TAMPERE UNIVERSITY OF TECHNOLOGY

Exhaust particles formed during engine braking: contribution on total particle emissions of GDI vehicles

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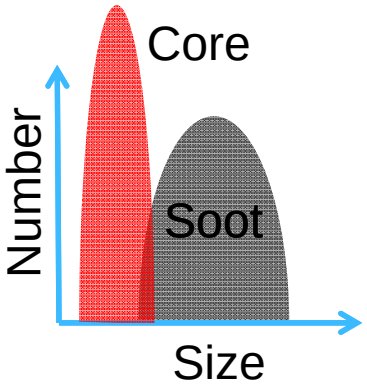
INTRODUCTION

Particle formation mechanisms

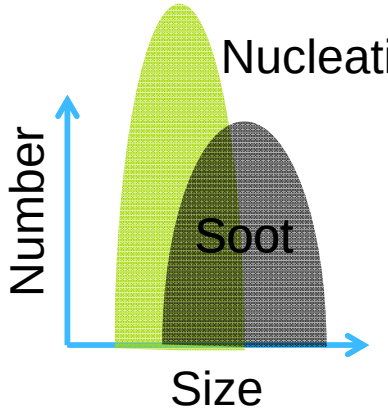
- Engine-out particles

Steady, trasient →



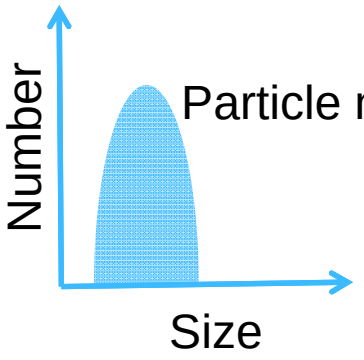
- After dilution & cooling

Steady, transient →



- Engine braking

Transient, Engine brake (negative torque) →



Our first observation (Rönkkö et al. 2014): Diesel truck

Environmental Science & Technology
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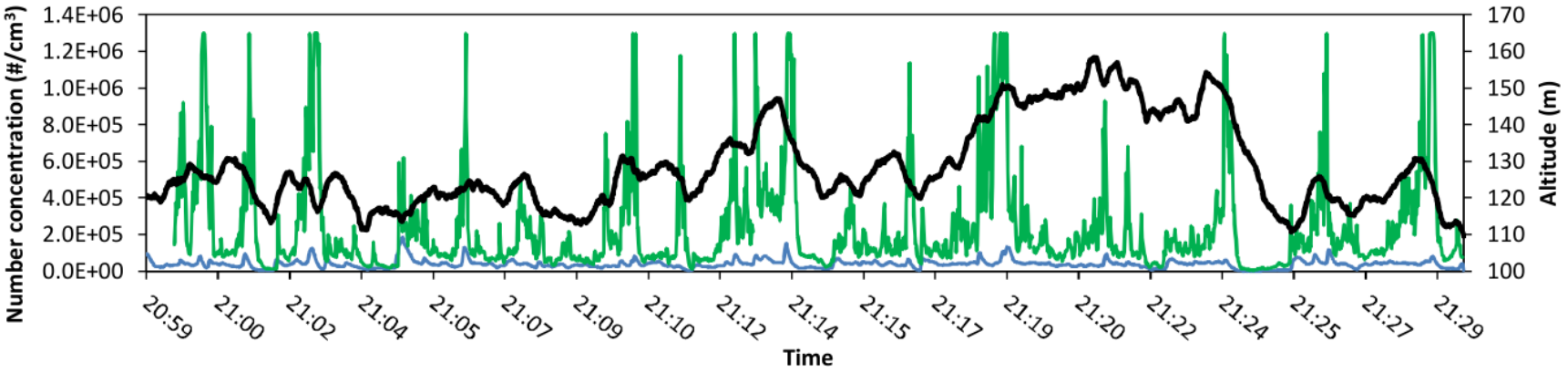
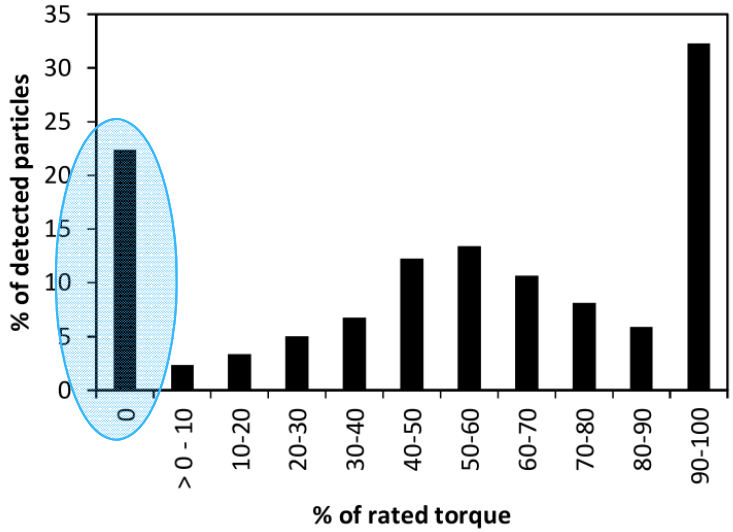
Vehicle Engines Produce Exhaust Nanoparticles Even When Not Fueled

