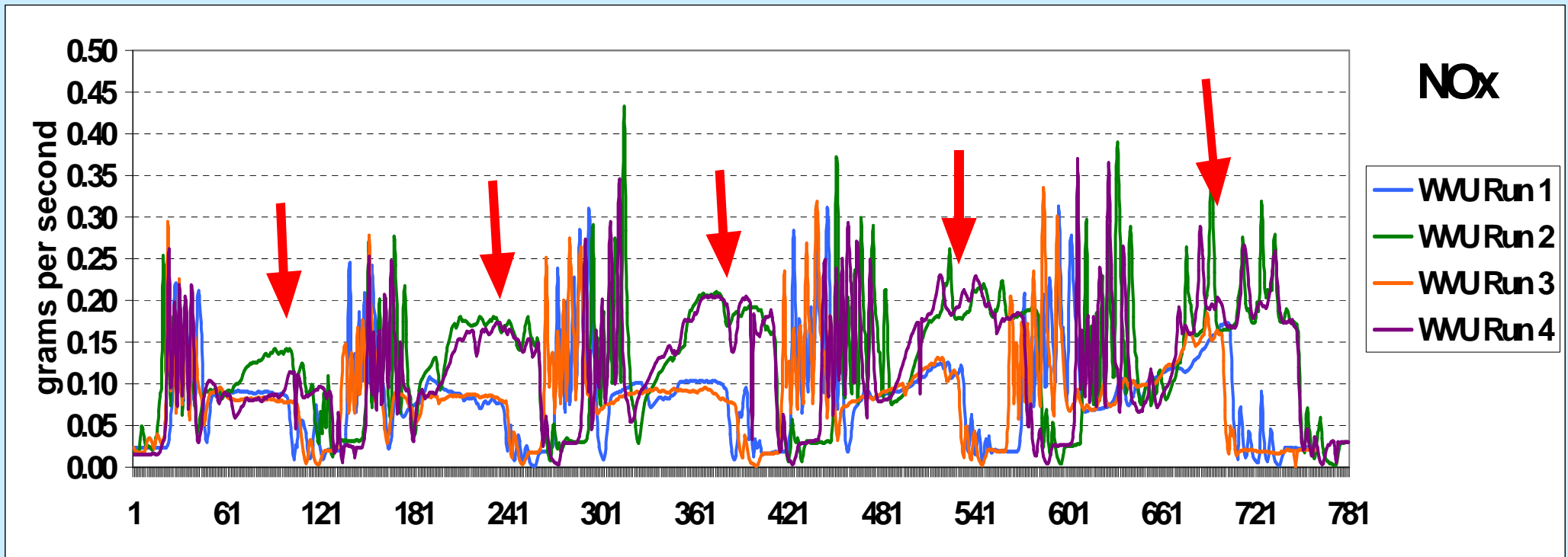
3000.0 kb/s

Do we mandate the installation of DPF through emissions limits, but then tolerate DPF removal?

„DieselGate“: If the engine is not running under „test conditions“, NOx emissions are considerably higher (while we save a small amount of fuel)

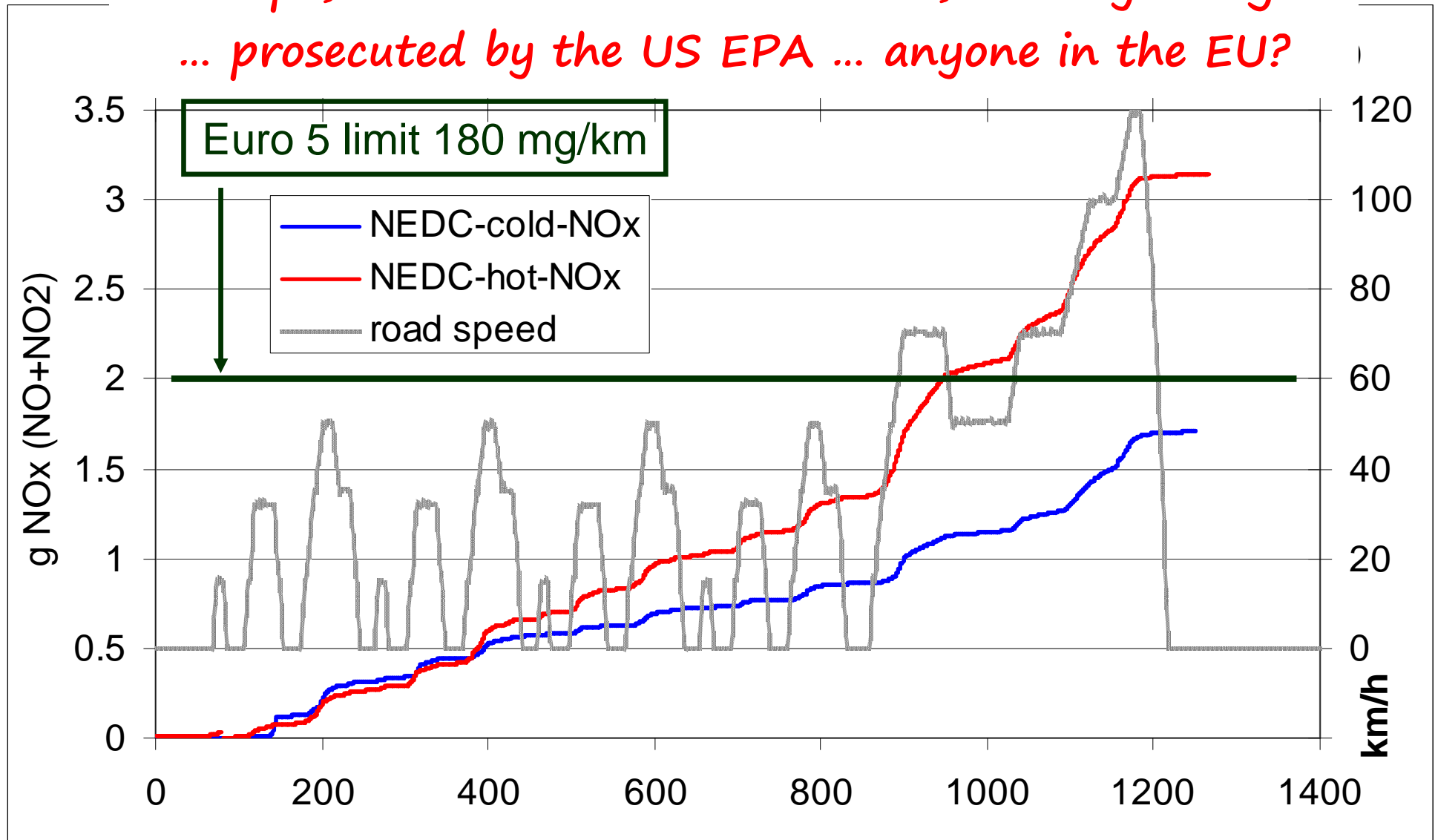
Run	Grams per cycle				
	NOx	HC	CO	CO2 [kg]	PM
1	65.31	94.30	11.32	5.92	0.256
2	100.05	92.49	11.84	6.44	0.305
3	65.29	91.88	18.52	6.15	0.296
4	95.31	93.74	16.50	6.35	0.314

USA, heavy-duty truck, 16 years ago



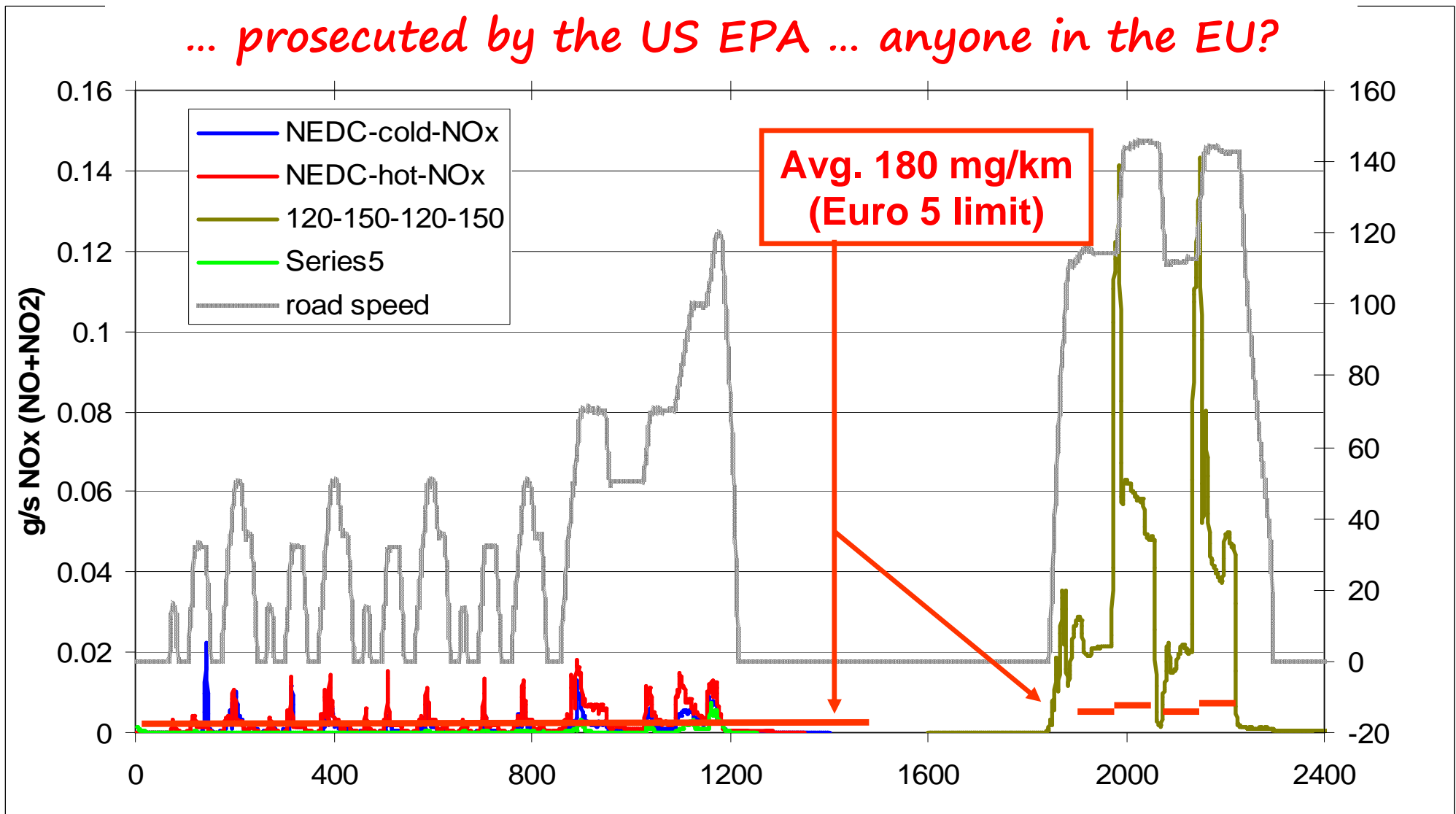
„DieselGate“: If the engine is not running under „test conditions“, NOx emissions are considerably higher (while we save a small amount of fuel)

Europe, VW and other automobiles, half a year ago ... prosecuted by the US EPA ... anyone in the EU?



„DieselGate“: If the engine is not running under „test conditions“, NOx emissions are considerably higher (while we save a small amount of fuel)

Europe, VW and other automobiles, half a year ago ... prosecuted by the US EPA ... anyone in the EU?



Diesel bus Euro 6 – Hradčany airport

Braunschweig cycle average: 195 mg/km (312 mg/mi) NO_x.

