22nd ETH Conference on Combustion Generated Particles

Zurich, June 19th – 21st 2018

Book of Abstracts Paper

Status: 15. Juni 2018

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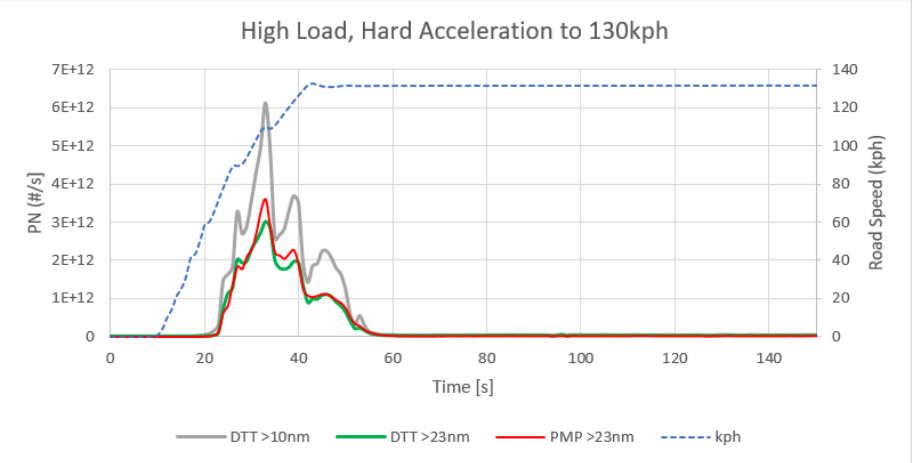
Publication title	First Results of Vehicle Technology Effects on sub-23nm Exhaust Particle Number Emissions using the DownToTen Sampling and Measurement System
Publication type	Presentation
Introduction & Background	The Horizon 2020 Green Vehicle “DownToTen” (DTT) project is developing a robust portable exhaust particle sampling system (PEPS) methodology that will enhance the regulatory approach towards particle number (PN) emissions in the sub-23 nm region. The focus is on the newest generations of direct injection gasoline and diesel engines under real world conditions. Based on detailed investigations of the nature and characteristics of these particles, DownToTen is evaluating a variety of sub-23 nm PN measurement instruments and sampling approaches, using rigorous criteria under conditions of challenging aerosol from a variety of sources. This study presents preliminary results from the assessment of different vehicle technologies using the PEPS in a chassis dynamometer environment, and when sampling from a constant volume sampler (CVS).
Methodology	The performance of the DTT PEPS was first assessed in comparison to commercial regulatory compliant sampling systems. The DTT system exhibited an excellent linear correlation (R2 >0.99) with a commercial system across four orders of magnitude, when considering measured particle concentration data from conventional >23nm particle counters. Particle Concentration Reduction Factors (PCRF), accounting for losses and dilution, verified improved penetrations of solid particles, in the
Results & Conclusions	After initial laboratory characterization, two DTT systems were employed to preliminarily survey existing and development vehicles for the presence and magnitude of both sub-23nm PN, measured primarily with 10nm d50 particle counters, and the current regulatory range, nominally “PN23” emissions. For specific tests, 4nm and 7nm d50 particle counters were also used. Evaluations indicated that when standard emissions cycles are considered, including some from EU, Japan and US, plus steady state cruises, the majority of emissions were below the Euro 6c limit value of 6x10^11#/km for >10nm PN. Drive cycles containing DPF regenerations showed elevated PN emissions above the limit value, but when the contribution of these events is adjusted for the frequency of regenerating to non-regenerating tests, even >10nm results fall back below the current regulatory particle number emissions limit. Some gasoline vehicles, both with and without GPF, and diesel applications including Lean NOx Trap (LNT), also produced PN emissions close to, but above, the limit for >10nm, and occasionally, >23nm particles. This indicates development immaturity of these emissions control technologies. Specific events, from both spark ignition and diesel vehicles, were shown to generate substantial levels of 7nm in the first few minutes of an active DPF regeneration may instantaneously be up to 100 times higher than the 23nm particle emissions (Figure 1). However, absolute levels of >7nm particles were less than 6x10^11/km for the duration of an entire DPF fill to regeneration cycle. A substantial particle production event was observed during a full-load acceleration on a three-way catalyst equipped Gasoline Direct Injection (GDI) vehicle (Figure 2). In this case, >10nm particle emissions substantially exceeded 10^12#/km for a period of one minute, with >23nm PN ~55% lower. Size distribution data, measured in parallel, indicated a bimodal size distribution with a minor peak at ~12nm and substantial particle levels below 10nm. Finally, there is some evidence that sub-23nm particles may be produced from urea-SCR (Selective Catalytic Reduction) systems, possibly from over-dosing of aqueous reductant. Extending these preliminary findings, work in the project continues towards the assessment

of the latest engine, emission control technologies and fuels under real drive emissions conditions.

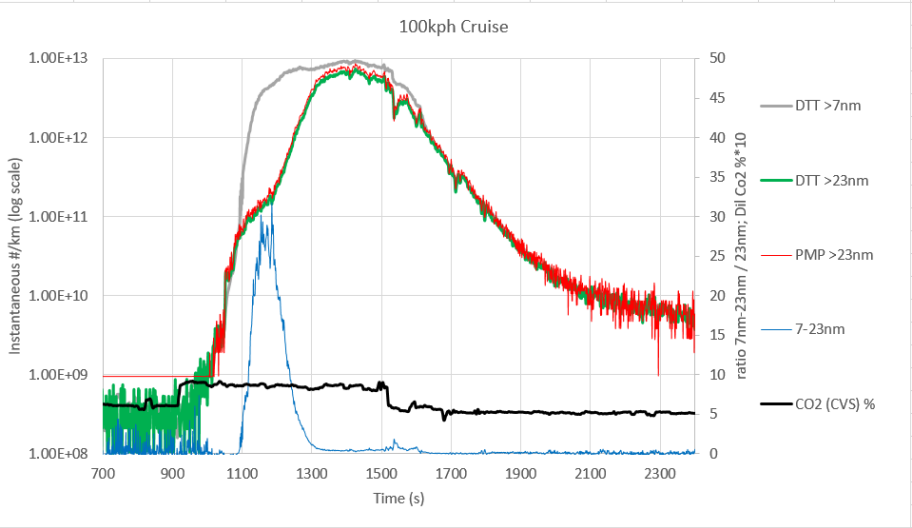
Images

Caption Figure 1:



PN Emissions from different size classes during an on-demand active DPF regeneration at 100kph

Caption Figure 2:



Emissions of particles at different size classes during a harsh acceleration of a GDI vehicle

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Publication title	Nucleation-Particle Formation in Jet-Aircraft and Diesel-Car exhaust: Formation-Mechanisms and Implications for Air Quality and Climate
Publication type	Presentation

Introduction & Background

Nucleation-Particle Formation in Jet-Aircraft and Diesel-Car exhaust: Formation-Mechanisms and Implications for Air Quality and Climate

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Abstract
The exhaust of combustion engine powered vehicles often contains large concentrations of nucleation particles (NUP; diameters around 10 nm). They form in the rapidly cooling exhaust by nucleation of highly supersaturated combustion-gases and grow by mutual coagulation and condensation. These NUPs and their grown products are of considerable current environmental concern as they potentially impact air quality and climate.
The present contribution is focused on NUPs formed by two outstanding types of combustion- powered vehicles, namely jet-aircraft and Diesel-cars. Aviation is outstanding as it releases exhaust species at high altitudes and as it represents the presently fastest growing form of transport. Diesel-cars are outstanding as they represent the environmentally most problematic form of ground-level transport in cities and urban areas. This is of mayor concern, since in modern industrialized countries the degree of physical urbanization is very large, which means that most people live in urban areas with a large car-traffic density and, therefore are exposed to car-traffic generated pollutants including also NUPs and their products.
However, important details of NUP formation in jet-aircraft and Diesel-car exhaust are still not well understood. This is particularly true, for the nature of NUP-precursors as well as nucleation mechanisms. Jet-Aircraft exhaust is special, as it contains large concentrations of chemiions which may facilitate NUP formation. Chemiions facilitate nucleation by electrostatic forces, lowering the required supersaturation of nucleating gases.
The present contribution reports on innovative investigations of NUP-formation and NUP-growth in jet-aircraft and modern Diesel-car exhaust. Our investigations include measurements of nucleating gases, condensing gases, and chemiions along with accompanying model simulations. Our key measurement-techniques used were CIMS (Chemical Ionization Mass Spectrometry) and Chemiion-Mass-Spectrometry. Differences of formation and effects of jet-aircraft and Diesel-car generated NUPs will be discussed.
The present contribution will also give an outlook of future possibilities in our NUP research, building on recent experimental progress. In the second half of the year 2017 we succeeded in increasing the detection sensitivity of our above mentioned mass spectrometric techniques by a factor of nearly 1000. (This factor exceeds even very markedly our previous expectation (factor of 120), which was mentioned in the outlook of our talk, given in June 2017 at this ETH-conference).

Methodology	Analysis of jet-aircraft and Diesel-car exhaust, using mass spectrometric techniques, partly developped by MPIK and DLR (see above)
Results & Conclusions	detection of numerous trace gases, involved in the formation and growth of nucleation-particles and their grown products. Implications for their impact on air quality and climate.

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Publication title	Impact of the Operation Strategy and Fuel Composition on the Emissions of a Heavy Duty Diesel Engine
Publication type	Presentation
Introduction & Background	Diesel engines are well known for their efficiency as well as for their expensive exhaust aftertreatment requirements. Modern engines offer numerous degrees of freedom in engine setup. Consequently, a certain engine load can be achieved with various engine operation parameter setups (i.e. injection timing EGR rate, fuel pressure, etc.), each with different emission characteristics, resulting in a three dimensional trade-off between fuel consumption, soot and NOx emission. Varying fuel properties (i.e. addition of fuel-bonded oxygen) additionally affect the abovementioned trade-off. This work illuminates the trade-off behaviour using various operating strategies with different fuel compositions.
Methodology	The present work has been carried out with a single cylinder research heavy-duty Diesel engine. The engine has four litre of displacement volume, a common rail system, an external charge air supply and an external EGR supply system. This setup allows operating conditions with extreme boost pressure and EGR rates. Furthermore, the engine contains an external fuel supply pump and a fuel injector with different nozzles (a 7-, 8- and 9-hole nozzles with 0.24 mm diameter). The operation with increased number of nozzles allows the addition of a certain oxygenated fuel portion with a reduced heating value, without adjustment of the injection parameters to cover a similar load condition. This is important to isolate the effect of the fuel composition on the trade-off behaviour.
Results & Conclusions	The investigation shows, that the addition of oxygenated fuel reduces the soot formation and therefore increase the possible EGR rate, without exceeding exhaust soot emissions. Consequently, lower NOx emissions allow a reduction urea consumption and possibly smaller SCR (selective catalytic reduction) dimensions. However, depending on the EGR-system, the increase in fuel consumption through pumping losses or external drive of an EGR blower limits this benefit. The optimum operation of a heavy-duty Diesel engine is strongly depending on the engine and aftertreatment layout. The beneficial operation of an engine with alternative fuels requires a higher system flexibility.

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Publication title	**Introduction**
Publication type	Presentation

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Publication title	Operational and Performance Demands for a Low-Cost Periodic Technical Inspection Particle Number Analyzer
Publication type	Presentation
Introduction & Background	With the anticipated widespread introduction of a light-duty Particle Number (PN) Periodic Technical Inspection program in Europe in the near future, Sensors Inc. has been developing a low cost Automotive Particle Bench (APB) for OEM integration and a complete Automotive Particle Analyzer (APA). The unique requirements of operating in the demanding PTI environment require the complexities of performing such measurements to be addressed with specific regards to operation, service and cost of ownership whilst endeavoring to maintain close links to the EU PN established measurement regulations. This presentation will cover the extensive testing of these products with specific attention on both robustness, ease-of-use and calibration. In particular, metrology studies examining the complexity of calibration in the framework of the resulting measurement uncertainties has been used to provide both value engineering requirements and a potential simplified lower-cost calibration methodology.
Methodology	Metrology studies of multiple units (both theoretical and experimental) have been used to determine measurement uncertainties for the individual components and the full system. Internal data has been supplemented by external third-party ULAC accredited laboratory data. The data has been used to define and potentially simplify the calibration and setup requirements for potential large-scale deployment of these products into PTI markets. For example, particle size / measurement efficiencies of the devices have been fully characterized from 10-200nm. This data has facilitated the assessment of measurement uncertainty for different engine / after-treatment technologies by simplification of the calibration methodology. The metrology studies examined flows, pressures, temperatures, size-related particle counting efficiencies, particle losses and system demands.
Results & Conclusions	The results provide clear "value engineering" information by balancing the complexity of the calibration methodology with the calculated and measurement uncertainties. The results clearly suggest that a much simplified calibration methodology, compared with, for example, ISO 27891:2015, could be adopted with only a small increase in the uncertainty budget. Furthermore, potential field calibration and daily check standard operating procedures, to maintain and validate the in-use devices, have been identified.

Caption Figure 1:

Sensors' Automotive Particle Bench

Caption Figure 2:

Sensors Automotive Particle Analyzer

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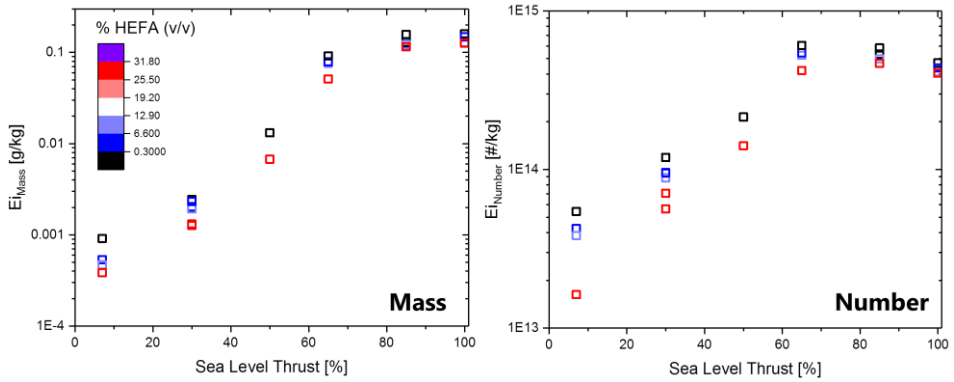
Publication title	Non-volatile Particulate Matter Mass and Number Emissions of an Aero Gas Turbine Fueled with Alternative Fuel Blends
Publication type	Presentation
Introduction & Background	Low-carbon propulsion technology is advancing in all areas of mobility driven by concerns about the environment, climate change and supply security of fossil fuel feedstocks. The non-commercial aviation sector is currently experiencing the dawn of electrical propulsion, but lightweight megawatt-scale drive systems far more powerful and lighter than those currently available for on-road mobility are needed if electric propulsion is ever to succeed in commercial civil aviation. Therefore, the civil aviation sector, in particular intercontinental flights, will likely rely on the combustion of liquid hydrocarbon fuels for decades to come. Airlines and the international civil aviation organization (ICAO) consider alternative aviation fuels from non-fossil feedstocks as the most viable way to lower and offset the carbon intensity of the aviation sector and five alternative fuel production pathways are currently approved for commercial use. Complex interactions between fuel chemistry and engine operating conditions determine the non-volatile particulate matter (nvPM) mass and number emissions of aero gas turbines. The link between the chemistry and the sooting propensity of fuels has long been the focus of research, and decreased levels of mono-aromatic and naphthenic hydrocarbons as present in alternative fuels have been associated with lower soot emissions. Aromatic compounds promote the formation of large polycyclic aromatic hydrocarbons (PAH) and the subsequent soot nucleation and growth in fuel-rich pockets in the combustion zone. A constant oxidation of these newly formed species takes place in parallel in lean zones; therefore, the engine operating conditions, in particular air to fuel equivalence ratio (AFR) and engine combustor temperature and pressure, are critical for the understanding of fuel effects.
Methodology	In this work, we conducted a fuel sensitivity study using native Jet A-1 fuel and Jet A-1 fuel blended with three ratios (5, 10 and 32% by volume) of alternative HEFA (hydro-processed esters and fatty acids) originating from used cooking oil. The experiments were conducted on an airworthy turbofan engine in the test cell of SR Technics at Zurich airport. The nvPM sampling system and measurements corresponded to the recommended practice (SAE International, 2013). Various other PM and gaseous measurements were employed in parallel.
Results & Conclusions	Preliminary analysis indicates that blending 32% HEFA into Jet A-1 reduces nvPM mass and number emissions by 60 and 70%, respectively at taxiing engine thrust (7%). This could potentially provide air quality benefits in the vicinity of airports if such fuel blends would become widespread. Besides the fuel composition- emission link, the impact on regulatory issues, such as fuel composition corrections for nvPM measurements, will be discussed in this work.

Caption Figure 1:



Non-volatile mass (left panel) and number (right panel) emission indices as a function of engine thrust and volumetric fraction of alternative hydro-processed esters and fatty acids (HEFA) fuel

Brugge Doug

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Publication title	Improving In-home Stand-alone Air Filtration for Ultrafine Particle Exposure and Health
Publication type	Presentation
Introduction & Background	Personal use of stand-alone home air filters, particularly high efficiency particulate arrestance (HEPA) filters, to reduce particulate pollution is becoming more common and widespread. Nonetheless, the ability of HEPA filtration to improve health is not well established.
Methodology	We completed two randomized cross-over pilot in-home intervention trials of HEPA filtration in non-smoking homes and a series of near highway 2-hour controlled exposure sessions. In both of the trails (N= 19 and 23 homes) we compared stand-alone HEPA units to the same units with sham filters. Indoor particle number concentration (PNC), a proxy for ultrafine particles (UFP) was measured with water-based condensation particle counters (CPC). Near simultaneous outdoor PNC measurements were made in the second trial as well as in a separate set of homes (N=18) without HEPA filters. Blood biomarkers of inflammation and blood pressure were recorded for the trials and blood pressure for the near highway exposure sessions. We also conducted tests of HEPA filtration under controlled conditions. Size fractionation of PNC was measured in controlled settings as well as during a subset of the near highway exposure sessions.
Results & Conclusions	We observed 20-85% reductions in indoor PNC relative to outdoor PNC in most homes (Figure 1a). However, we saw no benefit from these reductions in the biomarkers. Major limitations of our trials were: (a) reduced exposure contrast between HEPA and sham filtration because air movement alone appears to reduce indoor PNC; (b) limited information on participant time activity and likely contributions from microenvironments other than home (participants do not spend all their time in the room with the HEPA unit or even at home); (c) compromised effectiveness of the intervention resulting from frequent window opening and indoor-generation of PNC. Numerous indoor activities, particularly cooking resulted in brief “spikes” of PNC (Figure 1b) that weren’t immediately attenuated by filters. Such spikes generally occurred for 3% of the monitoring period but contributed to 15% of total indoor exposures. It is not yet clear how differences in composition between PNC from cooking, which is also present outdoors from restaurants, and from traffic affect their relative toxicity. In the controlled exposure work, we observed contrasts of 15- to 20-fold between HEPA intervention (ideal operating condition) versus no intervention (i.e., outdoor levels) (Figure 1c). Our controlled tests with a range of HEPA filters, including inexpensive ones, indicated that single stand-alone units could reduce total ambient PNC that infiltrated into a small room. However, filters failed to effectively remove particles in the 70-120 nm size range (see Figure 2). This was likely due to being below the size for impaction and above the size for diffusion removal mechanisms. The filters were also less effective at attenuating large indoor sources (we used a candle in controlled tests).