Topi Rönkkö,[†,*] Liisa Pirjola,[‡] Leonidas Ntziachristos,[§] Juha Heikkilä,[†,⊥] Panu Karjalainen,[†] Risto Hillamo,[∥] and Jorma Keskinen[†]





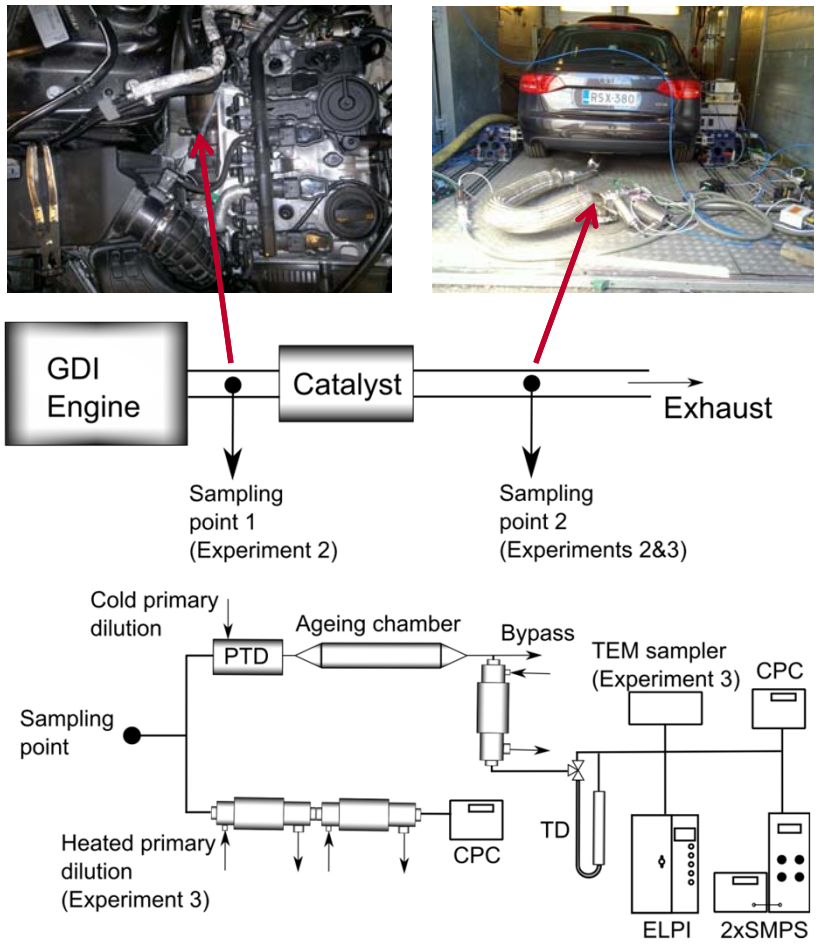
What is needed for the detection of particles during engine braking?