At 37 liters per 100 km, 220 g/kWh: 162 mg/kWh (Euro 6: 460 mg/kWh)

At 6.35 miles per gallon, 0.36 lb/bhp-h: 121 mg/bhp-h (Euro 6: 343 mg/bhp-h)



**EU diesel car limit: 180 mg/km Euro 5, 80 mg/km Euro 6
(290 mg/mi Euro 5, 129 mg/mi Euro 6)**

Real EU diesel car emissions, same for Euro 3-5: 1000 mg/km

**One Euro 5 diesel car = 1000 mg/km = five Euro 6 diesel buses
But 5 diesel buses can carry many more passengers !!!**

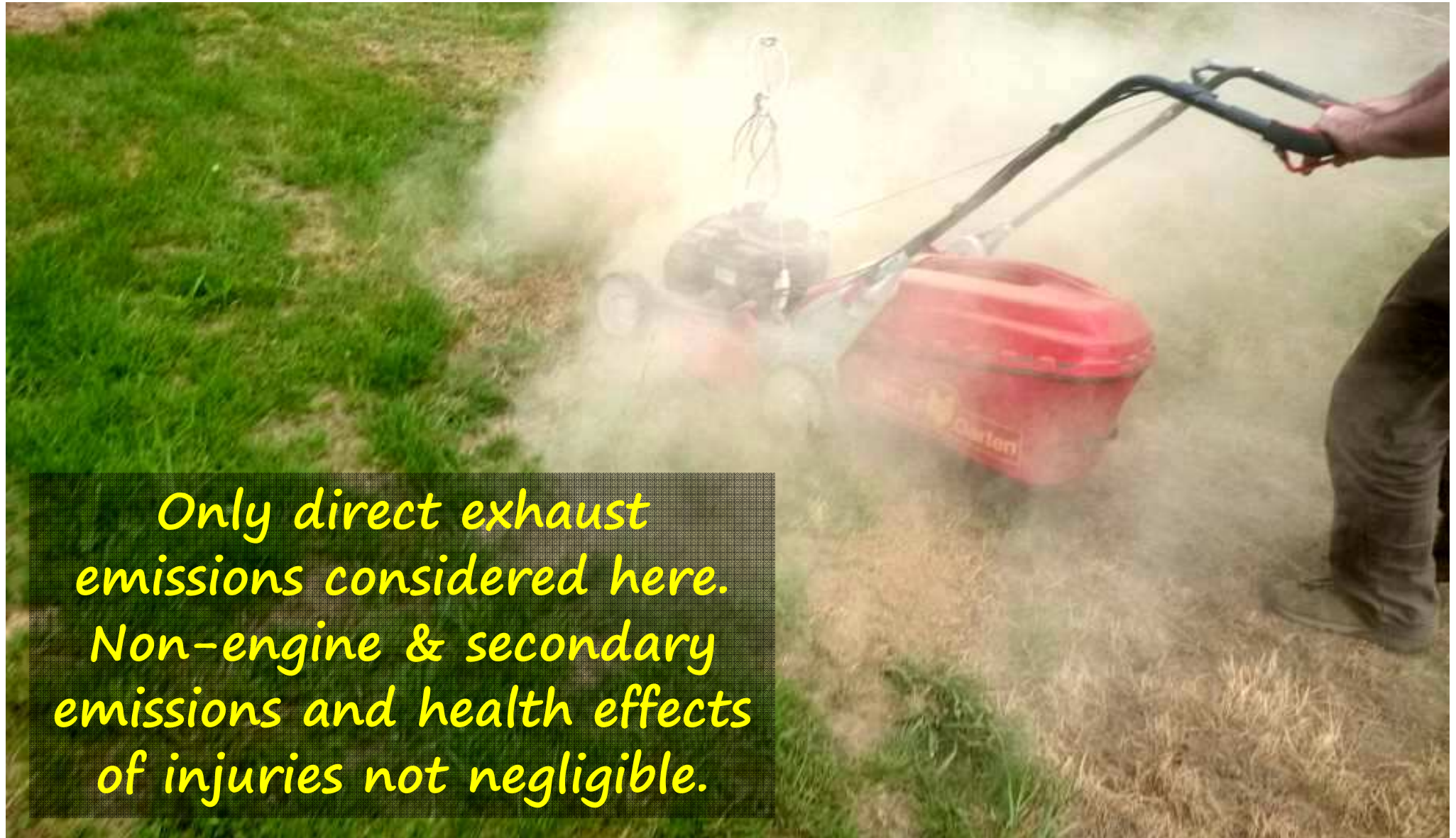
High-volume sampling for advanced analysis

30-60 m³/min
sampling on
142/150 mm
filters for analyses
(i.e. PAH) and
toxicological assays



Isokinetic or
constant flow
sampling is not
necessary as
100% of
exhaust is
sampled

Particle emissions from small engines under real “driving” conditions



*Only direct exhaust
emissions considered here.
Non-engine & secondary
emissions and health effects
of injuries not negligible.*

Lawnmower and weed-eater – test summary (PAH analysis and toxicology assays to follow)

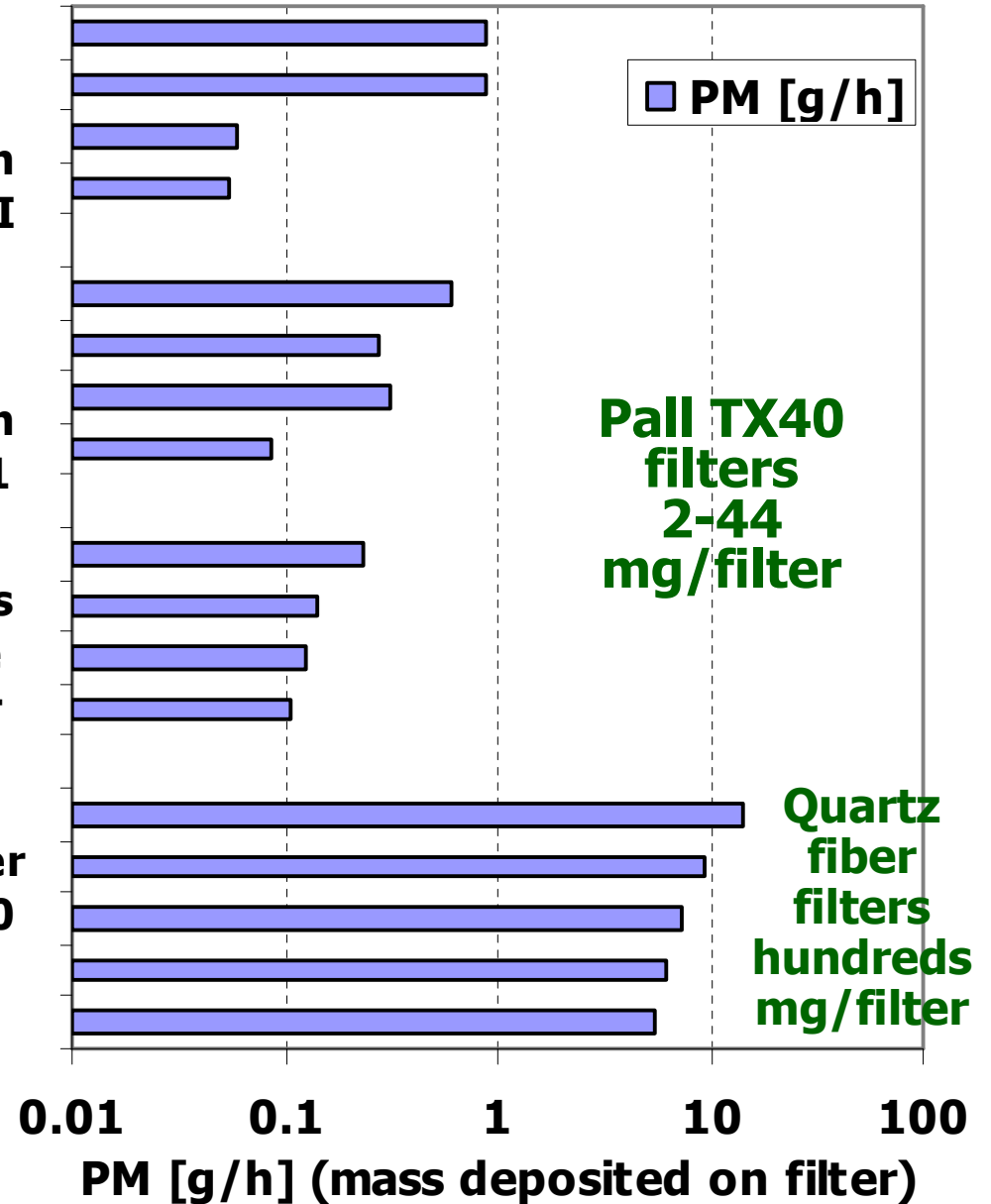


**Wolfgarden
4-cycle
Briggs&Stratton
US EPA Stage II**

**Stiga
4-cycle
Briggs&Stratton
US EPA Phase 1**

**Mid-90's
4-cycle
mower**

**Weed-eater
Stihl FS350
2-cycle**

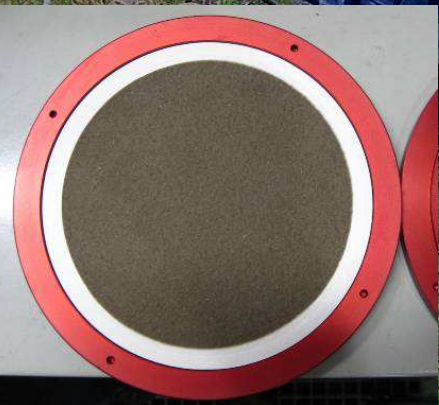


Just when we think we have solved the problem, we realize there is a long way to go:
What about small engines in garden machinery?

Cheap and primitive Chinese engines subject to no particle limit whatsoever (neither in EU nor in the US)

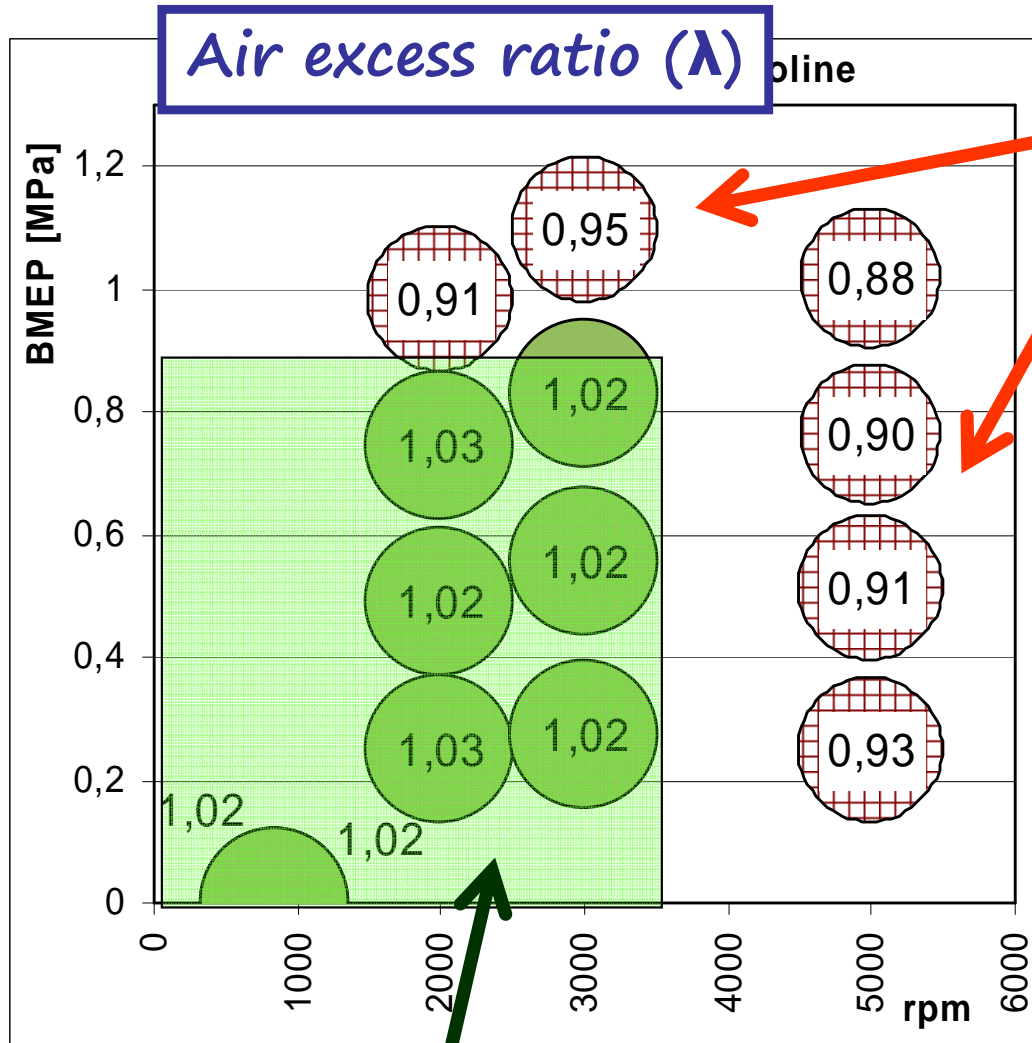


Don't they produce more particles than a DPF-equipped city bus?
Or more than about 10 buses?
Aren't those particles released about a meter (three feet) from one's head?

