Poster Abstracts

24th ETH-Conference on Combustion Generated Nanoparticles

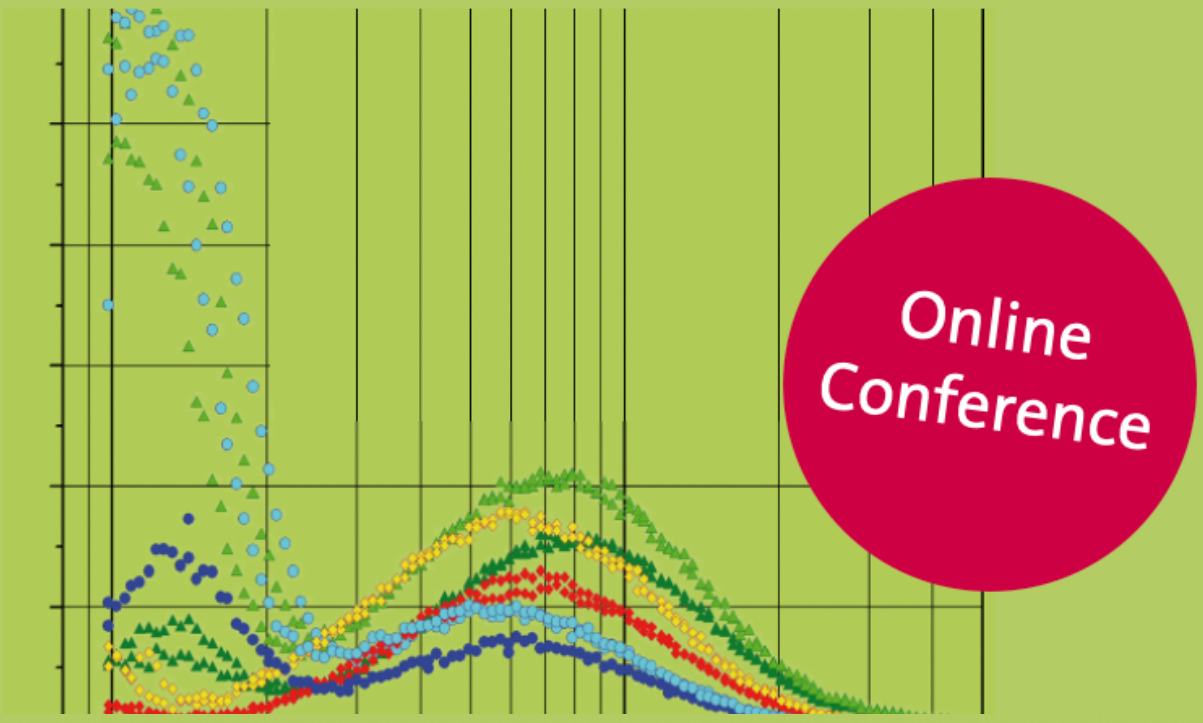
June 22 - 24, 2021, online conference

Focus Event: Combustion and Climate Change

Scope

The conference served as an interdisciplinary platform for expert discussions on all aspects of nanoparticles, freshly emitted from various sources, aged in ambient air, the impact of particles on health, environment and climate, technical mitigation and legislation. The conference briought together representatives from research, industry and legislation.

ETH zürich



SCS
Swiss Chemical Society

Elemental and ionic analysis of aircraft engine smoke number filter samples with micro-PIXE and IC

K. Saitoh[1,2], A. Fushimi[2], S. Matsuyama[3], M. Miwa[3], S. Toyama[3], Y. Kikuchi[3], L. Durdina[4], J. G. Anet[4], N. Takegawa[5]

[1]Environmental Science Analysis & Research Laboratory, Japan, [2]National Institute for Environmental Studies, Japan, [3]Department of Quantum Science and Energy Engineering, Tohoku University, [4]School of Engineering, Zurich University of Applied Sciences, [5]Department of Chemistry, Graduate School of Science, Tokyo Metropolitan University

Abstract

Smoke number (SN) is the measure of exhaust plume visibility of a jet engine, which correlates with non-volatile PM mass concentration in the exhaust. Usually, SN filter samples have not been used for any quantitative analysis of PM on the filter. Here, we have attempted to extract information on elemental composition and ionic species components and PM characteristics from the SN filters using elemental analysis by micro-PIXE and ion component analysis by ion chromatography. The SN filter samples were collected from in-service commercial aircraft turbine engines in the test cell at SR Technics, Zurich airport in 2019 and 2020. The elemental composition analyses of the SN filter samples were carried out using two X-ray Si(Li) detectors microbeam PIXE system at Tohoku University. Ionic species in the SN filter samples were determined using an ion chromatography.

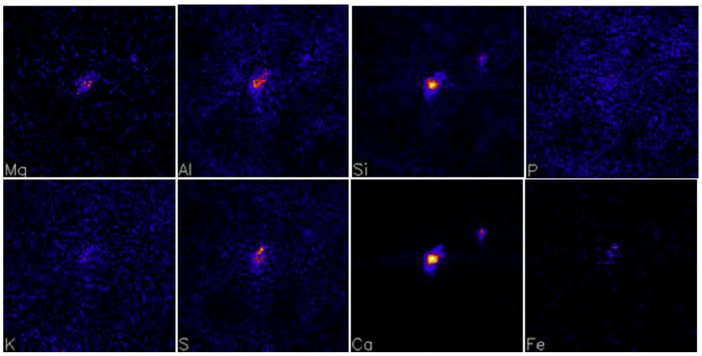


Figure 1 Elemental map of a gray-colored filter, analytical scanning area: 100 × 100 μm.

Particles formed from Mg, Al, Si, P, K, S, Ca and Fe have been confirmed from a gray- colored filter (high soot loading at high engine thrust) (Figure 1). In addition, some particles composed mainly of S and Ti have been found. For the elemental compositions, Na, Mg, Al, Si, Cl and Ca are major elements in a gray-colored filter. These elements make up 90% of the total mass of the measured elements. Although the concentration levels are different, major ionic species are F–, Cl–, Na+, K+ and Ca2+ in both the gray filter and the white filter (low loading at low engine thrust).

Acknowledgements
This work was supported by the Environment Research and Technology Development Fund (JPMEERF20205004) of the Ministry of the Environment, Japan. The work of the Swiss team was funded by the Swiss Federal Office of Civil Aviation (FOCA) projects AGEAIR SFLV 2017-030 and AGEAIR 2 SFLV 2018-048.

Organic analysis of aircraft engine smoke number filter samples with thermal-optical carbon analysis and thermal desorption–gas chromatography/mass spectrometry

A. Fushimi[1], K. Saitoh[2,1], L. Durdina[3], J. G. Anet[3], J. Edebeli[3], C. Spirig[3], Y. Fujitani[1], N. Takegawa[4]*

[1]National Institute for Environmental Studies, Japan, [2]Environmental Science Analysis & Research Laboratory, Japan, [3]Zurich University of Applied Sciences, Switzerland, [4]Tokyo Metropolitan University, Japan

From atmospheric measurement near an airport runway [1], we have recently found that jet engine lubrication oil [2] is a key component of aircraft exhaust nanoparticles [3]. However, it is uncertain where oil nanoparticles are emitted or formed in aircraft jet engine exhaust. In this study, we aimed to examine the organic composition of jet engine exhaust bulk particulate matter (PM) collected with a smoke meter, especially to see whether those PM samples have lubrication oil signature. The smoke number (SN) paper filter samples, collected at SR Technics, Zürich Airport, Switzerland in 2019–2020, were used. From carbon analysis, the volatile organic carbon (OC) concentrations (μgC cm^{-2}-filter) in the gray-colored SN filter samples were very low but significantly higher than the blank filters. The roughly estimated volatile OC concentrations in the undiluted exhaust was 1,200 μgC m^{-3} for the gray-colored samples. In the chromatograms of thermal-desorption gas chromatography/mass spectrometry (TD-GC/MS), oil marker compounds (tricresyl phosphate and likely fatty acid esters of pentaerythritol) were clearly and consistently detected from the gray-colored samples, and were not detected from the blank filters (Fig. 1). The mass spectra of the oil marker compounds in the gray-colored samples matched well with those of the jet engine lubrication oil. From the gray-colored samples, strong signals of C_{24}–C_{30} *n*-alkanes and some polycyclic aromatic hydrocarbons (PAHs) were also detected.

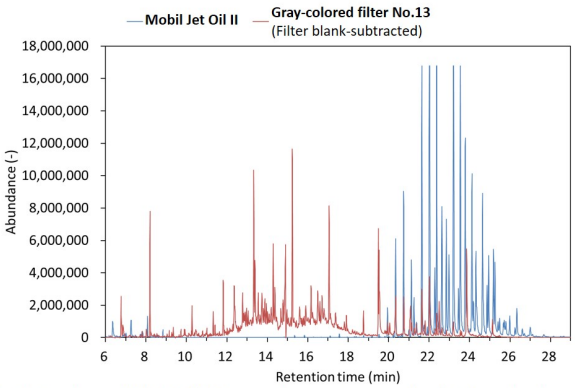


Fig. 1 Overlapped TD-GC/MS mass chromatograms (*m/z* 85: major ions of hydrocarbons) of the gray-colored SN filter sample and jet engine lubrication oil.

This work was supported by the Environment Research and Technology Development Fund (JPMEERF20205004) of the Ministry of the Environment, Japan, the NIES Research Funding (Type B), and the Scientific Exchanges grant of Swiss National Science Foundation (IZSEZ0_198063). The work of the Swiss team was funded by the Swiss Federal Office of Civil Aviation (FOCA) projects AGEAIR SFLV 2017-030 and AGEAIR 2 SFLV 2018-048.

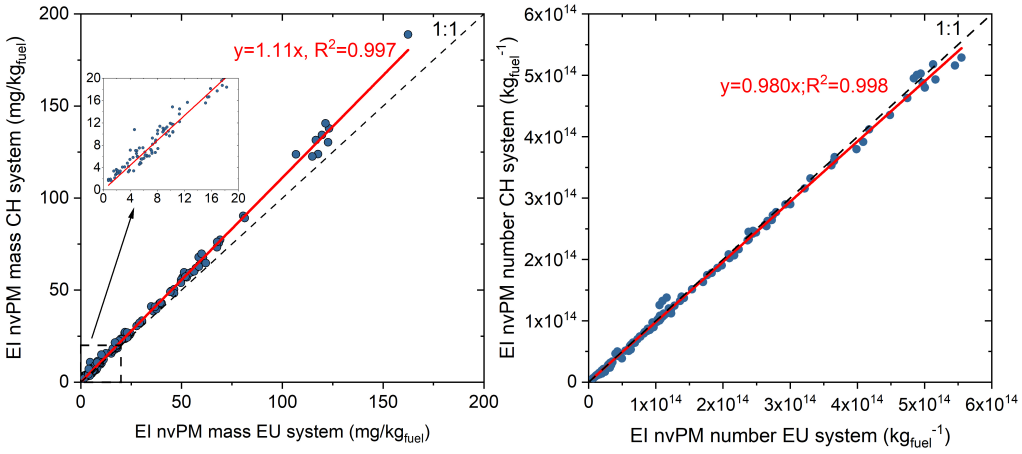
[1] Takegawa, N., Murashima, Y., Fushimi, A., Misawa, K., Fujitani, Y., Saitoh, K., Sakurai, H., *Atmos Chem Phys*, **2021**, 21, 1085-1104. [2] Saitoh K., Fushimi A., Sera K., Takegawa N., *Int J PIXE*, **2018**, 28, 85-92. [3] Fushimi A., Saitoh K., Fujitani Y., Takegawa N., *Atmos Chem Phys*, **2019**, 19, 6389-6399.

Intercomparison of two reference sampling and measurement systems for aircraft engine non-volatile PM using a small-scale RQL combustor rig burning conventional and sustainable aviation fuels

L. Durdina[1], E. Durand[2], C. Spirig[1], A. Magno[1], J. G. Anet[1], A. Crayford[2]*

[1]Zurich University of Applied Sciences, Switzerland, [2]School of Engineering, Cardiff University, Cardiff, UK

Aircraft gas turbine engines directly emit non-volatile PM (nvPM) with electrical mobility diameters mostly below 100 nm, affecting local air quality and the climate. To mitigate nvPM pollution, the International Civil Aviation Organization (ICAO) has introduced certification standards for nvPM mass and number emissions of aircraft turbine engines with rated thrust above 26.7 kN. However, further work is needed to characterise and reduce nvPM emissions measurement uncertainty and particle loss correction to provide better estimations of engine exit concentrations for airport emission inventories. As a part of the first campaign of the Horizon 2020 funded project RAPTOR, two nvPM reference sampling and measurement systems (Swiss and EU) were operated in parallel and sampled exhaust from a small-scale aero-engine rich-burn quick-quench lean-burn (RQL) combustor rig burning a range of conventional and sustainable aviation fuels at multiple rig operating conditions. Additional particle size measurements were performed using a TSI SMPS with a catalytic stripper in the Swiss system and a Cambustion DMS-500 fast spectrometer in the EU system.



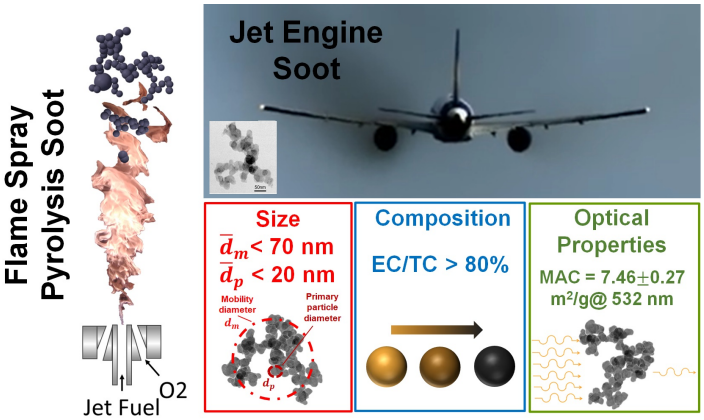
The preliminary results of this study show good agreement between the two systems for the nvPM number and mass emission indices (EIs). At low nvPM mass concentrations, larger discrepancies were observed between the two systems because of the shedding of particles accumulated in the PM1 cyclones installed in each system. At specific rig conditions, the RQL combustor produced bi-modal particle size distributions with no volatile fraction which were similarly captured by both the SMPS and the DMS-500. It was found that the standardised particle loss correction methodology (only requiring measured nvPM mass and number) was inaccurate when particle size distributions were bi-modal and or low nvPM mass concentration when compared with particle loss correction estimated using measured particle size distributions. This study will lead to a better understanding of the uncertainties of the regulatory nvPM data and supply data to improve the measurement methodology and more accurate prediction of aircraft engine nvPM emissions released into the environment.