Caption Figure 1:

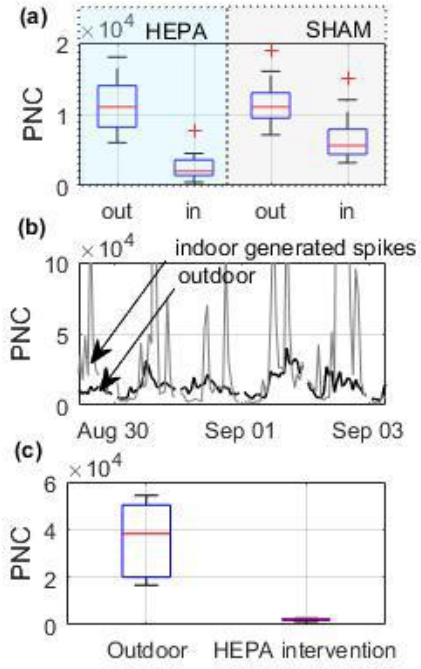

Figure 1: (a) Comparison of PNC between HEPA and sham intervention in homes. (b) time-series of PNC that illustrates indoor-generated spikes, (c) comparison of PNC between HEPA intervention and outdoor concentration during near-highway controlled exposures.

Caption Figure 2:

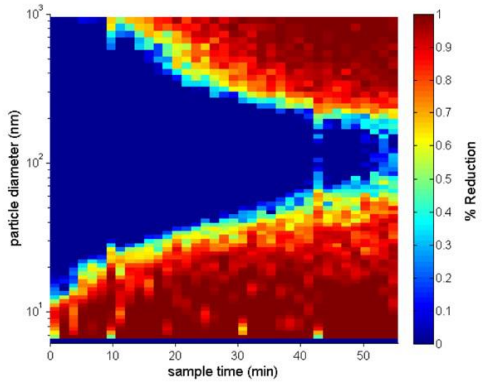

Figure 2. Size-dependent reductions in particle concentration with time. Data are the average of several stand-alone HEPA filters, and indicate that particles between 70 and 180 nm are not removed by HEPA filtration.

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Publication title	Insoluble Brown Carbon Emitted by Marine Engines: Relevance to a Warming Arctic
Publication type	Presentation
Introduction & Background	The majority of ships travelling through the Arctic operate on heavy fuel oil (HFO). The exhaust associated with HFO combustion contains light-absorbing black carbon (BC) particles but also substantial amounts of brown carbon (brC). This brC absorbs more strongly at shorter (blue) wavelengths than at longer (red) ones, and can dominate the total light aerosol light absorption by HFO-combustion aerosols.
Methodology	We characterized HFO PM samples using a combination of techniques, including thermal-optical analysis, single-particle laser-induced incandescence, multi-wavelength absorption spectroscopy (MWAA), and Raman spectroscopy. The solubility of HFO PM brC was investigated by sequential solvent extraction using water, hexane and toluene in combination with MWAA.
Results & Conclusions	We show that the light-absorbing "brC" in HFO PM is fundamentally different to brC produced by sources such as biomass-burning. We show that this brC is insoluble, thermally refractory, and absorbs in the near infrared. These properties resemble those of the tar balls which have been previously observed from biomass combustion, rather than to the light-absorbing organic molecules that have been the focus of recent brC research. These properties also mean that common techniques for measuring BC may result in strongly biased estimates of aerosol light absorption. The insolubility of this brC means that it may accumulate on snow and ice, perhaps explaining recent observations that 32% of albedo reduction in Arctic snow is due to non-BC particles. Further field measurements are needed to quantify these light-absorbing brC particles in order to understand anthropogenic impacts on the Arctic environment.

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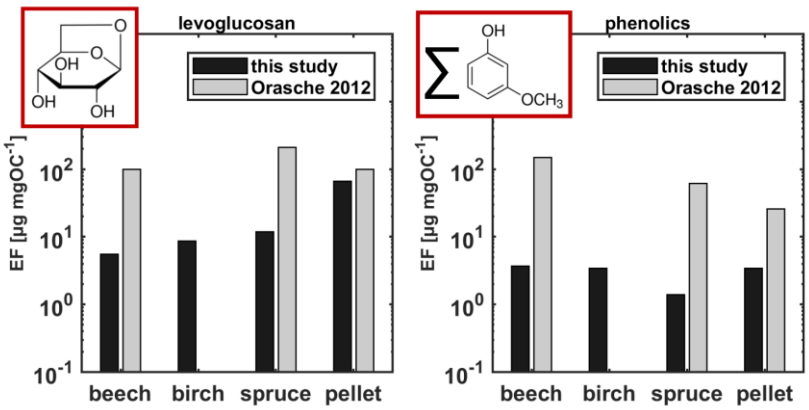
Publication title	Primary and Secondary Aerosol Emissions from Modern Small-scale Wood Combustion Appliances with Advanced Secondary Air Supply
Publication type	Presentation
Introduction & Background	Residential wood combustion emissions have been identified as important source of air pollution. In order to reduce these emissions, combustion technology is steadily improved and implemented in commercially available wood stoves and boilers. In total, emission factors of organic gaseous and particulate emissions are reduced, but because of different origins and formation mechanisms of the emission constituents, it can be supposed that the whole emission pattern, markers and characteristic diagnostic ratios as well as secondary organic aerosol (SOA) formation potential may change compared to conventional stoves.
Methodology	The chemical composition of primary and secondary aerosol emissions from a modern masonry heater (MMH), fuelled with beech, birch and spruce logwood, and a pellet boiler (PB), fuelled with softwood pellets, were investigated in a field campaign at the University of Eastern Finland. Both combustion appliances were equipped with air staging technology, which have been show to substantially decrease emission of CO, VOC and PM. Secondary emissions were studied by using ILMARI smog chamber for MMH emissions and potential aerosol mass (PAM) flow reactor for PB emissions. The involved analytical techniques comprise soot-particle aerosol mass spectrometer (SP-AMS), in situ derivatisation thermal desorption gas chromatography mass spectrometry (IDTD-GCMS), thermal-optical carbon analysis hyphenated to resonance-enhanced multi-photon ionisation time-of-flight mass spectrometry (TOCA-REMPI-TOFMS) for the carbonaceous particle fraction and single-photon ionisation (SPI) TOFMS and Fourier-transform infrared spectroscopy (FTIR) to characterise organic vapours.
Results & Conclusions	The pellet boiler emitted one order of magnitude lower emissions of organic gaseous (OGC), organic (OC) and elemental carbon (EC) than the MMH, which can be assigned to a more controlled combustion process in a small burner flame with constant fuel feed. Comparing the same type of combustion appliance with conventional combustion technology (Orasche Energy & Fuels, 2012, 26(11), 6695–6704), we observed one order of magnitude lower emissions for air staging equipped appliances and significantly lower OC/EC, in particular for birch wood combustion. However, the amount of frequently used wood combustion markers levoglucosan and several methoxy-phenols relative to the emitted OC was significantly lower, which have to be taken into account in source apportionment studies. Regarding volatile emissions, primary wood decomposition products were detected in low amounts in MMH emissions, but were absent in spectra of the pellet boiler under nominal load, which complicates its identification as wood combustion emission. Smog chamber experiments revealed similar enhancement ratios upon SOA formation in previous studies with older stoves (Heringa et al., Atmospheric Chemistry and Physics, 2011, 11, 5945-5957), but lower SOA emission factors related to mass of burned wood. In agreement with literature, no significant SOA could be detected for the pellet boiler. However, under reduced secondary air conditions (proxy for boilers of older types), we could observe doubling of organic particle mass, which we address to enhanced emission of volatile aromatic hydrocarbons with substantial SOA formation potential. This new, but already widespread technology leads to emissions less characteristic for wood combustion, which have to be considered in investigations of local and regional air quality in developed countries.

Caption Figure 1:



Emissions of wood combustion markers levoglucosan and particle-bound methoxy-phenols relative to emitted organic carbon (OC) from modern (black bars) and conventional combustion appliances (grey bars, taken from Orasche et al., Energy & Fuels, 2012, 26(11), 6695–6704).

Czerwinski Jan / FOCUS

New Periodic Technical Inspection Approaches for DeNOx-Systems

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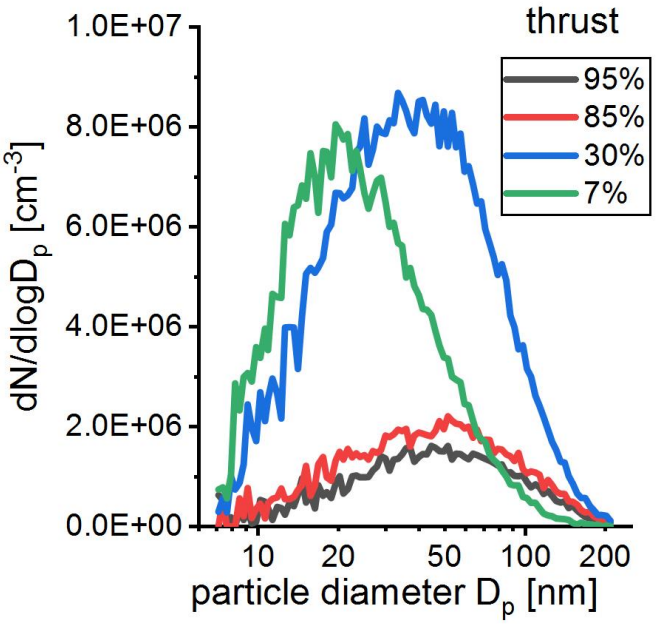
Publication title	Non-volatile PM Emissions of a Business Jet Aircraft: Ground Measurements and Cruise Estimates
Publication type	Presentation
Introduction & Background	As the demand for air travel expands, aircraft engine emissions increasingly affect the climate and the local air quality. Besides CO2 and water vapor, aircraft engines emit gaseous pollutants (NOx, CO, hydrocarbons), and soot or nonvolatile particulate matter (nvPM). Due to their potential health and climate impacts, researchers and regulatory agencies have focused in the past decade on characterization of aircraft engine nvPM emissions and development of a standardized measurement system for emissions certification. The International Civil Aviation Organization (ICAO) has adopted a new nvPM standard that applies to all engine types of rated thrust greater than 26.7 kN in production on or after 1 January 2020. However, the standard does not apply to small jet engines (rated thrust < 26.7 kN) used on general aviation aircraft (business jets) and their nvPM emissions are largely unknown. Although business aviation consumes only around 2% of the world's jet fuel, it may still contribute significantly to the overall aviation nvPM as smaller jet engines are less efficient and their pollutant emissions are not regulated (except for exhaust smoke visibility). In this contribution, we address the knowledge gap in the nvPM emissions of small jet engines. We measured gaseous emissions and nvPM emissions from a small turbofan engine of a Falcon 900EX aircraft using the Swiss Mobile Aircraft Engine Emissions Measurement System (SMARTEMIS). We report the nvPM emissions and particle size at ground for the standardized landing and take-off cycle (LTO). We also used a detailed engine performance model to estimate emissions at cruise altitude.
Methodology	The engine test (central engine of a Falcon 900EX) consisted of a warmup sequence and 11 test points on a descending power curve from take-off to idle. The test sequence was repeated three times. An exhaust sampling probe made of Inconel 600 alloy held by a forklift was positioned at the engine exit plane. The cruciform probe with 12 orifices provided a representative exhaust gas sample according to the emissions certification standard. The sampling and measurement system was compliant with the certification standard for nvPM emissions (Durdina et al., ES&T, 2017).
Results & Conclusions	The nvPM emission indices (EIs) and particle size were highly thrust dependent. The geometric mean diameter increased with thrust from 20 to 45 nm. The nvPM EIs increased from idle and peaked at low thrust (~10% for nvPM number and ~40% thrust for nvPM mass) and decreased with further thrust increase (Figure 1). The relatively high nvPM emissions at low thrust contributed most to the overall LTO cycle emissions. The LTO nvPM mass emissions of the Falcon 900 were found comparable to a single aisle airliner (Durdina et al., ES&T, 2017) and the nvPM number emission were found to up to a factor of 2 higher. At cruise altitude, we predicted mass-based EIs up to a factor of 10 higher than those of a representative airliner (Durdina et al., ES&T, 2017). Thus, nvPM emissions of business jet aircraft should be taken into account for the assessment of local air quality and in global emission inventories.

Caption Figure 1:



Particle size distributions at the engine exit plane as a function of engine thrust.

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Publication title	In-use Particle Filter Inspection with Simple Electrical Particle Detectors
Publication type	Presentation
Introduction & Background	Diesel particle filters remove 99% or more of the cancerogenic soot particles produced by the engine, and they have been successfully deployed in millions of cars. However, filters are usually made from brittle materials and thermal and mechanical stress in use may cause mechanical failure of the filters, e.g. by the formation of cracks. Therefore, it has been suggested that filter integrity should be verified during the periodic technical inspection. This will necessitate a new generation of simple particle number testers that are robust enough for use in the field, and are easy enough to use. Here we present a potential solution for such an instrument.
Methodology	We modified a standard handheld particle detector (partector, naneos) for use as a PN-tester. The partector measures charge transfer to the particles, which is approximately proportional to the lung-deposited surface area (LDSA). This quantity is also approximately proportional to N·daverage, i.e. larger particles give a stronger signal. The partector thus doesn't give a true PN signal. However, it is well known that particles from Diesel engines are typically around 70 nm in diameter, and therefore, we calibrated the partector to report a particle number for 70 nm soot particles. For "normal" engines, this will give a good agreement with particle number. Furthermore, due to high humidity in the exhaust gas, a heater was added to the partector which enables us to heat it (in the first version up to about 35°C, in the second version up to 50° C); and as a consequence, a larger internal battery was used. The modified partector was used in different smaller and larger measurement campaigns.
Results & Conclusions	In an initial test, 26 Diesel passenger cars with and without filters were tested at a fuel station during idling, where the high air-to-fuel ratio of the Diesel engine (λ≈10) provides an automatic dilution of the exhaust gas and a correspondingly low humidity. As expected, large variations were seen (from 103 to 107 pt/cm3). In a further application, our device was used by the office of waste, water energy and air during the periodic technical inspection in Zürich to measure hundreds of vehicles, revealing a failure rate of about 10% of the installed DPFs . Finally, since modern GDI engines also emit particles and are subject to the particle number emission limit, we also performed a few measurements on 5 gasoline engines, where the air-to-fuel ratio is much lower. In one of 5 tested engines, problems with condensation occurred even at 50°C, but only after about 30 seconds of measurement. We have demonstrated that – with minor modifications - it is possible to use a small and simple existing electrical detector to easily verify DPF integrity in the field. Technically, no new developments are necessary; however, a potential regulation would have to accept LDSA normalized to PN at 70nm as alternative metric so that this simple solution could be implemented.

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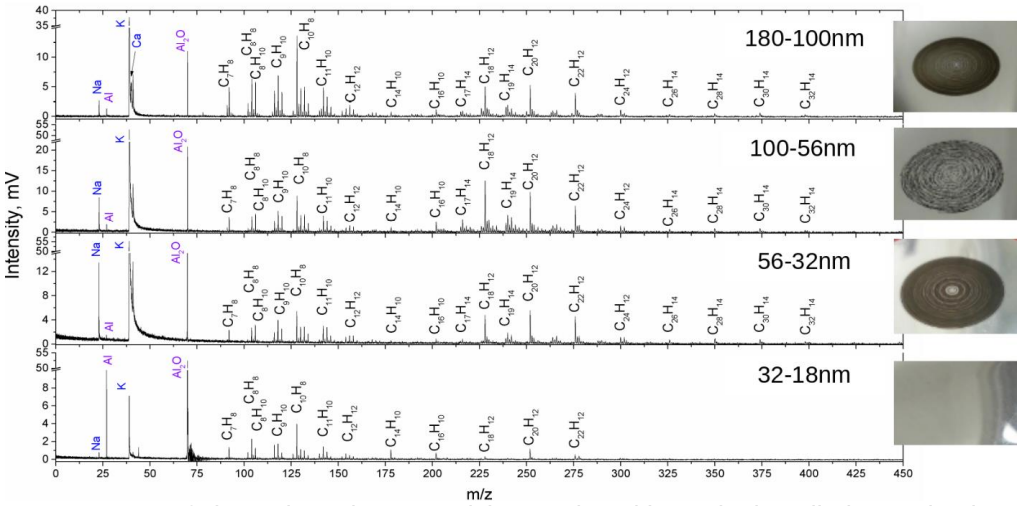
Publication title	Measuring Ultrafine Particles Emitted by Gasoline Direct Injection Engines: the PEMS4Nano Project
Publication type	Presentation
Introduction & Background	Particulate emissions from on-road motor vehicles are the focus of intensive current research due to the acknowledged connection between ambient particulate matter levels and health effects. Constant improvement in engine technology has led to significant decrease in the number and mass of emitted particles, but particular concern is raised nowadays by the ultrafine particles. In this context, there is a critical lack of certification procedures for the measurement of these smallest-size (The H2020 PEMS4Nano project (www.pems4nano.eu) aims to develop a portable emission measurement system for particles below 23 nm, providing a contribution to future regulations on emissions in real driving conditions. The development of this instrument (and the associated measurement methodology) requires a deep understanding of the emitted particle characteristics, including a thorough characterisation of the size-dependent chemical composition, structure and morphology.
Methodology	Particulate matter studied in this work was produced by a conventional single-cylinder engine (Robert Bosch GmbH, Renningen, Germany). Operating conditions of this engine (injection timing, applied load, etc.) could be easily changed, thus allowing us to simulate different engines and working regimes, in a controlled environment. Additionally, every operation regime was characterized with several particle sizers (SMPS, EEPS). Produced particulates were sampled using a cascade impactor (NanoMoudi-II, TSI) which allows size-separation of the sampled particles into 13 different size bins. Chemical characterization of the collected particles was performed using a custom built two-step laser mass spectrometer (L2MS), which gives access to extensive and detailed molecular information on chemical classes of critical interest such as organosulphates, oxygenated hydrocarbons, nitrogenated hydrocarbons, heavy metals and polycyclic aromatic hydrocarbons – main precursors of soot particles. The L2MS instrument provides selective detection of different chemical compounds, such as aliphatic and aromatic species. Additional high-resolution chemical mapping is performed using a Secondary Ion Mass Spectrometer (IONTOF) with high sensitivity for both inorganic and organic species. The morphology of the emitted particles was probed with a SEM instrument (SEM Merlin, Zeiss). Additionally, the topography, electronic properties, structure, and chemical composition of individual particles down to a few nm was studied using various modes of atomic force microscopy (AFM) with coupled tip-enhanced Raman spectroscopy (TERS). Statistical procedures such as principal component analysis and hierarchical clustering analysis were used to highlight subtle differences, as well as similarities, between different-sized soot particles.
Results & Conclusions	Mass spectrometric studies provide extensive information on the chemical composition of size-selected soot particles. Apart from the present chemical species, one can also derive important information regarding the elemental carbon content of the analysed particles. Species responsible for the variation of the chemical composition with the size can be identified and separated by origin. It was determined that, in normal operating conditions, the highest elemental carbon content as well as sulphur bearing compounds are concentrated mostly on the ultra-fine particles. At the same time, hopanes are evenly distributed across different size bins. This data allows us to determine the primary source of different-sized particles (e.g.: hopanes are markers of lubricating oil combustion). Since the contribution of primary sources onto size-selected particles changes with the operating conditions, we are also able to distinguish between different engine working

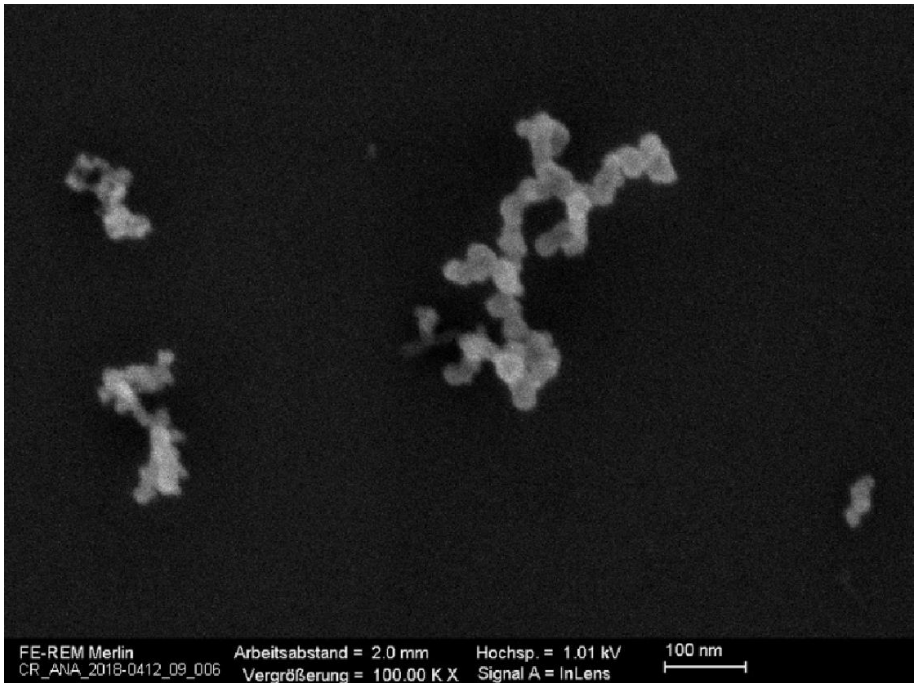
regimes. Therefore, it was possible to determine that in regimes characterized by “rich” air/fuel mixing ratios, the combustion of oil is affecting mainly larger particles (>100nm). SEM measurements revealed that the size of primary particles ranges from 10 to 25 nm, with relatively low dependence on the engine working regime.
In conclusion, the combination of mass spectrometric studies with statistical procedures reveals indisputable evidence of the size-dependent chemical composition. It also allows to identify chemical species that are accountable for the earlier mentioned variation, and therefore to pinpoint the origin of particles in different size bins. This information helps to better understand the main processes responsible for particle emission in a gasoline direct injection engine and represents critical physico-chemical data necessary to develop a reliable portable measurement procedure for ultra-fine particles below 23 nm.