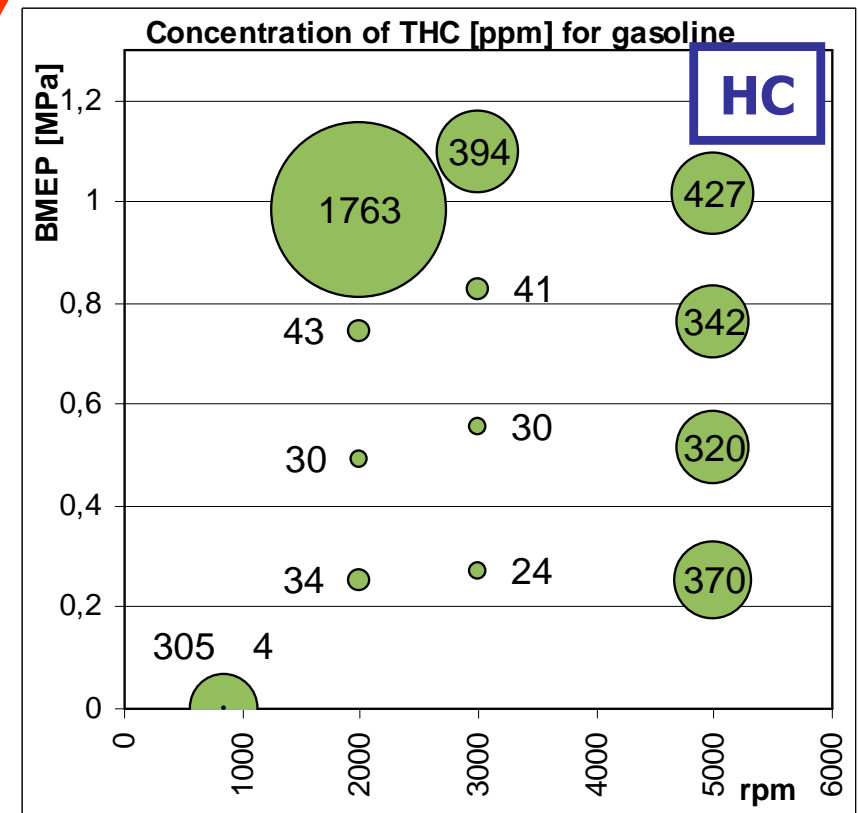


Challenges of EU automobile gasoline engines

Euro 4 Skoda Fabia – engine dynamometer runs



Reducing exhaust gas temperatures (catalyst protection) by fuel-rich operation at high rpm and at high loads

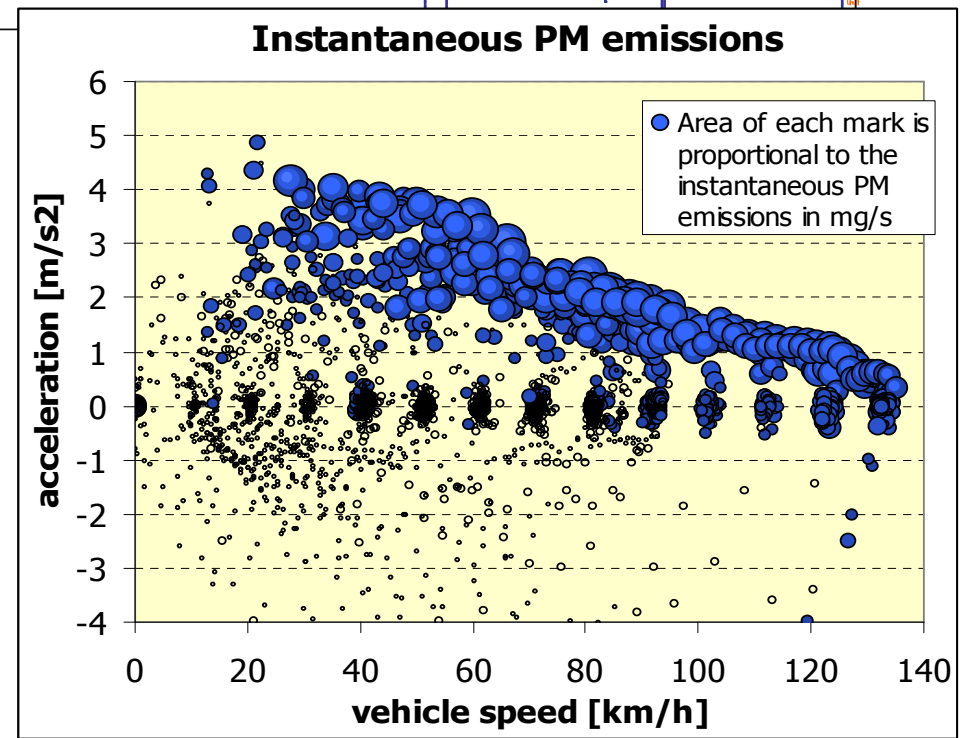
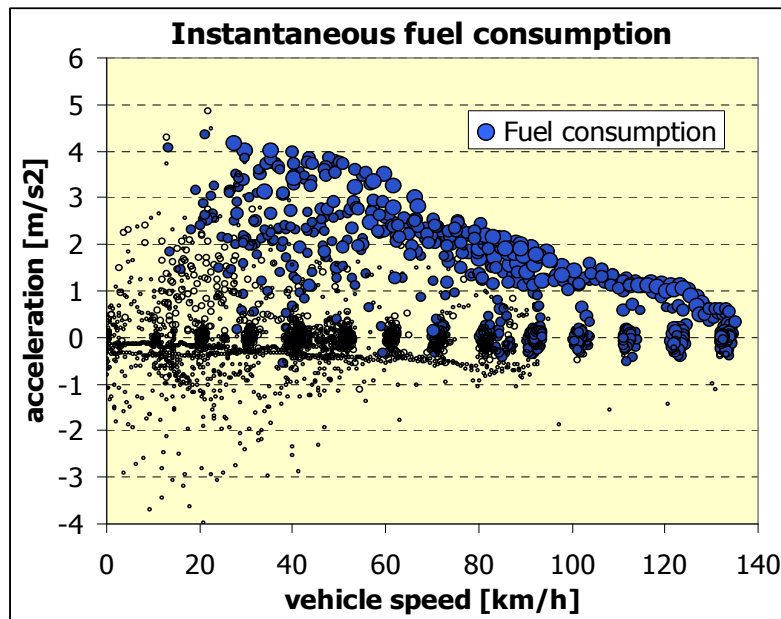
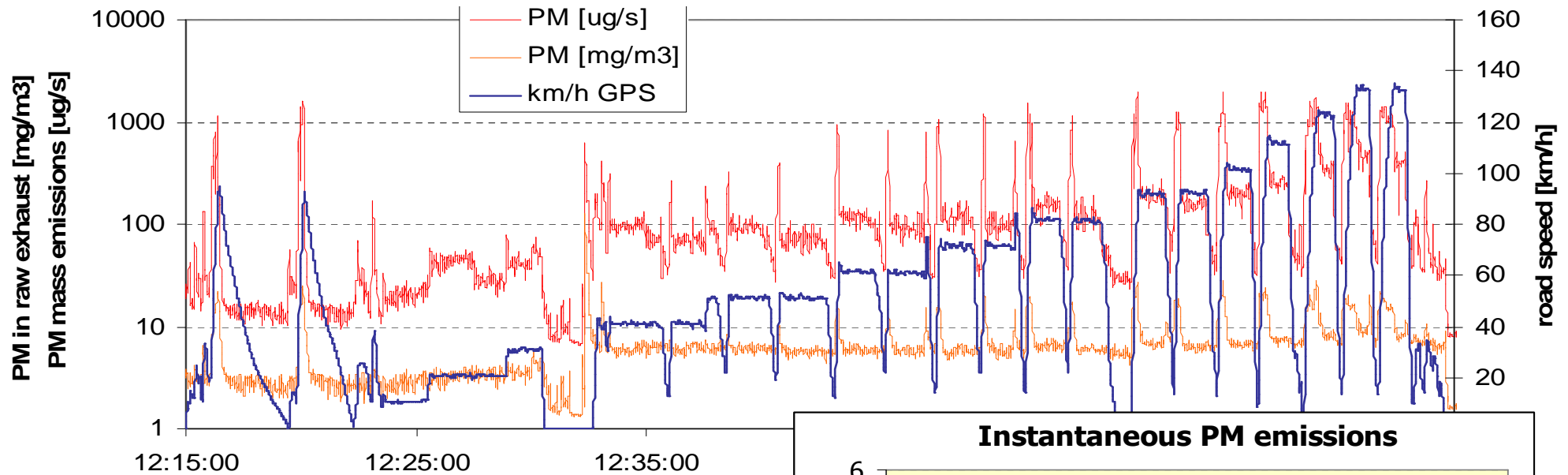


Stoichiometric operation

Gasoline engine real-driving PM emissions



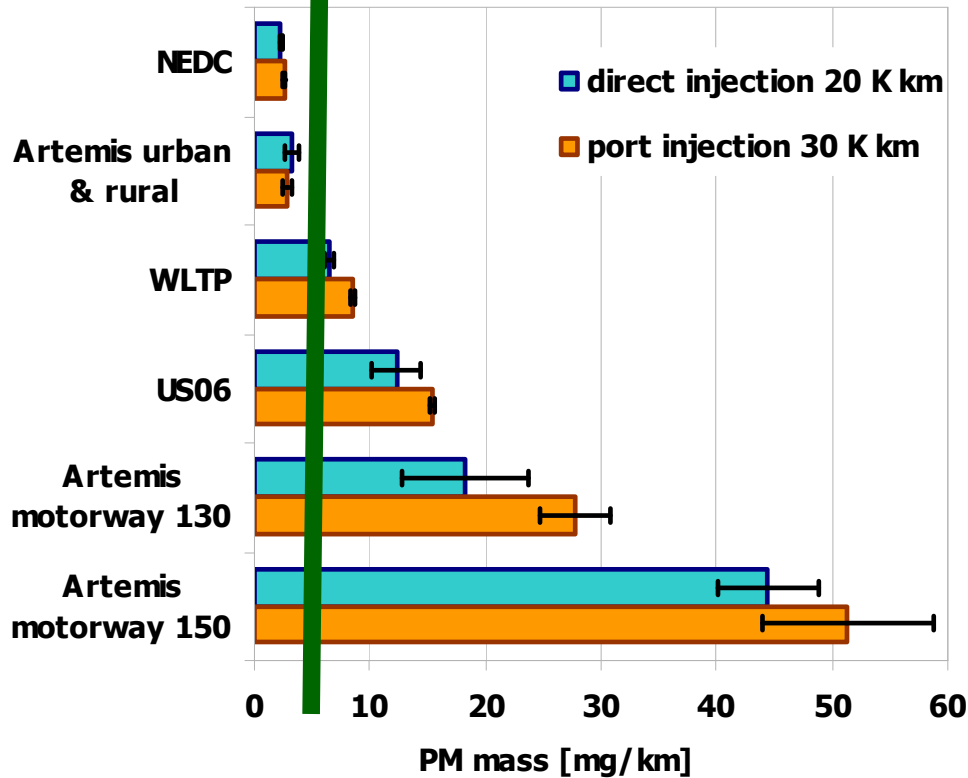
Gasoline engine on-road PM emissions: steady speed vs. full-power acceleration