1. Careful choice of exhaust sampling location
2. Sampling without typical exhaust tracers such as CO_2
3. Real-time (~1 Hz) particle instruments capable to detect sub-10 nm particles
4. Possible ways to separate different particles from each other and
5. Data related to exhaust flow rate and temporal differences in it
6. Time delay correction from exhaust manifold to the particle instrument

EXPERIMENTAL

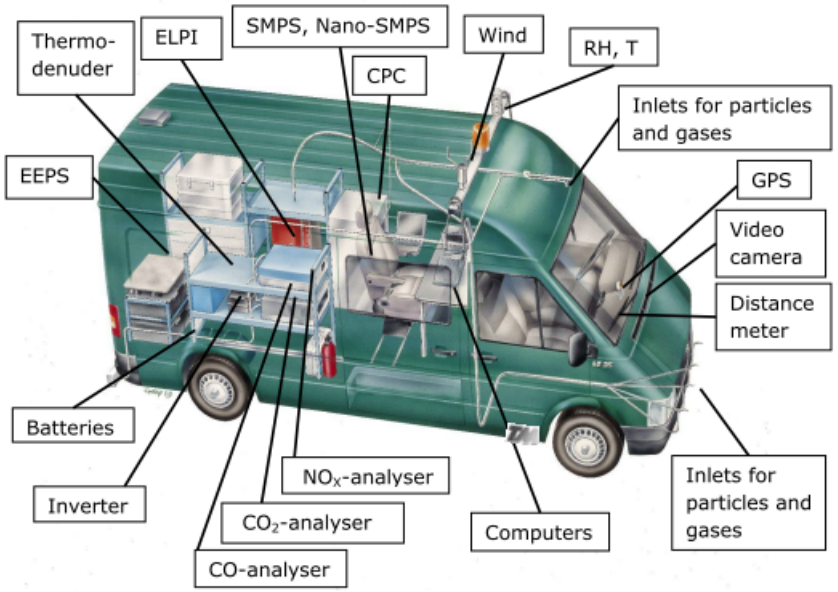
Methods

Laboratory studies



Real-time instruments & Sampling mimics real-world particle formation

On-road chase studies



Mobile laboratory ”Sniffer” (Pirjola et al. 2004)