Caption Figure 1:



Mass spectra of size-selected soot particles produced by a single-cylinder engine in normal operating conditions with medium load

Caption Figure 2:



SEM image of soot particles emitted by the single-cylinder engine in normal operating conditions with high load. Primary particles sizes in the range 10-25 nm

Friedrich Axel / FOCUS

Diesel DeNox-System
Failures and Manipulations

Gloor Beat / **FOCUS**

Diesel Particle Filter
Failure Statistics of a Swiss In-Use Fleet

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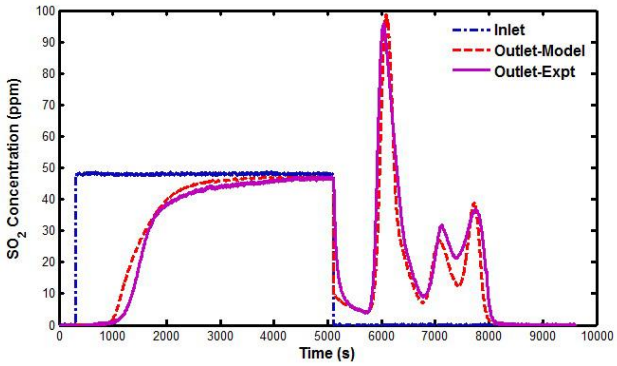
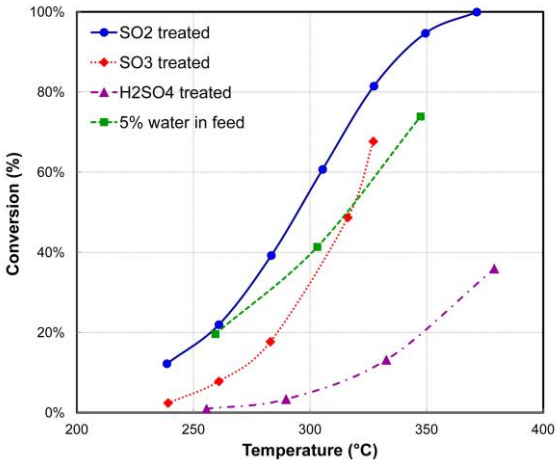
Publication title	Sulfur Storage and Release over a Diesel Oxidation Catalyst: The Different Deactivation Impacts of SO2, SO3 and H2SO4
Publication type	Presentation
Introduction & Background	Sulfur species in diesel engine exhaust interact with the diesel oxidation catalyst (DOC) as well as other aftertreatment catalysts leading to performance loss over time. SO2 is the main sulfur species in diesel exhaust gas, which in turn can be further oxidized to SO3 over a DOC with subsequent formation of H2SO4 in the presence of water. SO2, SO3 and H2SO4 could have substantially different deactivation impacts on DOCs, as well as the catalysts further downstream. Therefore, decoupling those effects would provide new insights into the sulfur poisoning mechanism as well as the design of effective regeneration procedures. On the other hand, analysis of particulate matter (PM) in diesel exhaust gas has shown that the sulfates contribution in the PM can increase in the presence of DOCs, mainly due to release of sulfur species stored on the catalyst (which could be significant at temperatures above 300°C). Such sulfate release phenomena can lead to an undesired increase in “secondary emissions” from diesel exhaust. In the present work, sulfation of a model Pt/γ-Al2O3 catalyst upon exposure to SO2, SO3 and H2SO4 are experimentally studied and a kinetic model for SO2 storage-release over the catalyst is developed.
Methodology	The experimental study was performed using temperature programmed desorption (TPD) experiments and in-situ diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS). The role of support was decoupled by using bare alumina samples in the TPD and DRIFTS experiments. Based on the DRIFTS and TPD studies, multi-step reaction mechanisms were proposed for SO2 adsorption and desorption on/from Pt/γ-Al2O3 and a microkinetic model was developed. The kinetic parameters were optimized to describe the SO2 TPD experimental data.
Results & Conclusions	Adsorption data verified that γ-Al2O3 as a catalyst support significantly affects the SO2 and SO3 storage and release over a Pt/γ-Al2O3 catalyst. In-situ DRIFTS experiments were performed to identify surface species formed during SO2 and SO3 adsorption on γ-Al2O3 and Pt/γ-Al2O3. According to the TPD and DRIFTS results, the sulfur uptake as well as the contribution of the stable sulfate species on the catalyst decreases in the following order: H2SO4 > SO3 > SO2. Sulfur loadings of 2.5, 32.3 and 139.9 μmol/m2 were obtained for the SO2, SO3 and H2SO4 saturated samples, respectively, indicating significant sulfate formation in the alumina bulk upon H2SO4 exposure. SO2 oxidation activity tests were performed using samples exposed to different sulfur treatments (Figure 1). The results showed a higher inhibition effect of SO3 compared to SO2, with H2SO4 leading to even further inhibition. Water inhibition effect was also evaluated using 5% water in the feed and its effect on the catalyst activity is presented in Figure 1. The results of kinetic model are presented in Figure 2. The kinetic model was able to accurately predict the SO2 adsorption along the monolith channel as well as the desorption/decomposition of the species formed. The modeling results can be used to predict the storage-release behavior of the DOC upon exposure to SO2 under different operating conditions, through which the estimated amount of sulfur species released as “secondary emissions” can be evaluated.

Caption Figure 1:



Steady state SO2 oxidation activity as a function of temperature for the SO2 treated, SO3 treated and H2SO4 treated Pt/γ-Al2O3 catalysts along with the activity in the presence of 5% water.

Caption Figure 2:



SO2 adsorption-desorption over Pt/γ-Al2O3 as a function of time: experimental data (Outlet-Expt) and model predictions (Outlet-Model). Saturation conditions: 48 ppm SO2, 157°C; Desorption: temperature ramp of 20°C/min to 925°C.

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Publication title	Nitration Chemistry in Non-catalyzed Diesel Particle Filters: A Consequence of the Co-release of Nitrogen Oxides, Soot and Soot Adsorbates
Publication type	Presentation
Introduction & Background	In 2012 the WHO has classified non-treated diesel exhaust as class 1 carcinogen inducing lung cancer in humans. As a consequence such engines can only be applied in work places, if best available abatement technology (BAT) is used to minimize cancer risks of exposed workers. Particle filters are nowadays considered as BAT and have been implemented in diesel passenger cars, light- and heavy-duty vehicles, buses and construction machinery. Filters will also be a necessity in gasoline direct-injection (GDI) vehicles to lower particle emissions which exceed those of modern diesel vehicles (> Euro-5) by orders of magnitude [1]. Thus high quality particle filters are available today that can remove soot nanoparticles from combustion exhaust. This means that soot is accumulating in filters offering large surface areas for adsorption of semi-volatile compounds. In other words, soot and adsorbates represent a playground for heterogeneous catalysis. Nitration of compounds like polycyclic aromatic hydrocarbons (PAHs) can lead to nitro-PAHs. This might increase the exhaust genotoxicity. We have studied nitration reactions in catalyzed particle filters [2,3] and have seen filters that indeed support PAH nitration. It is our hypothesis that nitration chemistry can also be supported by non-catalyzed particle filters and applied high-resolution Orbitrap mass spectrometry to investigate this hypothesis.
Methodology	Exhaust samples including solid, condensed and gaseous matter were collected with all-glass sampling devices downstream of a heavy-duty diesel engine (6.6 L, type D934S, Liebherr) at the engine dynamometer of the UASB Biel. Two non-catalyzed filters were tested in new and soot-loaded form in the 8-stage ISO8178/4C1 cycle for construction machinery. Samples were recovered from the sampling devices, cleaned and fractionated with a three-column liquid chromatography system. Purified extracts were analyzed by GC-HRMS (Orbitrap, Q-Excective-GC).
Results & Conclusions	The diesel engine released a wide range of volatile, semi- and non-volatile PAHs including several genotoxic compounds. Emissions were within the range of previous measurements of non-treated diesel exhausts [2,3]. Nitro-PAH emissions of non-treated diesel exhausts are one to two orders of magnitude lower than those of respective parent PAHs. Efficiencies of the non-catalyzed filter varied for different PAHs and nitro-PAHs. The soot loading of the filter also affected the penetration of individual PAHs and nitro-PAHs. Evidence was found that certain nitro-PAHs indeed were formed in the DPF. Overall we conclude that non-catalyzed DPFs have to be considered as temporary storage devices for semi-volatile compounds which form adsorbates on accumulated soot. Due to the high surface area of filter materials solid soot can't escape from a filter, while adsorbates can. Dependent on exhaust temperatures and amount of adsorbates, even more of this semi-volatile material can be released from a filter at certain times than is entering. Moreover, our data indicates that nitration of adsorbed PAHs can also occur in non-catalyzed filters. Respective nitro-PAH emissions can exceed those of the engine. Thus, a secondary formation of nitro-PAHs in non-catalyzed filters has been observed. The impact on the genotoxic potential will be discussed. [1] Munoz et al., Atmos. Environ. 2018, 178, 242-245. [2] Heeb et al., Environ. Sci. Technol. 2008, 42, 3773-3779. [3] Heeb et al., Environ. Sci. Technol. 2010, 44, 1078-1084.

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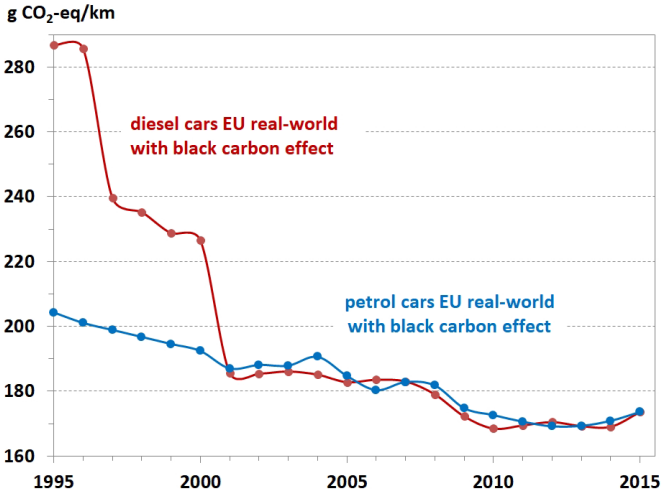
Publication title	Radiative Forcing from European Passenger Vehicles in the Years 1995-2015 Based on Real-World Use
Publication type	Presentation
Introduction & Background	The EU's climate change mitigation efforts for road transport have focussed on reducing the average CO2 emissions of newly registered cars (e.g., EEA, 2017). These emission values are measured using standardized driving cycles such as the New European Driving Cycle (NEDC), which is conducted under idealized laboratory conditions, and not representative of real-world driving conditions. On-cycle measurements, however, today differ very much from emissions under real-world driving conditions. In recent years, the gap between on-cycle and real-world emissions has been growing, reaching an average deviation of +42% for new passenger cars in 2015 in Europe (Tietge et al., 2016).
Methodology	We calculate the balance of real-world CO2 emissions of passenger cars differentiated by diesel and petrol engines during the period from 1995 – 2015 using the real-world emission factors from Tietge et al. (2017). In addition to direct CO2 emissions, we consider the additional radiative forcing due to primary-emitted BC, in order to compare diesel and petrol vehicles in terms of CO2-equivelant emissions (CO2-eq). In order to more specifically assess the effectiveness of the European diesel boom on reducing the overall climate impact of the passenger car fleet, we calculate the expected lifetime CO2-eq emissions of all European passenger cars (use phase only) registered between 1995 and 2015, and compare this historical case with two alternative scenarios: a "constant 1995 diesel" scenario; and an "alternative mitigation" scenario in which we promote electric hybrids and natural as well as liquefied petroleum gas.
Results & Conclusions	• Diesel cars had much higher climate relevant emissions until the year 2001 • From 2001 to 2015 CO2-equivalent emissions from new diesel cars and petrol cars were hardly distinguishable • The difference in modelled CO2-equivalent emissions between a historical case and a scenario avoiding the diesel car boom is only 0.1% • Also an advanced mitigation scenario would have been able to achieve only 2.7 % reduction in total CO2-equivalent emissions • The European diesel car boom appears to have been ineffective at reducing climate-warming emissions from the European transport sector

Caption Figure 1:



Average GHG emissions of new cars in Europe including black carbon emissions

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Publication title	Systematic Review on Ultrafine Particle Health E ffects
Publication type	Presentation
Introduction & Background	Due to their small size, inhaled UFPs may enter into alveoli and are even capable to penetrate cell membranes. Consequently, UFPs may pass into the blood system, overcome the placental barrier, and finally diffuse into all organ systems including the brain and nervous system. Toxicological studies suggest that UFPs contribute to the development and progression of various diseases. However, epidemiological evidence for health effects of UFPs is scarce in comparison to that of larger particles. Nevertheless, numerous studies examining the exposure of the population and health effects of UFPs have been published in the last decade. The aim of this presentation is to give an overview of the epidemiological literature on the effects of UFPs on health.
Methodology	We conducted a systematic literature review searching MEDLINE and LUDOK data bases (time period January 2011 - May 2017) and by hand search of review articles and conference proceedings, with a focus on epidemiologic studies that investigate health effects of UFPs and include quantitative effect measures. Included studies had to comprise at least one of the following UFPs-measures: Particle numbers (PNC) for particles with a diameter of less than 100 nm, PM0.1, Aitken mode particles, or the following quasi-UFPs-measures: PNC for particles with a maximum diameter of > 100 nm, PM0.25, surface area concentrations and accumulation mode particles. Data extraction and quality assessment using standard instruments was conducted by two reviewers.
Results & Conclusions	Overall 85 unique references could be identified and were included in the review. Most of these studies were conducted in North America (n=37) or Western Europe (n=27). The majority of the studies were related to the investigation of short-term effects (n=75) measuring outcomes during hours to months after exposure. Ten studies investigated long-term associations using exposure estimates averaged over a period of months to years. Short-term studies were dominated by panel studies with repeated measures, scripted exposure studies and time-series studies (n=11). Conclusions: The investigation of health effects in epidemiological studies is a rapidly increasing field of research and substantial developments have been made during the last 7 years. First, several studies on long-term health effects of UFPs/quasi-UFPs have been conducted and published. Second, specifically the more recent studies have undertaken efforts to control for co-pollutants to identify the independent effect of UFPs/quasi-UFPs. Despite the obvious development in the field, the overall conclusions have not changed substantially over the time period investigated in this study. The evidence on health effects remains inconclusive or insufficient for most of the studied out-comes. Exposure assessment in the population remains difficult and the most important challenge for research, due to the specific characteristics of UFPs/quasi-UFPs. The independence of UFPs/quasi-UFPs cannot be evaluated at the moment, due to the low number of studies with adjustment and the limitations to exposure assessment for UFPs/quasi-UFPs. There is still an urgent need for long-term studies on health effects of UFPs/quasi-UFPs.

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Publication title	Performance Evaluation of FBC-DPF using PEMS instruments
Publication type	Presentation
Introduction & Background	FBC-DPFs were introduced into Iranian market in 2014. Since then, other than monitoring normal operation of the filter using exhaust back-pressure, no further studies have been done. Occasional high sulfur content diesel fuel (up to 150 ppm), lack of proper preventive maintenance, and high sulfate ash lubricating oil are special conditions in which the filters are operated. The purpose of this study is to measure and monitor the emissions of a Euro II level OM457 Daimler engine equipped with FBC-DPF after a relatively long operational time in the real-world driving condition at Tehran's high elevation from sea level. For the purpose of the study, a normal operating bus has been equipped with PEMS instrument for gaseous emission analyzers and a Testo NM3 particle counter.
Methodology	The test vehicle is a city bus equipped with a non-catalyzed FBC-DPF and a Daimler OM-457 engine. The tests are performed under real driving conditions of the bus with changing parameters such as road grade and bus payload. Gaseous emissions were measured using PEMS. Exhaust emitted particle count was measured using a NanoMet3 device. To monitor DPF temperature and back-pressure, CPK data logger was used.
Results & Conclusions	The number and mass measurement of exhaust emitted particles under real driving conditions showed that the number and mass filtration efficiency of the installed DPF was 99.7% and 98%, respectively. These filtration efficiencies were consistent with results from engine dynamometer tests. The effect of road grade and bus payload on the filtration efficiency was investigated, and as it was predicted the increase in road grade or bus payload had an adverse effect on emitted particle count; even though, the filtration efficiency remained unchanged. The emission factor of total nitrogen oxides and unburnt hydrocarbons was 3 times the euro II standard and equal to 5.46 [g/km]. The number and mass emission factor of particles was 4.23×108 [#/km] and 0.0039 [g/km], respectively.

Kadijk G. / FOCUS

New Periodic Technical Inspection:
Concept for DPF Proven and Ready to Introduce

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Publication title	From Nascent to Mature Soot Light Absorption During Agglomeration and Surface Growth
Publication type	Presentation
Introduction & Background	Optical characterization of soot (e.g. Laser Induced Incandescence, LII) and its impact on climate largely depend on light absorption. As soot grows, its morphology changes affecting its optical properties. Soot primary particles (PPs) are incepted by reactive dimerization of small polycyclic aromatic hydrocarbons [1] and grow by reactions with acetylene molecules [2]. Nascent soot PPs collide and surface reactions chemically bond them forming compact aggregates [2]. At residence times larger than 10 ms, surface growth stops and single PPs coagulate with aggregated ones into large mature soot agglomerates [3]. Understanding the evolution from nascent to mature soot light absorption during surface growth and agglomeration is essential to soot characterization, assists the development of cleaner and more efficient combustion processes and can improve the accuracy of climate models.
Methodology	Here, the impact of the morphology of soot on its light absorption is investigated by coupling Discrete Element Modeling (DEM) with Discrete Dipole Approximation (DDA) during soot surface growth and agglomeration. The mass absorption cross-section, MAC, of nascent and mature soot agglomerates is estimated by DDA and validated against atomistic point dipole interactions [4] and mesoscale DDA calculations [5].
Results & Conclusions	Using a refractive index, m, for mature soot yields constant average and absorption function , that overestimate the nascent soot light absorption up to 100 %. Interpolating m between those of nascent and mature soot for wavelengths, λ = 532 and 1064 nm results in excellent agreement of the DEM-derived evolution of , and ratio R = / with LII measurements in premixed [6,7] and diffusion flames [8]. The nascent soot mass-mobility exponent, Dfm, decreases by agglomeration, doubling the and increasing by 65 %. A quasi-asymptotic Dfm of 2.45 is attained faster by larger soot volume fractions, accelerating the increase of and reaching nearly constant m = 1.61 – 0.63·i and 1.69 – 0.70·i at λ = 532 and 1064 nm, respectively, for residence time, t > 30 ms. The R decreases from 1.34 to 0.95 by coagulation and slowly converges to the asymptotic 0.89 of mature soot measured in diffusion flames.