Morphology, Composition and Optical Properties of Jet Engine-like Soot Made by Flame Spray Pyrolysis

J. P. Scott[1], R. Kholghy[1]*

[1]Carleton University

Particulate matter soot emissions from aviation is a major source of anthropogenic pollution at high altitudes. Reference soot is needed for calibration of realtime optical instruments used for regulatory measurements of non-volatile PM (nvPM) from jet engines that have average mobility, d_m, and primary particle, d_p, diameters less than 70 and 20 nm, respectively with mass mobility exponent (D_{fm}) of 2.5, elemental to total carbon ratios (EC/TC) larger than 0.8 and mass absorption cross section (MAC) of 7.46 m^2/g at 532 nm. Such soot agglomerates are difficult to make with current gas-fueled soot generators that use laminar flames where agglomerates experience high-temperature particle residence times that are quite different from those of jet engine combustors. Here flame spray pyrolysis (FSP) is used to generate soot agglomerates from turbulent flames made by spraying liquid jet fuel. The d_m of FSP made soot agglomerates is systematically modified from less than 13 to more than 91 nm by changing common FSP process parameters while agglomerates maintain EC/TC > 0.8. The FSP made soot with $2.39 < D_{fm} < 2.65$ has effective densities similar to emissions from turbofan and turboshaft engines and MAC = 8.23 and 5.21 m^2/g at 532 and 870 nm, respectively, in excellent agreement with recent measurements for nvPM emissions from jet engine turbines.



Ultrafine particle dispersion modelling at Frankfurt airport and Rhine-Main-Area, Germany

H. Gerwig[1], U. Janicke[2], H. Jacobs[3], W. Schmidt[4], H. Lorentz[4], P. Hellebrandt[5], M. Ketzel[6], K. Wirtz[1]*

[1]German Environment Agency, [2]Janicke Consulting, Environmental Physics, [3]RIU at the University of Cologne, [4]Ingenieurbüro Lohmeyer, [5]MUVEDA, [6]Aarhus University

Air pollutant emissions represent a significant hazard to human health. Mobile measurements of ultrafine particles (UFP) show high variability in time and space in cities (Schneidemesser *et al.*, 2019). In epidemiologic studies it has been difficult to separate negative health effects of UFP from effects of other aerosol fractions (Ohlwein *et al.*, 2018). In recent studies, airports have been identified as a significant source of increased atmospheric UFP number concentrations. There is a need to further understand the airport contribution to ambient near-ground UFP concentration by means of measuring and modelling. In this project (Lorentz *et al.* 2021), total UFP number concentration was estimated using a combination of two well-established small-scale models (LASAT, LASPORT) and a large-scale CTM model (EURAD, MADE) in a 35 km square with centre Frankfurt a. M. airport to model the year 2015.
Emissions were determined for aircraft traffic, road traffic, airport ground services and regional/mesoscale background using standard national and international inventories (HBEFA, ICAO, GRETA) and specific data obtained from the airport. The series of hourly mean apportioned by different source groups were compared to measurements.
The model results suggest that aircraft main engines are the dominant local source of UFP number concentrations (90%), mainly with high contributions from taxiing. Long-time averages of UFP number concentration are dominated by background contributions at locations further away from the airport, while the airport contribution to hourly mean concentrations can be significant even at some distance from the airport. Up to 25% of UFP in the airport surrounding was attributed to airport and aircraft, considering only non-volatile (nv) particles.
The maximum of measured total UFP during three annual cycles occurred in summer. In contrast, modeled background (CTM) showed highest concentrations in winter.
An important aim was to identify shortcomings of current state-of-the-art modelling of UFP in the context of airports. Inconsistent UFP diameter ranges in the applied databases, models and measurements are significant. Also emission databases like the one applied for aircraft engines do not include information on volatile UFP. For future projects, the use of thermo denuders would allow to separately assess volatile and non-volatile UFP.

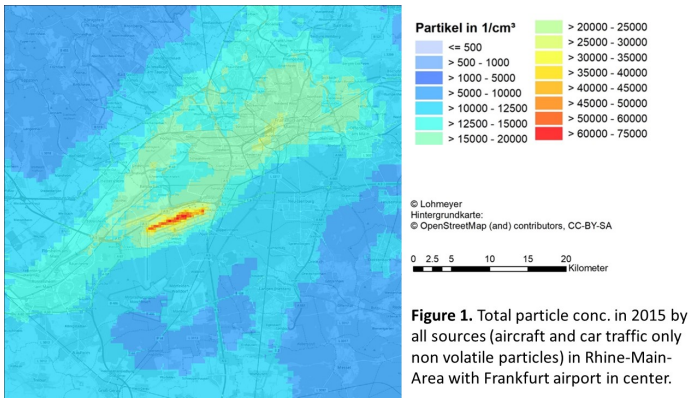


Figure 1. Total particle conc. in 2015 by all sources (aircraft and car traffic only non volatile particles) in Rhine-Main-Area with Frankfurt airport in center.

Helmut Lorentz *et al.* **2021** UBA-Texte 14/2021.
Simone Ohlwein *et al.* **2018** UBA Texte 5/2018.
Erika von Schneidemesser *et al.* **2019**, Sci. Tot. Env., **688**, 691 - 700.

Soot particle ice nucleation ability dependence on their volatile content

K. Gao[1,3], C. Zhou[1]*, H. Koch[2], Z. Kanji[3]*

[1]School of Energy and Power Engineering, Beihang University, Beijing, 100191, China, [2]Bruker Switzerland AG, [3]Department of Environmental Systems Science, Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, 8092, Switzerland

Aviation traffic in the upper troposphere can significantly influence the climate via CO_2 and non-CO_2 emissions. Soot particles, as important non-CO_2 particulate emission, interacting with water vapor in the atmosphere can act as ice nucleating particles (INPs), and are able to impact the aviation contrail evolution and further cirrus clouds formation. The latter has a larger coverage than contrails globally and plays an important role in modulating the Earth's radiative forcing and climate. Therefore, the ice nucleation ability of aviation soot particles is of particular interest.

In this study, the dependence of soot particle ice nucleation ability on volatile content (organics) is investigated at mixed-phase and cirrus cloud conditions. Four types of soot sample can be classified into two classes, first, two types of nonporous propane flame soot used as aviation soot surrogates (Ess and Vasilatou, 2018; Marhaba et al., 2019) and second, two types of porous commercial carbon black with different levels of volatile composition. The results show that thermal denuding at 573 K in a pure N_2 and a compressed air (N_2 + O_2) atmosphere modifies the soot particle ice nucleation abilities in a non-systematic manner between 218 and 233 K. However, the same treatments have pronounced effects on the nonporous propane flame soot particle ice nucleation activities. In particular, our results show that organic carbon removal by thermal denuding in compressed air supresses the ice nucleation ability of organic lean propane flame soot particles at $T < 233$ K. On the other hand, organic rich propane flame soot particles treated at the same conditions have a tendency for an enhanced ice nucleation activity. This is contrary to the previous study that reports organic carbon can considerably supress propane soot particle ice nucleation (Mohler et al., 2005).

In brief, this laboratory study demonstrates that soot particle ice nucleation activities show dependence on particle treatment which potentially affects their properties, inclusion of chemical composition and surface oxidization condition changes, as well as aggregate structure compaction. Thus, transport and ageing in the atmosphere that perturb the chemical properties of soot particle should be considered to accurately reflect ice nucleation activities. The findings about propane flame soot are of significance to evaluate the impacts of aviation emissions and contrail evolution on the climate. In particular, the role of volatile substances like organic carbon coating and its effects on soot particle ice nucleation ability deserve further investigation.

Acknowledgement This work is supported by the Chinese Scholarship Council (Grant No. 201906020041) and the the Experimental Atmospheric Physics Professorship, ETH Zurich.

[1] Ess Michaela, Vasilatou Konstantina, *Aerosol Science and Technology*, **2018**, 53(1), 29-44.
[2] Marhaba Iman, Ferry Daniel, Laffon Carine, Regier Thomas, Ouf François-Xavier, Parent Philippe, *Combustion and Flame*, **2019**, 204, 278-289.
[3] Möhler Ottmar, Linke Claudia, Saathoff Harald, Schnaiter Martin,Wagner Robert, Mangold Alexander, Krämer Martina, Schurath Ulrich, *Meteorologische Zeitschrift*, **2005**,14(4), 477-484.

Detection and quantification of combustion-derived particles in aqueous media: towards the development of a diagnostic biomedical assay

I. Aslam[1], M. B.J. Roeffaers[1]

[1]CMACS, Department M2S, KU Leuven, Celestijnenlaan 200F, 3001 Leuven, Belgium

Abstract:

The detection and quantification of combustion-derived particles (CDPs) such as carbonaceous particulate matter (PM) in biological samples is important to understand their toxicity. Different techniques, such as absorption photometry and laser-induced incandescence, used for measuring CDP concentrations in gaseous environments, cannot be employed for the label-free detection of CDPs in biological samples. Hence, there is a need for the development of diagnostic tools for selective and label-free detection of CDPs to evaluate the exposure at the level of individual persons. Recently, we have shown that CDPs could be detected in biological samples based on non-incandescence-related white light (WL) emission under illumination with femtosecond (fs) pulsed near-infrared (NIR) lasers using a multiphoton microscope.[1-4]

In this work, we study the effects of stirring and concentrations of suspensions on the label-free detection and quantification of particles under illumination with fs pulsed NIR laser. We performed measurements on CDP suspensions with different concentrations in ultrapure water and buffered medium as exemplary conditions for wet biomedical samples. We observe that the number of detected particles increases linearly with the concentration of the suspension. This opens the ways for label-free quantification of CDPs in liquid biopsies.

In addition to CDPs, ambient PM also includes other types of nanoparticles such as silica and metal oxides. This increases the likelihood of interference from other common nanoparticles in the detection of CDPs based on WL emission. In our recent study[5], we could observe that the WL emitted by the CDPs under illumination with fs pulsed NIR lasers is unique and was not observed for other common nanoparticles. Hence, interference from other types of common nanoparticles based on WL emission is not expected when detecting CDPs in aqueous media.

We believe that these results are a step towards the development of diagnostic biomedical assays for direct and label-free detection of CDPs at the level of individual persons.

Keywords: particulate matter, combustion-derived particles, nanoparticles, femtosecond pulsed laser, white light emission

References

[1] Bové H, Steuwe C, Fron E, et al. *Nano Lett*. **2016**, 16, 5, 3173–3178.

[2] Saenen ND, Bové H, Steuwe C, et al. *Am J Respir Crit Care Med*. **2017**, 196,7.

[3] Bové H, Bongaerts E, Slenders E, et al. *Nat Commun*. **2019**, 10, 3866.

[4] Witters K, Plusquin M, Slenders E, et al. *Environ Pollut*. **2020**, 266, 1.

[5] Aslam I, Roeffaers MBJ. Manuscript submitted for publication **2021**.

Towards the reduction of brake and tire emissions: The Zero Emission Drive Unit (ZEDU-1)

L. Bondorf[1], L. Köhler[2], T. Schripp[1], F. Philipps[2]

[1]Insitute of Combustion Technology, German Aerospace Center (DLR), Stuttgart, 70569, Germany,
[2]Institute of Vehicle Concepts, German Aerospace Center (DLR), Stuttgart, 70569, Germany

Technological advances, standardized testing, and legislation regarding engine-related emissions have been effective in reducing particulate emissions from newly registered vehicles. In order to achieve further progress here, it is important to conduct similar efforts at vehicle components that receive less attention in the context of particulate matter reduction but are relevant for any form of propulsion. This includes tires, which play a major role in the generation of coarse particles, and brakes, which emit high levels of ultrafine particles during operation. The goal of the Zero Emission Drive Unit (ZEDU-1) research project is to design and characterize a first-generation drive axle that enables zero-emission driving with high efficiency and effectiveness while remaining suitable for everyday use. Specifically, this includes a new concept for the effective minimized release of particles in the environment via absorption of tire abrasion and the development of a brake system that is free of fine dust emission even at full braking performance. From a range of braking technology, a viscous brake was selected for the battery-electric ZEDU demonstrator vehicle, to prevent any particulate emissions to the environment. Other technologies to reduce brake emissions such as new coatings of disc brakes, and the use of an induction hybrid brake are also investigated in the scope of the project.

For the technology evaluation, particle emissions will be investigated not only based on the total mass but the entire particle size distribution. This includes online measurements of particles from the range of ultrafine up to PM10 with an EEPS, OPS, and a DMS500. For offline chemical analysis, particles are size-selectively collected with an ELPI+. Besides, the fraction of non-volatile particles is determined by using a catalytic stripper.

A multi-stage test concept is planned to ensure reliable and realistic investigation of the non-exhaust particle emissions: First, a baseline for brake and tire abrasion is determined using a conventional electric vehicle (BMW i3). For this purpose, a specific enclosure was designed that allows mobile measurements on the vehicle and direct source identification. Chassis dynamometer measurements with the WLTP cycle and the new WLTP braking cycle allow reproducible measurements, as well as an estimation of various influencing factors. Second, the developed and tested sampling setup is used to evaluate the new brake coatings. Particulate emissions are measured under identical conditions and directly compared with emissions from a conventional brake. Finally, the emissions of the ZEDU demonstrator vehicle will be determined on a chassis dynamometer under the same driving cycles and environmental conditions. Additional mobile measurements are planned during runs on a test site.