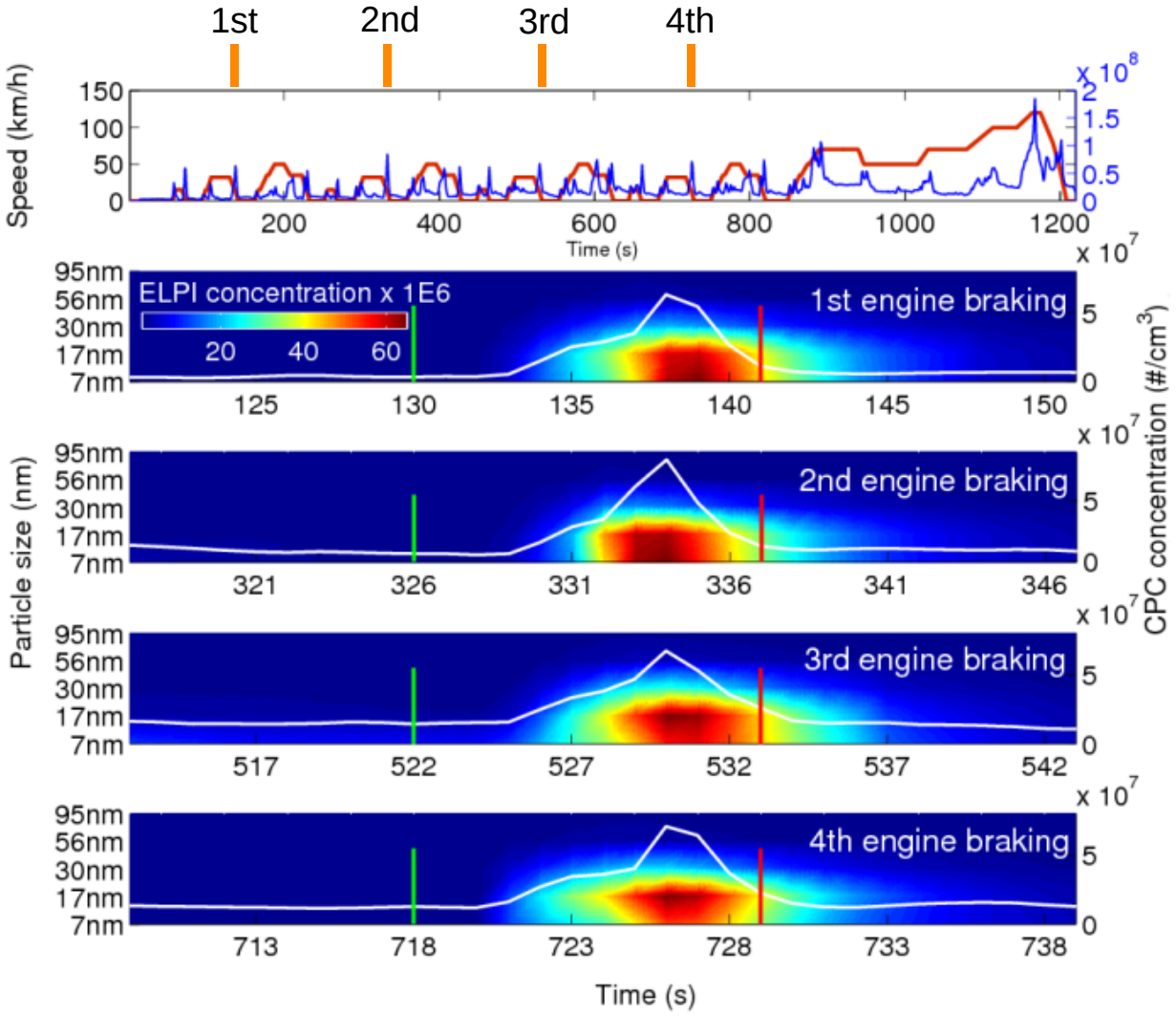
Real-world driving and dilution

Gasoline vehicles

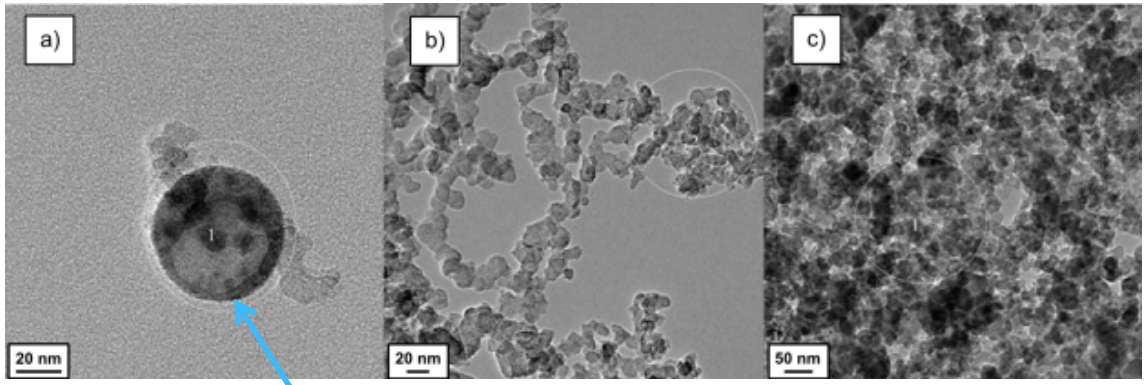
Vehicle	1	2	3
Year	2011	2011	2012
Displacement (l)	2.0	1.8	1.8
Turbocharged	Yes	Yes	Yes
Injection	GDI (Stratified)	GDI (Stratified)	GDI (Stratified) + PFI
Tested in	Chassis dyno	Chassis dyno	On-road
Test routine	NEDC	NEDC	Acc./Dec. patterns