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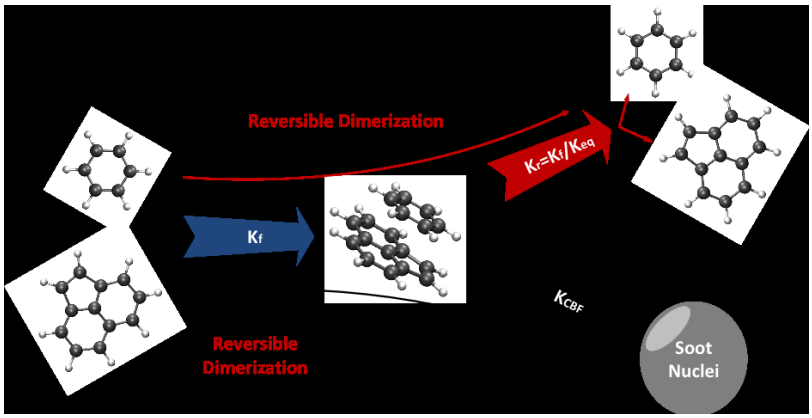
Publication title	Reactive Polycyclic Aromatic Hydrocarbon Dimerization Drives Soot Nucleation
Publication type	Presentation
Introduction & Background	Nucleation is one of the least understood steps in soot formation. The exact mechanism as well as the species involved in soot nucleation are still unknown. Neutral molecules and their radicals, such as Polycyclic Aromatic Hydrocarbons (PAHs) have been suggested as nucleating species. PAHs are traditionally considered as such because of their thermodynamic stability at flame temperatures as well as observed Bragg diffractions from stacked PAH crystallites in High Resolution Transmission Electron Microscope (HRTEM) images of soot particles. There are experimental data and theory supporting the role of PAHs in soot nucleation and surface growth. In addition, experimental and theoretical investigations highlight the bimodal particle size distributions caused by the second order kinetics of soot nucleation ruling out single species growth pathway into soot nuclei below 2500 K. Two scenarios are commonly used for soot nucleation from PAHs: A) irreversible formation of stacked PAH clusters held together by van der Waals (vdW) forces and B) formation of crosslinked three-dimensional PAH structures held together with carbon-carbon covalent bonds. Pathway “A” explains rapid nuclei formation in low to intermediate temperature flames with a collision factor ranging from 1e-6 to 1. However, it cannot explain how PAHs stay bonded with weak dispersion forces and overcome the entropic penalty of dimerization beyond 1000 K. With pathway “B” dimers can survive high temperatures due to strong carbon-carbon covalent bonds. However, at low temperatures with limited hydrogen abstraction and subsequent covalent bond formation, this pathway fails to predict rapid nucleation.
Methodology	A kinetic mechanism is proposed here that inherits the properties of the reversible PAH dimerization as well as the PAH crosslinking mechanism. However, the present mechanism differs from both by a) chemical bond formation reactions that do not need H atoms to proceed, b) considering a fully reversible dimerization as the first step in PAH reaction for soot nucleation and c) chemical bond formation after reversible dimerization. The mechanism describes both reversible “PAH clustering” by vdW forces and irreversible “chemical bond formation” between PAH radicals and molecules in a dimer The motivation for including reactions for covalent bond formation is the emerging evidence that physical nucleation of PAHs is not strong to yield enough soot nuclei even at low temperatures.
Results & Conclusions	Here, the importance of reactive PAH dimerization in reducing soot nucleation reversibility is investigated by simulating soot formation in a so-called “nucleation” flame (Desgroux et al., Combust Flame, 184 (2017) 153-166). There, inception of soot particles is prolonged at minimal subsequent growth. With only reversible PAH dimerization, the simulated soot concentration is negligible. Accounting however for PAH chemical bond formation after physical dimerization, stabilizes dimers by covalent bonds and increases the soot concentration by four orders of magnitude, in good agreement with Laser Induced Incandescent measurements. In particular, dimers of benzene with benzene, phenylacetylene, naphthylene, toluene, acenaphthylene and cyclopentapyrene make significant contributions to the total soot concentration. The abundance of dimers with small PAHs highlights the dominant role of PAH concentration over their size and dispersion forces on dimer formation. Higher collision factors are used for irreversible dimerization models using larger PAHs because of their lower concentrations and not their larger dispersion forces leading to reduced reversibility and more stable dimers. The qualitative trend of main peaks agrees well with stochastic simulations and aerosol mass spectra measured in the above “nucleation” as well as premixed flames highlighting the abundance

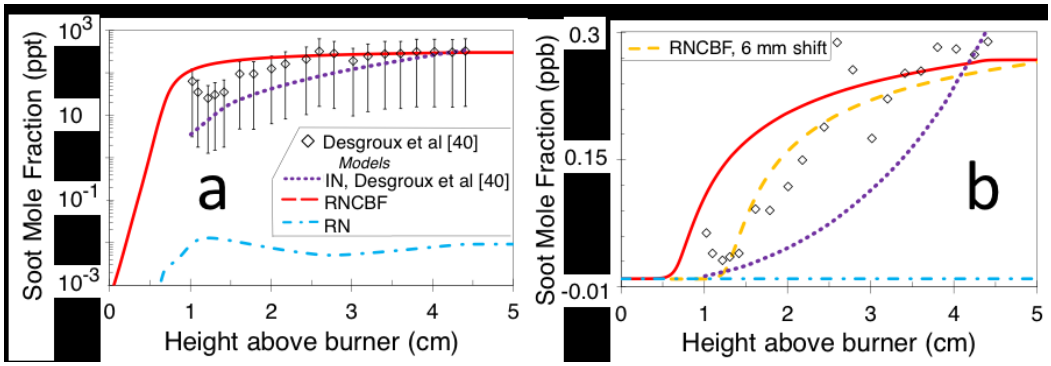
of PAHs with five-membered rings and substituted aliphatic chains in incipient soot. The predicted number of trimers is very low, i.e. less than 3% of the total soot nuclei formed, indicating that covalently bonded PAH dimers can be the main contributors to soot nucleation.

Caption Figure 1:



Physical vs chemical soot nucleation pathways

Caption Figure 2:



Comparison of the concentration of incipient soot measured by LII with predicted total dimer concentration using, Reversible Nucleation and PAH Chemical Bond Formation (RNCBF), Irreversible Nucleation (IN) and Reversible Nucleation (RN) models in a) log scale and b) linear scale. Even with k_eq calculated by the intermolecular potentials of which favor dimer formation, predicted dimer concentrations using the RN model are at least four orders of magnitude lower than the measurements.

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Publication title	Particle Number Emissions from In-Use Transit Buses with Advanced SCR Systems
Publication type	Presentation
Introduction & Background	Solid nanoparticle emissions from modern diesel engines have largely been eliminated using properly functioning diesel particulate filter (DPF) technology. However, recent studies have suggested the possibility of solid particle emissions originating from downstream selective catalytic reduction (SCR) systems designed to mitigate nitrogen oxide (NOx) emissions. This study examines the tailpipe total solid particle number emissions from two in-use transit buses operating on slow and fast routes in the metropolitan Minneapolis and St. Paul, MN area.
Methodology	A TSI (Shoreview, MN) Nanoparticle Emission Tester (NPET) Model 3795 was used in the experimental investigation incorporating a catalytic stripper to remove semi-volatile materials and a condensation particle counter with a 23-41 nm cut size range. “Solid particle” is an operational definition included in the EU solid particle number standard and associated measurement system. It may include low volatility material both organic and inorganic. One tested bus had a 2013MY emissions system installed and the other a more advanced 2015MY system. The buses were operated in normal passenger service.
Results & Conclusions	Our previous work showed that the newer emissions system had an average ammonia-to-NOx (ANR) ratio higher than stoichiometric and a more effective dosing control strategy, leading to lower in-use NOx emissions on the same routes. Other work has shown increased PM and especially PN with SCR plus DPF compared to DPF alone and that PN increases with urea dosing – increasing ammonia to NOx ratio, ANR. Thus, in our study, it was expected that the 2015 bus would exhibit higher PN emissions, which it did. The 2015MY bus had significantly higher “solid” particle emissions than the 2013MY bus over the same duty cycles, even when correcting for a DPF regeneration event that occurred on the 2015MY bus. However, neither the 2015 nor the 2013 bus showed a clear trend of increasing PN with ANR. Thus the reasons for higher PN with the 2015 bus are still to be determined. Although the measured particle emissions were not high enough to warrant concern for violating particle number standards imposed in Europe, the results presented here show that SCR systems emit nanoparticles at concentrations detectable by instruments designed mostly to detect solid carbonaceous particles. However, given the known high efficiency of DPFs for removing solid carbonaceous particles, it is likely that some of the measured “solid” particles are non-carbonaceous.

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Publication title	Effect of an Oxidizing Catalyst on PAH Emissions at Log Wood Combustion
Publication type	Presentation
Introduction & Background	Catalysts have been shown to be an effective measure against emissions from biomass combustion. Especially for gaseous emissions but also for particulate emissions a significant reductive effect was shown. Nonetheless, the impact on the composition of bulk parameters like OGC and PM is not clarified yet. Polycyclic aromatic hydrocarbons (PAHs) have received increasing attention, because of their genotoxic and carcinogenic properties. So far the impact of oxidative catalysis on the composition of PAHs in the flue gas of biomass combustion is not clarified.
Methodology	In this work a highly effective metallic oxidation catalyst (EnviCat® LongLife) was tested for its effect on PAH emissions from log wood stoves. The tests were conducted with a special test device, which enables parallel measurements of catalytically treated and untreated flue gas. In the parallel flue gas lines the flue gas passes either the Pt/Pd-honeycomb EnviCat® catalyst or a uniform dummy without catalytic layer. Therefore the flow conditions are equal in both lines. PAH sampling was conducted by filtration of diluted flue gas with quartz fiber filters. The filters were extracted with cyclohexane and dichlormethane (1:1) and analyzed with GC-MS (Quadrupole – mass spectrometer) for 19 different PAHs.
Results & Conclusions	In this work the high reduction of CO (-90%) and OGC (-45%) according to a previous work was confirmed. The sum of the 19 determined PAHs decreased by more than 60%, whereas higher (4- to 6-ring PAHs) decreased mostly by more than 75% and lower (2- and 3-ring PAHs) actually clearly increased. It seems that a share of higher PAHs is transformed to lower PAHs, which are typically less toxic. However, the PM which was sampled in this work from the diluted and thus cooled flue gas indicated an increase of 15% after catalytic treatment which is different compared to measurements of PM from hot flue gas in previous measurements. In a previous study it was shown that after catalytic treatment of Diesel soot the concentration of PAHs decreased but the concentrations of some higher toxic nitro-PAHs increased. Therefore the present samples are also analyzed for nitro-PAHs, as the high reduction rates of up to >90% for example for Benzo(a)pyrene could be also a consequence of nitrification processes. Processes occurring at heterogeneous catalysis like nitrification might be also an explanation for the increases of PM at the respective sampling conditions, as vapor pressures of various compounds are lowered for example by the addition of nitro-groups. Analyses on nitro-PAHs are currently conducted and the results will be presented at the conference. The results of this work show the impact of oxidative catalysis on the toxicity of flue gas from biomass combustion, which depends not only on concentrations changes but also on possible transformations into lower toxic PAHs with lower molecular masses or higher toxic nitro-PAHs.

Køcks Morten

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Publication title	Retrofit of Three Danish Ferries with DPF and NOx-reducing Technology – a New Danish Venture
Publication type	Presentation
Introduction & Background	Particle and gas emissions from diesel engines have profound impact on human health. As marine engines have not nearly experienced the same regulations as e.g. the on-road sector (EU EURO norms), emissions from marine engines are now under scrutiny. In 2015, the maximum allowed sulphur content in marine fuel was limited to 0.1% in emission control areas (ECAs), and will be globally limited to max 0.5% in 2020 – a tremendous challenge, both for fuel logistics and for monitoring compliance. NOX emissions are also regulated and will be further restricted in 2021. Particulate matter (PM) is partly regulated through the maximum allowed sulphur content in fuel but PM is in itself unregulated for marine engines. PM is however expected to be regulated in the future, e.g. through black carbon. Thus, emissions from ship traffic is a very hot and much debated topic these years, not least in Denmark, where a huge costal line exists. In addition, there is an urban tendency for movement towards the harbour fronts making air pollution from ships highly unwanted in these urban areas. Thus, different mitigation strategies are presently being exploited including implementation of emission-reducing technologies such as particle filters, SCR catalysts and scrubbers. In this study, emission data from three different Danish ferries are presented, as part of a larger Danish venture co-financed by the Danish EPA (2017-2020).
Methodology	The emissions were characterized at different engine loads and measured according to the ISO 8178 steady state method (slightly modified). PM was measured using both gravimetric and optical methods. Particle size distribution and number concentration (PN) was measured using a NanoScan SMPS (TSI) in connection with a rotating disc diluter (Testo) and further connected with a catalytic stripper (Catalytic Instruments) for measuring the solid particle fraction. Gas emissions were measured using standard laboratory gas analyzer equipment as well as a Thermo Scientific Antaris IGS FTIR analyzer.
Results & Conclusions	For one ferry (M/F Isefjord), the PN concentration in exhaust was measured to be 1-5x10^7cm-3, dependent on engine load, and with a mean particle size of about 70 nm. A quite low NOx emission in the interval 5-700 ppm was measured. For a second ferry, the PN concentration was lower, about 1-7x10^6 cm-3, again dependent of engine load, and with a mean particle size at about 110 nm. For this particular ferry, the NOx emisisons were relatively high (900-1400 ppm) strongly indicating that a combined particle and NOx reducing system, as presently being installed, is suitable for this particular application. In conclusion, emissions have been characterized for a number of Danish ferries and in addition, all ferries are in the process of being retrofitted with different particle filter and SCR (Selective Catalytic Reduction) systems from different Danish manufacturers. Presently, one installation is finalized with the two others in progress. In addition to direct emission measurements, it is expected that results from DPF/SCR efficiency measurements with focus on particle number, particle size and NOx can be presented in June 2018 at the ETH conference.
Images	

Caption Figure 1:

M/F Isefjord

Kreyling Wolfgang / Key-lecture

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Publication title	Is there Sufficient Evidence of Adverse Effects of Nanoparticles on Neuro-degenerative Diseases when Compared to their Cardiovascular and Respiratory Health Effects?
Publication type	Presentation
Introduction & Background	Since almost two decades the scientific, epidemiologic and toxicologic communities Discuss possible adverse health effects of the ambient urban aerosol and, in addition, its nano-sized action. Indeed, there is a plethora of epidemiologic studies on cardiovascular and espiratory health effects which initially showed associations between morbidity and mortality of urban citizens, particularly in vulnerable groups, and PM10 and PM2.5 fractions of the ambient urban aerosol.
Methodology	This keynote lecture cannot give all methodologies of this review.
Results & Conclusion	More recently epidemiologic biomarker studies provided more causal evidence and also human clinical and experimental toxicologic studies found (a) pulmonary and systemic inflammatory and pro-coagulatory responses, (b) promotion of atherosclerotic lesions, (c) dysfunction of the autonomic nervous system and (d) ischemic responses in the myocardium. Evidence of the role of the nano-sized fraction in these effects is less strong and more limited compared to PM10 and PM2.5. Regarding adverse health effects of the ambient urban aerosol and its nano-sized fraction on neuro-degenerative diseases is still in its infancy and the evidence is more a matter of faith than of scientific proof. So, more data are urgently needed. From a pre-cautionary point of view there is an alert which may not be neglected but any measures need to be carefully balanced between any benefits and harm both on the individual and the societal side. This presentation will provide an overview over the existing literature and discuss the existing knowledge and pending gaps with a cautious conclusion.

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Publication title	Engineered Nanoparticles versus Ambient Ultrafine Particles: How Comparable are their Interactions with the Organism and what do we Know and where are the Gaps?
Publication type	Presentation
Introduction & Background	A plethora of reports has demonstrated adverse human health effects following exposure to ambient air particulate matter (PM), with strong support for an important role for ultrafine (nanosized) particles (UFP). At present, relatively little human health or epidemiology data exists for engineered nanomaterials (ENP) despite clear parallels in their size between 1-100 nm. ENP are available in a range of well defined physicochemical characteristics which allow a more systematic toxicological analysis. Therefore, the study of UFP provides an opportunity to identify plausible health effects for ENP, while the study of ENP provides an opportunity to facilitate the understanding of the mechanism of toxicity of UFP.
Methodology	This presentation reviews a number of recent publications whose large number of methodologies cannot be addressed here.
Results & Conclusion	Rather than listing endless headlines without any data of all the many recent exciting findings and achievements, this presentation will pick a few scientific highlights which are less well known in the nanoparticle community. (1) Accumulation of inhaled gold ENP at sites of vascular disease (Miller et al., 2017): A combined pre-clinical and toxicological study on human volunteers proved for the first time that freshly generated, inhaled gold nanoparticles ((2) Relocation and re-entrainment within the lungs of rats (Semmler-Behnke et al. 2007): Inhaled 20 nm ENP consisting of either iridium or gold or titanium dioxide can relocate from their sites of deposition on the alveolar epithelium of rat lungs into interstitial spaces for long-term retention. Moreover, these retained ENP gradually re-entrain from the interstitial sites back onto the epithelial surface for subsequent macrophage-mediated transport to the larynx and gastro-intestinal tract for fecal excretion. By this clearance pathway most of the retained ENP are eliminated out of lungs while clearance via the lymphatic or vascular system is less prominent. (3) ENP disagglomeration (Balasubramanian et al., 2013): Rats inhaled gold ENP of different primary particle sizes, but agglomerated to give the same diameter in air of 45 nm. The authors demonstrated size related translocation, with the smaller, primary 7 nm gold particles translocating more across the air-blood barrier than the primary 20 nm gold particles, suggesting disagglomeration of the 45 nm agglomerates in the lung. These three highlights may show that our understanding of the ENP dynamics and interaction in the lungs still lacks comprehensive knowledge.

Künzli Nino / Kutlar Joss Meltem

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Publication title	Defending Public Health Priorities at Times of Scandals and Media Hypes around “Dirty Diesel”
Publication type	Presentation
Introduction & Background	The global outcry around the manipulation of diesel exhaust technologies has not only disclosed ethical values of an industry that adopted meticulous strategies to mislead the public. It also resulted in distorted discussions, perceptions and evaluations of health risks and its management. Discussions about health and clean air policies got reduced to one single gas (NO2) in the complex mixture of hundreds of toxic traffic-related pollutants. Particles of various sizes and compositions lost its pole position in the air pollution debate and discussions about trade-offs and benefits of cleaner diesel technologies were marginalized. Moreover, despite the urgent need for globalized clean air policy discussions, policy makers (and media) used the scandal for the promotion of “immediate” and “local” action to protect the health of their (electoral) constituencies irrespective of the science. This presentation will put the health issues of air pollution into context of a comparative view at different characteristics of traffic related air pollution with a critical look at local and global policy needs to protect global health.