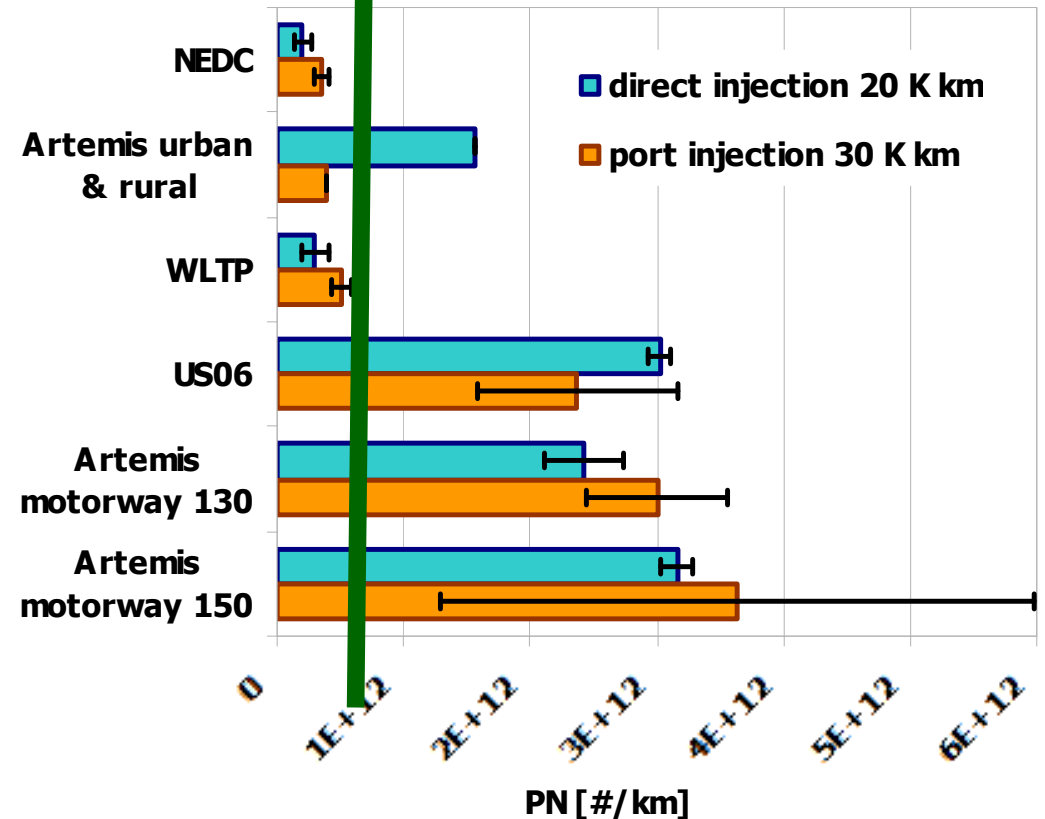
Gasoline engine PM: Choice of cycles

WLTP is “not as lame as NEDC”, but does it cover the problematic enrichment at high load (prohibited by EPA)?
 US06 and Artemis motorway cycles as a supplement?

EURO 5 PM mass limit



EURO 5 PN limit



Particle metrics:

Total mass (what is retained on the filter)

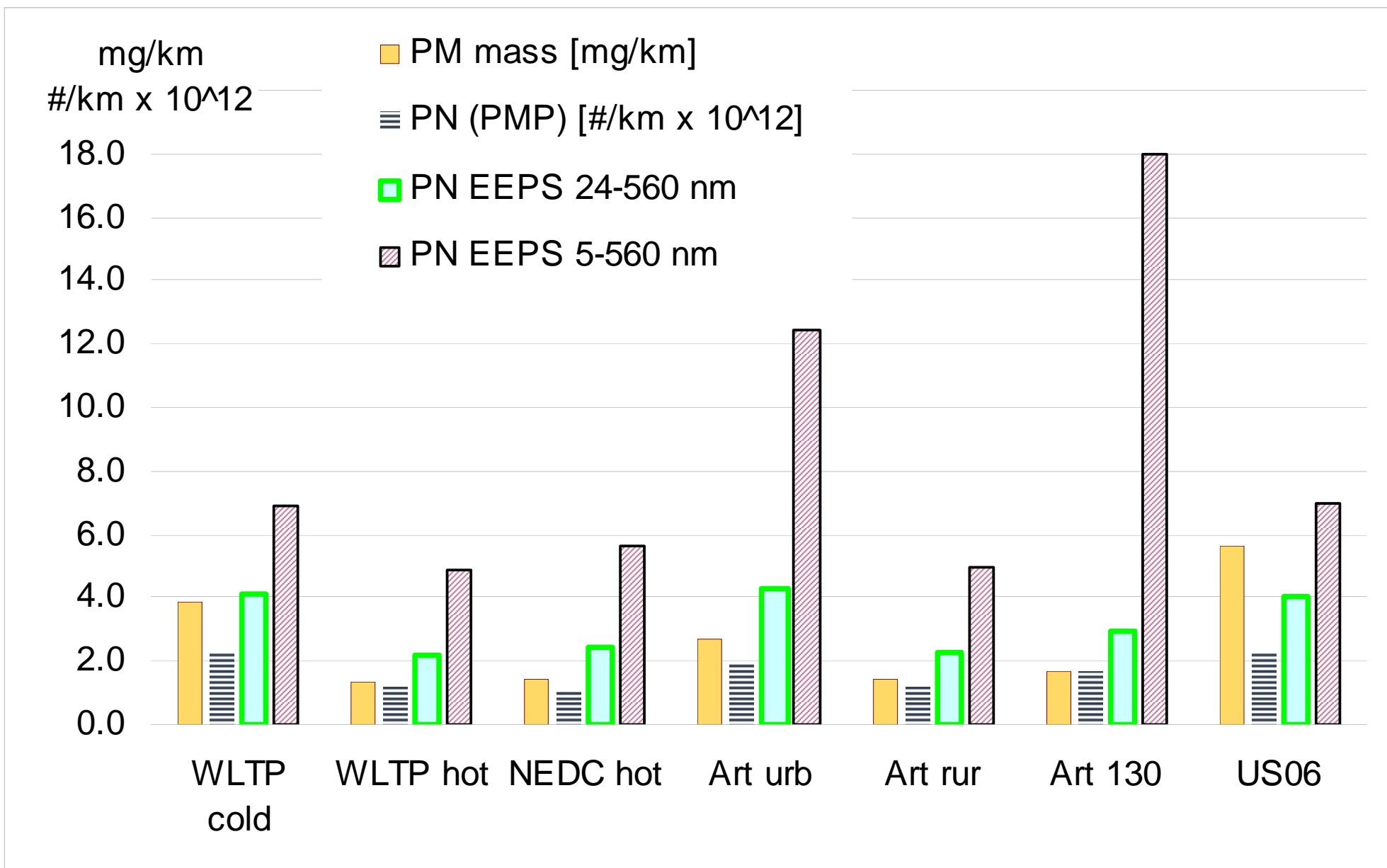
Total count (EU, Particle Measurement Programme: count of non-volatile particles, 50% counting efficiency at 23 nm)

I want my RDA of vitamin C of apples.

Sorry.
We sell fruits like we measure particles – by count or by kilogram.



Effect of cycle & effect of "PN" definition: PN (PMP), PN (EEPS 5-560 nm), PN (EEPS 23-560 nm) Gasoline, PM is gravimetric on TX40HI20-WW Emfab filters



Experimental setup:

Ambient size and time resolved nanoparticle measurement in inhabited areas
Portable vehicle emissions monitoring instrumentation used for ambient measurement

Fast mobility spectrometer (Engine Exhaust Particle Sizer, Model 3090, TSI Inc.)
Condensation counter (UF-CPC 200, Palas)
notebook, GPS, batteries mounted on hand carts (or a baby carriage).

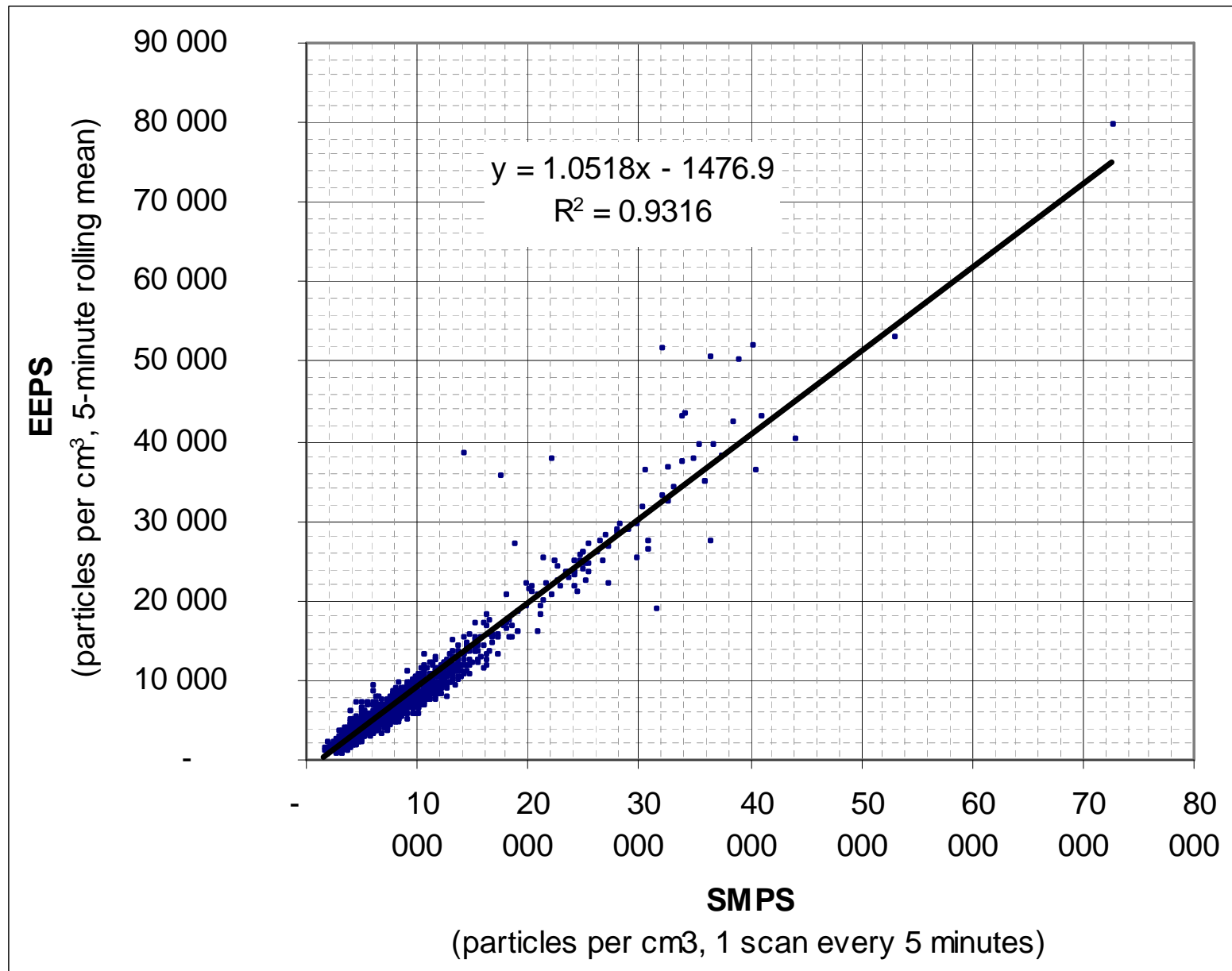
Study designed, measurements done, and data interpreted by an interdisciplinary team of engine – combustion – aerosols – toxicology specialists.