This work is carried out as part of the ZEDU-1 project and supported by the Baden-Württemberg Ministry of Economics, Labour and Housing.

Effects of Outdoor Smoke Events on Indoor air Quality

J. Pauraite[1], G. Mainelis[2], S. Kecorius[3], A. Minderytė[1], V. Dudoitis[1], K. Plauškaitė[1], J. Ovadnevaite[4], I. Garbarienė[1], S. Byčenkienė[1]*

[1]SRI Center for Physical Sciences and Technology, [2]Rutgers, The State University of New Jersey, [3] Leibniz Institute for Tropospheric Research, [4]School of Physics, Ryan Institute's Centre for Climate & Air Pollution Studies, and Marine Renewable Energy Ireland, National University of Ireland Galway

It is known that climate change has greatly enhanced the probability of extreme wildfires. While people spend most of the time at home or at the workplace, little is investigated how indoor air filtering systems are performing under intensive outdoor smoke conditions. For this aim, particle number size distribution and concentration in a size range 0.5 – 18 µm and equivalent black carbon (eBC) mass concentration were measured in outdoor and indoor office air simultaneously.

7-wavelenght Aethalometer (Magee Scientific AE31) and Aerodynamic Particle Sizer (APS) (TSI 3321) were deployed in the Center for Physical Sciences and Technology (FTMC) campus located in the urban background environment in Lithuania from 30th September to 6th October 2020.Since all parameters were evaluated for indoor and outdoor air during the event (fire) and non-event (no fire) days, the air filtration system's performance during a long-range wildfire event were evaluated. Outdoor and indoor office air was investigated through various metrics: particle size distribution, $PM_{2.5}$, $PM_{10,}$ and eBC mass concentrations. Filters selectivity for different eBC sources (biomass burning versus traffic) and chemical composition of carbonaceous aerosol particles (eBC versus brown carbon (BrC)) was tested as well. It was found that the coarse particle number concentration was found to be 14 times higher in comparison with clean periods in indoor air. The smoke event resulted in twice higher indoor and outdoor eBC mass concentrations. Because of lower removal rate for small particles, eBC had higher contribution to total $PM_{2.5}$ mass concentration in indoor air than in outdoor air.

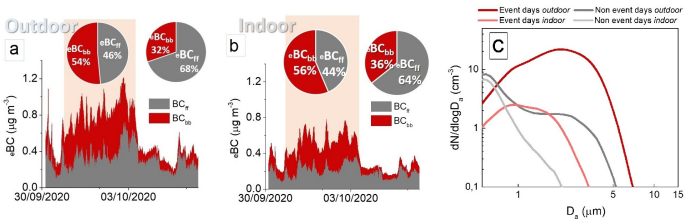


Fig 1. Time series of eBC_{ff} and eBC_{bb} mass concentrations in outdoor (a) and indoor (b) air. The pink areas mark the smoke event. Pie charts represent contributions of each parameter during non-event and event days. Particle number size distribution in outdoor and indoor air for the event and non-event days (c).

Acknowledgments. This research was funded by a grant (No. S-MIP-20-28) from the Research Council of Lithuania.

Combustion-generated carbonaceous urban ultrafine atmospheric UFPs: Waterborne-flora traps

U. K. Onwukwe[1], I. Jaffer AL-Timimi [1], P. A. Sermon[1]*

[1]Laboratory for Nanoscale Materials, Bragg Building, CEDPS, Brunel University, Uxbridge, Middx., UB8 3PH, UK

The New Yorker [1] saw London as the cradle of air pollution and there is an element of truth in this. We know that there is a myriad of particulates in the atmosphere and some threaten human health [2]. These include primary (formed at source) or secondary (formed in the atmosphere) particles, such as dust, smoke, ash, carbon black and liquid droplets and can cause haze or fog if their size is 100nm-80□m. PM_{10} and $PM_{2.5}$ have particulate matter with average sizes ≤10□m and 2.5□m respectively. EPA defines UFPs as d<100nm (100x smaller than PM_{10}). In an urban environment, most UFPs come from vehicle exhausts; they contribute little to mass concentrations but rather contribute to particle number concentrations. It is this number concentration of 20nm NPs that is lowered by roadside vegetation. Thus the air we breathe [3] (averaging 13.6kg [4] or 10,000 litres of air per day for the average adult) potentially contains 0.1-10 trillion particles [4] that target people [5]/animals/plants [6]. Some of these may be ultrafine combustion- and traffic-generated particles (UFPs) smaller than 100nm [7]. It has been known for many years [8,9] that such airborne particulate pollutants can be biomonitored [10] and attenuated/arrested [11] by terrestrial plants, urban forests [12] and green facades [13]. Figure 1 shows moss on which combustion-generated carbonaceous urban ultrafine particles (UFPs) have been sequestered. Here we explore with temporal and spatial resolution [14] the use of wetland/waterborne with *portobello mushroom spores* (PMS), *chlorella vulgaris* (CV) and *rotala rotundifolio* (RR) to control diesel-engine emitted carbonaceous ultrafine particles and the mechanism by which that occurs. In future we need such green technology in improved cities that will protect us from this pollution as we transition to zero-carbon economies.

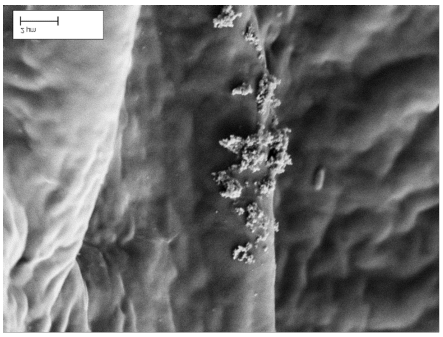


Figure 1. Diesel-emitted UFPs sitting on the surface of roadside moss (scale 2mm).

References: [1] The New Yorker (April 13, 1968); [2] O.Velentza Exronika 21,233,(2016); [3] N.Pham-Thi Rev.Franc.d'Allerg. 59,524,(2019); [4] A.Tsuda Compr.Physiol. 3,1437-1471 (2013); [5] Sermon and Rust ETH 2021; [6] M.W.Holgate Philo.Trans.Roy.Soc.London 290A,591,(1979); [7] H.S.Kwon Expert.Molec.Med. DI 10.1038/s12276-020-0405-1 (2020); [8] L.H.Gindon The Manchester Flora William White, London (1859); [9] Atmospheric pollution in Leicester HMSO, London (1945); [10] M.A.Urosevic Ecological Indicat. 109,105828,(2020); [11] S.K.Shailendra Sust.Environ.Res. 29,37,(2019); [12] M.J.Kwak Forests 10,960,(2019); [13] A.M.Hunter Ecol.Engin. 63,102,(2014) [14] F.A.Y.Gailey Sci.Tot.Environ. 133,201,(1993)

Simple proxy model of Lung-Deposited Surface Area (LDSA)

P. Fung[1]

[1]Institute for Atmospheric and Earth System Research / Physics, University of Helsinki

Lung deposited surface area (LDSA) has been considered to be a better metric to explain nanoparticle toxicity instead of the commonly used particulate mass concentration. LDSA concentrations can be obtained by direct measurements and by estimation from the empirical lung deposition model and measurements of particle size distribution. However, these measurements are neither compulsory nor regulated by the government; as a result, the data of LDSA has been scarce spatially and temporally. In light of this, we develop a novel proxy model, input-adaptive mixed-effects (IAME) model, to estimate LDSA by other already existing air pollutant variables and meteorological conditions.

During the measurement period of two full years 2017–2018, we retrieved LDSA measurements measured by Pegasor AQ Urban and other variables in a street canyon (SC, average LDSA = 19.68±11.29 μg m^{-3}) site and an urban background (UB, average LDSA = 11.17±7.1 μg m^{-3}) site in Helsinki, Finland. For the continuous estimation of LDSA, IAME is automised to select the best combination of a maximum of 3 fixed effects, together with 3 temporal categories as random effects, as inputs. Altogether, 696 sub-models are generated and ranked by the coefficient of determination (R^2), mean absolute error (MAE) and centred root-mean-square differences (cRMSD) in order. At the SC site, LDSA concentrations can be mostly estimated by mass concentration of particle of diameters smaller than 2.5 μm ($PM_{2.5}$), total particle number concentration (PNC) and black carbon (BC), all of which are closely connected with the vehicular emissions, while they are found correlating with $PM_{2.5}$, BC and carbon monoxide (CO) the best at the UB site. The accuracy of the overall model is higher at the SC site (R^2 = 0.80, MAE = 3.74 μm^2 cm^{-3}) than at the UB site (R^2 = 0.77, MAE = 2.30 μm^2 cm^{-3}) because the source of LDSA is more homogeneous at a street canyon. The results also demonstrate that the additional adjustment by taking random effects into account manages to improve the sensitivity of the fixed effect model to the existing diurnal, weekly and seasonal pattern. Due to its adaptive input selection and inclusion of random effects, IAME could serve as virtual sensors of LDSA in support with the reference measurements (Fung, et al., 2021). This continuous and reliable estimation could even provide a foundation for the inclusion of LDSA as one of the indicators in air quality index.

Abundance and distribution of nitrogen dioxide (NO2) and particulate nitrate (*p*NO3−) at an urban site of Delhi-NCR

M. NASEEM[1], U. C. KULSHRESTHA[1]*

[1]JAWAHARLAL NEHRU UNIVERSITY

The unprecedentedly increasing fuel combustion to fulfil the ever-increasing human population's energy demand changing the atmospheric composition, especially in terms of NO_2 and its transformational product (pNO_3^-), which exhibit a multitude of implications for the earth system and human health. The present study reports abundance and distribution of NO_2 and pNO_3^- at an urban site of one of the world's most populated and polluted region (Delhi-NCR). The samples were collected from October 2017 to September 2018 at an urban site of Delhi-NCR. The annual mean (± standard error) concentrations of NO_2 and pNO_3^- were observed to be 44.56 ± 3.19 μg m^{-3} and 10.86 ± 1.61μg m^{-3} respectively. Further, the NO_2 concentrations exhibited the transgression of National Ambient Air Quality Standards (NAAQRS) for NO_2, which is set to be 40 μg m^{-3} for urban areas. The day/night (D/N) ratios of both NO_2 and pNO_3^- concentrations were less than unity; therefore, they showed a good congruence with the atmospheric boundary layer's diel dynamics. The seasonal mean concentrations of NO_2 were observed as post-monsoon (77.84 ± 3.56 μg m^{-3}) > winter (39.79 ± 2.22 μg m^{-3}) > pre-monsoon (26.78 ± 2.44 μg m^{-3}) > monsoon (26.54 ± 1.33 μg m^{-3}). Similarly, the seasonal mean concentrations of pNO_3^- were observed as post-monsoon (19.20 ± 4.36 μg m^{-3}) > winter (11.72 ± 2.14 μg m^{-3}) > pre-monsoon (8.92 ± 1.58 μg m^{-3}) > monsoon (2.14 ± 0.42 μg m^{-3}). The higher NO_2 and pNO_3^- concentrations during the post-monsoon period can be attributed to the stubble burning in the Indo-Gangetic plains during this period, while their lower concentrations during the monsoon period can be attributed to the intermittent atmospheric cleansing by precipitation. The one-way ANOVA suggested that these seasonal variabilities in precursor gaseous NO_2 and pNO_3^- concentrations at the sampling site were statistically significant ($p < 0.05$). The transport paths of air masses reaching the site during sampling days were delineated by backward trajectory analysis, which showed that the NO_2 and pNO_3^- at this site were contributed from both local and transboundary sources.

Air Quality Variation in Six Most Polluted Cities of Northern India during Diwali 2020

A. LAWRENCE[1]

[1]Isabella Thoburn College, Lucknow,India

India is witnessing a re-surge in the fresh COVID-19 cases presently, after attaining the peak or the highest daily average reported on September 17th, 2020, India had seen a decline in the active cases, but the situation is worsening again. In India, the spread of the virus may be influenced by ambient air pollution. The impact of COVID-19 may be more severe in cities with high air pollution with compromised immunity of those who are exposed. The re-surge has been witnessed after winters which coincided with Diwali, one of the biggest festivals in India, The traditional firecracker burning during the festival leads to a huge variation in air quality as the perilous aftermath. Last year, Indian government imposed ban on firecracker burning in the wake of the ongoing pandemic. This study was undertaken between 4th-21st November, 2020 to monitor the air quality variation with respect to PM_{10} and $PM_{2.5}$ in six North Indian cities including Delhi, Lucknow, Ghaziabad, Muzaffarnagar, Greater Noida and Bulandshahar, covering the Diwali to know whether there was any impact of the warnings. The hourly variations in the AQI were very poor between 8:00 p.m.-10:00 p.m. on Diwali day. The maximum AQI with respect to $PM_{2.5}$ as reported from Lucknow, Delhi, Ghaziabad, Greater Noida, Muzaffarnagar and Bulandshahar were 709, 530, 552, 520, 824, 999 and 999, 999, 729, 618, 999, 999 for PM_{10} respectively on Diwali day. The highest and lowest $PM_{2.5}$ concentrations (µg/m^3) for these cities were 391, 340, 482, 456, 292, 494 and 54.5, 74, 70.9, 67.1, 24.4 and 55 respectively, whereas the PM_{10} concentrations (µg/m^3) were 594, 565, 532, 586, 587, 548 and 103, 154, 183, 181, 105 and 155 respectively. A weak positive correlation was obtained between the temperature and AQI, whereas a negative relationship was established with humidity. As compared to 2019, AQI, higher values were obtained during Diwali 2020. In future, long-term exposure to air pollution and COVID-19 infection may have an additive adverse effect on health, particularly related to heart and blood vessels, leading to greater vulnerability and less resistance to COVID-19.