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Publication title	Global Real Driving Emissions (RDE) Reduction Technology Modeling and Vehicle Demonstration Results
Publication type	Presentation
Introduction & Background	Introduction: The innovative Cool Particulate Regeneration (CPR) technology has been model with 3D Computational Fluid Dynamics (CFD) and a sophisticated unsteady 1D model. The results of the modeling along with demonstration vehicle results will be presented. Background: Real Driving Emissions (RDE) have demonstrated challenges for OEMs to meet current Euro VI emissions standards. Dense urban vehicle operation combined with low ambient temperatures place significant challenges for the introduction of Ad-Blue. Utilization of a sulfur tolerant Selective Catalytic Reduction (SCR) catalyst allows the removal of the oxidation catalyst and enables Ad-Blue to be injected into the exhaust manifold. This provides the benefits of gaseous ammonia injection with the simplification of currently commercially available Ad-Blue reductant. In order to successfully utilize sulfur tolerant and temperature intolerant catalyst, the utilization of a non-thermal Diesel Particulate Regeneration (DPF) is required. The effective and efficient removal of Particulate Matter (PM) from the filter is accomplished with Cool Particulate Regeneration (CPR), an innovative technology, that physically backflushes the PM and ash from the filter. CPR generates the required exhaust pressure by the positive displacement pumping action of the engine during waste vehicle braking conditions. The reverse flow is then induced by a rapid sequence of digital valves. In vehicle applications, the current thermal regeneration technology requires 10-40mins for regeneration. This amount of time is not available in dense urban environments. This requires operator training for forced regeneration. Additionally, the removal of high temperature thermal regeneration eliminates the thermal aging stresses on the SCR catalyst and filter substrate along with ongoing ash removal. These advantages open up the potential for the aftertreatment system to operate effectively for the life of the engine. CPR's low cost and Sulfur tolerance makes it the Best Available Technology (BAT) for developing countries. Furthermore, in developed countries, efficiency regulations will require more efficient powertrain designs such as future diesel electric hybrid systems and exhaust waste recovery. CPR enables the emissions equipment to placed downstream of the exhaust waste recovery system along with low temperature hybrid exhaust.
Methodology	Sophisticated 3D Computational Fluid Dynamics (CFD). CFD has been conducted utilizing the Florida Polytechnic University super computer. Particle trace analysis has been used to determine effectiveness of regeneration. Unsteady 1D modeling of CPR technology. Model output of CPR regeneration reverse flow velocity, mass flow, and differential pressure is achieved. The simulations have been automated to allow for extensive parametric studies of valve size, settling tank volume, and other system configuration parameters. Empirical data, from previous engine demonstration units and bench testing, has enhanced model accuracy. 1D cycle analysis of sulfur tolerant catalyst over Euro VI emissions cycles to determine the

ability of CPR to meet Euro VI emissions without a DOC.

Results & Conclusions

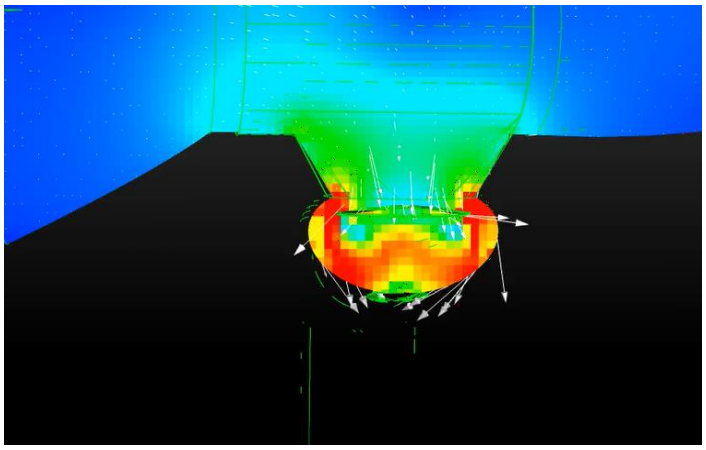
CPR CFD
Full three-dimensional Computational Fluid Dynamics (CFD) has been achieved with a moving regeneration valve. Particle tracers have shown the ability for gases located downstream of the Particulate Filter (PM), to pass through the filter and enter the settling tank.

CPR 1D Model:
Sophisticated unsteady 1D modeling has been conducted. The results mirror the outcome of the CFD analysis, but with a fraction of the computing power requirements. Modeling of any engine and packaging arrangements can be conducted in minutes.

CPR Demonstration Vehicle:
Volkswagen Jetta has achieved over 50,000 kilometers without an active thermal regeneration. The technology fitment, to the test vehicle, proves that CPR technology is capable of packaging installation and operation in small light duty vehicles.

Conclusion:
CPR has achieved Euro VI PM emissions with a low cost simple engine and exhaust system. Euro VI NOx and PM emissions utilizing commercially available Euro VI emissions cycles results will be presented. The modeling demonstrates the potential for Global Euro VI emissions on nearly all available fuels.

Caption Figure 1:



CPR with Moving Regeneration Valve

Caption Figure 2:

CPR Installation in 2011 Volkswagen Jetta Sportwagen

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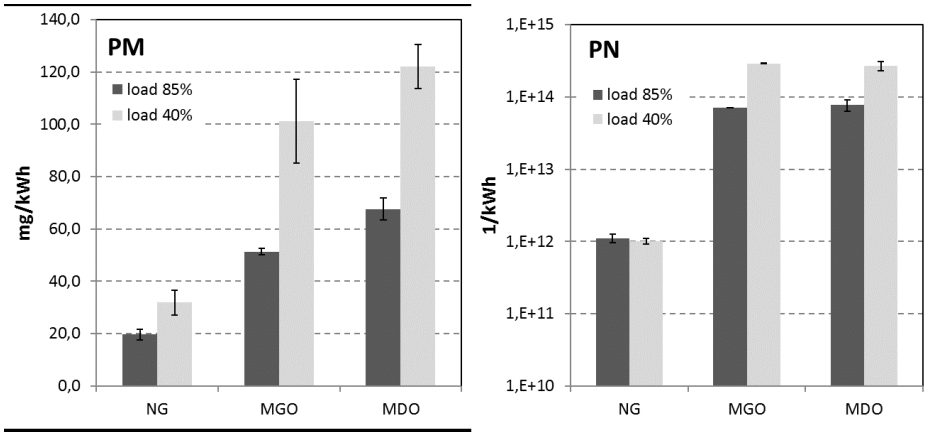
Publication title	Particle Mass and Number Emissions from Marine Engines Preparing for the Upcoming Sulphur Cap Limits
Publication type	Presentation
Introduction & Background	The International Maritime Organization (IMO) has implemented regulations to reduce emissions from ships. So far, these regulations consider only emissions of NOx and SOx globally, and stricter limits exist for special emissions control areas (ECAs) and in ports. The SOx regulation is expected to have an indirect impact on the contribution of shipping to particle emissions, i.e. the decrease of fuel sulphur level would also decrease the formation of sulphate particle emissions. In SOx emission control areas (SECA) the sulphur content of fuel is already limited to 0.1 %. Marine distillates, such as marine diesel oil (MDO) and marine gas oil (MGO) and low-sulphur residual marine fuel oils (hybrid fuels) are currently utilized in ships operating in SECAs. Also, the usage of alternative fuels such as liquefied natural gas (LNG) is increasing. Moreover, one option to achieve the SOx limit is by using exhaust after-treatment like scrubbers in combination with higher sulphur level fuels. In present study, we investigated how the different options in fulfilling the latest SECA limitations influence the particle emissions. These technologies include lower sulphur level liquid fuels, conversion to natural gas and utilization of scrubbers. Both, the particulate mass (PM) and particle number (PN) emissions were studied by experiments performed on-board and at marine engine laboratory.
Methodology	Particle mass (PM) and number (PN) concentrations were studied. PM was measured following the ISO 8178-1:2006 standard. The PN measurement method originated from the PMP (Particle Measurement Programme) work and considered non-volatile particles with a diameter greater than 23 nm. Experiments with low sulphur fuels i.e. with natural gas, MGO and MDO, were conducted with marine engine in laboratory. The engine was a Wärtsilä Vasa 4R32, a four cylinder medium-speed diesel engine which was modified to run with natural gas (NG) in dual fuel (DF) mode. The NG was from the Nordstream and had high methane content. The MGO was of diesel quality (EN 590) with few ppm levels of sulphur, while the MDO fulfilled the SECA criteria (0,1% S) with a sulphur content of 822 ppm. The engine was operated on 40% and 85% loads that were selected to represent the conditions at sea (85%) and maneuvering at harbour area (40%). Similar particle measurements as in engine laboratory were also conducted on board a cruise ship that utilized scrubbers in combination with higher sulphur level fuel (heavy fuel oil, HFO).
Results & Conclusions	The PM and PN levels when utilizing NG, MGO and MDO as fuels are presented in Figure 1. The NG usage resulted to 63-69% lower PM than the MGO usage while the MGO usage resulted to 17-25% lower PM than the MDO usage. However, there was no remarkable change in the PN levels when comparing MGO and MDO usage. From NG combustion the PN was found to be significantly lower (98-99%) than from the MGO or MDO combustion. One reason for this is, that there is no elemental carbon or fuel related ash/metals expected from the natural gas, which most probably has an effect on the observed PN (non-volatile). Comparison to an earlier study (conducted with same engine and PM method), showed that the current MGO or MDO PM levels are significantly lower than the level of 280 mg/kWh measured with HFO (1% S) at 75% load (Ntziachristos et al., 2016). Measurements done onboard revealed that the scrubber decreased the HFO PM levels by 41% when operating at sea with the main engine at 75% load. However, in that case, no significant difference was found in the PN levels measured upstream and downstream of the scrubber.

These results indicate that the fuel change to lower sulphur level fuels or to usage of scrubbers in combination with higher sulphur level fuels can have a significant decreasing effect on the PM, while the effect on PN is not straightforward.

This work was conducted in to three different projects, namely HERE and SEA-EFFECTS BC funded by Tekes and several Finnish companies, and Hercules-2 funded by EU.

Caption Figure 1:



PM and PN emissions at two different engine loads with natural gas, MGO and MDO fuels. Error bars show the standard deviation.

Li Zepeng

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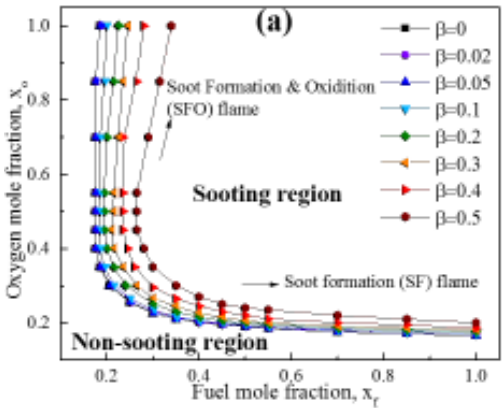
Publication title	Effect of Dimethyl Ether Addition on Sooting Limits in Counterflow Diffusion Flames at Elevated Pressures
Publication type	Presentation
Introduction & Background	The emission of soot particles attracts significant public concerns in recent decades. The development of technologies to reduce soot and other pollutants needs a better comprehensive understanding of the underlying mechanisms. Since fuel type is one of the dominant factors in soot formation, several quantitative metrics have been proposed to evaluate sooting tendency, such as the threshold soot index [1], yield soot index [2], and sooting limits [3,4]. In the regard of the low particulate emission of dimethyl ether (DME), a systematic investigation of the effect of DME addition on sooting limits in ethylene counterflow diffusion flames are conducted at elevated pressures.
Methodology	In this study, the laser scattering technique is the primary experimental method to determine sooting limits in counterflow flames. A counterflow burner inside a pressure vessel is used to provide the counterflow flames. The burner has a pair of contoured nozzles, the fuel stream coming from the bottom nozzle is composed of ethylene, DME and nitrogen; and the oxidizer stream coming from top nozzle is composed of oxygen and nitrogen. Here, xf and xo represent the fuel and oxygen mole fractions, respectively. The DME mixing ratio (β) is defined as the volumetric flow rate ratio between DME and fuel mixture (ethylene+DME).
Results & Conclusions	The effects of pressures and dimethyl ether (DME) addition on sooting tendencies are investigated using sooting limits, which is based on the fuel mole fraction (xf) and oxygen mole fraction (xo) in counterflow diffusion flames. The behaviors of sooting tendencies are different in Soot formation (SF) flames and soot formation & oxidation (SFO) flames. Sooting tendencies are less sensitive in SF flames compared with SFO flames, and the dependence of pressure is relatively mild in SF flames irrespective of DME addition. While in SFO flames, DME addition increases the dependence of pressure on the sooting limits. Besides, dilution affects the impact of DME addition on sooting tendency, when the fuel is diluted, the dependence of dilution on sooting tendency increases. Additionally, under high pressure, the sooting tendency is extended, and the sooting limits are more sensitive to the change of xo and xf. The most important, the range of DME mixing ratio (β) in increasing soot propensity expands with pressure. It means that in order to reduce soot emission, much more DME should be added at high pressure.

Caption Figure 1:



Sooting limit map at several DME mixing ratios (β) at atmospheric pressure

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Publication title	Soot Aerosols as a Source for Ice Nucleating Particles in the Cirrus Regime – the Role of Soot Particle properties.
Publication type	Presentation
Introduction & Background	A quantitative understanding of the aerosol-cloud interactions of soot particles, especially their ability to form ice, remains a key factor to reduce the uncertainties in the estimates of the net radiative forcing of black carbon [1]. However, previous studies have revealed significant spread, when reporting the ice nucleation ability of soot. This is partly caused by the diverse physico-chemical properties associated with morphologically complex soot aggregates.
Methodology	These varying results are the primary motivation of this study, which aims to better understand the ice nucleation behavior and mechanism of soot particles in relation to the particle properties. In this study, we present a systematic laboratory-based investigation of the ice nucleation behavior of different soot types. Various commercial soot samples are used, including an amorphous industrial black carbon, a fullerene soot, and Lamp Black carbon. In addition, soot generated from a propane flame Combustion Aerosol Standard Generator (miniCAST, JING AG), is investigated. Such soot has previously been used for ice nucleation studies and is frequently taken as proxy for atmospheric soot particles [e.g. 2]. We tested the ice nucleation ability of the above soot samples on DMA (Differential Mobility Analyzer) size-selected aerosol over a temperature range from 253 K to 218 K, covering both the mixed-phase and cirrus cloud regime. The heterogeneous freezing ability of soot at low temperatures is especially important, as aircraft emissions are a direct source of combustion particles in the upper troposphere, where cirrus temperatures prevail. The ice nucleation ability of soot is probed using the Horizontal Ice Nucleation Chamber (HINC, Lacher, Lohmann [3]), a Continuous Flow Diffusion Chamber. A suite of auxiliary measurements complements ice nucleation observations to characterize the physio-chemical properties of the tested aerosol particles that ultimately aid in determining their ice nucleation behaviour: Thermogravimetric Analysis (TGA) was performed over a temperature range between 0 to 1000 °C to estimate the proportion of volatile components associated with the different soot types. Nitrogen adsorption following the BET-method [4] was conducted to obtain specific surface area. Water adsorption isotherms of the soot particles are also collected to allow assessment of the hydrophilicity and the porosity of the samples. Size and aggregate morphology are investigated by a dedicated set of coupled DMA – CPMA (Centrifugal Particle Mass Analyzer) experiments to determine fractal dimension of the soot particles. Finally, Transmission Electron Microscopy studies, performed on size selected particles, using the Zurich Electron Microscopy Impactor, complement our aerosol characterization.
Results & Conclusions	Our results reveal droplet activation for all soot types at RHw > 100% at temperatures above 233 K with absence of any heterogeneous freezing. However, in the cirrus cloud regime, some soot types show significant heterogeneous freezing, depending on the aerosol size. These soot types are associated with relatively high porosity and water affinity, whereas those soot types with poor ice nucleation ability show considerably reduced water adsorption characteristics. We discuss our result in context of a pore condensation and freezing type ice nucleation mechanism [5] being responsible for the observed ice nucleation ability of the soot particles.

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Loaded Tests for Petrol and Diesel Engines

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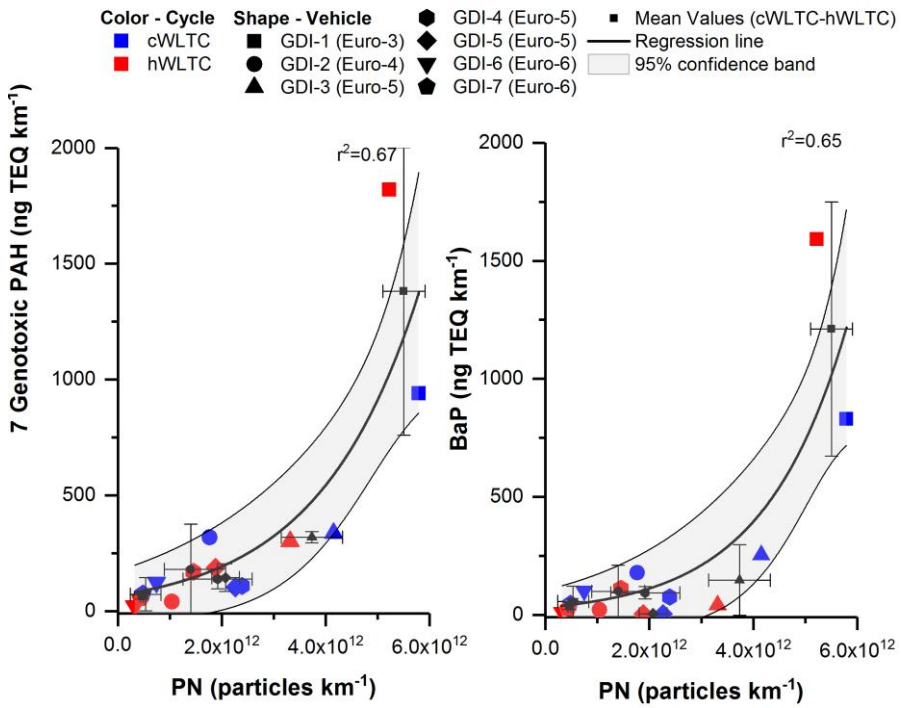
Publication title	Co-formation and co-release of genotoxic PAHs and nanoparticles from GDI vehicles support the Trojan-horse effect
Publication type	Presentation
Introduction & Background	GDI vehicles are soon accounting for a 30% of the European fleet. It has been shown that particle emissions of GDI vehicles exceeding those of a modern diesel vehicle which are equipped with particle filters (DPFs) 100 to 1000-fold [1,2]. While diesel vehicles with DPF release nanoparticles far below the Euro-6 limit of 6x1011 particles/km GDI vehicles, not equipped with filters, often exceed this limit. The co-release of genotoxic PAHs adsorbed on such soot nanoparticles is an important issue due to the Trojan horse effect describing the ability of sub-200 nm particles to reach the alveoli of the human lung and with it deposit genotoxic compounds there. We hypothesized that combustion of gasoline at increased pressures also induces the formation of polycyclic aromatic hydrocarbons (PAHs) in the same moment in which soot nanoparticles are formed. In the GASOMEP Project, several GDI vehicles from Euro-3 to Euro-6 technology were tested and compared with a Euro-5 Diesel vehicle with DPF. Complete exhausts were sampled and the genotoxic potential of the PAH fraction was determined. Also GDI exhausts must be carefully characterized to know whether they are as toxic as non-treated diesel exhausts which since 2012 are considered as group 1 carcinogen by the WHO inducing lung cancer in humans.
Methodology	In this study, complete exhaust samples including solid, condensed and gaseous fractions, have been collected in all-glass sampling devices from seven Euro-3 to Euro-6 GDI vehicles and a Euro-5 diesel vehicle with DPF at the chassis dynamometer of the UASB (Biel, Switzerland). Vehicles were driven following the WLTC under hot and cold start conditions. Diluted exhausts were sampled from a CVS tunnel. Samples were processed following several extraction and cleanup procedures. Final extracts were analyzed by GC-HRMS and concentrations of PAH and alkyl-PAHs s were determined. A CPC, an SMPS and a nano-SMPS were used to determine particle number emissions and size distributions from 9-400 nm.
Results & Conclusions	The final GASOMEP report is now available [1]. The project revealed that the GDI fleet emits on average 2.5x1012 particles/km, 64-fold higher than the bench mark diesel vehicle with DPF. Mean and toxicity-weighted emissions of genotoxic PAH were 710-750 ng TEQ/m3 being 16- and 17-fold higher than those of the diesel vehicle [1,2]. A moderate trend towards lower PN and PAH emissions was observed when comparing Euro-3 and Euro-6 technologies. Emissions of both PAH and PN are orders of magnitude higher at transient operation, corroborating the hypothesis that PAHs and soot nanoparticles are formed and released under the same conditions. The exponential regression curves shown in Figure 1 describe on one hand the PN and genotoxic PAH emissions are correlated to some degree. Whereas PN emissions seem to approach a limit value, the genotoxic potential still is increasing. Fig. 1 also shows that older technology emits more PN and PAHs. In other words, our hypothesis is confirmed that nanoparticles and genotoxic PAHs are formed and released together from GDI engines and as a consequence are deposited together in the alveolar region of the human lung supporting the Trojan-horse effect. It is clear that GDI vehicles would need efficient catalytic filters to reduce emissions of both soot nanoparticles and genotoxic PAHs..