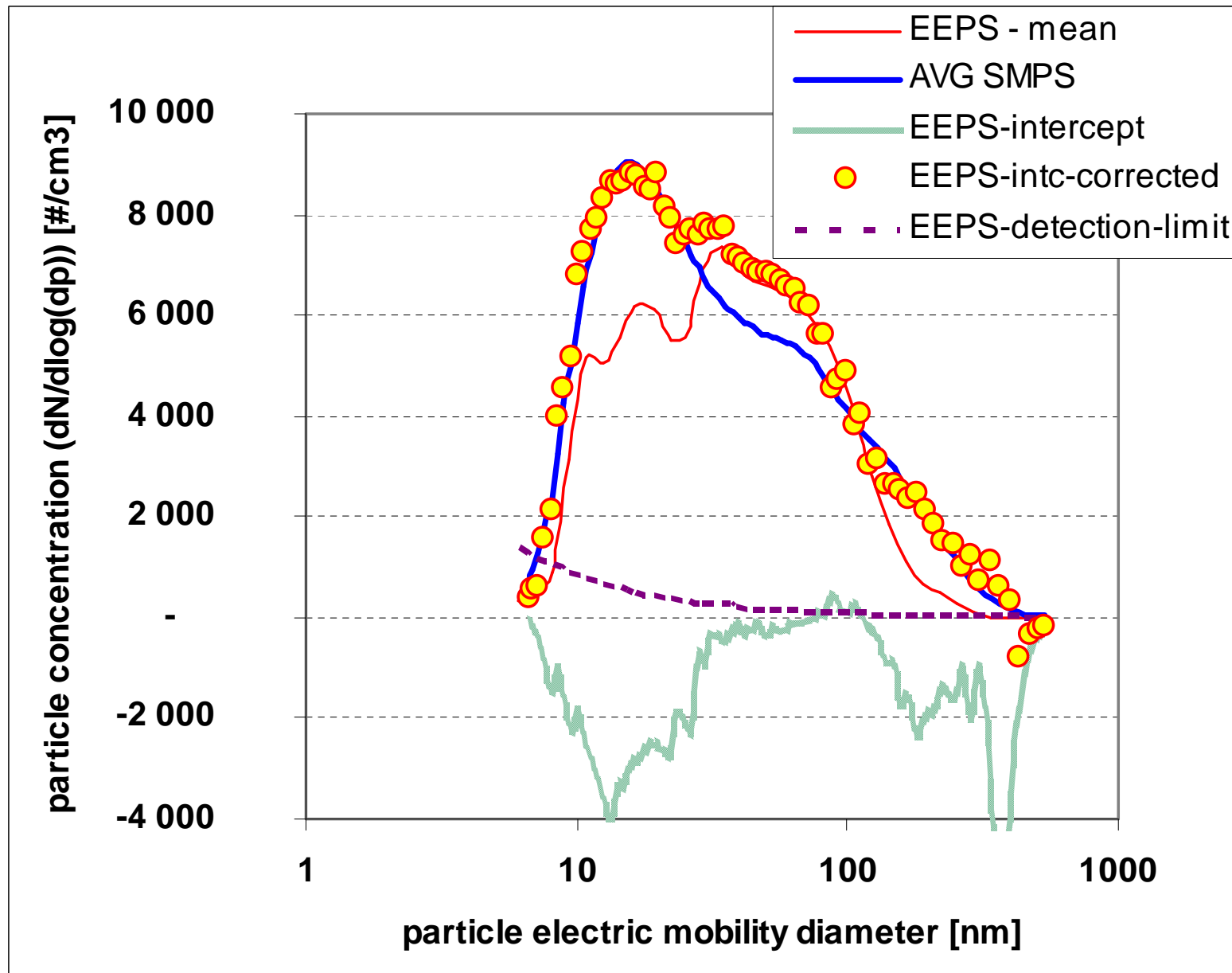
EEPS
5-560 nm

CPC
> 4 nm

Validation of EEPS for ambient measurements: co-location with SMPS+CPC (UFIREG project, 28.6.-3.7.2014) total particle count



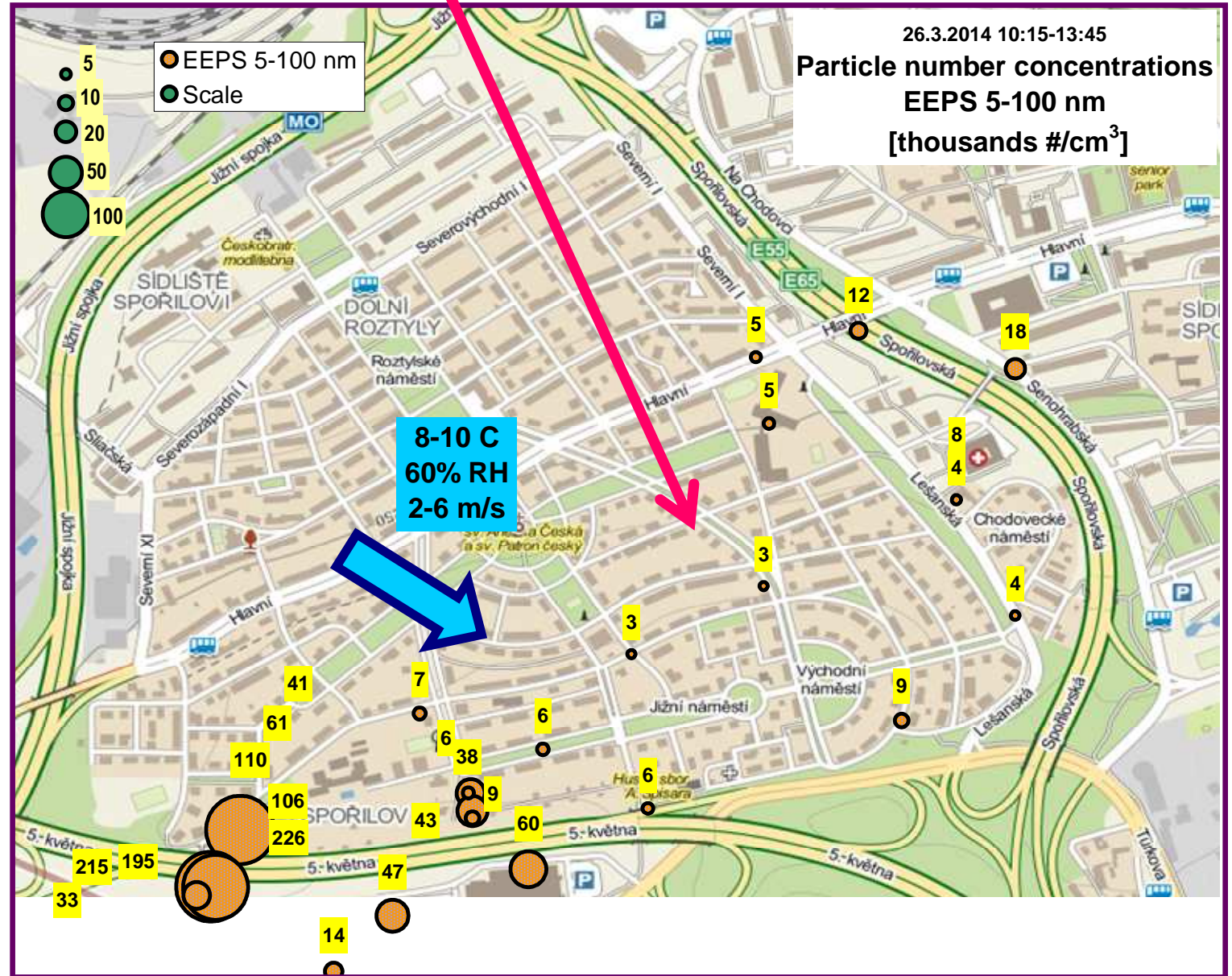
Validation of EEPS for ambient measurements: co-location with SMPS+CPC (UFIREG project, 28.6.-3.7.2014) average particle size distribution



Results: Neighborhood of Spořilov instrumented walking tour

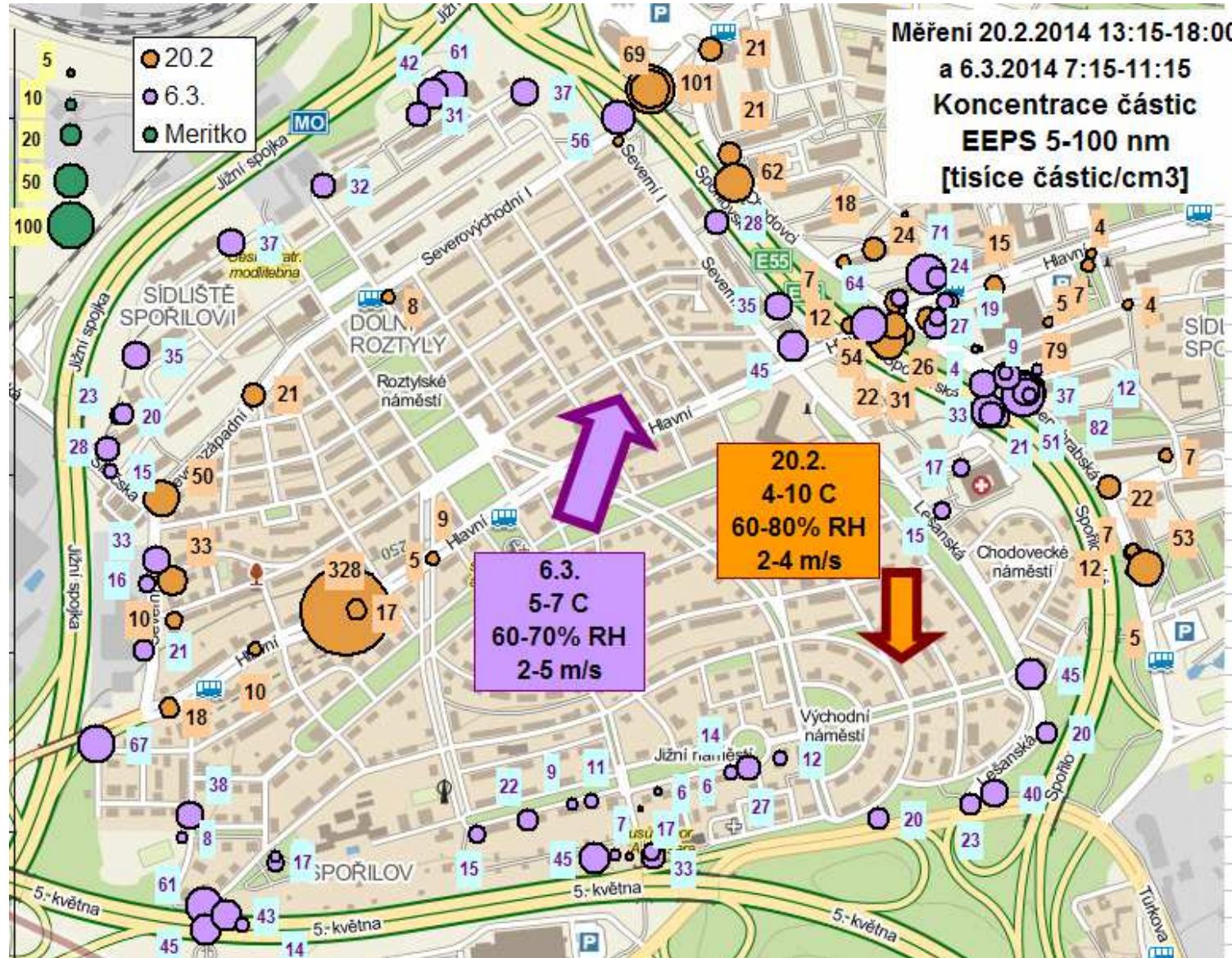
Absence of larger particles & absence of higher concentrations in the inner neighborhood away / upwind from traffic

Assuming that home heating appliances are evenly distributed throughout the neighborhood, why don't we see anything upwind of the road?