RESULTS

Vehicle 1. Size distributions



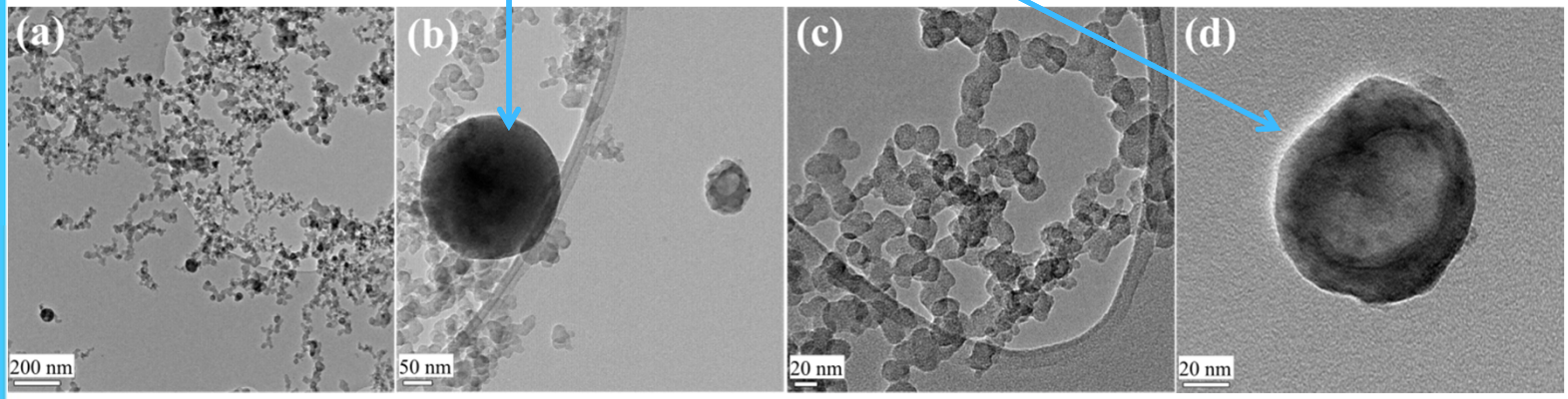
Vehicle 2. Particles collected over the NEDC