Caption Figure 1:



Correlations of the sum of 7 genotoxic PAHs, benzo(a)pyrene (ng TEQ/km) and PN (particles/km) in the cold (blue) and hot WLTC (red) of 7 GDI vehicles. Mean values (cold and hot) for individual vehicles are indicated in black with standard deviation bars. Exponential regression curves, uncertainties and r2 values are also included.

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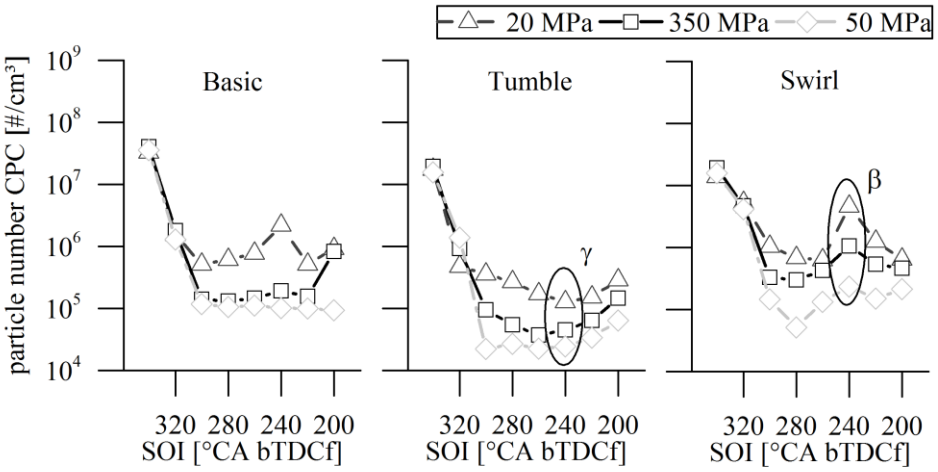
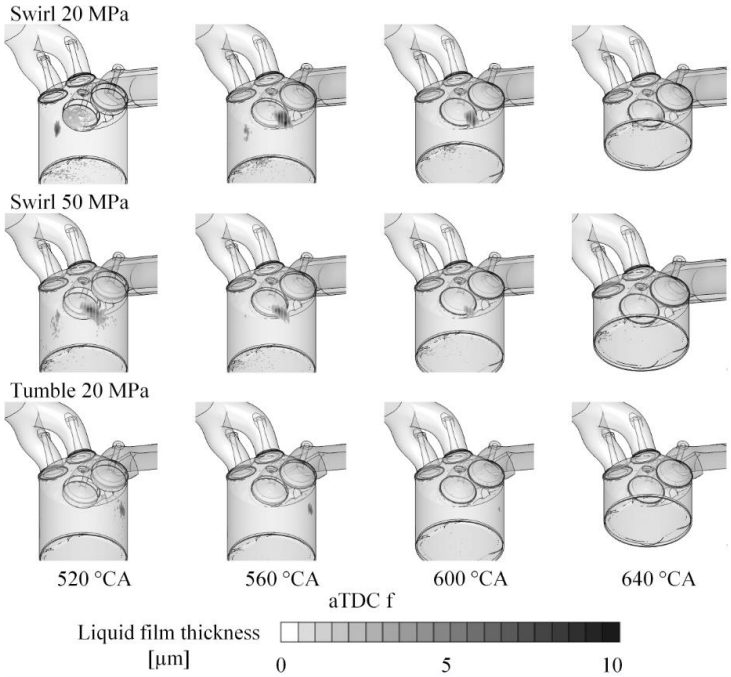
Publication title	Investigation on PN Formation at GDI Engines at High Loads
Publication type	Presentation
Introduction & Background	To increase engine efficiency and accordingly to reduce the tank-to-weel CO2 emissions of the fleet, gasoline engines are increasingly equipped with direct injection systems (GDI). However particle number emissions of GDI engines is much higher than of port fuel injection (PFI) engines. Reasons for particle emissions are nonhomogeneous mixture formation, the presence of local rich zones and liquid fuel in the combustion chamber. In context with the increasingly restrictive emissions regulations the reduction of particle number emissions at high engine loads is becoming increasingly important. Especially challenging are higher engine loads at lower engine speeds where fuel injection is stronger and the in-cylinder charge motion is weaker. This causes increased wall wetting and a degraded mixture formation which in turn leads to increased particle emissions.
Methodology	The particle number formation in GDI engines at high load conditions were investigated experimentally and by numerical simulation. Measurements of particle number emission of a single cylinder research engine in combination with in-cylinder optical spray visualization and soot luminescence were performed. The measurements were combined with CFD-simulation of the in-cylinder mixture preparation. To vary the charge motion, special inlays were designed for the intake port. For a variation of the injection flow rate two injectors are used for the investigations: A high flow injector with a static flow of 820 g/min and a low flow injector with a static flow of 620 g/min. The low and the high flow injector operates at a injection pressure of up to 50 MPa and 35 MPa respectively. The Particle number was measured with a “TSI 3790 Condensation Particle Counter” (CPC) and the size distribution was measured with a “TSI 3090 Engine Exhaust Particle Sizer” (EEPS). Additionally, the influence of important injection and flow parameters on the mixture formation were studied in a pressure chamber and in a flow bench.
Results & Conclusions	Major influencing parameters of particle formation in GDI engines were investigated. Additionally to the particle number measurement, optical measurements and numerical investigations were done to understand the effects on particle formation. Low particle number emissions are possible at high engine loads. The effect of individual measures to reduce the particle number formation is not cumulative and strong cross-correlation effects are present. The numerical simulations reproduce the trend of the particle measurement results. In comparison to the optical investigations, it could be shown that the spots of diffusive flame could be predicted by the liquid film spots present in the numerical simulation. Based on the CFD-simulations it is concluded that the highest influence on particle number emissions can be attributed to the remaining liquid phase in the cylinder.

Caption Figure 1:



SOI-Variations with different injection pressures and different charge motions

Caption Figure 2:



Comparison of different injection pressure and inlays at a SOI of 240° CA bTDCf

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Publication title	Investigation of the Simplified Measurement Technique of the Secondary Aerosols Formed from Gaseous Emissions of Vehicle Exhaust
Publication type	Presentation
Introduction & Background	[motivation] In order to grasp the contribution of vehicle emissions to PM2.5 concentrations, it is necessary to clarify the secondary aerosols formed from gaseous emissions. Recently, it was reported the simplified measurement techniques of the secondary aerosols formed from gaseous emissions with the flow reactors (PAM: potential aerosols mass chamber or MSC: micro smog chamber). It is concerned that the secondary formation in the timing unlike the actual situation may be detected by those techniques, because the condition in the flow reactor changes every moment. Our objective is to clarify the problems and the appropriate testing conditions to measure the secondary aerosols with the flow reactor. In this work, we investigated the effect of hydrocarbons (HC) concentration and seed particles in the flow reactor to the formation of secondary aerosols from gaseous emissions in the several concerns.
Methodology	[methods] A quartz glass chamber (250mmφ*500mm) was used as a flow reactor. The conditions of the reactor were as follows. Flow rate; 12 L/min, temperature; 25 °C, relative humidity; 50%, and hydroxyl radical exposure; 3.8E+11 molec/cm3*sec. The secondary aerosols and their precursors were analyzed with SMPS, EEPS (TSI), GC-FID and GC-MS (Shimadzu). The effect of HC concentration was examined by changing the ratio of purified/humidified air and the dilution vehicle exhaust with the ejector dilutor (Palas and Dekati). The effect of seed particles was examined using the aerosol generator ATM-226 (TOPAS) and the carbon particles generator DNP-2000 (Palas). In this study, the formation of secondary aerosols from vehicle exhaust of WLTC or toluene gas as aromatics included in those exhaust were investigated.
Results & Conclusions	[results] In the flow reactor, the higher dilution ratio of vehicle exhaust became, the lower total volume of secondary aerosols became after having revised each dilution ratio. It is thought that the ratios of low HC concentration (which cannot form secondary aerosols) increased. Next, we investigated the effect of three seed particles (sulfate, carbon or secondary organic particles) to the formation of secondary aerosols from toluene gas. The volume of toluene-derived secondary aerosols was decreased by coexisting with each seed particles. It is thought that the secondary formation of toluene-derived precursors was inhibited by every seed particles because the toluene concentration of the flow reactor exit did not have a difference. [conclusions] It is necessary to be careful about the following points to evaluate the secondary aerosols formed from vehicle exhaust with the flow reactors. 1) To select the suitable dilution ratio of vehicle exhaust in consideration of the reactivity of low HC concentration in a flow reactor. 2) To control the seed particles (including secondary formation particles) staying in a flow reactor.

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Publication title	Similarities between Soot Properties from Low Temperature Combustion to a Heavy Duty Diesel Engine and MiniCAST Flame Soot
Publication type	Presentation
Introduction & Background	A commonly used approach to reduce NOx emissions is exhaust gas recirculation (EGR). Recirculating a fraction of the essentially inert exhaust gases reduces in-cylinder O2 concentrations and subsequently, combustion temperatures. Low temperature combustion achieved by very high EGR levels has the potential to reduce both NOx and PM emissions by mass. Both EGR and the introduction of renewable fuels may affect the in-cylinder soot formation and oxidation processes and consequently the concentration and characteristics of emitted PM. The altered particle characteristics include the reactivity towards oxidation in after-treatment systems, the biological activity of PM deposited in the respiratory tract, as well as climate relevant effects.
Methodology	The effects of increasing amounts of EGR, including low temperature combustion at O2 concentrations down to 8%, on diesel engine exhaust were investigated in a modern heavy-duty diesel engine fueled with renewable Rapeseed Methyl Esther (RME), Hydrotreated Vegetable Oil (HVO), and a standard petroleum-based diesel. In addition, separate experiments were carried out with a miniature combustion aerosol standard (miniCAST, model 5201C) soot generator over a wide range of combustion conditions. Properties of the emitted particles were characterized using a range of techniques: a fast mobility analyzer (DMS500), a soot particle aerosol mass spectrometer (SP-AMS), a photo-acoustic sensor (AVL Micro Soot Sensor), and an Aethalometer (model AE33). This was complemented with off-line thermal-optical analysis for organic and elemental carbon (OC/EC) and high-resolution transmission electron microscopy (HR-TEM) for soot morphology and nanostructure.
Results & Conclusions	Striking similarities were observed between the particle characteristics when using increasing amounts of EGR in the diesel engine and increasing amounts of N2 to dilute the fuel in the miniCAST soot generator. This includes trends of increased PAH (Fig. 1) and OC fractions as well as increased light absorption in the UV-region (increased Angstrom exponent) in both experiments. Replacing conventional diesel fuel with RME showed a reduction in average particle sizes and equivalent Black Carbon PM emissions. However, the observed trends with increasing EGR were similar for all fuels. A detailed analysis of miniCAST soot showed that with increased N2 fuel dilution and increased fuel equivalence ratio the soot nanostructure was altered, which resulted in decreased carbon lamellae fringe lengths, decreasing black carbon fraction (indicating the mass absorption coefficient of the PM was altered) and occurrence of large carbon clusters in the SP-AMS mass spectra. Experiments with thermal denuders showed that a substantial fraction of the organic carbon and the increased UV absorption was persistent at temperatures up to 500 °C (Török et al. 2018). Similar soot properties to those observed at very high EGR were recently observed in soot extracted shortly after ignition from the cylinder of the same diesel engine (Malmborg et al. 2017). On-going research aims to investigate the oxidation reactivity and biological activity of these new forms of soot. References Malmborg, V. B., Eriksson, A. C., Shen, M., ... & Pagels, J. (2017). Evolution of In-Cylinder Diesel Engine Soot and Emission Characteristics Investigated with Online Aerosol Mass

Spectrometry. Environmental science & technology, 51(3), 1876-1885.

Török S., Malmborg, V. B. et al. . (2018) Investigation of the absorption Ångström exponent and its relation to physicochemical properties for mini-CAST soot. Accepted for publication in Aerosol Science & Technology

Acknowledgements: Financial support from the Swedish Research Councils FORMAS and VR is greatly acknowledged.

Caption Figure 1:

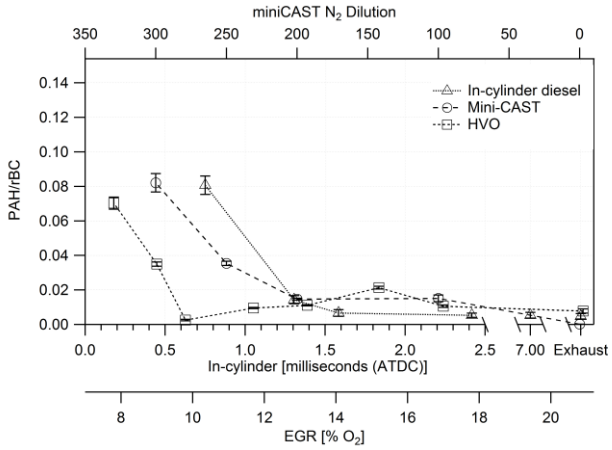

Fig 1. Ratio of particle phase PAHs to refractory Black Carbon as determined with the SP-AMS.

Panessa-Warren Barbara

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Publication title	Wood Combustion Emission Nanoparticle Morphological/ Elemental Characterization, and TEM Visualization of In-vitro Attachment, Entry and Fate of Nanoparticles within Human Bronchiolar Epithelial Monolayers
Publication type	Presentation
Introduction & Background	Wood combustion emission nanoparticles(NPs) and nano-aggregates were collected during specific burn cycle phases, from cordwood-fired advanced technology indoor-, and conventional outdoor boilers/ stoves. All operating conditions (type/amount of fuel, gas levels, temperatures in the firebox, stack, dilution tunnel) were recorded. Carbon NPs and their aggregates were collected and characterized, as were the smallest nano-salt NPs [measuring1.2 nm to 7.7nm diameter]. All of the NPs harvested and analyzed showed variable compositions from simple salts, to toxic heavy metal compounds depending on the boiler/stove studied. To observe how these NPs may interact with human bronchiolar epithelium if inhaled, characterized NPs were incubated at low and high concentrations, for 2 or 4 hrs with human epithelial monolayers, and analyzed by light microscopy vital staining, and high resolution transmission electron microscopy (HRTEM) to reveal NP binding, uptake, transport, intracellular fate and signs of cytotoxicity.
Methodology	Combustion NPs (collected from 5 cordwood boilers/stoves) were harvested at specific times in the burn cycle, and stored in clean grid boxes within desiccators (to reduce moisture contamination). All samples were imaged, measured and elementally analyzed using field emission TEM and SEM, and an LaB6 high resolution analytical TEM. Elemental composition/crystallinity were verified by energy dispersive, or SDD, x-ray microanalysis and SAED. For lung epithelial cell (NCI-H292) exposure testing, monolayers were grown to confluency and exposed to a low (0.1 µg/ml), or high dose (3.0 µg/ml) of either graphene and graphitic spherule combustion NPs, or isolated nano-salt crystalline NPs, for 2 or 4 hr incubation. Following incubation, monolayers were rinsed to remove unattached NPs, the cells were vital stained, photographed and necrotic and healthy cells counted. This data was compared to the HRTEM images showing NP binding, uptake, interactions with cell organelles, and excretion.
Results & Conclusions	Both the advanced technology and conventional outdoor cordwood boilers produced carbon, and nano-salt crystalline NPs, however the amount produced, and their elemental composition varied with each system tested. Systems operating with catalysts revealed reduced carbon debris, and virtually no toxic metals. The boilers/stoves that produced cleaner and reduced emissions, had catalysts, specific 'operating conditions' and better quality, clean wood fuel. HRTEM revealed that carbon and nano-salt crystalline NPs attached, and entered the cells within 2 hrs. Cell damage caused by uptake of nano-salt crystalline spherules was due to intracellular aggregation and continual accumulation of these smallest NPs into islands, that damaged internal membranes and destroyed organelles, forming NP-islands that filled the cytoplasm (bioaccumulation), and produced cell death. At 4 hrs exposure, graphitic and graphene chains of NP-spherules were seen localized within cell nuclei and nucleoli. Carbon NP-spherules passed through the apical membranes and entire carbon spherule chains and fractal aggregates passed through the nuclear membrane into the cell nuclei. Strangely these cells with nuclear NPs showed no signs of cell death. These findings suggested that NP carbon emissions may not all be cytotoxic. Perhaps cleaner operating wood stoves not only

reduce the amount of emissions but also reduce the organic materials thereby reducing resins and PAHs attached to the carbon NP surfaces, thereby reducing respiratory cell cytotoxicity.

Caption Figure 1:

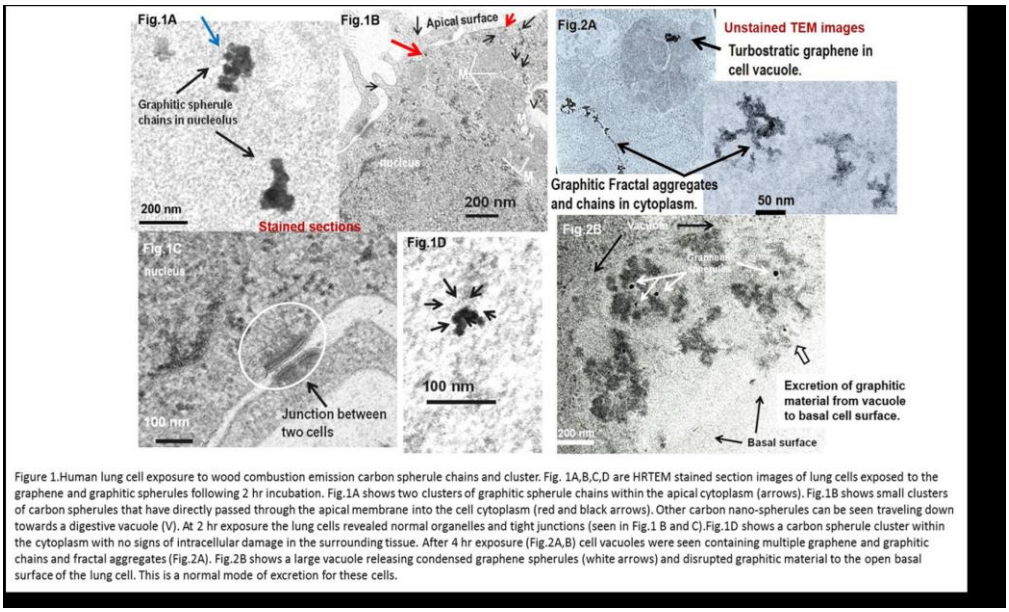

Figure 1.Human lung cell exposure to wood combustion emission carbon spherule chains and cluster. Fig. 1A,B,C,D are HRTEM stained section images of lung cells exposed to the graphene and graphitic spherules following 2 hr incubation. Fig.1A shows two clusters of graphitic spherule chains within the apical cytoplasm (arrows). Fig.1B shows small clusters of carbon spherules that have directly passed through the apical membrane into the cell cytoplasm (red and black arrows). Other carbon nano-spherules can be seen traveling down towards a digestive vacuole (V). At 2 hr exposure the lung cells revealed normal organelles and tight junctions (seen in Fig.1 B and C).Fig.1D shows a carbon spherule cluster within the cytoplasm with no signs of intracellular damage in the surrounding tissue. After 4 hr exposure (Fig.2A,B) cell vacuoles were seen containing multiple graphene and graphitic chains and fractal aggregates (Fig.2A). Fig.2B shows a large vacuole releasing condensed graphene spherules (white arrows) and disrupted graphitic material to the open basal surface of the lung cell. This is a normal mode of excretion for these cells.