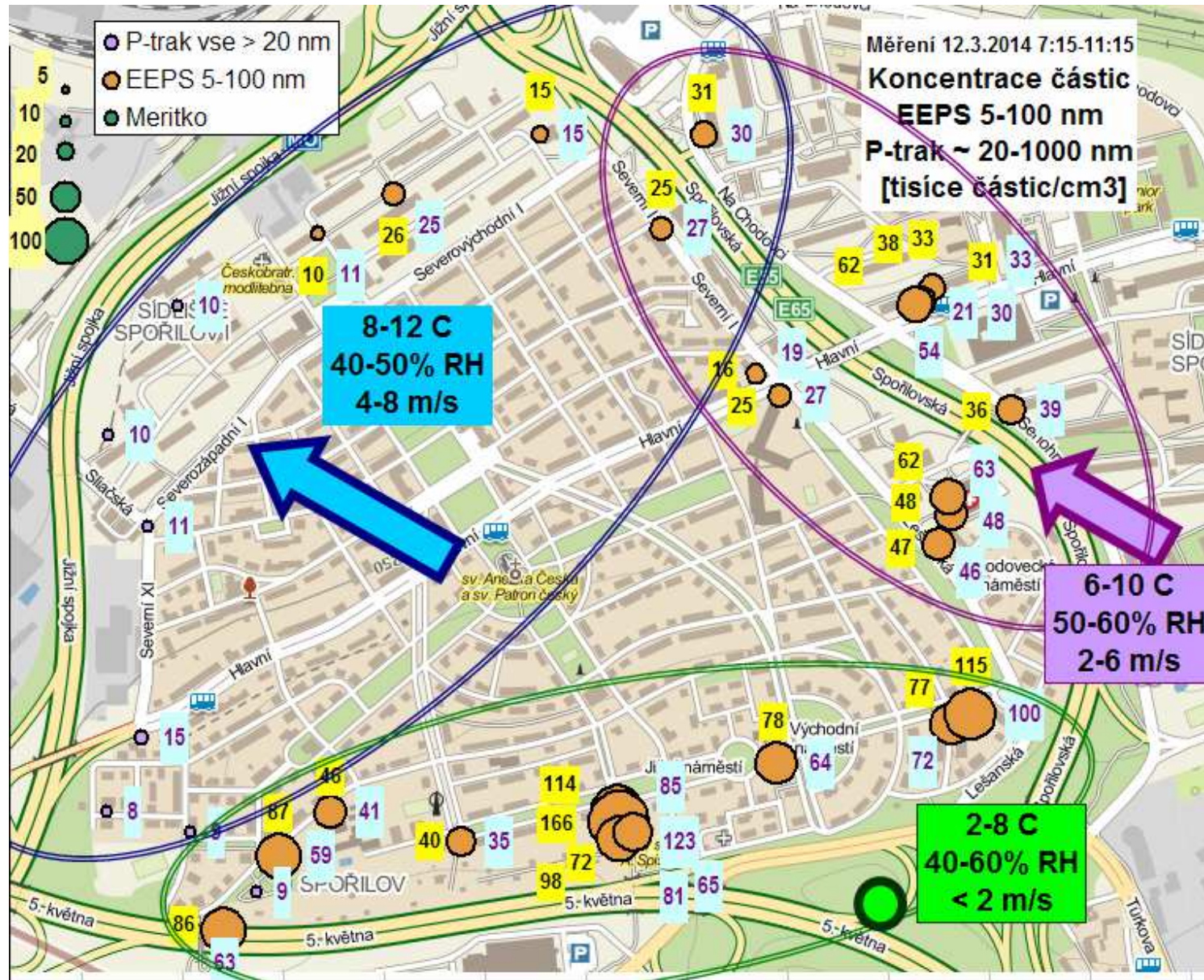
Results: Neighborhood of Spořilov instrumented walking tour

Absence of larger particles & absence of higher concentrations in the inner neighborhood away / upwind from traffic



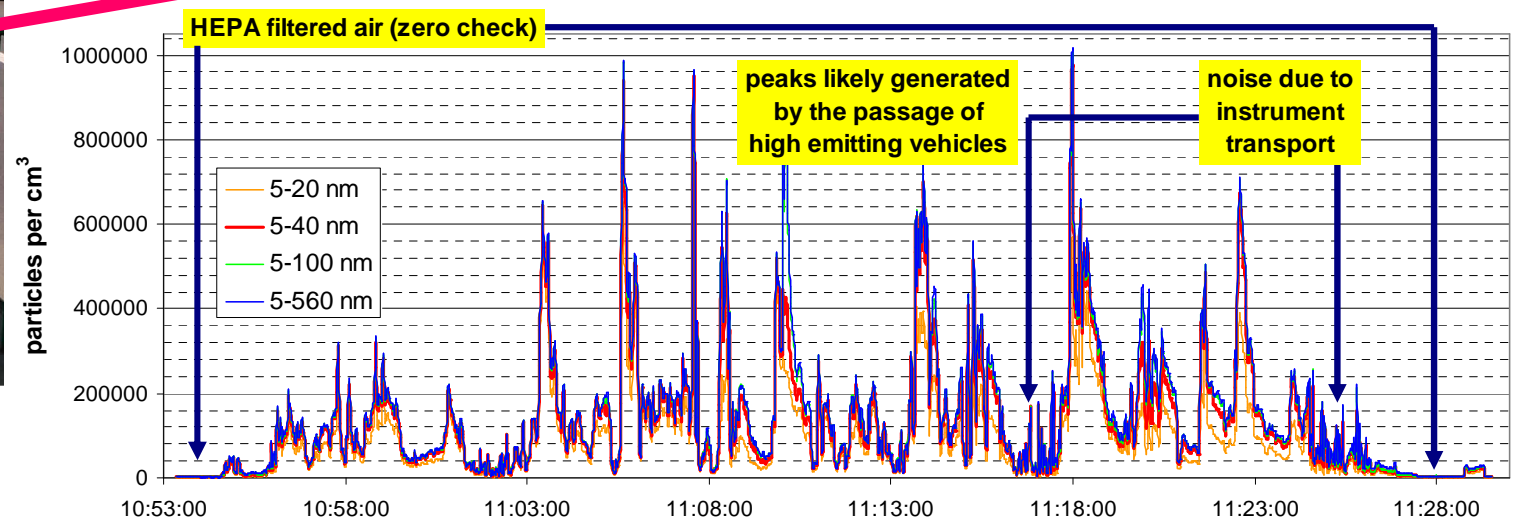
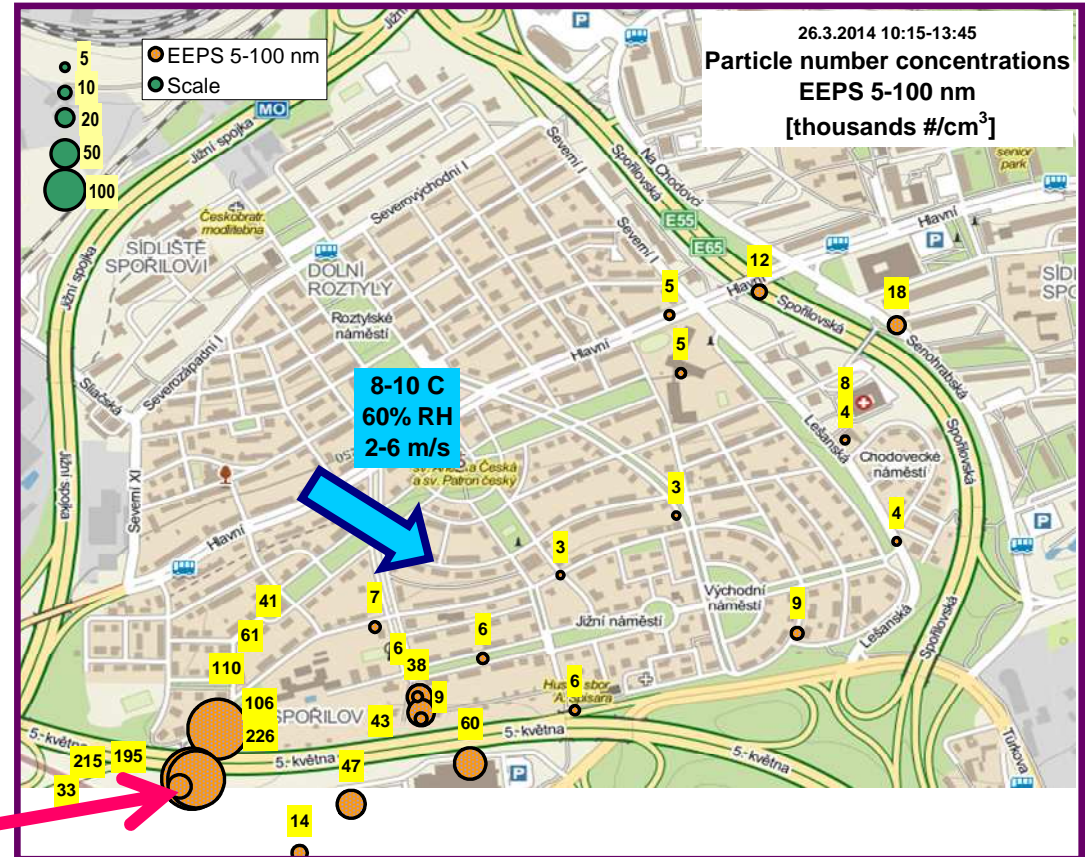
Results: Neighborhood of Spořilov instrumented walking tour

Absence of larger particles & absence of higher concentrations in the inner neighborhood away / upwind from traffic



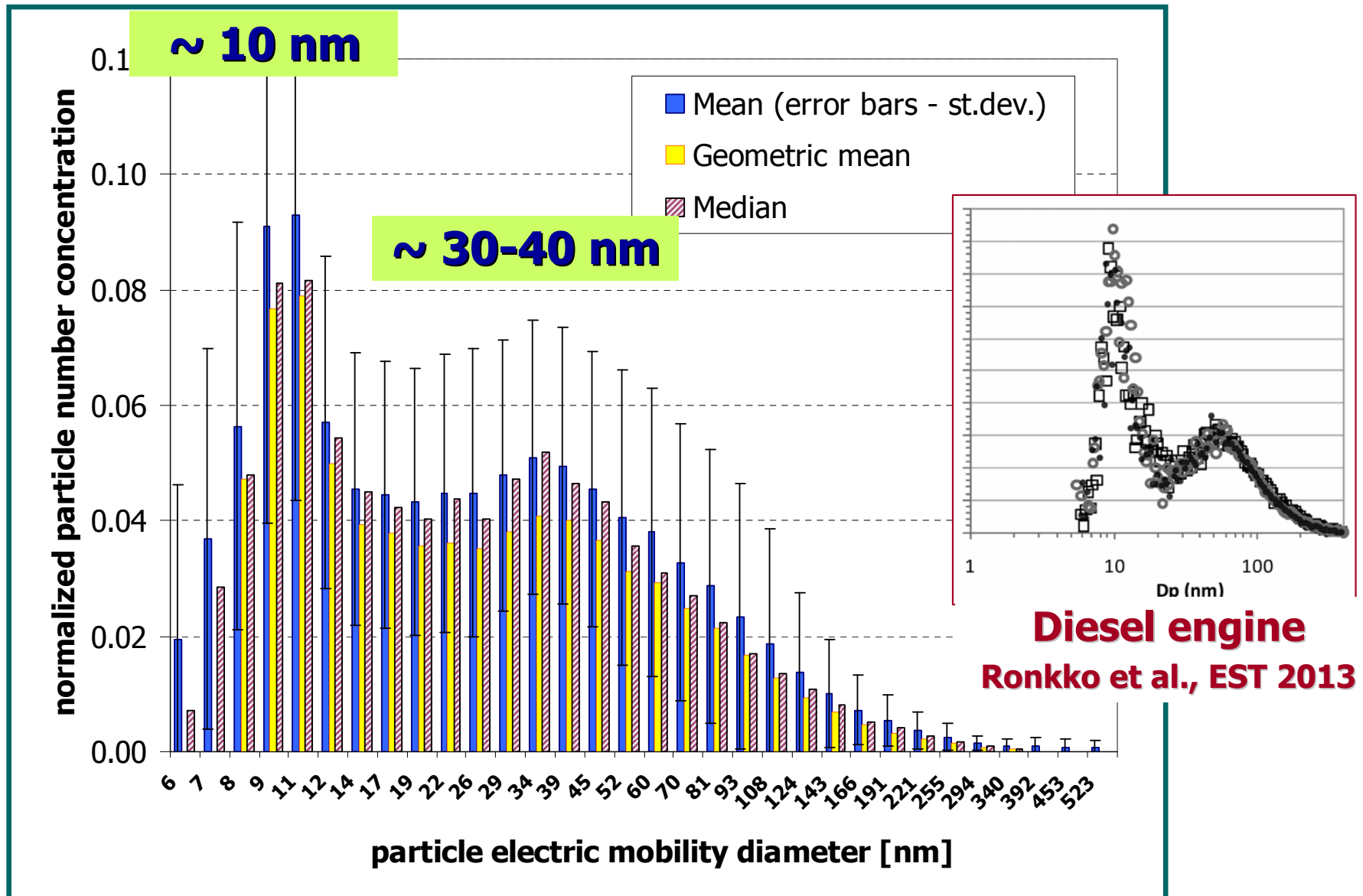
Results: Neighborhood of Spořilov instrumented walking tour

“Spořilov hotspot”:
 After low-speed travel through congested area of Prague, heavy trucks accelerate onto a freeway and climb a hill – “reentrainment” of material deposited in the exhaust system.