Outdoor-indoor concentration of black carbon during high pollution events in urban environment

D. Pashneva[1], J. Pauraite[1], A. Minderytė[1], I. Garbarienė[1], V. Dudoitis[1], K. Plauškaitė[1], S. Kecorius[2], G. Mainelis[3], J. Ovadnevaite[4], S. Byčenkienė[1]*

[1]SRI Center for Physical Sciences and Technology, Saulėtekio av. 3, LT-10257 Vilnius, Lithuania, [2] Leibniz Institute for Tropospheric Research, Permoserstraße 15, 04318 Leipzig, Germany, [3]Rutgers, The State University of New Jersey, 14 College Farm Road New Brunswick NJ 08901, USA, [4]School of Physics, Ryan Institute's Centre for Climate & Air Pollution Studies, and Marine Renewable Energy Ireland, National University of Ireland Galway, H91 CF50 Galway, Ireland

Biomass burning, transport, wildfires are a significant sources of fine airborne particulate matter ($PM_{2.5}$) which was linked to various health issues [1]. Its component **aerosol black carbon** (BC) is widely known for its negative effect on human health. Due to its small size (less than 2.5 μm), large specific surface area, and irregular morphology, BC can simply adsorb carcinogenic/mutagenic pollutants like polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) and can penetrate deep into the bronchial tree [2]. Studies demonstrated consistent evidence of the link between fine aerosol particles and BC exposure with respiratory health effects such as asthma and chronic obstructive pulmonary disease [3]. Lack of testing of filtering systems under high pollution levels associated with BC mass concentration rises a doubt over indoor air quality during high pollution event days.

For this aim, eBC were measured in a modern office with a mechanical ventilation system. Measurements took place from during cold season in 2021 in the FTMC campus located in the urban background environment in Lithuania. Aethalometer used in this study were connected to the sampling system which automatically switches sampling from outdoor to indoor every 30 minutes.

During measurement campaign an intensive pollution episodes related to biomass burning, traffic and long range transport of wildfire smoke were observed. During high pollution event observed outdoor and indoor BC levels were approximately twice higher. A strong correlation between eBC in indoor and outdoor air was observed. Air filtering efficiency was found to be highly dependent on particles size. Ambient concentrations of BC can be used as a good approximation of indoor concentrations in the absence of indoor particle sources in office buildings.

This research was funded by a grant (No. S-MIP-20-28) from the Research Council of Lithuania.

[1] R. Aguilera, T.Corringham, A. Gershunov, and T. Benmarhnia, *Nat Commun* 12**:** 1493, 2021.
[2] S. K. Pani, S. H. Wang, N. H. Lin, S. Chantara, C. Te Lee, and D. Thepnuan, *Environ. Pollut.*, vol. 259, Apr. 2020.
[3] W. Knorr, F. Dentener, J.-F. Lamarque, L. Jiang, and A. Arneth, *Atmos. Chem. Phys.*, vol. 17, no. 14, pp. 9223–9236, Jul. 2017.

Emissions of NH_3, NO_2 & their secondary aerosols during biomass burning at an agricultural area in NCR-Delhi, India.

S. Yadav[1]

[1]Sudesh and Umesh Kulshrestha* School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067 INDIA

Burning of agricultural residue emits enormous amounts of reactive Nitrogen species (Nr) into the atmosphere every year. It represents a significant source of chemically and radiatively important trace gases and aerosols to the atmosphere thereby causing a major concern for global change. Emissions from agricultural residue burning are further aggravated due to other anthropogenic sources viz. vehicular exhaust, power plants, crustal dust etc. enhancing the air pollution level in urban areas like New Delhi. This study is carried out at a rural agricultural site in Haryana (India) which mainly focuses on the emissions from rice paddy residue burning (October–November) and wheat residue burning (April–May) in the year 2017 & 2018. Measurements of NH_3, NO_2, NH_4^+, NO_3^- were carried out using a low volume pump operating at a flow rate of 1 LPM. Average concentrations of NH_3, NO_2, NH_4^+, NO_3^- were 99.3, 30.5, 5.3, 8.1 μgm^{-3} and 32.3, 29.9, 1.2, 4.1 μgm^{-3} during rice paddy and wheat residue burning respectively. Concentrations of measured pollutants were higher during October–November months which corresponds to rice paddy residue burning period in the IGP (Indo-Gangetic Plain). Burning of crop residues from rice-wheat cropping pattern of Punjab, Haryana and western Uttar Pradesh at large scale is a matter of serious concern not only for GHG emission but also associated with numerous environmental problems such as pollution, health hazards and loss of nutrients. The present study suggests the need for immediate attention and introducing alternative methods for management of crop residue. Incorporation of crop residues into the soil can be a sustainable alternative to the burning of crop biomass. Consequently, validating the emission estimates experimentally along with their associated uncertainties is the need of the hour.

Keywords: Agricultural residue, NH_3, Atmospheric Chemistry, Rice-paddy residue, Wheat residue, etc.

Optical properties of light-absorbing carbonaceous aerosols from on-road vehicles

N. Raparthi[1], S. Debbarma[2], H. C. Phuleria[1,2]

[1]Environmental Science and Engineering Department, Indian Institute of Technology Bombay, Mumbai, India, [2]Interdisciplinary Programme in Climate Studies, Indian Institute of Technology Bombay, Mumbai, India

Introduction: Light-absorbing carbonaceous aerosols, black carbon (BC), and brown carbon (BrC) can absorb light in the atmosphere that leads to climatic imbalance. There is a dearth in vehicular specific optical properties (such as aerosol light absorption ($b_{abs,\lambda}$), Absorption Angstrom exponent (AAE), and Mass absorption efficiency (MAE)) in the real-world driving conditions. The objective of the study is to find the optical properties ($b_{abs,\lambda}$, and AAE) of light-absorbing carbonaceous aerosols specific to the vehicular emissions from the kerb-side and road-tunnel measurements having different traffic characteristics. And also investigated the contribution of light-absorbing particulate organic carbon (BrC) to total vehicular light-absorbing carbonaceous aerosols.

Methodology: Gravimetric $PM_{2.5}$ was collected on the Teflon filters (47mm, Whatman) by using a low volume $PM_{2.5}$ sampler (MiniVol, Airmetrics, USA) at the kerb-side (KS) of an arterial road (JVLR), and entry and exit of the road-tunnels (Freeway (FT) and Kamshet (KT) tunnel) in Mumbai, India. Light absorption by the $PM_{2.5}$ was measured with a SootScan Model OT21 optical transmissometer (Magee Scientific, USA) at wavelengths of 370 nm and 880 nm.

Results&Discussion: The light absorption (370 and 880nm) at KT was ~1.5 and ~5.3 folds higher than the kerbside and EFT, respectively due to the prevalence of more HDVs (~20%) at KT than at the kerbside (~8% HDVs) and EFT (~2% HDVs), which emit relatively more light-absorbing carbonaceous aerosols than other vehicle types. At kerbside, the average (±SD) contribution of particulate BrC absorption was 28 (±9)% at 370 nm whilst it is negligible at FT and KT. AT KS, BrC contribution to total absorbing carbon is 29% more in afternoon hours than during the morning hours, likely due to enhancement in the formation of secondary organic aerosols which are more absorbing. At KS the measured AAE was 1.40, which suggests that, other than vehicle emissions, BrC contribution is from other nearby sources such as residential cooking and also through the secondary formation. The measured AAE at the exit of KT (AAE=0.52) and EFT (AAE=0.54) was 9.5% and 33% higher, respectively as compared to the entry, suggesting the enrichment in the absorption of aerosols as the vehicle moves from entry to exit of the tunnel and indicating the contribution of vehicular emissions inside the tunnel. At KT, the AAE is 6% higher in the afternoon hours compared to morning whereas at FT, it is quite similar suggesting low to negligible secondary organic PM transformation inside the tunnels.

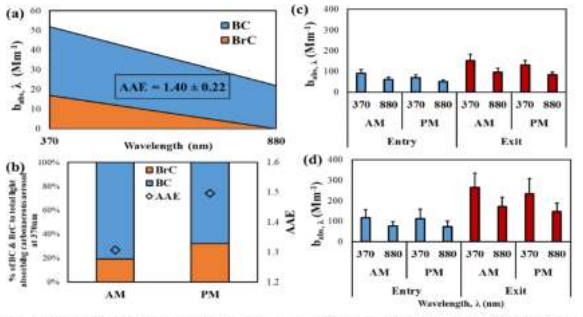


Fig.1. (a) Light absorption coefficient, $b_{abs,\lambda}$, of BrC and BC, and the AAE (370-880nm), (b) variation in the contribution of BrC to total absorbing carbon at 370nm and AAE (370-880nm) during morning and afternoon periods at the kerbside (KS)location, and average vehicular specific $b_{abs,\lambda}$, and AAE (370-880nm) at entry and exit of (c) the Freeway tunnel (FT), and (d) the Kamshet tunnel (KT). *Error bar represents the standard deviation.*

Determination of Absorption Ångström Exponent Values for Black Carbon source apportionment Aethalometer Model in Urban Background Environment

A. Minderytė[1], J. Pauraite[1], V. Dudoitis[1], J. Didžbalis[1], K. Plauškaitė[1], V. Ulevičius[1], A. Kilikevičius [2], J. Matijošius [2], S. Byčenkienė[1]*

[1]SRI Center for Physical Sciences and Technology, Department of Environmental Research, Saulėtekio av. 3, LT-10257 Vilnius, Lithuania, [2]Vilnius Gediminas Technical University - Vilnius Tech, J. Basanavičiaus St. 28, LT-03224 Vilnius, Lithuania

One of the most abundant light-absorbing components of atmospheric aerosols emerging from fossil fuel combustion and biomass burning in urban areas is black carbon (BC) which is strongly associated with air pollution and climate change. Its significance as the second highest anthropogenic contributor for global warming after CO_2 was acknowledged in a special report *Global Warming of 1.5 ºC* by IPCC [1]. Therefore, it is crucial to identify the specific sources of carbonaceous aerosol pollution in each region and develop mitigation strategies to control their radiative effects on the climate. Carbonaceous aerosol particles originating from various sources exhibit different chemical composition and consequently different physical properties. Aethalometer model for BC source apportionment is based on the dependence of aerosol absorption on the wavelength of light which is defined as source specific absorption Ångström exponent (AAE) and describes the wavelength variation in aerosol absorption.

In our study an Aerosol Chemical Speciation Monitor (ACSM) and a 7-wavelength Aethalometer were deployed in Vilnius (urban background site) in October (2014) and May - June (2017). The aim of the study was to perform a systematic source apportionment for BC by examining dynamics of mass concentration and optical properties alteration during heating and non-heating seasons. In order to separate sources of BC, the most suitable values of AAE (absorption Angstrom exponent) were selected for BC_{tr} (originated from traffic emissions) and BC_{wb} (originated from biomass burning): 0.9 and 2.2, respectively. The BC_{tr} absorption increased more than 50 % in the period 2014 – 2017 which suggests that there was a significant increase in BC_{tr} mass concentration due to a rise in diesel vehicles number in the city. Organic aerosol (OA) source apportionment analysis was performed by applying positive matrix factorization (PMF) which revealed five main sources during cold season in 2014: primary OA (POA), local OA (LOA), two different biomass burning OA (BBOA-1 and BBOA-2) and oxygenated OA (OOA). Meanwhile in spring 2017 five main sources included two different oxygenated OA (more and less oxygenated OA (LVOOA and SVOOA, respectively)) and local hydrocarbon-like OA (LOA). Our results show significant alteration of aerosol optical properties over the course of the day related to traffic rush hours and residential heating during both heating and non-heating seasons. The results of this study provide most suitable combination of AAE values for BC source apportionment and additional insights into air quality in urban environment.

This project has received funding from European Regional Development Fund (project No. 01.2.2-CPVA-K-703-03-0016).

[1] P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.), IPCC, 2019: Summary for Policymakers, 2018.

Fine Particulate Matter Bound Polycyclic Aromatic Hydrocarbon Species in Ambient Atmosphere of Delhi: Concentration, Sources, and Associated Health Risk Assessment

A. K. Yadav[1], P. S. Khillare[1]*

[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi- 110067

The present study was carried out to determine the concentration of fine particulate ($PM_{2.5}$) bound polycyclic aromatic hydrocarbons (PAHs) in the ambient atmosphere of Delhi, their sources, and associated health risk to the general population living in the area. $PM_{2.5}$ samples were collected for a time period of 4 months between November 2017 and February 2018 with a sampling frequency of one sample per week. The mean $PM_{2.5}$ and associated 16 USEPA priority PAHs (Σ_{16}PAHs) concentration was 263.9±187.0 μg/m^3 and 117.1±83.3 ng/m^3 respectively and they shown a good correlation (r = 0.59) during the study. The mean concentration of 5-ring PAHs was found highest during the study period followed by 3-ring, 6-ring, 4-ring, and 2-ring species (Scheme 1). Particulate bound high molecular weight species (4-ring, 5-ring, and 6-ring) were dominant over low molecular weight species (2-ring and 3-ring) and their mean concentration was 77.4±73.2 ng/m^3 and 38.6±16.0 ng/m^3 respectively.

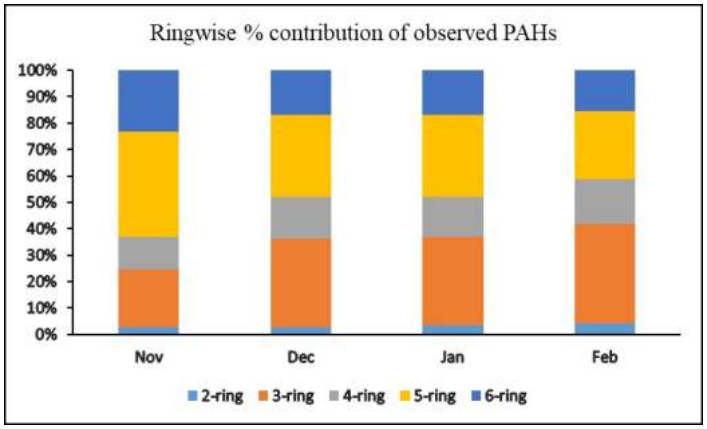


Figure: Ringwise % contribution of observed PAHs at the sampling site.