Fig. 1: Both the advanced technology and conventional outdoor cordwood boilers produced morphologically comparable carbon spherule- and nano-salt crystalline-NPs, however the elemental analysis of these nanoparticles from each boiler tested had different elemental compositions. Systems operating with catalysts greatly reduced carbon debris, and the more toxic nano-salt crystalline NPs. The 'operating conditions' were a major factor in NP production and composition. HRTEM imaging of NP-exposed lung cells, compared to normal control lung cells, revealed that combustion emission NPs attached, and entered the bronchiolar epithelium within 2 hrs, but did not cause significant increases in cell death compared to controls. However, 4 hr samples revealed significant cell necrosis by vital staining, especially for nano-salt crystalline NP-exposed cells; and in many cells TEM revealed entire graphitic and graphene chains of spherules passing through nuclear membranes or lodged within cell nuclei.apical cytoplasm (arrows). Fig.1B shows small clusters of carbon spherules that have directly passed through the apical membrane into the cell cytoplasm (red and black arrows). Other carbon nano-spherules can be seen traveling down towards a digestive vacuole (V). At 2 hr exposure the lung cells revealed normal organelles and tight junctions (seen in Fig.1 B and C). Fig.1D shows a carbon spherule cluster within the cytoplasm with no signs of intracellular damage in the surrounding tissue. After 4 hr exposure (Fig.2A,B) cell vacuoles were seen containing multiple graphene and graphitic chains and fractal aggregates (Fig.2A). Fig.2B shows a large vacuole releasing condensed graphene spherules (white arrows) and disrupted graphitic material to the open basal surface of the lung cell. This is a normal mode of excretion for these cells.

Caption Figure 2:

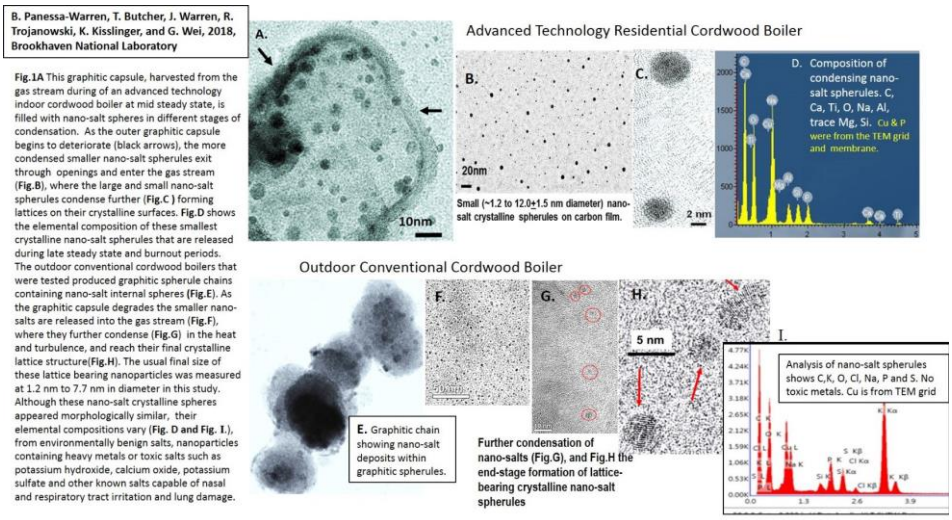

Fig.1A This graphitic capsule, harvested from the gas stream during of an advanced technology indoor cordwood boiler at mid steady state, is filled with nano-salt spheres in different stages of condensation. As the outer graphitic capsule begins to deteriorate (black arrows), the more condensed smaller nano-salt spherules exit through openings and enter the gas stream (Fig.B), where the large and small nano-salt spherules condense further (Fig.C) forming lattices on their crystalline surfaces. Fig.D shows the elemental composition of these smallest crystalline nano-salt spherules that are released during late steady state and burnout periods. The outdoor conventional cordwood boilers that were tested produced graphitic spherule chains containing nano-salt internal spheres (Fig.E). As the graphitic capsule degrades the smaller nano-salts are released into the gas stream (Fig.F), where they further condense (Fig.G) in the heat and turbulence, and reach their final crystalline lattice structure(Fig.H). The usual final size of these lattice bearing nanoparticles was measured at 1.2 nm to 7.7 nm in diameter in this study. Although these nano-salt crystalline spheres appeared morphologically similar, their elemental compositions vary (Fig. D and Fig. I.), from environmentally benign salts, nanoparticles containing heavy metals or toxic salts such as potassium hydroxide, calcium oxide, potassium sulfate and other known salts capable of nasal and respiratory tract irritation and lung damage.

Peeters H. / FOCUS

Legislation Must be Adapted
on EU-Level and on Member-State Level

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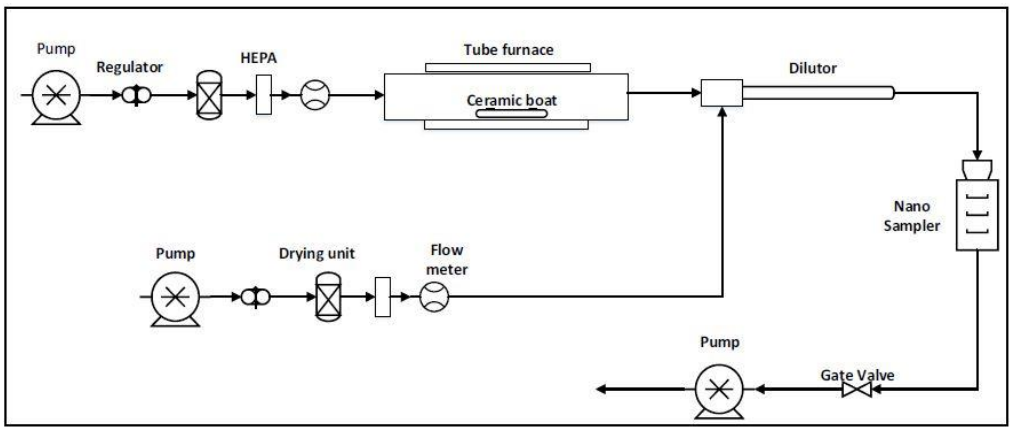
Publication title	Development of Emission Factors of Nanoparticles (PM0.1) from Solid Biomass Combustion.
Publication type	Presentation
Introduction & Background	The direct combustion of biomass fuel dominates the utilization of biomass fuels and is most important. On the other hand, it produces many air pollutants such as ion in the form of carbon dioxide (CO2), nitrogen oxides (NOx), particulate carbons and other pollutants. Particularly, much of ultra to nanoparticle are generated as reported elsewhere. Therefore, knowledge about characteristics and the control of pollutant emission is essential for biomass utilization with the minimum environmental load. However, such point of view has not been taken into account for the biomass fuel utilization but focused only on so-called “carbon neutral” behavior so far. This is not only important in Thailand but also in other regions in the world where the direct biomass fuel burning is usually used on a small scale without a full set of pollution control devices. The current emission estimate of biomass burning in each fuel type is vital to air quality management and environmental protection. Emission Inventory of PMs in developing countries are rarely developed so far. To our best knowledge, the PM0.1, or nanoparticle emission inventory from solid biomass burning have not been study so far in Thailand and Asian countries. The lack of data both of activity level and corresponding Emission Factor (EF) would lead to large uncertainty inventory. So, the result of EF evaluation of solid biomass fuel will be important to develop high quality emission inventory.
Methodology	Six types of biomass selected based on data of the solid biomass utilization in Thailand. Material solid biomass fuel 6 types including para-rubber wood, rice straw, oil palm kernel, bagasse, sugarcane leave, and corn stem was investigated, respectively. Each sample prepared into a small piece before chamber experiment. The solid biomass burned in a horizontal tube furnace with an inserted quartz column. The particulate matters and the flue gas were respectively sampling using a Nano-sampler with four impactor stages (>10, 2.5-10, 1-2.5, 0.5-1 μm), an inertial filter stage (0.1-0.5 μm) and a backup filter (
Results & Conclusions	The EFs values for six types of solid biomass burning in the laboratory range from 0.11 to 0.22 g/Kg. The highest EFs come from Bagasse (0.22 g/Kg), the minimum EFs derive from rice straw and sugarcane leave (0.11 g/Kg). The Emission Factors is important for the development of strategies for pollution control and decrease the biomass burning.
Caption Figure 1:	 Pararubber fuelwood in agroindustry, Thailand

Caption Figure 2:



Schematic diagram of combustion system

Pieber Simone

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Publication title	Aromatic Hydrocarbon Conversion through Catalytic Converters Significantly Reduces Secondary Organic Aerosol Formation from Wood Burning Emissions
Publication type	Presentation
Introduction & Background	Residential wood burning is often reputed as a climate-neutral heating method due to its renewable nature and the emission of biogenic CO2 formed from carbon recently accumulated by plants. However, residential wood burning performed under non-ideal burning conditions is a known and significant source of primary particulate matter (PM) and volatile organic compounds (VOCs) impacting air quality and human health. In addition to primary PM emissions, secondary organic aerosol particles (SOA), formed from the transformation of reactive precursors in the atmosphere, is significant. Compounds emitted during non-ideal wood burning include toxic carbon monoxide (CO), as well as harmful aromatic, oxygenated aromatic and polycyclic aromatic hydrocarbons (denoted as ArHC). Those have been identified also as important SOA precursors in combustion emissions, due to their high reactivity towards the hydroxyl radical (OH), and the formation of low volatility compounds upon only few OH radical interactions. ArHC oxidation products condense into the particle phase rapidly under typical atmospheric conditions. Additionally, incomplete wood burning leads to methane (CH4) emission. CH4, while having only limited relevance as SOA precursor, has a significant global warming potential and is a critical greenhouse gas to be mitigated. Primary wood burning emissions (PM, CO and VOCs including CH4) can be reduced by improving burner technology or burner operation. However, changing from log wood to potentially cleaner wood chip or pellet operation can be costly and strongly depends on feedstock availability. Moreover, changing operating procedures and switching to automated operating systems requires educational outreach or incentives. It is important to note that cleaner burning technologies and procedures do not reduce the emissions to close-to-zero levels and secondary pollutant abatement strategies may become necessary in the future. Mechanical measures such as electrostatic precipitators may reduce primary PM, however, catalytic conversion is required for efficient CO and VOC removal, and the associated abatement of SOA. Catalytic converters have been studied in lab scale applications or in pilot studies. Their application remains challenging and scientific studies to highlight their performances are at need.
Methodology	In this work, we study the clean-up of a model gas feed (including CO, VOCs and CH4) and complex log wood burning emissions using Pt-based honeycomb catalytic converters (Pt/Al2O3 and Pt/CeO2-Al2O3). We prepare the catalytic material as powder and subsequently coat honeycomb monoliths for our experiments. The non-methane VOCs emitted from log wood burning and their conversion rates upon catalytic treatment at simulated exhaust temperatures of 150 to 600°C are characterized using proton-transfer-reaction mass spectrometry. Further, we evaluate the effect of the catalytic converters on the SOA formation potential of the emissions using an oxidation flow reactor, and monitoring the sub-micron organic particulate matter using an Aerodyne Aerosol Mass Spectrometer.
Results & Conclusions	In this work, we demonstrate significant emissions and SOA formation reduction from model gas feed (including CO, VOCs and CH4) and complex log wood burning emissions using Pt-based honeycomb catalytic converters (Pt/Al2O3 and Pt/CeO2-Al2O3). We link the reduced SOA formation to the effective removal of critical SOA precursors, such as naphthalene, phenol and benzene.

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Publication title	Vehicles are a Major source of Atmospheric Sub-3nm Particles
Publication type	Presentation
Introduction & Background	Vehicle traffic emits significant amounts of primary particles, semivolatile compounds contributing the amount and properties of particles in diluted exhaust, and secondary aerosol precursor gases. Exhaust particles emitted by traffic have relatively complicated physical and chemical characteristics and they cover a large particle size range. Several studies have shown that the traffic originated particles affect air quality and human health in urban areas. Here we present a new observation that the traffic emits significantly the nanocluster aerosol (NCA), i.e., the particles in a size range of 1.3–3.0 nm (Rönkkö et al., PNAS,114 (29), pp. 7549-7554), and extend the NCA emission characterization to real-world emission measurements of city buses with different exhaust after-treatment systems (Järvinen et al., submitted to ES&T).
Methodology	The study consisted of stationary measurements at the roadside of a main road in a semiurban area, stationary measurements in a street canyon environment, a long-distance on-road experiment through the Western Europe and on-road experiments for real-world emissions of city buses using a mobile aerosol laboratory. These atmospheric measurements were fulfilled by experiments in engine laboratory where the particle emissions of a modern heavy-duty diesel engine equipped with a DOC, DPF and SCR were studied at three engine load conditions. In the engine experiments, the exhaust was sampled using a partial flow sampling and dilution system shown to reproduce the real-world exhaust nanoparticle formation. In all the experiments, the NCA measurements were performed using combinations of Particle Size Magnifier (PSM, Airmodus Oy) and CPCs. CO2 concentrations were measured parallel with the NCA measurements in order to determine the emission factors of the NCA. NCA measurements were reinforced e.g. by DMPS, SMPS and ELPI.
Results & Conclusions	In stationary measurements conducted in roadside environments, the NCA concentration depended significantly on the wind direction; when the wind was blowing from the road toward the monitoring station, the NCA concentrations exceeded 10^5 cm^(-3) in the semiurban environment and 10^4 cm^(-3) in the street canyon environment. In the semiurban roadside environment, the NCA represented 20–54% of the total particle concentration in ambient air. The NCA concentrations correlated with simultaneously measured CO2 concentrations, indicating that the NCA was originated from combustion. Engine laboratory experiments supported this observation; especially at high engine load the NCA had a significant contribution to the total particle number concentration of the exhaust sample. When determined from ambient air measurements, the NCA emission factors of traffic varied from 2.4·10^15 / kg of fuel to 2.9·10^15 / kg of fuel, while in engine experiments they varied from 1.6·10^12 / kg of fuel at 50% engine load to 4.3·10^15 / kg of fuel at 100% engine load. Real-world NCA emission emissions of city buses depended on driving situations and emission reduction technologies. In general, this study showed that a significant fraction of particle number of urban ambient air belonged to the particle size range of 1.3–3.0 nm, and this NCA was largely emitted by traffic. The NCA emissions directly affect particle concentrations and human exposure to nanosized aerosol in urban areas.

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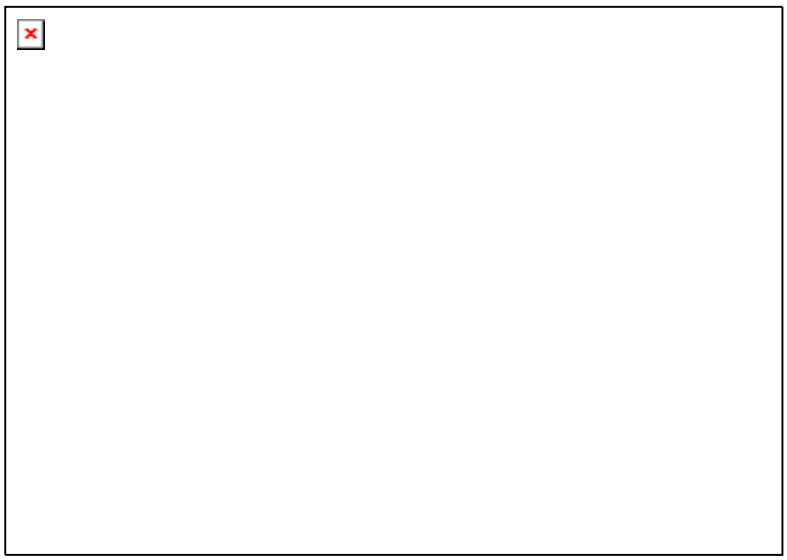
Publication title	An Electrical Detector for Particle Counting below 23 nm
Publication type	Poster
Introduction & Background	Current particle number emission limits for vehicles in the European Union are based on the PMP protocol, which prescribes a 50% counting efficiency cutoff (d50) of 23nm. Smaller particles are not counted. In recent years, such smaller particles have received more interest; in particular, three different EU projects are investigating techniques to measure solid particle number for diameters down to 10 nm. The background of this development is the realization that the sub-23 nm fraction also contains solid particles that may be relevant for human health.
Methodology	Within the EU-funded SUREAL 23 project, we have modified an existing electrical particle number detector, the automotive partector by naneos (AP). This device was originally designed for a 23 nm cutoff. The instrument response of the AP can be tuned by adjusting various parameters, and we have optimized these parameters to achieve a d50 of 11nm. Lowering d50 comes at the price of an overall lower instrument response (by about a factor 2); so we also modified the AP that it can operate at high temperatures (up to 150°C), and call it the HAP (heated automotive partector). The high temperature operation reduces the requirements for dilution of the exhaust gas. In a previous application in a PN-PEMS system, the AP is being used with a 1:10 dilution, but the high temperature will allow a reduction to at least 1:5 (keeping total signal constant) or maybe even undiluted operation.
Results & Conclusions	The HAP prototypes were calibrated with monodisperse soot aerosol. The counting efficiency for monodisperse particles is close to that of a hypothetical 10nm CPC; with a small overshoot of the efficiency at small diametes (see figure 1). The performance for monodisperse aerosols is not really relevant in reality, as engine exhaust will always be polydisperse. Simulating the reponse of the HAP to a lognormal size distribution shows that features in the monodisperse counting efficiency are smeared out (figure 2). The two prototypes show d50 cutoffs of 11 and 14nm. We have successfully designed and built 2 prototypes of electrical particle counters with a d50 cutoff very close to 10nm, demonstrating that electrical particle counting also remains a viable alternative to CPCs even for very low particle sizes. Thanks to the high-temperature capability, operation at very low or even no dilution should be possible.
Caption Figure 1:	Measured counting efficiency of two HAP prototypes for monodisperse soot particles compared to a hypothetical 10nm CPC

Caption Figure 2:



Simulated counting efficiency of two HAP prototypes for lognormal size distribution

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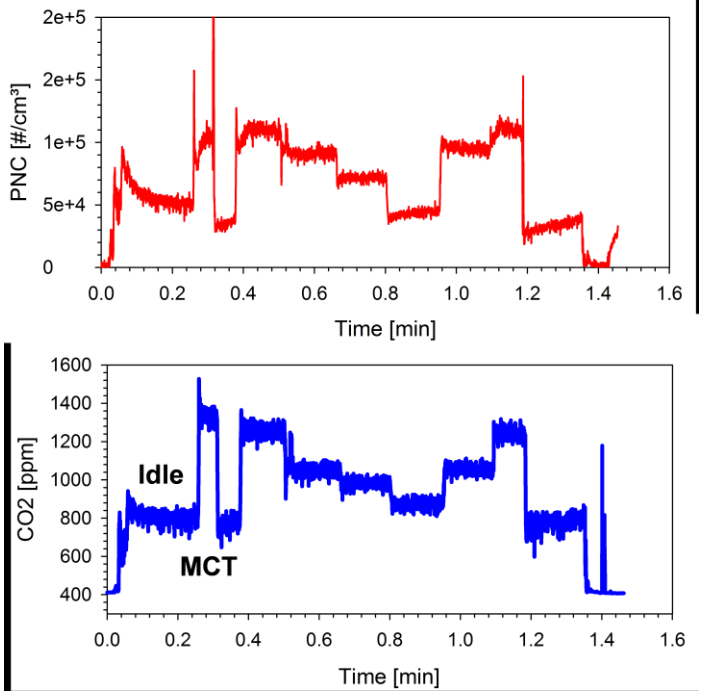
Publication title	Ground Measurements on Aircraft Exhaust for a Series of Alternative Jet Fuels during the ECLIF and ND-MAX Campaign
Publication type	Presentation
Introduction & Background	Understanding the impact of fuel parameters on the soot formation is an important aspect in exposure reduction, contrail avoidance and fuel design. Recognizing the connections between these parameters requires lab experiments but also sophisticated field studies. In the latter case, ground measurements allow a precise determination of the emission due to the non-moving source. However, they have to be accompanied by flight measurements since the environmental conditions at ground are not necessarily transferable to cruise conditions. Within the framework of the campaigns Emissions and CLimate Impact of alternative Fuels (ECLIF) and NASA/DLR-Multidisciplinary Airborne Experiment (ND-MAX), several ground measurements were accompanied by inflight chase measurements. Fuel blends of different aromatic content and composition of aromatics were selected for these campaigns. This contribution focuses on the ground measurement results of the most recent campaign ND-MAX in 2018 and describes the observed changes in soot emission.
Methodology	The ND-MAX campaign was performed in 2018 at the Ramstein Air Base in Germany. The DLR Airbus A320-232 "D-ATRA" with V2527 engines was operated with 2 reference Jet A-1 and 3 sustainable alternative jet fuels (SAJF1-3). The exhaust was characterized with a series of different particle counters (EEPS, SMPS, stand-alone CPC, etc.) and combustion gas monitors (FT-IR, NOx monitor). The aircraft was operated at 5 different power settings ranging from idle (23% N1 fan speed) to maximum continuous thrust (approx. 80% N1 fan speed).
Results & Conclusions	The ground measurements allowed the determination of the exhaust composition at high precision (see Fig. 1). A reduction in particle emission in the range of 40% can be observed from the highest emitting reference fuel to the alternative jet fuel with highest hydrogen content. The difference is negligible at MCT conditions. With regard to combustion gases, no significant difference between the fuels could be observed. Even though SAJF1 (9%) featured a lower aromatic content than SAJF2 (10.1%), the soot emission was higher in case of SAJF1. This is in good alignment with results from the previous ECLIF campaign (2015) which showed a non-strict trend between aromatic content and soot emission but good correlation for H/C ration and particle mass emission.