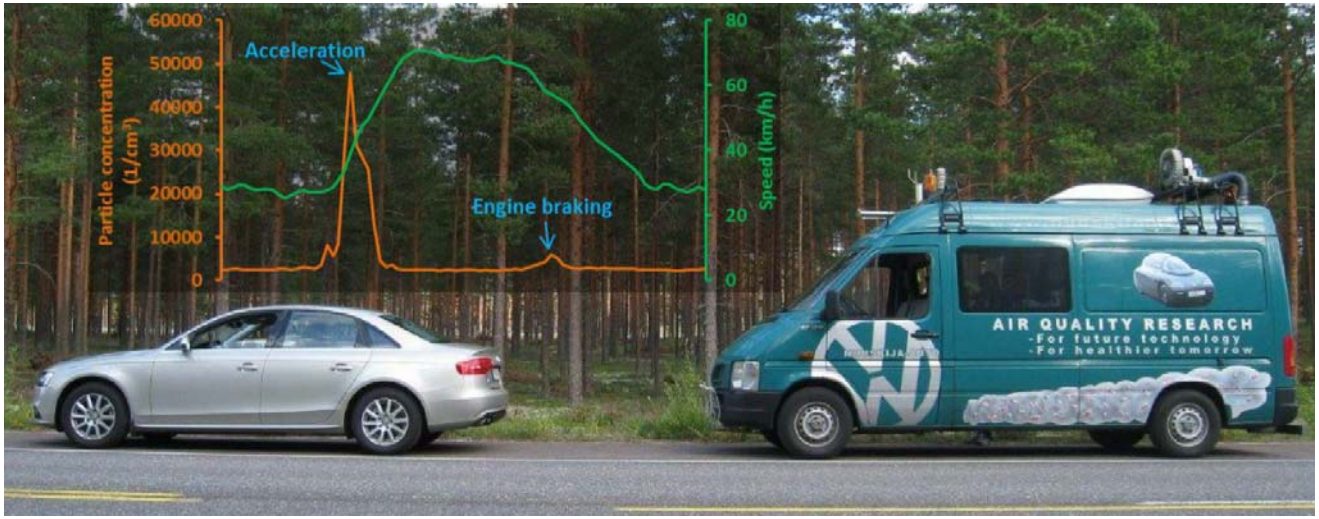
Spheres contain oxygen, zink, phosphorus and calcium that are components of lubricant