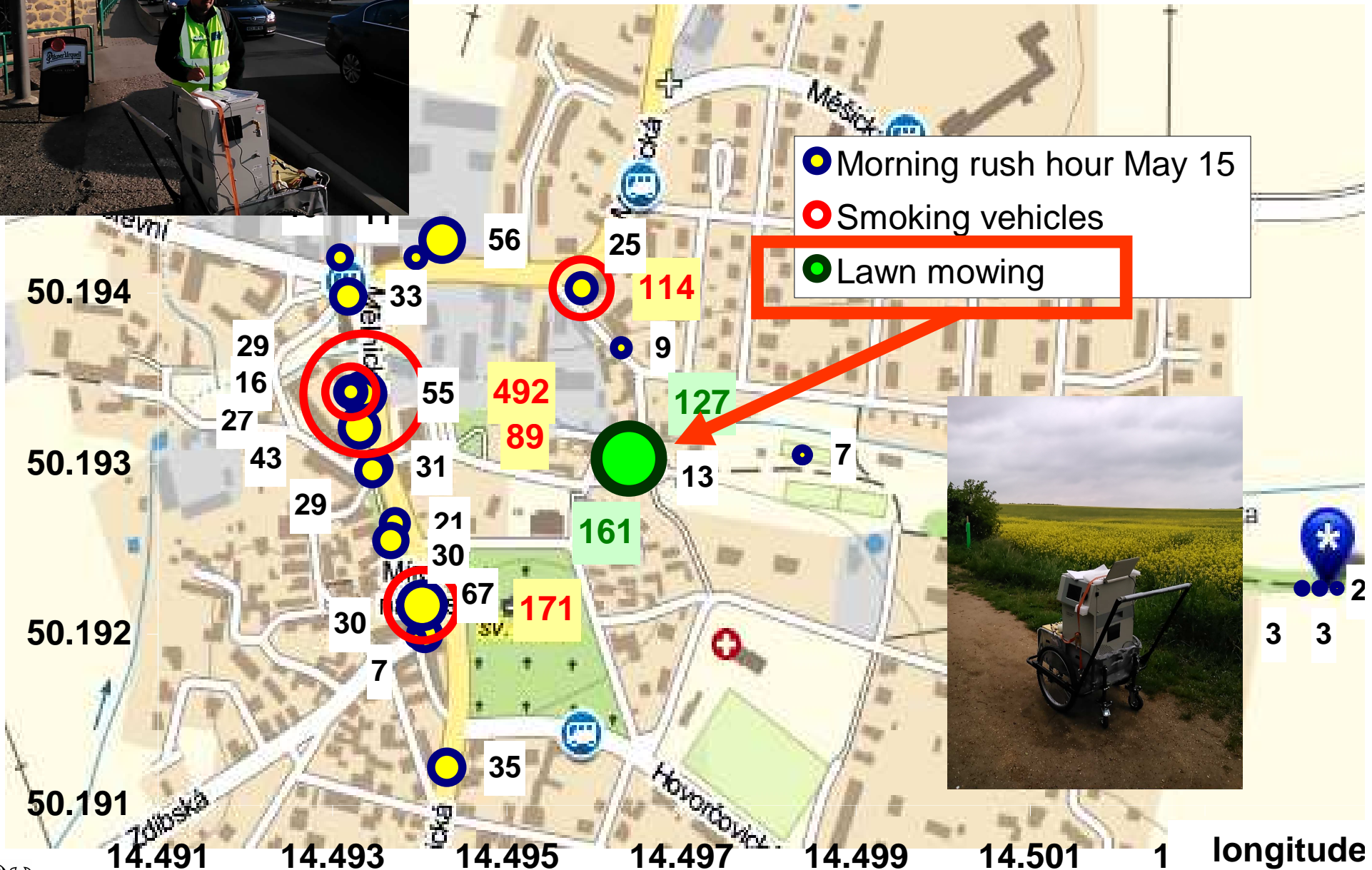
Particle concentrations vary, size distributions remain similar near roadways, and match engine exhaust size distributions

Spořilov, February 2014, mean of 40 normalized distributions

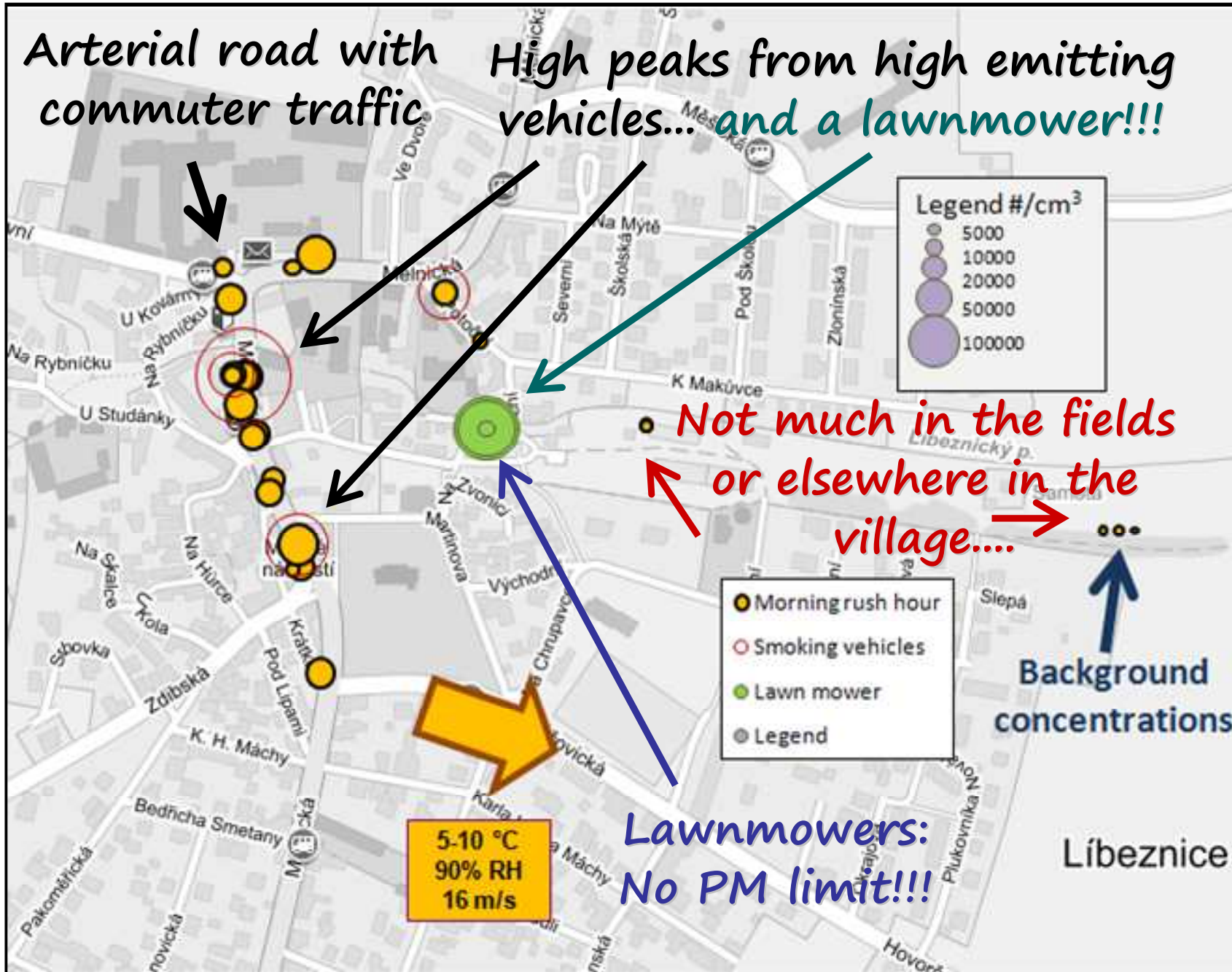


Vojtišek et al., NanoCon 2014

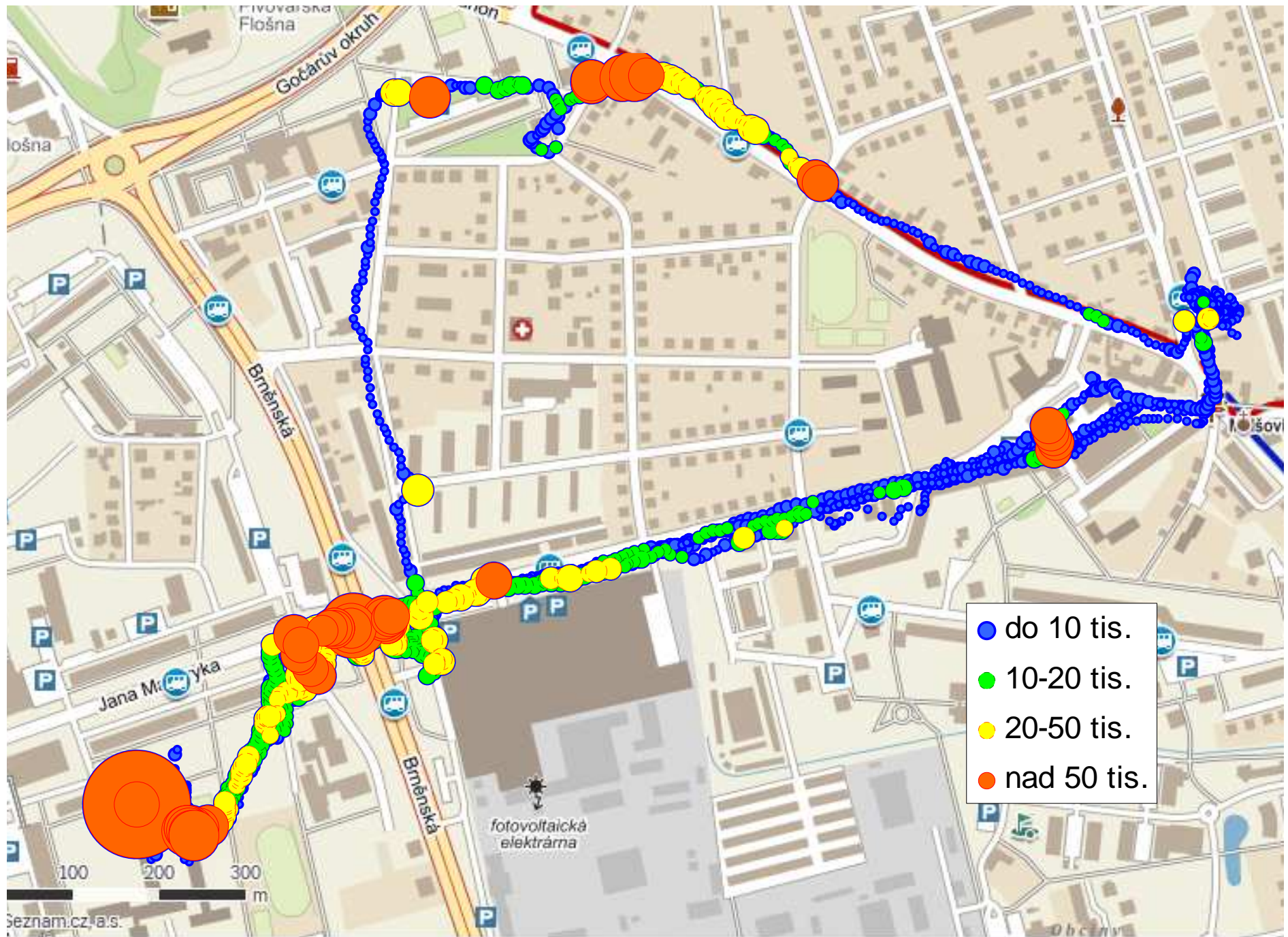
Total particle counts, 10-500 nm thousands of particles per cm³ Libeznice, 15. 5. 2014, morning rush hour