Caption Figure 1:



Development of the particle number concentration (5-560 nm; EEPS) and the carbon dioxide concentration during the test cycle of SAJF1.

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Publication title	A New Portable Test Instrument for the Reliable Measurement of Particle Number Emissions from Combustion Engines During Periodic Technical Inspection
Publication type	Presentation
Introduction & Background	Diesel vehicles with a working particulate filter (DPF) reduce particle emissions by more than 99% while those vehicles without a particulate filter emit high numbers of particles. The emitted particles are in the nanometer size range from 10-500 nm and are considered to cause adverse health effects as they can penetrate deep into the lung. The Particulate Measurement Programme (PMP) first introduced particle number (PN) measurements that resulted in amendments to UNECE Regulation No. 83. Since September 2011, the Euro 5B and later Euro 6 standards require a PN limit of 6×1011 particles/km for type approval of all new light-duty diesel vehicles [1]. The corresponding measurements of the PN emissions are exclusively done with condensation particle counters (CPC). Experience has shown that emission after-treatment systems can fail due to aging, poor maintenance, poisoning or manipulation. In addition, the recent awareness about discrepancies between laboratory testing of emissions over a drive cycle and real-world in-use measurements are furthering the need for a periodic technical inspection (PTI). While PTI is mandatory in many European countries, current PTI test procedures as specified in UNECE Regulation 24 for the free acceleration smoke emission test for LD and HD diesel vehicles are too insensitive to detect DPF failures in the latest generations of vehicles. Recently, Switzerland pioneered using portable PN instruments for periodic control of off-road construction machinery [2].
Methodology	Implementing a reliable measurement of the PN emission for PTI purposes requires the availability of a suitable, proven device and a well-defined test procedure. The device itself needs to be sensitive to nanoparticle number concentrations, portable, rugged, and affordably priced. Details of the PTI-PN test procedures as well as instrument performance requirements are currently under discussion. Building on the experience with the NPET instrument developed for the Swiss Ordinance SR 941.242, TSI Inc. developed a battery-operated PN emission tester capable of rapidly assessing the performance of DPFs during periodic inspection. The PTI-PN tester is a light-weight, mobile device that incorporates 20:1 dry dilution and true single particle counting using the same proven CPC technology already adopted for UNECE Regulation No. 83 emission testing. The device's measurement probe can be directly attached to the tailpipe and the operator is guided through the measurement process step-by-step by a graphical touch screen interface. The measurement test cycle and threshold is currently user-configurable to support the development of the PTI-PN test procedure. Measurement results are available instantly and backed up in internal memory.
Results & Conclusions	Counting particles with a CPC is the only direct and highly accurate method to measure PN emissions. In fact this technique requires no assumptions and is supported by a traceable calibration as outlined in ISO 27891:2015. While other technologies have been adopted to arrive at PN values, CPC measurements are the only method that has been used for type approval testing around the world for more than 5 years as well as for field emissions tests in Switzerland. We will report on recent advances towards a unified PTI test procedure, introduce further details of TSI's PTI-PN instrument, and present data of recent measurement campaigns.

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Publication title	Verification of NPTI-Instruments for Diesel and Petrol Vehicles – first Results
Publication type	Presentation

Abstract

Diesel particulate filters (DPFs) are very efficient proxy to reduce particle emissions from diesel vehicles exhaust. Recent studies conducted in the Netherlands and Switzerland have shown that approximately 10 % of Euro 5 and Euro 6 passenger cars the DPF was removed or malfunctioning resulting in higher particle emissions than otherwise expected. In the current roadworthiness test procedure an opacity test (measurement of black smoke by the principle of light absorption) is performed as part of the evaluation performance of the vehicle emissions. However, due to the high limit of detection of these instruments, DPF failures are difficult to be identify using this technique. As part of the evaluation of an alternative procedure to assess the condition of DPFs, seven different particle counting instruments, including some prototypes, were compared against the Particulate Measurement Programme (PMP) method during an intercomparison campaign performed at the European Commission Joint Research Centre. The instruments were used on a series of Euro 6 diesel and petrol passenger cars. They measured volumetric concentration of particles (volatile and/or solid) from the tested vehicles' raw exhaust during low idle operation. A partial bypass was applied to one of the tested diesel vehicle to allow investigating the performance of the instruments at different particle concentrations, from very low levels (below 1000 # cm^{-3}) up to 10^6 # cm^{-3}. Most of the studied instruments were able distinguish between a vehicle that would present PN emissions factors slightly below diesel Euro 6 PN emission limits (6×10^{11} # km^{-1}) and a tampered vehicle that presented a PN emission factor above 10^{12} # km^{-1}. While the PMP method remove the volatile fraction of the measured sample and limits the size to particles >23nm, some of the instruments do not remove volatile particle or measured particles smaller than 23nm. As consequence, the PN concentrations measured by these instruments during low idle operation were substantially higher than the ones measured using the PMP method. Finally, the experimental campaign helped endorsing that DPF condition can be assessed during low idle operation.

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Publication title	**The New World of Omics in Environmental Epidemiology**
Publication type	Presentation
Introduction & Background	The identification of hazardous environmental pollutants is complex, particularly in relation to chronic, non-communicable diseases. The main contributors to this complexity are the diversity of hazards that may exist, the typically low levels of environmental contaminants/pollutants, long latency periods, and largely unknown modes of action. The unravelling of environmental causes of disease is also limited by the technical difficulties in defining, and accurately measuring exposures, and by considerable spatial, temporal, and intra-individual variation. The complex and partially unknown interaction with underlying genetic and other factors that modulate susceptibility and response to environmental exposures further complicates the process of delineating and understanding environmental hazards. I will show examples from recent projects in the field.
Methodology	To address such difficulties, the concept of the “exposome” was proposed, initially by Wild [2005], with more recent detailed development in relation to its application to population-based studies [Wild, 2012]. The original concept was expanded by others, particularly Rappaport and Smith [2010] who functionalized the exposome in terms of chemicals detectable in biospecimens. The exposome concept refers to the totality of exposures from a variety of sources including, but not limited to, chemical agents, biological agents, radiation, and psychosocial component from conception onward, over a complete lifetime, and offers a conceptual leap in studying the role of the environment in human disease [Rappaport and Smith, 2010; Wild, 2012; Vineis et al, 2017].
Results & Conclusions	I will show examples from recent projects in the field.

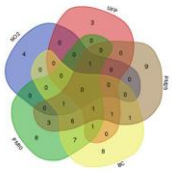

Figure 1: (A) The figure shows the overlap as well as the specificity of the pollutant-specific circulating miRNAs associated with exposure to NO2, UFP, PM2.5, BC and PM10 of subjects in Hyde Park and Oxford Street. Krauskopf et al, 2017

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Publication title	THE SUREAL-23 PROJECT: Understanding and Measuring sub-23 nm Particle Emissions from Direct Injection Engines Including Real Driving Conditions
Publication type	Presentation
Introduction & Background	One of the problems identified with the standard sampling procedures of the total emitted particle number from direct injection engines, both Diesel and GDI, is the potential formation of particles in the sub-23 nm region, the so-called artefacts, despite the dilution applied, by pyrolysis of hydrocarbon-derived precursors and sulfuric acid re-nucleation (Swanson and Kittelson, 2010). Since current regulation limits measured particles from 23 nm and above, this does not affect the compliance-relevant PM concentrations. Difficulties in introducing a robust measurement protocol in this particle size range of currently available technologies led regulation authorities to ignore their contribution to ambient pollution. Fushimi et al. (2011) report that particles in the 10-30 nm size range, regarding composition, may be solid (amorphous or graphitised carbon, metals etc) or liquid (hydrocarbons and sulphur species). In light of the changing engine technology landscape and the focus on vehicle emissions, mainly due to evolution in engine and exhaust after-treatment technology, the need to measure below the currently enforced 23 nm cut-off in particle size is now well established. Further, better measurement and understanding of these sub-23 nm exhaust particles will also benefit fuel, IC engine and emission control development efforts.
Methodology	SUREAL-23 is an EU-funded project that endeavours to investigate in detail the sub-23 nm solid particles emitted by direct injection engines. Starting from October 2016, SUREAL-23 is hosting numerous efforts to: • Develop new instrumentation to complement standard PMP and extend the available analytical toolset, by providing transient PN measurement as well as size and composition classification specifically for the sub-23 nm size region, while pursuing the reduction/elimination of requirements for exhaust sample conditioning by applying high-temperature operation instruments. • Provide a simple and robust exhaust aerosol sample treatment with increased volatile material removal efficiency and minimal particle losses. • Investigate the effect of different diesel and gasoline engine operating conditions (fuel additives, bio-content, gas fuel addition, after-treatment type and operation, etc.) on sub-23 nm particle emissions • Integrate the most suitable components of the proposed developments of sub-23 nm measurement into PEMS and verify their measurement capability in real driving conditions.
Results & Conclusions	An overview of developments achieved in the EU-funded project SUREAL-23 for the robust measurement of sub-23 nm vehicle emitted particles are presented. In particular we show two advanced measurement methods: a HM-DMA able to classify exhaust particles with high efficiency in the 1-30 nm size range at elevated temperatures (~180 °C) and an advanced charge-based particle counter (ICAD) with a reduced cut-off size at 15 nm and capable of operation at up to 150 °C. Following the instrumentation development, the effect of different diesel and gasoline engine operating conditions will be elucidated and, more specifically, studies will be performed on the effect of fuel additives, bio-fuel content, gas fuel addition and after-treatment devices on sub-23 nm particle emissions. Finally, the most suitable components of the extended sub-23 nm measurement toolset will be integrated into PEMS and particle emissions under real driving conditions and their performance will be examined.

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Publication title	Roadside and Riverside Measurement of PM/PN Emissions from Individual Vehicles and Ships in Prague
Publication type	Presentation
Introduction & Background	Despite the fleet-wide deployment of diesel particle filters on major categories of vehicles, ultrafine particles emitted by internal combustion engines represent one of the major environmental problems in most (not only) European cities. High emitters, vehicles with elevated emission levels due to malfunction, miscalibration, tampering or excessive wear, are responsible for significant share of the total fleet emissions, and repair or removal from service of high emitters may be a relatively fast and relatively inexpensive way to improve our air quality. Remote sensing employing open-path absorption spectroscopy, traditionally used to detect high emitters, is not very sensitive to nanoparticles which are much smaller than the wavelength of visible or even UV light. This work explores the sampling approach, where air sampled in the proximity of the operating engine is analyzed by fast-response instruments, to provide at least approximate emissions factors expressed per kg of fuel.
Methodology	Several fast-response instruments were assembled in a support van: An electric mobility particle sizer to monitor particle size distributions, a portable non-volatile particle counter, a photoacoustic black soot monitor to monitor elemental carbon composition, and a Fourier transform infra-red analyzer yielding spectra that were analyzed for concentrations of CO2, CO and NO. Fuel-specific emissions factors were obtained by rationing concentrations of the pollutant of interest to CO2 (or CO and CO2). The sample was taking from a location where there was a reasonable expectation of engine operating at moderate load and of individual vehicles passing relatively close one after another. For measurement of emissions from river boats, the instruments were sampling air near the surface of water at the exit from a lock. For measurement of buses, the sampling was done at the exit from a small bus terminal near a metro station. For general vehicle fleet, sample was taken at two on-ramps featuring a small incline and a sharp curve.
Results & Conclusions	The results suggest that the sampling approach allows for emissions from individual vehicles to be discerned and assessed at a success rate on the order of tens of percent, depending on the conditions. Particles not concurrent with a readily detectable CO2 peak were excluded as non-combustion particles. Simultaneous measurement by multiple instruments allows for discerning of the possible cause of high particle concentrations, including filter regeneration, operation of diesel engine with excess fuel, and poor fuel or oil combustion. Due to the widespread practice of fuel enrichment of EU gasoline engines, a practice prohibited in the U.S., it is not clear to what extent the approach can be used on gasoline engines. Overall, the sampling approach appears to exhibit a reasonable potential to detect high emissions of nanoparticles when used in a similar fashion as remote sensing devices.

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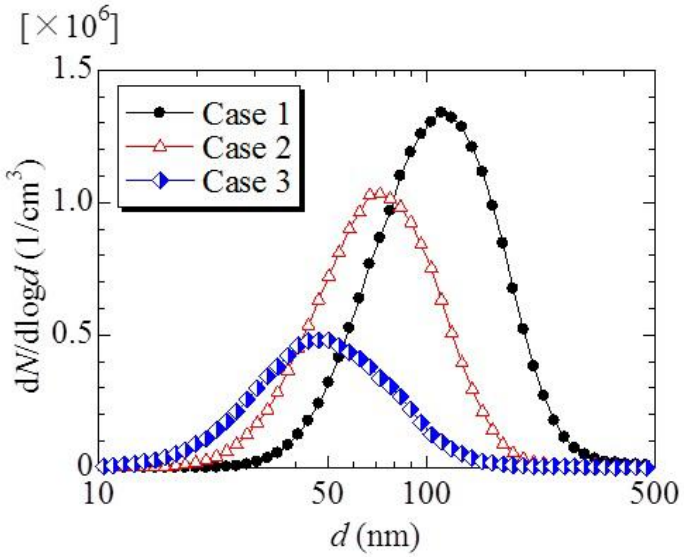
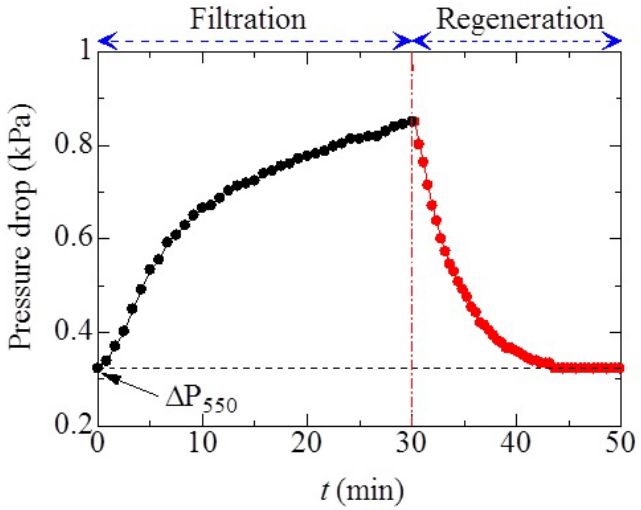
Publication title	Pressure Response during Filtration and Oxidation in Diesel Particulate Filter
Publication type	Presentation
Introduction & Background	Combustion-generated soot particles that arise from diesel vehicles are known to cause substantial damages to the environment as well as to human health. A diesel particulate filter (DPF), which is a porous ceramic, is needed to trap nanoparticles in the exhaust after-treatment. Since the filter would be clogged by collected particles with a rise of the filter backpressure (pressure drop), resulting in subsequent worsening of fuel efficiency and a decrease in the engine output. For this reason, a filter regeneration process is required, by which an incineration step is conducted to oxidize and remove deposited particles. For the efficient filter regeneration process with less fuel usage, we need to evaluate the pressure response during the filtration and the filter regeneration. However, it is difficult to discuss these processes, because characteristics of real emitted particles depend on fuel properties, the exhaust gas component, and engine conditions.
Methodology	In the present study, using carbon particles as model soot, we evaluated the filtration and regeneration performances of SiC-DPF. Especially, particles with different size distributions were tested. The carbon particle generator of DNP-2000(Palas GmbH, Germany) was used. Figure 1 shows the size distribution of carbon particles used in experiments. Three different size distributions were considered. The condition of the maximum concentration capable of the carbon particle generator was Case 1, where the peak diameter in the size distribution was 111 nm. In Case 2, the peak diameter was 72 nm. To consider the mimic gasoline particulate, the peak diameter was set to be 47 nm in Case 3. The total number concentrations in three cases were 2.1 × 10^7, 1.6 × 10^7, 8.1 × 10^6, respectively. The mass of carbon particles deposited in the DPF, m, was obtained by the direct weight measurement with an electronic balance.
Results & Conclusions	Results show that, independent of the particle size, the pressure drop raised by the particle deposition almost exhibits the same dependence on the deposited particle mass. In the filter regeneration process, CO and CO2 concentrations initially increase with the lapse of time, reach the maximum, and then decrease gradually. The decreasing rate in the pressure drop is the largest in Case 3 of the smallest particle distribution, followed in order by Cases 2 and 1. Since the particle density in Case 3 is the lowest, it is derived that the sparse deposition layer composing of smaller particles is oxidized more easily, resulting in the shorter period of the filter regeneration. Figure 2 shows the relationship between the mass of carbon particles and the pressure drop during the filtration or the oxidation of carbon particles. By comparing the variation of the pressure drop, the dependence of the pressure drop on the deposited particle mass is quite different, showing the hysteresis in the transition of the pressure drop. This information is indispensable to predict the filter regeneration rate based on the pressure drop.

Caption Figure 1:



Particle size distribution in Cases 1 to 3.

Caption Figure 2:



Relationship between mass of carbon particles and pressure drop during filtration and regeneration.