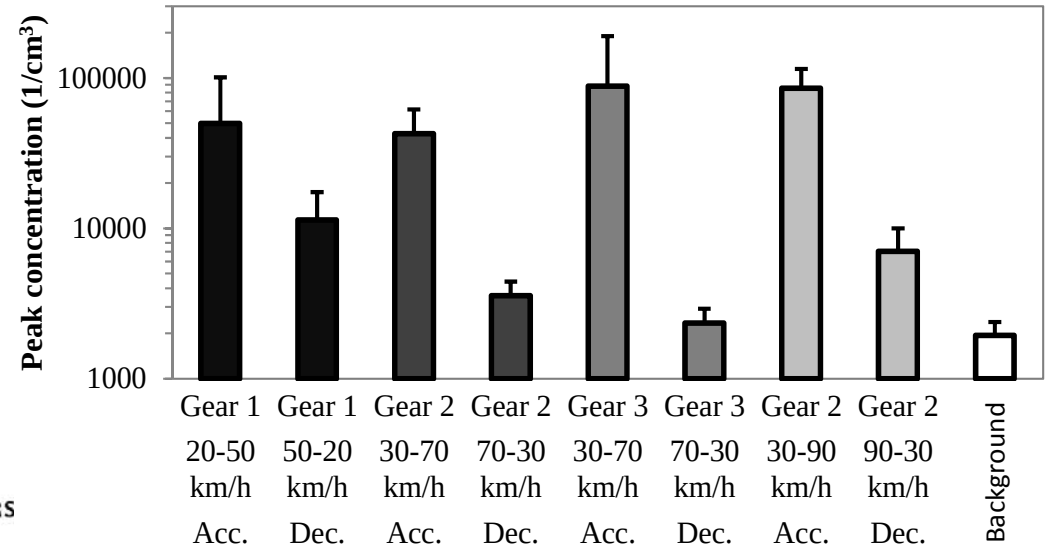
Particles absent during steadys

We propose these were emitted during decelerations



Vehicle 3. Particle emissions during engine braking under on-road conditions





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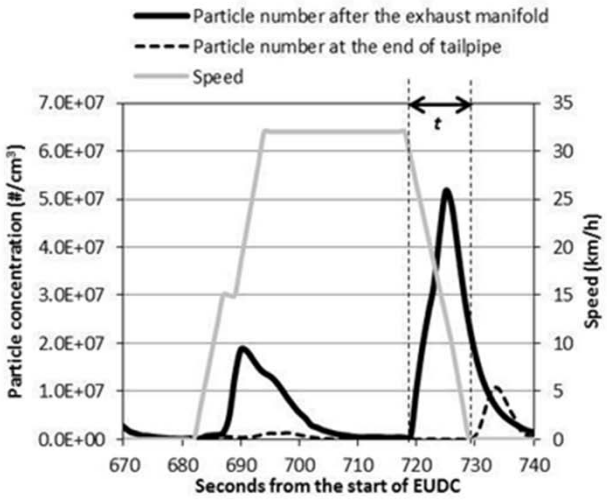
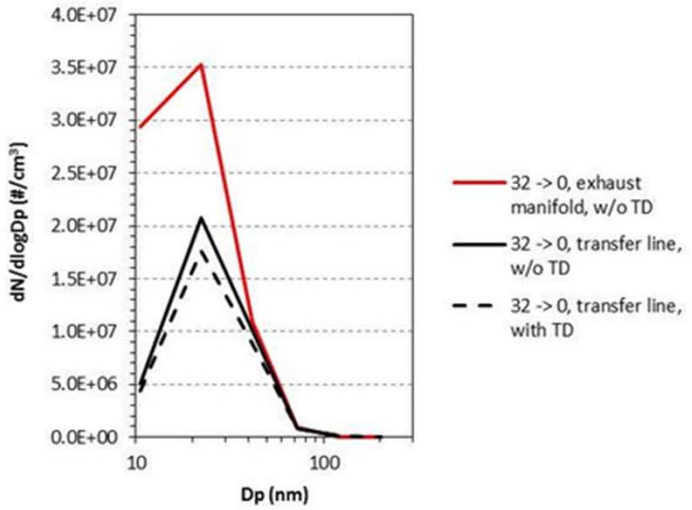
Engine braking particle emissions of vehicles (table revisited)

Vehicle	1	2	3
Year	2011	2011	2012
Displacement (l)	2.0	1.8	1.8
Turbocharged	Yes	Yes	Yes
Injection	GDI (Stratified)	GDI (Stratified)	GDI (Stratified) + PFI
Tested in	Chassis dyno	Chassis dyno	On-road
Test routine	NEDC	NEDC	Acc./Dec. patterns
Fraction of total particle concentrations	**–**	**~35%**	**–**
Fraction of total particle emissions	**23–29%**	**~10%**	**3–18%**

Future work

- Time delay from exhaust manifold to particle instrument varies depending on the driving conditions
  - Longer delay during engine braking (low exhaust flow)
- When plotting NEDC time series, the time axis for particle concentrations is not linear
- Requires modeling to stretch and compress to compare vehicle parameters and exact particle concentrations on the same axis





CONCLUSIONS

To conclude about particles during engine braking

- Depend largely on e.g. vehicle type, driving routine…
- Potentially harmful because contain metals (zink, phosphorus, calcium)
- Exact formation mechanism not yet known
- Can be removed by particle filtration
- Can also be affected by choice of lubricant?
- Topic needs further research

References

Karjalainen, P., Pirjola, L., Heikkilä, J., Lähde, T., Tzamkiozis, T., Ntziachristos, L., Keskinen, J., Rönkkö, T. Exhaust particles of modern gasoline vehicles: a laboratory and an on-road study (2014) under review in *Atmospheric Environment*.

Pirjola, L., Parviainen, H., Hussein, T., Valli, A., Hämeri, K., Aaalto, P., Virtanen, A., Keskinen, J., Pakkanen, T.A., Mäkelä, T., Hillamo, R.E. "Sniffer" - A novel tool for chasing vehicles and measuring traffic pollutants (2004) Atmospheric Environment, 38 (22), pp. 3625-3635.

Rönkkö, T., Pirjola, L., Ntziachristos, L., Heikkilä, J., Karjalainen, P., Hillamo, R., Keskinen, J. Vehicle engines produce exhaust nanoparticles even when not fueled (2014) Environmental Science and Technology, 48 (3), pp. 2043-2050.

Acknowledgements

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