Seven PAHs, namely B[a]A, Chry, B[b]F, B[k]F, B[a]P, DB[ah]A, and I[cd]P classified as carcinogenic (Group 1), and probable and possible carcinogen (Group 2A and 2B) by USEPA contributes about 42.6% to Σ_{16}PAHs. The concentration of B[a]P, the most carcinogenic species among the known PAHs was 8.2±9.5 ng/m^3, which is more than 8 times the annual B[a]P National Ambient Air Quality Standard in India (1 ng/m^3). The total carcinogenicity due to the observed concentration of 16 PAHs was calculated as B[a]P equivalent (B[a]P_{eq}) using toxic equivalency factor values given by Nisbet and Lagoy[1], and that was 29.3 ng/m^3. Incremental lifetime cancer risk calculated using mean B[a]P_{eq} values as a surrogate for the total toxicity due to Σ_{16}PAHs and it was found that if the observed concentration of B[a]P_{eq} is inhaled by the Delhi population for a lifetime, then for a unit cancer risk of 8.7E−05, ~36 cancer cases per million population may occur. The source apportionment tools viz. molecular diagnostic ratio and principal component analysis have identified vehicular emission, fossil fuel, wood, and biomass burning as the leading sources of PAHs in Delhi. Backward wind trajectories constructed with the help of HYSPLIT transport and dispersion model suggest incursion of regional and transboundary pollutants in Delhi.

[1] Nisbet, I. C., & Lagoy, P. K. (1992). Toxic equivalency factors (TEFs) for polycyclic aromatic hydrocarbons (PAHs). *Regulatory toxicology and pharmacology*, *16*(3), 290-300.

Carbonaceous Aerosol at Breathing Height during Wintertime in Ambient Atmosphere of National Capital Region (NCR) of Delhi, India

A. Rathee[1], S. Yadav[1]*

[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi- 110067

Size distribution, water-soluble organic carbon (WSOC), water-soluble inorganic carbon (WSIC), organic carbon (OC), and elemental carbon (EC) in fine particles ($PM_{2.5}$) were investigated at breathing height (~2m) during winter 2017 over Rohtak, Haryana (RTK) and Karol bagh, New Delhi (NDK). The average mass concentration of fine particles exceeded the Indian National Ambient Air Quality Standard (NAAQS: 60 µg m $^{-3}$ for 24 hours) over RTK (5.6 times) and NDK (4.8 times). The WSOC in fine particles was 39.14 and 21.21 μgm^{-3} over RTK and NDK, respectively. The WSOC/OC was 0.8 in RTK and 0.6 in NDK, which suggests the formation of photochemical haze in the suburban atmospheric environment and the impact of biomass burning in the study area. At both sites, OC dominates over EC. The total carbon (TC = OC+ EC) concentration was 73.47 μgm^{-3} and 57.57 μgm^{-3} over RTK and NDK, which was 21.7% and 19.8% of the total $PM_{2.5}$ load of both the sites, respectively. OC and EC concentration over RTK was 47.61 μgm^{-3} and 25.86 μgm^{-3}, and over NDK, was 32.65 μgm^{-3} and 24.92 μgm^{-3}, respectively. Among the four organic carbon fractions, OC1 comes from biomass burning, OC2 from coal combustion, OC3, and OC4 from road dust, whereas, in three elemental carbon fractions EC1 comes from motor vehicle exhaust, and EC2, and EC3 from the high-temperature combustion process.

Non-Linear Correction Methods Applied to Long Term Deployment of Low-Cost Air Quality Sensors

P. Wahman[1], J. Swanson[3]*, M. Vadali[2]

[1]Department of Integrated Engineering, Minnesota State University, Mankato, 56001, [2]Minnesota Pollution Control Agency, [3]Catalytic Instruments GmbH

Combustion generated particulate matter and gases impact local air quality. “Low-cost air” quality sensor suites introduced commercially in the past ten years have promised to allow significant increases in spatial resolution of sensing networks to improve source apportionment. The Minnesota Pollution Control Agency (MPCA) has deployed a network of 50 AQ-Mesh sensors around the Minneapolis-St. Paul Metro Area. The sensor suite includes electrochemical sensors for nitrogen monoxide (NO), nitrogen dioxide (NO2), carbon monoxide (CO), and ozone (O3). The suite also has an Alphasense OPC-N2 particle counter for PM measurements, along with temperature, pressure, and relative humidity sensors. The deployment of the sensors has lasted two years, much longer than other large-scale deployments. This work examines the quality of the measurements and focuses on using corrective models to improve the quality of the measurements to be used in further work.

A correlation analysis was conducted at sites where a low-cost AQ-Mesh sensor suite was collocated with a suite of federal equivalent method sensors to determine which features and the most predictive power individually. Then those features were used to create a predictor that analyzed the data and made corrections. The predictors were three types, Random Forests (RF) and Neural Networks (NN), and a common correction method, linear regression. There were two general sets of data used to train predictors; the first was the sensors collocated at FEM sites during the whole deployment period of two years. The second set of predictors were built from mass colocations before and after the two-year deployment. The corrections were tested against the data from the long-term colocation sites.

The results show a reduced relative error of the sensors for all predictors meaning that the correction models improve the accuracy of the sensors. However, the RF and NN corrections showed a reduced linear correlation between the AQ-Mesh Sensor output and a Federal Equivalent Method (FEM).

Combustion-generated carbonaceous urban ultrafine atmospheric UFPs: Waterborne-flora traps

U. K. Onwukwe[1], I. Jaffer AL-Timimi [1], P. A. Sermon[1]*

[1]Laboratory for Nanoscale Materials, Bragg Building, CEDPS, Brunel University, Uxbridge, Middx., UB8 3PH, UK

The New Yorker [1] saw London as the cradle of air pollution and there is an element of truth in this. We know that there is a myriad of particulates in the atmosphere and some threaten human health [2]. These include primary (formed at source) or secondary (formed in the atmosphere) particles, such as dust, smoke, ash, carbon black and liquid droplets and can cause haze or fog if their size is 100nm-80□m. PM_{10} and $PM_{2.5}$ have particulate matter with average sizes ≤10□m and 2.5□m respectively. EPA defines UFPs as d<100nm (100x smaller than PM_{10}). In an urban environment, most UFPs come from vehicle exhausts; they contribute little to mass concentrations but rather contribute to particle number concentrations. It is this number concentration of 20nm NPs that is lowered by roadside vegetation. Thus the air we breathe [3] (averaging 13.6kg [4] or 10,000 litres of air per day for the average adult) potentially contains 0.1-10 trillion particles [4] that target people [5]/animals/plants [6]. Some of these may be ultrafine combustion- and traffic-generated particles (UFPs) smaller than 100nm [7]. It has been known for many years [8,9] that such airborne particulate pollutants can be biomonitored [10] and attenuated/arrested [11] by terrestrial plants, urban forests [12] and green facades [13]. Figure 1 shows moss on which combustion-generated carbonaceous urban ultrafine particles (UFPs) have been sequestered. Here we explore with temporal and spatial resolution [14] the use of wetland/waterborne with *portobello mushroom spores* (PMS), *chlorella vulgaris* (CV) and *rotala rotundifolio* (RR) to control diesel-engine emitted carbonaceous ultrafine particles and the mechanism by which that occurs. In future we need such green technology in improved cities that will protect us from this pollution as we transition to zero-carbon economies.

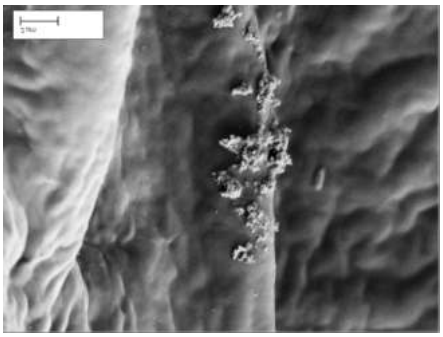


Figure 1. Diesel-emitted UFPs sitting on the surface of roadside moss (scale 2mm).

References: [1] The New Yorker (April 13, 1968); [2] O.Velentza Exronika 21,233,(2016); [3] N.Pham-Thi Rev.Franc.d'Allerg. 59,524,(2019); [4] A.Tsuda Compr.Physiol. 3,1437-1471 (2013); [5] Sermon and Rust ETH 2021; [6] M.W.Holgate Philo.Trans.Roy.Soc.London 290A,591,(1979); [7] H.S.Kwon Expert.Molec.Med. DI 10.1038/s12276-020-0405-1 (2020); [8] L.H.Gindon The Manchester Flora William White, London (1859); [9] Atmospheric pollution in Leicester HMSO, London (1945); [10] M.A.Urosevic Ecological Indicat. 109,105828,(2020); [11] S.K.Shailendra Sust.Environ.Res. 29,37,(2019); [12] M.J.Kwak Forests 10,960,(2019); [13] A.M.Hunter Ecol.Engin. 63,102,(2014) [14] F.A.Y.Gailey Sci.Tot.Environ. 133,201,(1993)

Distribution of Hg and As in the process of lignite and subbituminous coals combustion in the pulverised and fluidized bed reactor

M. Marczak-Grzesik[1,4], F. Wieronska-Wiśniewska[1], L. Pilar[2], J. Górecki[1], K. Borovec[3]

[1]AGH University of Science and Technology, Faculty of Energy and Fuels, Mickiewicz Avenue 30, 30-059 Krakow, Poland, [2]Czech Technical University in Prague, Faculty of Mechanical Engineering, Energy Department, Technicka 4, 166 07 Pragule 6, Czech Republic, [3]VSB-Technical University of Ostrava, Energy Research center, 17.listopadu 2172/15, 70800 Ostrava-Poruba, Czech Republic, [4] AGH University of Science and Technology, AGH Centre of Energy, Czarnowiejska 36, 30-054 Krakow, Poland

The reaserch aims to determine the distribution of Hg and As in the process of lignite and subbituminous coals in a pulverised bed reactor and assess the impact of the post-treatment on speciation and emissions of Hg and As into air.

The results of the research will be used to develop regression models and artificial neural networks models, which will give the ability to continuously monitor the concentrations of Hg and As in the flue gases leaving the installation, based on the information about the fuel and combustion conditions.

In the case of Hg emission limits exceedance, this tool will allow taking actions to recover the desired concentration levels of Hg and As in gases emitted into the atmosphere.

Additional methods of post-treatment (dedicated only for Hg or As) can be used optionally, but not as a continuous unit.

To verify the targets, an existing database for mercury (data regarding the distribution of Hg between the various coal combustion products, the content of Hg in Polish coals and their chemical composition, the influence of flue gas cleaning methods on the Hg speciation) will be used.

The measurements been taken on Polish power plants operating on bituminous coal and lignite and supplemented with denitrification systems, dust collection and flue gas desulfurization. The analysis been carried out for a typical block of 370-390 MW and 858 MW lignite-powered units for the boiler and a block of 370-390 MW dust coal-powered boiler.

In-vehicle CO_2 and ultrafine particle (UFP) Microenvironments: Climate Change

R. Padman[1], P. A. Sermon[1], W. Johnson[1]

[1]Laboratory for Nanoscale Materials, Bragg Building, CEDPS, Brunel University, Uxbridge, Middx., UB8 3PH, UK

There are many current threats whose potential impact we need to prioritise (climate change, air pollution, antibiotic resistance and violent crime) in terms of our response.

Atmospheric CO_2 and climate change were linked long ago by Arrhenius. Humans exhale CO_2. Inhalation of *air pollution*has been linked to 7 million premature deaths annually worldwide by the WHO, saying that more than 9 out of 10 people in the world live in regions breaking WHO air-quality guidelines. The aims of the present study were to map $CO_2$and UFP emissions inside-outside a Euro 3 diesel vehicle (chosen because of its high emissions) as it drove to London's Heathrow airport through the tunnelled spur road from the M4 motorway and while the two 17-year-old investigators inhaled-exhaled urban air. NDIR and CPC analysers were used in real-time.

CO_2 levels inside the Euro 3 diesel Seat Leon with closed windows were initially lower (400ppm) than outside (425ppm) but rose rapidly during the drive (400s-1600s) to and from LHR reaching 1650ppm CO_2. Outside there were two major sharp CO_2 maxima in concentration in the passage through the LHR tunnel (of 520 and 630ppm). Concentrations of 50nm UFPs inside the Euro 3 diesel Seat Leon were also lower than outside, but as those outside rose during at traffic lights and on the approach to the airport tunnel there was leakage into the car.

Interestingly the ratio of CO_2 exhalation to UFP retention by the investigators is very different.

It is concluded that microenvironments on board vehicles should be monitored in real-time for climate change and pollution control reasons.

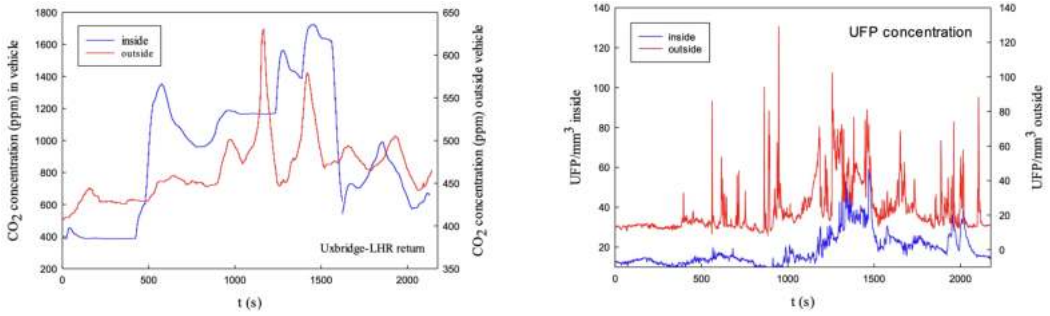


Figure 1 CO_2 and UFP concentrations inside and outside a diesel Seat Leon vehicle driving to London Heathrow airport

Non-regulated emissions from the gasoline vehicles – an ion chromatography analysis of the anions

W. Pacura[1], K. Szramowiat-Sala[1], J. Golas[1], P. Bielaczyc[2]

[1]AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Krakow, Poland, [2]BOSMAL Automotive Research and Development Institute Ltd., Ul. Sarni Stok 93, 43-300 Bielsko-Biala, Poland

Introduction

In 2019 over 600 thousands of new passengers and light duty vehicles were registered in Poland, one should add this to the total number of 25 millions registered cars. While the European Emissions Standards limits most harmful compounds such as hydrocarbons or various oxides, there is a number of non-regulated pollutants that are so far omitted by legislation. Taking into account that half of the vehicles travel over 10.000 km per year even seemingly insignificant levels of emission add up to a great number.