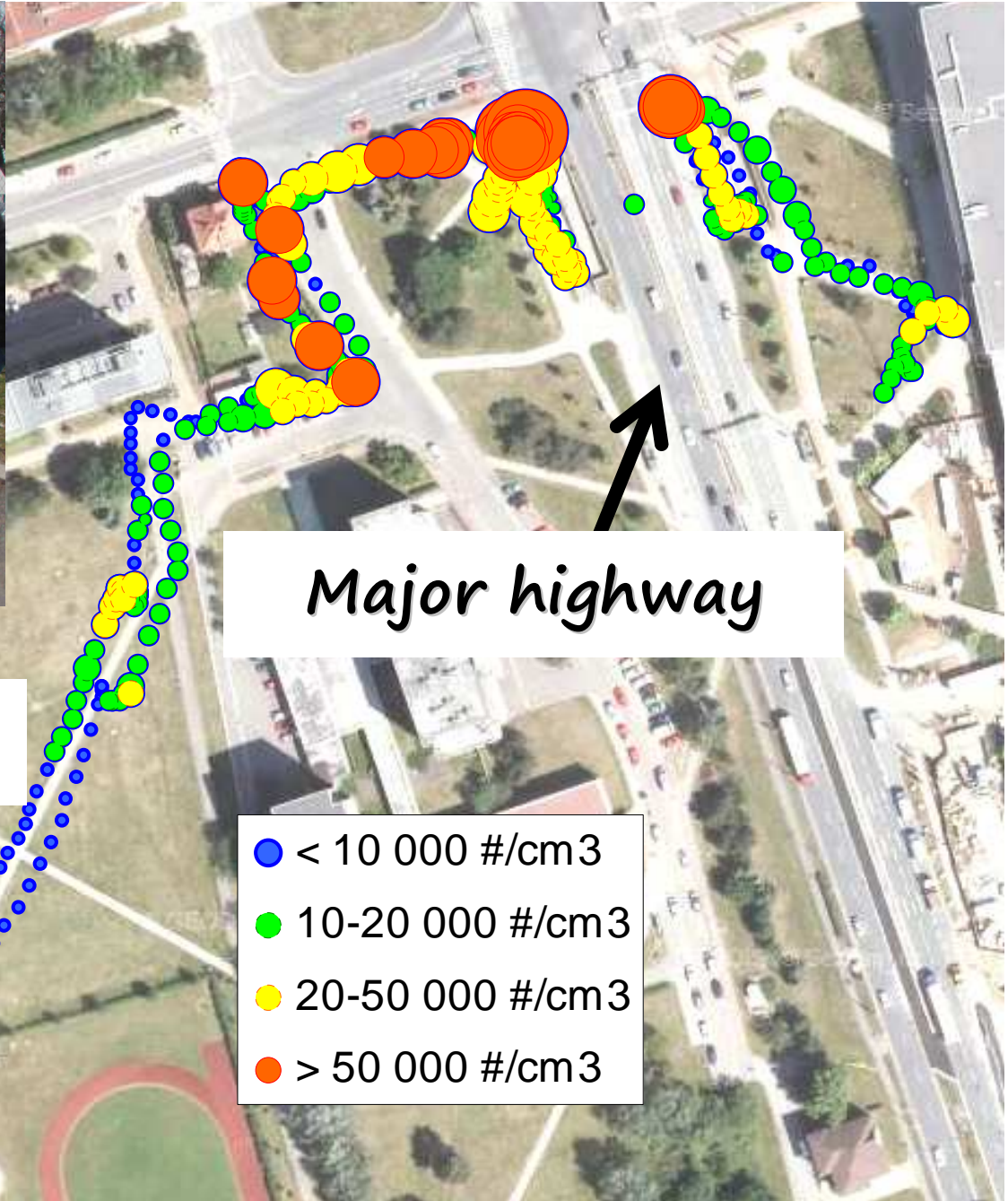
Results: Village of Libeznice instrumented walking tour



Results: Sion Elementary School instrumented walking tour



Results: Sion Elementary School instrumented walking tour



School entrance

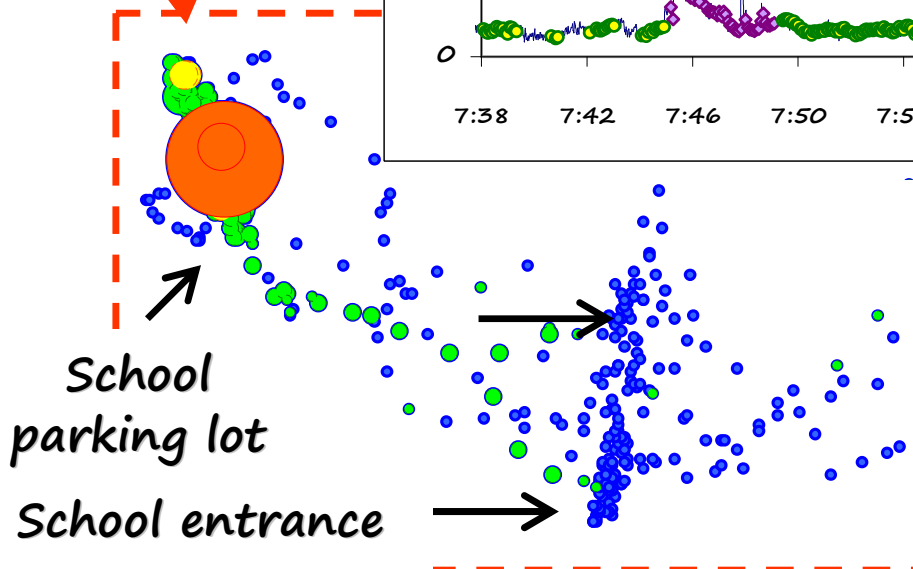
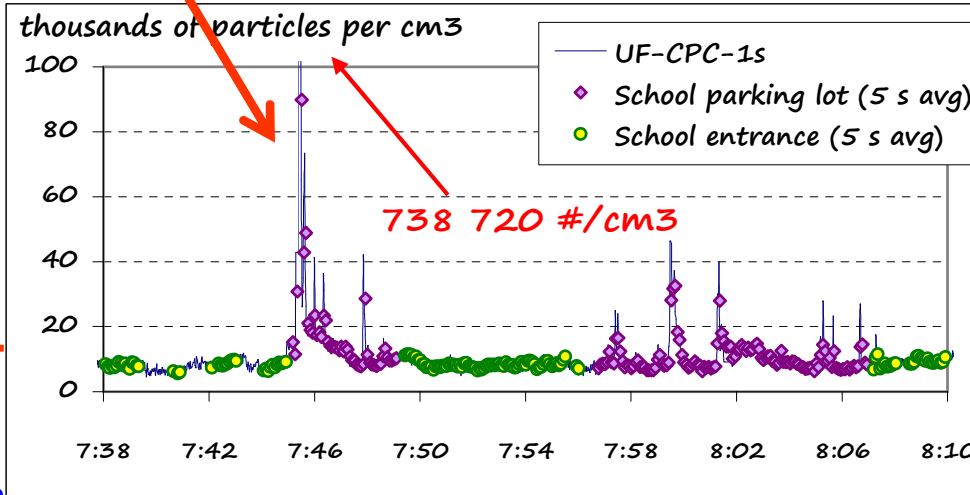
Major highway

- < 10 000 #/cm³
- 10-20 000 #/cm³
- 20-50 000 #/cm³
- > 50 000 #/cm³

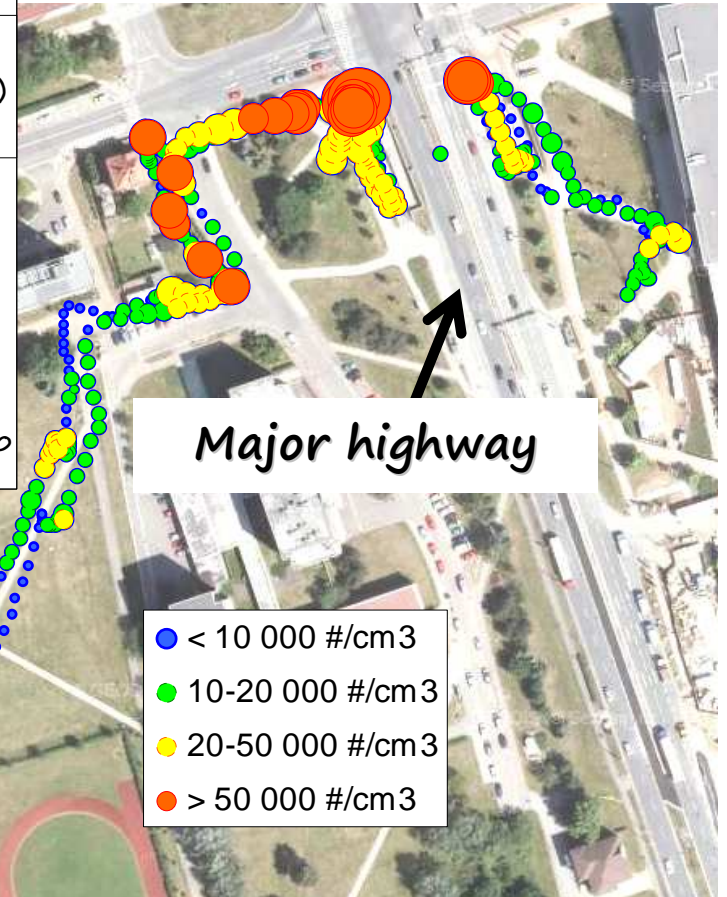


Results: Sion Elementary School instrumented walking tour

Highest concentrations:
High emitting engines
 (vehicles in bad shape, small engines, idling vehicles, etc.)



School entrance



In France, manufacture or handling of over 100 g of nanomaterial requires registration...

JORF n°0043 du 19 février 2012 page 2863
texte n° 4

Décret n° 2012-232 du 17 février 2012 relatif à la déclaration annuelle des substances à l'état nanoparticulaire pris en application de l'article L. 523-4 du code de l'environnement

NOR: DEVP1123456D

ELI: <https://www.legifrance.gouv.fr/eli/decret/2012/2/17/DEVP1123456D/jo/texte>
Alias: <https://www.legifrance.gouv.fr/eli/decret/2012/2/17/2012-232/jo/texte>

Le décret précise, à cet effet, que la déclaration est à envoyer au ministre chargé de l'environnement avant le 1er mai de chaque année.

Elle est obligatoire dès lors qu'une quantité minimale de 100 grammes de substance a été produite, importée ou distribuée.

... and driving a truck ... ???



~ 0.25 g/km
~ **0.05 g/km < 100 nm**
Prague-Paris and back:
2000 km x 0.05 g/km
= **100 g**
Released into the air
One trip (2-3 days)

Are we consistent?

What we have learned summarized

Large temporal and spatial variance of nanoparticle concentrations.

Higher number concentrations of nanoparticles always correlated to the presence of internal combustion engines upwind and/or in the vicinity. Away / upwind from roads, concentrations were low.

Normalized size distributions generally agreed with engine exhaust size distributions.

Despite measuring during heating season, no other major sources of nanoparticles (home heating) identified.

High emitting engines – vehicles in bad shape, small engines (lawnmower, scooter) with no PM limit – responsible for peaks.

Highest concentrations found where expected based on knowledge of engine emissions: traffic were entering a freeway after extended idling, at intersections, etc.

Working knowledge of engines and their emissions helpful in data interpretation, engines are complex non-linear dynamic systems.

Findings useful for transportation & land-use planning.

Lessons learned from diesel nanoparticle measurements

Non-uniform distribution over time and among engines:

Large share of emissions from short high-emissions episodes

High emitting engines – vehicles in bad shape – large share of total emissions from the fleet.

Disproportional strictness of regulations – small engines (lawnmower, scooter) with no PM limit emit more than highly regulated buses.

Working knowledge of engines and their emissions helpful in data interpretation, engines are complex non-linear dynamic systems.

State of the art and discipline to be followed.

Interdisciplinary cooperation.

Keeping the view of the large picture.

Consistency of regulations.

Lessons learned from diesel nanoparticle measurements

We, as a society, have the technology and know-how to monitor adverse effects of nanomaterials, and while there will be surprises, we are able to, sooner or later, develop technology to prevent adverse health effects resulting from exposure to nanoparticles.

The question is whether we really want to and are willing to pay the cost, and whether the protection of human health is effectively limited to a few high-income countries such as USA, Switzerland and few others.



Thank you !

**European Social Fund, CZ.1.07/2.3.00/30.0034
Support of Research Teams at Czech Technical University in Prague.**



Warning: This engine may produce nanoparticles that are harmful when inhaled.



EU LIFE+ program, project MEDETOX - Innovative Methods of Monitoring of Diesel Engine Exhaust Toxicity in Real Urban Traffic (LIFE10 ENV/CZ/651)

Czech Science Foundation project BIOTOX (13-0148S): Mechanisms of toxicity of particles from biofuels