Methodology:

The passenger and light duty vehicles under 3500 kg were tested according to the Worldwide Harmonised Light Vehicle Test Procedure (WLTP) requirements on the chassis dynamometer. Part of the emitted solid particles was collected on the 47 mm filters and weighted to establish particulate matter mass (PM) and number of the particles (PN). The anions adsorbed on the solid particles surface were extracted and analysed using Thermo Scientific ICS-1100 Ion Chromatograph equipped with IonPac AS22 Column.

Results & Conclusions:

The analysed particulate matter origins from the four Euro 6b compliant vehicles powered by the gasoline engine. The PM was analysed with ion chromatography to measure the ion concentration, such as fluorides F^-, chlorides Cl^-, bromides Br^-, nitrites NO_2^-, nitrates NO_3^-, sulphates SO_3^{2-} and phosphates PO_4^{3-}. Sulphates were of the highest concentration, what can be explained by the legally allowed level of the sulphur in the gasoline, while the bromides were below the detection limit. In total, all anions accounted for about 6% of the PM mass. Anions might be part of salts, therefore cation analysis is the subject of current studies. The additives improving the properties of gasoline or engine oil may be the source of the positive ions.

Study of the non-regulated compounds is crucial in the establishing of the influence of solid particles on health and environment. Furthermore extended studies can provide a basis for the further research of vehicle emission or other fields such as medicine or material engineering.

Acknowledgment:

The work has been supported as a part of the research subvention at the AGH UST in Krakow (no. 16.16.210.476) and using infrastructure of the Centre of Energy, AGH UST in Krakow.

The investigations of emission of a variable compress ratio internal combustion engine driving the power generator

M. Wozniak[1], K. Siczek[1], M. Glogowski[1], P. Kubiak[2], G. Ozuna[3]

[1]Lodz University of Technology, Poland, [2]Warsaw University of Technology, Poland, [3]University of Sonora, Mexico, [4]Lodz University of Technology

Introduction & Background

The purpose of the investigations is to obtain characteristics of the variable compress ratio engine as a function of rotational speed and load. Currently, the improvement in the efficiency and emission level of the engine can be obtained using a variable compression ratio enabling combustion under almost constant pressure. This approach is used in the tested engine cooperating with a power generator.

The control of such an engine requires the use of a control unit and the selection of the appropriate strategy. The control in the present engine is based on the knocking beginnings. The appearance of such a phenomenon causes the need to reduce the throttle opening angle. The displacement of the additional piston automatically adjusts to the pressure constituting the cylinder. The principle of the ACC motor is shown in figure 1.

The principle of its operation is as follows: when the pressure in the engine cylinder overcomes the initial load on the pneumatic spring (3), an additional piston (2), constituting a barrier in the active combustion chamber, rises while storing energy in the spring (3). When the piston (2) reaches its maximum position, the energy accumulated on the spring (3) reaches its highest value. At this time, all forces acting on the piston (3), including inertia forces, remain in balance. From that moment - the piston falls, the energy accumulated in the spring is recovered (3). This energy can then be used to keep the pressure and volume in the combustion chamber relatively constant. The control of the lower docking position of the piston (2) is provided by a unidirectional pneumatic spring (5) and a unidirectional shock absorber (6). The adaptability of the ACC system results from a change in the pneumatic stiffness of the spring (3): a change in the volume of the spring caused by a movable partition (4) or a change in pressure supplied by the spring.

Adjusting the compression ratio is an immanent feature of the ACC engine. This is advantageous because the higher initial velocity of the additional piston in this system in the initial combustion phase reduces the reaction time during combustion. A direct consequence of the more vigorous reaction is the possibility of further increasing the compression ratio to values that are not achievable in most engines with the VCR system.

Methodology:

A converted DG6700RC-S aggregate engine with 12 HP and 3000 rpm is used, in which the cylinder head is converted to allow the installation of gasoline injectors and a special patented piston design is used, which includes an additional movable auxiliary piston, which movement allows changing of the combustion chamber volume and, as a result, of the compression ratio. The knocking combustion is monitored by knock sensor during operation. The engine characteristics are obtained by measuring the speed of the crankshaft and the torque is estimated by measuring the electrical power lost on the resistors loading the aggregate. Fuel consumption is measured and exhaust gas analysis is performed using by analyzer.

Results & Conclusions:

The obtained results of the engine characteristics are presented: power and torque of the analyzed

engine as a function of speed as well as its fuel consumption and emissions. The obtained characteristics are compared with these of the original diesel engine.

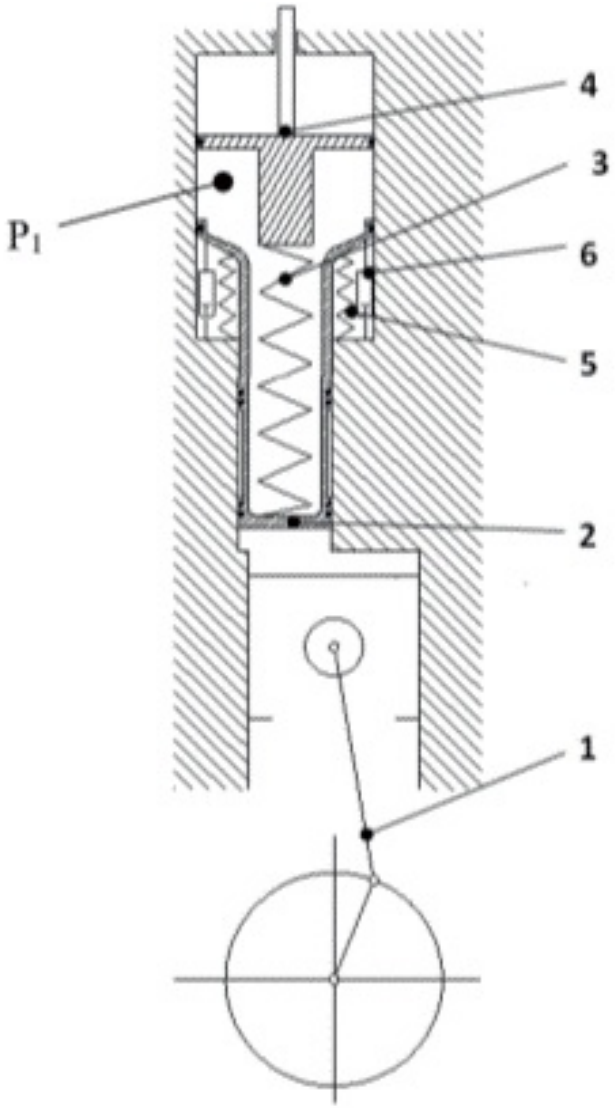
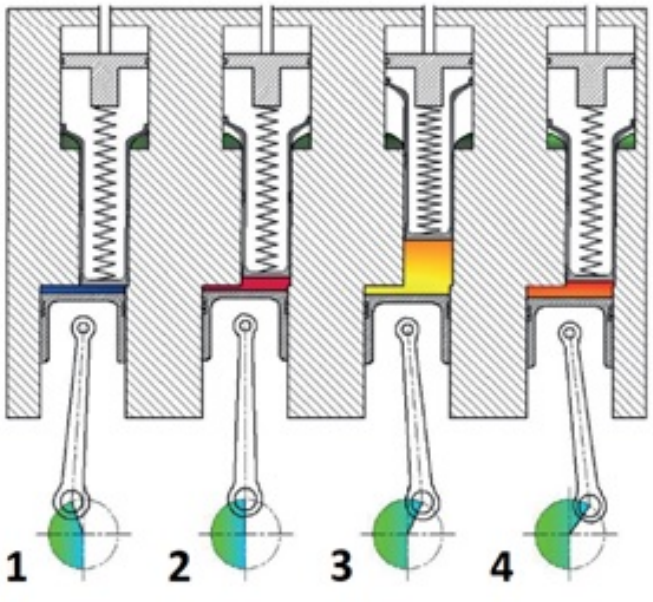


Fig. 1. Schematic diagram of ACC engine operation

Fig. 2. The principle of operation of ACC system with VCR function in real ACC engine with spark ignition, in its the most characteristic working points (1, 2, 3, 4).

Typical for real ACC system is the position of 3 point, which is the point of ignition, located between 20°*ca* and 30°*ca* after top dead center point. Point 4 is located between 40°*ca* and 65°*ca* after top dead center point. A significant impact of ACC system takes place between points 1 and 4, i.e. between 340°*ca* and 410°*ca* for the cycle of the ACC engine. Energy wis absorbed by ACC system between points 1 and 3, when the compression ratio decreases. The energy is always recuperated between points 3 and 2.



[1] Lazinski, P., Glogowski, M., Leyko J., Research on a prototype spark ignition variable compression ratio engine fitted with a pneumatic energy accumulator. *Combustion Engines,* **2014**, 159(4), 54-65.

[2] Woś P. , Kuszewski H. , Ustrzycki A., Exhaust emission features of variable compression ratio (VCR) diesel engine, *Journal of KONES*, **2010**, 17(3):521-526.

[3] Lejda, K., Woś, P., A Preliminary Project of Multi Cylinder, Variable Compression Ratio (VCR) Engine for Research Purposes, *Combustion Engines*, **2009**, Vol. SC2, Paper No PTNSS-2009-062, pp. 152-157.

[4] Shaik, A., Shenbaga Vinayaga Moorthi, N., Rudramoorthy, R., Variable compression ratio engine: a future power plant for automobiles – an overview, *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, **2007**, Vol. 221, No. D9, pp. 1159-1168.

[5] Verma, A., Hasan, M., Karnwal, A., and Vibhanshu, V., The Effect of Variable Compression Ratio on Performance and Emission Characteristics of Diesel Engine Fuelled With Blends of Diethyl Ether, Linseed Oil Biodiesel and Diesel, *SAE Technical Paper*, **2015.**

[6] Thomas R., Sreesankaran M., Jaidi J., Paul D., Manjunath P., Experimental evaluation of the effect of compression ratio on performance and emission of SI engine fuelled with gasoline and n-butanol blend at different loads, *Perspectives in Science*, **2016**, 8, 743-746.

[7] Sivaramakrishnan K., Investigation on performance and emission characteristics of a variable compression multi fuel engine fuelled with Karanja biodiesel–diesel blend, *Egyptian Journal of Petroleum*, **2018**, 27(2), 177-186.

[8] Kumar R., Anoop K. D., Combustion and Emission Characteristics of Variable Compression Ignition Engine Fueled with *Jatropha curcas* Ethyl Ester Blends at Different Compression Ratio, *Journal of Renewable Energy*, **2014**.

[9] Ramalingam S, Chinnaia P, Rajendran S. Influence of Compression Ratio on the Performance and Emission Characteristics of Annona Methyl Ester Operated DI Diesel Engine. *Advances in Mechanical Engineering*. **2014.**

[10] Mănescu B., Stănescu ND., Popa D., Pandrea N., Determination of the Dynamic Reactions for a Variable Compression Ratio Mechanism. *Acoustics and Vibration of Mechanical Structures—AVMS 2019*. **2021**.

[11] Satyanarayana K., Naik R.T., Uma-Maheswara R. Performance and Emissions Characteristics of

Variable Compression Ignition Engine. *Advances in Automobile Engineering*, **2016**, Vol. 5, Issue 2.

[12] Ambarish D., Bijan K. M., Effect of compression ratio on the performance, combustion and emission from a diesel engine using palm biodiesel, *AIP Conference Proceedings*, **2016**, 1754

[13] Vasudeva M, Sharma S, Mohapatra SK, Kundu K. Performance and exhaust emission characteristics of variable compression ratio diesel engine fuelled with esters of crude rice bran oil. *Springerplus,* **2016**, Vol. 5, article number 293

[14] Venkatesan H., Ramani V.S., Optimization of performance and emission parameters of single cylinder direct injection CI engine by varying compression ratio and injection timing," *2015 International Conference on Robotics, Automation, Control and Embedded Systems (RACE)*, **2015**, 1-5.

Numerical Investigation of Soot Formation and Oxidation in Wankel Rotary Engine Using Particulate Mimic Soot Model

S. Pisnoy[1], S. Frankel[1], L. Tartakovsky[1]

[1]Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, 3200003 Haifa, Israel

The stringent legislation regulating pollutant emissions brings the industry and academia to invest significant efforts in finding feasible ways to reduce the carbon footprint, and to mitigate the NOx and particulate matter (PM) formation in internal combustion engines (ICEs). The focus of this effort is mainly concentrated on reciprocating spark-ignition (SI) and compression-ignition (CI) ICEs, alternative low carbon intensity fuels, waste heat recovery, novel combustion processes (such as homogeneous charge compression ignition), etc. However, other types of engines are also developed and used, one of which is the Wankel rotary engine. This type of ICE is known by its notably high-power density, but also by its incomplete combustion and difficulty to meet the emission requirements. The reported study has evaluated numerically the emission formation in Wankel engines, with an emphasis on the formation and oxidation of soot. To do so, a three-dimensional computational fluid dynamics (CFD) model of commercial Wankel engine coupled with detailed chemistry solver and with a particulate mimic soot model was built using the commercially available CONVERGE software. Prediction and analysis of the soot mass and size distribution in the baseline Wankel engine was performed. Likewise, the influence of the rotor design and spark-plug arrangement on particle emission was also investigated.

Study for Reducing Fuel Consumption of Internal Combustion Engine Vehicles using OBD Driving Data and Machine Learning

D. H. shin[1], J. P. Cha[2], S. H. Park[3]*

[1]Department of Mechanical Engineering, Graduate School of Chonnam National University, [2]School of Mechanical and Automotive Engineering, Korea National University of Transportation, [3]School of Mechanical Engineering, Chonnam National University

Since Alpha Go ‘Google's AI Go program’ won Lee Se-dol in Korea in March 2016 there is a growing interest in AI and machine learning in various fields. In the automotive field many studies are being conducted to apply AI and machine learning. Artificial intelligence and machine learning applications require huge data sets. In the case of companies such as Hyundai Motor Company, engine data such as driver's driving pattern, speed, and RPM are converted into big data using the connected function of its specialized program, but general researchers do not have easy access to car data. However, there is one way to access the vehicle's engine-related information. In 1970, the US Environmental Protection Agency (EPA) required the standard OBD established by the American Automobile Manufacturers Association (SAE) to be installed in all vehicles to monitor the legal regulations of the vehicle. Korea has also mandated the installation of the OBD-II system on all passenger cars sold in Korea since 2005.

In this study, a machine learning model for predicting vehicle fuel consumption was studied based on the data measured through vehicle OBD-Ⅱ equipment. Reducing CO2 emissions is directly related to fuel consumption. Vehicle speed, engine rotational speed (RPM), fuel level, voltage, fuel/air ratio, throttle position, and manifold pressure were measured every day and big data was produced by inputting the weather and traffic volume of the day. The latitude, longitude, and altitude of the test road were measured using the XGPS 160 model that can measure 10hz, and ELM327 was used as the OBD-II scanner. In future research, deep learning (CNN, RNN, Decision Tree, SVM) is applied to model fuel efficiency prediction models of various eco-friendly vehicles with higher accuracy.

Reference

[1] Bratislav Predic, Milos Madic, Automatic Control and Robotics, 2016, 15, 105~116
[2] Zhigang Xu, Computer-Aided Civil and Infrastructure Engineering, 2018, 33, 209-219
[3] Sandareka Wickramanayake, Moratuwa Engineering Research Conference, 2016,
[4] Daeseok HAN, Inkyoon YOO, International Journal of Highway Engineering, 2017, 19, No.4

ACKNOWLEDGMENTS

This study was financially supported by Basic Science Research Program (2019R1A2C1089494) and Korea-India Joint Research Project (2020K1A3A1A19088692) through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (Korea).

Effect of High Temperature Fuel Injection on Atomization Characteristics of Gasoline Direct Injection Injector

M. Chang[1], S. Park[2]*

[1]Department of Mechanical Engineering, Graduate School of Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 61186, Republic of Korea, [2]Chonnam National University

To alleviate the increasing air pollution problem and continuously improve the performance of gasoline direct injection (GDI) engines, researchers are employing various methods, including the optimization of combustion and injection strategies, in addition to the selection of renewable fuels. Better combustion characteristics of engine are expected to achieve by improving the atomization characteristics of GDI injectors. Because smaller droplets accelerate evaporation process, promote a uniform air-fuel mixture formation and, finally control the combustion process. Atomization characteristics can be promoted by high-pressure injection, which has become the development trend of GDI engines. However, it has recently been discovered that the atomization of the fuel will also be greatly promoted under flash boiling conditions Flash boiling occurs when liquid fuel is injected into an ambient environment below its saturation pressure, which can be achieved by increasing the fuel temperature and lowering the ambient pressure. However, for most studies, only the atomization characteristics of the plume center point are measured, but we still lack knowledge of the overall atomization characteristics of the spray. In this study, about 100 measurement points are taken on a plane 30mm below the injector by using Phase Doppler particle analyzer (PDPA), and the overall atomization level and atomization uniformity of the spray under flash boiling and non-flash boiling conditions are analyzed through these measurement points.

The left side in Figure 2 shows spray pattern 30mm below injector tip and the measurement position of spray droplet. The right side in Figure 2 compares the droplet diameters of injector under subcooled and flash boiling conditions. The red symbol connected by solid line represents the saute mean diameter (SMD) calculated at 0.2 ms intervals. As the fuel temperature increases from subcooled conditions to flash boiling conditions, the standard deviation of the SMD at plume center decreases from 5.90 μm to 3.20 μm, and the standard deviation at spray center decreases from 3.73 μm to 1.60 μm. The smaller standard deviation of the SMD under flash boiling conditions means a uniform droplet diameter. A more uniform droplet diameter promotes the synchronous combustion of spray droplets and reduces the burning time, which will improve the instantaneous power of the engine, and reduce the soot particles produced due to insufficient combustion.

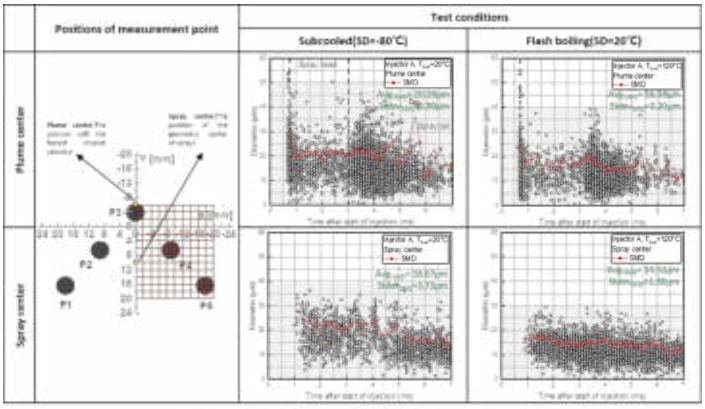


Figure 1. Spray droplet diameter at different measurement points.

[1] Lee Ziyoung, et al., Fuel, 2020, 259: 116209.
[2] Kale Rakesh, et al., SAE Technical Paper, 2018-01-0280.

Real Driving Characterization of DPF Regeneration Events in Euro-5 Light Duty Diesel Vehicles in the Australian fleet

S. Bagheri[1]

[1]University of Technology, Sydney

Recently developed Diesel Particulate Filters (DPFs) are able to remove more than 90% of the solid particle numbers produces as the result of diesel combustion. The accumulated soot in the filters is usually removed from the filters during periodic regeneration events. Many studies have highlighted raised Particle Number (PN) emissions during regeneration events [1-3]. In this study, two recent model (year of manufacture ≥ 2015) diesel sports utility vehicles were tested with and without regeneration events over real driving routes using a portable emission measurement system (PEMS) in Sydney, Australia. Test vehicles were selected based on their sales performance in Australia, thereby being representative of the most popular diesel vehicles. The tests were performed to determine the extent to which DPF regeneration events adversely affect emissions performance. Results show a considerable rise in PN emissions during the tests that include a regeneration event up to 16.7 times more than that during normal operation without regeneration. According to the results, one of the test vehicles did not pass the Euro-5 PN standard during the regeneration test while neither of the vehicles passed the Euro-5 standard during the regeneration period.

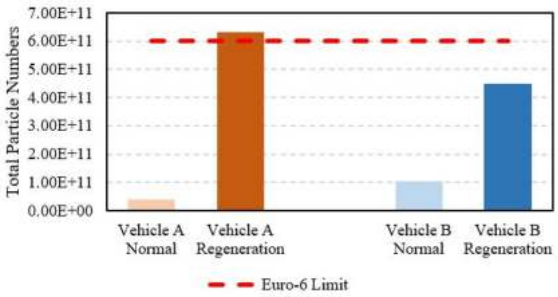


Figure 1-Total PN emissions for all tests in this study.

In addition to PN emissions, gaseous pollutant emissions were also elevated in regeneration tests compared to normal operation; for NO_x and THC by 14% and 99% on average, respectively. Compared to the Euro-5 limit values, both test vehicles fail to comply with NOx and THC+NO_x limits [4].

1. Yamada, H., *PN emissions from heavy-duty diesel engine with periodic regenerating DPF.* SAE International Journal of Engines, 2013. **6**(2): p. 1178-1189.
2. Smith, J.D., et al., *Real-time particulate emissions rates from active and passive heavy-duty diesel particulate filter regeneration.* Science of The Total Environment, 2019. **680**: p. 132-139.
3. Beatrice, C., et al., *How Much Regeneration Events Influence Particle Emissions of DPF-Equipped Vehicles?* 2017, SAE International.
4. Ko, J., C.-L. Myung, and S.J.A.E. Park, *Impacts of ambient temperature, DPF regeneration, and traffic congestion on NOx emissions from a Euro 6-compliant diesel vehicle equipped with an LNT under real-world driving conditions.* 2019. **200**: p. 1-14.

Investigation of the aging effect on the activity of a wiremesh oxidation catalyst as an emission control device for 4-stroke gasoline carburetor motorcycles

T. Hamzehlouyan[1], A. Taheri[1]

[1]Chemical and Petroleum Engineering Dept., Sharif U

Over one million motorcycles operating in the city of Tehran, capital of Iran, account for significant emissions of carbon monoxide (CO), volatile organic compounds (VOCs) and particulate matter (PM). Oxidation catalysts, as exhaust aftertreatment system of motorcycles, can reduce emissions of CO, VOC and PM. Due to the specific features of motorcycles under study, such as ultra-rich combustion and significant lubricating oil burning selection of an active, durable and cost-effective exhaust catalyst is a challenge. In addition, stability of such catalyst over high mileage needs to be investigated. In the present work, oxidation of CO and propylene (as a representative of VOCs) over a commercial Pt-Pd-based wiremesh catalyst is studied in a flow reactor set-up under simulated conditions relevant to 125 cc 4-stroke gasoline carburetor motorcycles. The effect of high-temperature hydrothermal aging is investigated using Temperature-Programmed Oxidation (TPO) tests along with catalyst characterization. To evaluate the effect of air-fuel ratio on the fresh catalyst activity, TPO tests were run for CO and C_3H_6 oxidation under ultra-rich, rich, stoichiometric, and lean conditions (corresponding to lambda values of 0.6, 0.8, 1.0, 1.2, respectively). It was found that increasing oxygen concentration shifts the light-off profile toward lower temperatures. Self- and mutual inhibition effects of CO and propylene was observed on the TPO profiles, consistent with previous results. The fresh catalyst was characterized using FE-SEM. An accelerated aging procedure, was conducted by exposing the sample to 10% water vapor at 900°C. Activity tests for the aged catalyst showed that by switching from ultra-rich toward lean condition, the CO and C_3H_6 light-off curves were shifted toward lower temperatures indicating the beneficial role of oxygen on the catalyst activity. It was found that the aging process shifts the light-off toward higher temperatures. The extent of deactivation under the rich and ultra-rich conditions were more significant compared to stoichiometric and lean conditions. According to the FE-SEM analysis, the aging increased the particle size range from 10-29 nm to 23-70 nm indicating particle agglomeration leading to catalyst deactivation. Our results suggest that injecting secondary air in the motorcycle exhaust gas can be used as a practical technique for enhancing CO and hydrocarbon oxidation efficiency over a Pt-Pd-based wiremesh catalyst.

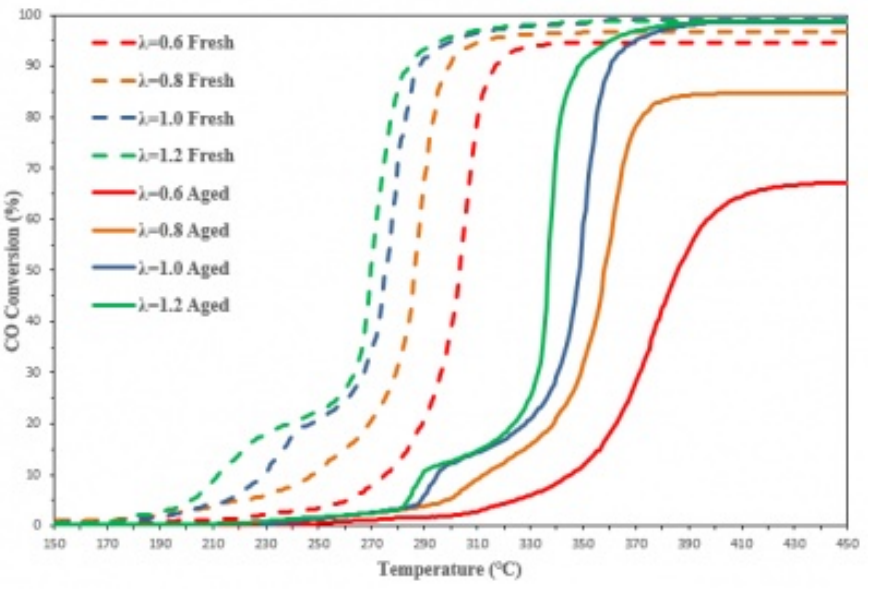


Fig. 1- CO conversion in the presence of C_3H_6 as a function of temperature at different air:fuel ratios; fresh catalyst (dashed line) vs. aged catalyst (solid line)

Sub-23 nm particle contribution from DI spark ignition engines fueled with gasoline and ethanol blends: PMP compliant measurement and digital filtering

A. Magno[1], S. Di Iorio[1], F. Catapano[1], B. M. Vaglieco[1], S. A. Pfau[2], A. la Rocca[2]

[1]CNR - STEMS, Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili, Napoli (Italia),
[2]Fluids and Thermal Engineering, University of Nottingham (UK)

Several studies evidenced a large presence of sub-23 nm particles at the exhaust of internal combustion engines. The particle nature, size and concentration are strongly influenced by the engine configuration and operation condition and above all by the fuel.

This work focuses on the sub-23 nm particles emitted from a 250 cc single cylinder SI engine equipped with direct injection (DI) system at different operating conditions with gasoline and ethanol both pure and in a blend at 25 % v/v (E25). Particle number and size were measured by an Engine Exhaust Particle Sizer (EEPS). A PMP compliant system was used for the sampling and conditioning of the sample. The measures were performed in both PMP than in not-PMP sampling conditions. The last configuration was aimed to promote nucleation and condensation phenomena in order to distinguish the volatile fraction by comparing the distributions measured in both configurations. Quantitate metrics based on the shift ratio calculated as $GMD_{NO\ PMP}/GMD_{PMP}$ revealed inception of nucleation particles for SR<1 (Figure 1-a) and condensation onto particles for SR>1. Alternative methods to achieve results comparable to PMP measurements were developed, one of these is the Digital Filtering of the linear approximation of the particle size distribution function, which was initially proposed by Leach et al. [1]. It is based on the application of counting efficiency function, based on the structure of a Wiebe, to the particle size distribution function. Pfau et alt. [2] developed a function suitable for the counting efficiencies proposed by the new regulation that will take in to account the particles from 10 nm. The Digital Filers proposed by Leach (Filter #1) and Pfau (Filter #2) were applied to PSD measured by EEPS. Linear regression yields good fits for both filters (Figure 1-b). Higher contribution of sub-23 nm particles for higher particle number (N_p) is evident from stronger reduction with Filter #1. The little reduction by applying Filter #2 reveals a smaller contribution of sub-10 nm particles overall.

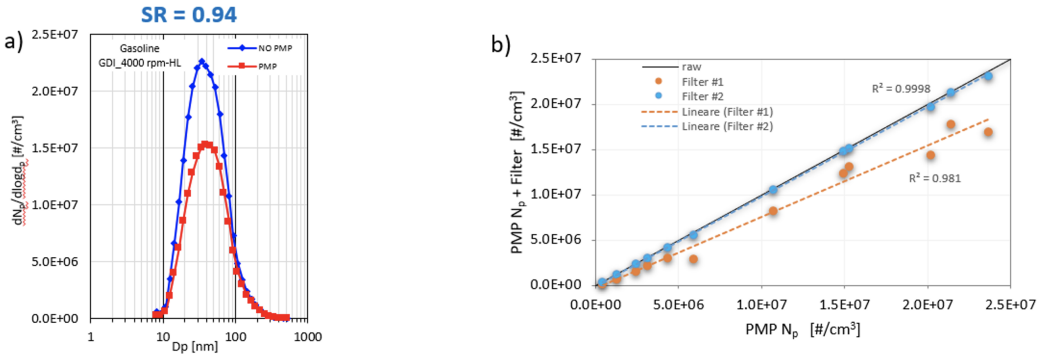


Figure 1. a) PSDF measured at both PMP and NO PMP conditions, b) Digital Filter application

[1] Leach F, Lewis A, Akehurst S, Turner J, Richardson D. Sub-23 nm Particulate Emissions from a Highly Boosted GDI Engine. SAE Tech Pap 2019;2019-Septe. https://doi.org/10.4271/2019-24-0153.
[2] Pfau SAM of S-23 nm PE from GE: AC of PM, Hafftner-Staton E, La Rocca A. Measurement of Sub-23 nm Particulate Emissions from GDI Engines : A Comparison of Processing Methods. SAE Tech Pap 2019.

Effects of overlapping in the evaluation of volume and surface area of complex soot aggregates in flames

J. Morán[1], A. Poux[1], F. Liu[2], F. Escudero[3], A. Fuentes[3], J. Yon[1]*

[1]Normandie Univ., UNIROUEN, INSA Rouen, CNRS, CORIA, 76000 Rouen, France, [2]Metrology Research Centre, National Research Council of Canada, Ottawa, Ontario, Canada, [3]Departamento de Industrias, Universidad Técnica Federico Santa María, Av. España 1680, Casilla 110-V, Valparaíso, Chile

The release of ultrafine soot particles to the atmosphere can cause detrimental effects on the environment for example by influencing the formation of clouds and/or by changing the radiative properties of the atmosphere [1]. In most numerical works, soot particles are typically considered either spherical in some numerical simulations or fractal aggregates in advanced codes that neglect the overlapping between primary particles. These approximations lead to significant deviations in the surface area and volume of soot particles, which in turn can cause large uncertainties in modeling soot physicochemical processes depending on particle sizes, such as collision rates and surface reaction rates (both surface growth and oxidation).

Fractal-like aggregates representative of flame-made soot (fractal dimension 1.78, prefactor 1.30, and 2-1000 number of spherical monodisperse primary particles) are generated by using a recently developed sequential algorithm called FracVAL [2]. Subsequently, primary particles are enlarged uniformly to induce a desired level of overlap in the 0-90% range. The volume and surface area of these aggregates are then calculated using the accurate but expensive (in CPU time) SBL library [3]. Based on these calculations, different equations to approximate their volume and surface area are proposed. In addition, a new method to estimate the population average overlapping coefficient is introduced. This requires the total number of collisions to be known at all times. As a test case, the method is implemented to predict the total surface area and volume of soot aggregates in an ethylene (C/O=0.94) laminar premixed flame [4].

The proposed equations extend the works of [4,5] to determine total soot volume and surface area in time. Current expressions are accurate for aggregates of any size relevant to soot particles produced in flames at atmospheric pressure. Under the test case conditions (premixed flame), neglecting primary particle overlapping leads to a maximum overestimation of soot particle total volume and surface area of 91 and 218%, respectively. The proposed approach exhibits a maximum error of 0.6% for total volume and 5.75% for total surface area. This method only requires the total number of collisions in time, the surface growth rate (the rate of change in primary particle diameter), and the number of primary particles per aggregate. All of these parameters are readily available in most population balance simulations making its implementation in existing codes straightforward. The proposed method can also be used in future Monte Carlo or Langevin Dynamics discrete element simulations to potentially reduce the CPU time associated with the evaluation of aggregate volume and surface area.

[1] Lohmann, U., *et al*. *Nature Geoscience*, **2020**,*13*(10), 674-680.

[2] Morán, J., Fuentes, A., Liu, F., & Yon, J. *Comput. Phys. Commun.*, **2019**, *239*, 225-237.

[3] Cazals, F., *et al*. *ACM Trans. Math. Software (TOMS)*, **2011**, *38*(1), 1-20.

[4] Morán, J., Poux, A., & Yon, J., *J. Aerosol Sci.,* **2021**, *152*, 105690.

[5] Brasil, A. M., *et al*., *J. Aerosol Sci.*, **2001**, *32*(4), 489-508.

A Silver Particle Generator for PN-PEMS Calibration and Validation

M. Irwin[1], J. Swanson[1,2], V. Berger[1], U. Sonkamble[1], A. Boies[1,3], H. Schulz[1]

[1]Catalytic Instruments GmbH, [2]University of Minnesota, [3]University of Cambridge

There currently exist few commercial options for the consistent and reliable generation of solid aerosol particles in the 1-50 nm size range. These options include spark generators, tube furnaces, electrosprays, and gas burners utilising diffusion flames. Thus, there is a need for additional options for a simple-to-use, particle generator capable of producing sufficiently high concentrations of small, solid aerosol particles. Uses for such a device include the calibration of condensation particle counters, measuring filtration efficiencies, and the calibration and complex measurements made possible with specialist aerosol equipment, including cutting-edge emissions measurements such as PN-PEMS. The efficiency of PN-PEMS is checked with monodisperse aerosol, and linearity is checked usually with polydisperse aerosol in order to reach high concentration levels [1]. Silver particles can be used as a proxy for soot particles and given their single elemental composition this approach may offer reduced uncertainties to other generation techniques. Tube furnaces can be used to generate silver nanoparticles for calibrated CPCs, but aside from the size, cost, and inconvenience of a tube furnace, it is challenging to generate repeatable concentrations and size distributions from a typical tube furnace.

Here we present the characterisation of a new Silver Particle Generator, capable of producing sufficiently high concentrations of particles in the 1 - 50 nm size range. Data presented include CPC calibration, and repeatability measurements across its operational range. This novel Silver Particle Generator solves several key aspects associated with the production of metallic nanoparticle aerosols. By fixing the location and surface of metal exposed to the supplied gas stream, the stability of the nanoparticles produced is greatly enhanced compared to a typical tube furnace. Further, day-to-day variability is greatly reduced, in both concentration and size domains. The SPG has been finely tuned to generate a repeatable solid aerosol size distribution for each set point, and thermal cycling has been optimised, such that the device is operational from standby in under 10 minutes. Importantly, our novel and patented design allows for a more compact device that allows for lower energy consumption.

[1] Barouch Giechaskiel, Real Driving Emissions (ROE): Particle Number (PN) Portable Measurement Systems (PEMS) calibration, EUR 29036 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978·92-79-77482-9, doi: 10.2760/553725, JRC110424

Effects of ambient CO_2 and H_2O on soot formation in n-dodecane spray combustion

M. Zhang[1], J. C. Ong[1], K. M. Pang[2], X. S. Bai[3], J. H. Walther[1,4]

[1]Technical University of Denmark, [2]MAN Energy Solutions, [3]Lund University, [4]ETH Zurich

In this study, large eddy simulation (LES) is performed to investigate the effects of ambient carbon dioxide (CO_2) and water (H_2O) on the soot formation in an n-dodecane spray flame. A two-equation soot model, in which acetylene (C_2H_2) is set as the soot precursor and surface growth species, while OH is selected as the one of the soot oxidizers, is implemented here. The ambient oxygen (O_2) level and temperature are fixed at 15% (mole basis) and 900K, respectively. The predicted ignition delay, lift-off length, and soot distributions show good agreement with experimental data. The effects of ambient CO_2 and H_2O on the soot formation can be separated into thermal and chemical effects. For the thermal effects, the ambient CO_2 and H_2O enhance the formation of C_2H_2 but reduce the formation of OH radicals by lowering the flame temperature. This leads to a higher soot mass formed. Conversely, the ambient CO_2 and H_2O reduce the soot formation due to their chemical effects. The reaction $CH_2^* + CO_2 \leftrightarrow CH_2O + CO$ is found to be main pathway for reducing C_2H_2 formation when the ambient CO_2 is present. The ambient H_2O results in a lower C_2H_2 mass formed due to a higher amount of OH radicals produced. As a result, these collectively lead to a lower soot mass formed.

Morphology and structure of biofuel combustion generated particles

F. Jaliliantabar[1], R. Bin Mamat[1], S. Kumarasamy[2], A. Abdullah[2], M. Bin Muhammad Azlan[1]

[1]College of Engineering, Department of Mechanical Engineering, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia, [2]Faculty of Mechanical and Automobile Engineering, Universiti Malaysia Pahang, Pekan, Kuantan, 26600, Malaysia

Soot emission or carbon black has increasingly gained more attention in recent years. This can be attributed to its high toxicity characteristics which can cause serious human health problems such as lung cancer and pulmonary diseases. Generally, internal combustion engines have been introduced as the main source of these materials specially in urban areas. Furthermore, the particles in the range of nano size, so-called nano particles, or NPs, are counted as the most carcinogenic particles in term of the size which are produced during the combustion process. On the other hand, the production of NPs during combustion in compression ignition engines is an undeniable fact. Different methods have been proposed to reduce engine soot emissions such as DPF (Diesel particulate filter) which is attached to the engine exhaust line and microstructure and size of NPs were introduced as important parameters on its efficiency. In addition, biodiesel has become widely accepted as an appropriate substitution for diesel fuel, however, the using of biodiesel fuel may change engine emissions and performance characteristics. It is observed that biofuel fuel has higher soot oxidative reactivity, and it is more reactive than diesel fuel, which is an advantage for DPF regeneration. Smaller size of NPs in biodiesel fuel soot compared to diesel fuel is mentioned as a reason for this phenomenon. Filtration efficiency which is a crucial characteristic of the DPFs for biodiesel fuel and diesel fuel was found to be much different. These differences are attributed to the morphology of the produced soot of the fuel burning. The source of the biodiesel fuel is introduced as an impactful parameter on engine NPs morphology and size. Then in this study, the effects of biodiesel fuel on the combustion generated particles are discussed comprehensively.

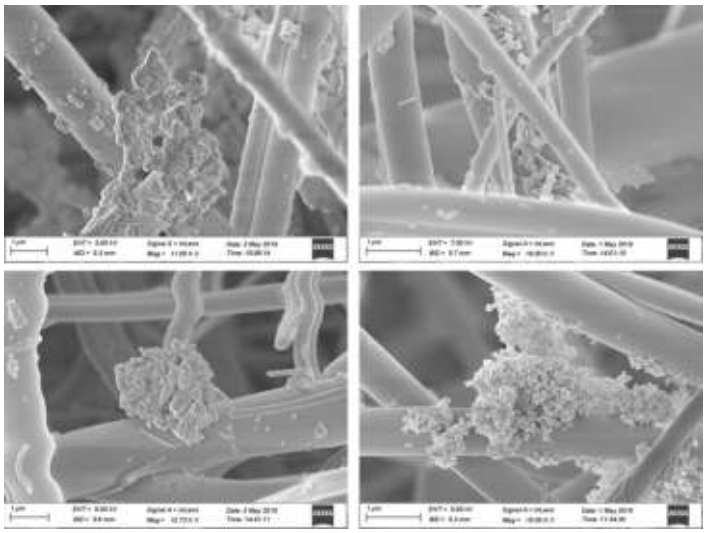
Surface Electron Microscope Based Morphological and Chemical Characterization of Combustion Generated Aerosols

P. Kaur[1], A. Guha[1]

[1]Department of Physics, Tripura University, Tripura

Smoldering and Flaming combustion phases are very important combustion phases in biomass burning due to their different burning characteristics with respect to climate and health effects. In the present study, we have used a scanning electron microscope (SEM) to characterize the surface morphology of the samples collected during the burning of different woods and branches (Bamboo, Teak, Coconut shell, Jackfruit, Arjun, Akashi, Mango, Blackberry, Guava, and dry leaves) under flaming and smoldering combustion phases. Energy dispersive X-ray (EDS) coupled with SEM is used for the chemical characterization of samples collected during different combustion phases. We have noticed a variation in the morphology of particles for both the combustion phases. We have identified different shapes of particles that vary from regular to irregular including spherical, nearly spherical, triangular, capsule-like shapes. We have found different clusters of particles like chain-like structure, soot structure, and other irregular structures. We have found different morphological characteristics when the same wood sample is identified using SEM but for different combustion phases. Also, we have noticed a difference in the elements present in the sample for different combustion phases but same biomass. We have noticed the major contribution by elements like O, Si, C, and B in the scanned samples. Different elements such as C, O, K, Ca, B, Cr, Mn, Fe, Cu, Zn, Na, Mg, P, Nb, S, Pb, Cl, Al, Kr, Y, Ta, Rb are identified with change in their elemental weight percentage. Details will be presented.

Keywords: Atmospheric Aerosols; Smoldering; Flaming; Morphology; Elemental Composition



Soot morphology and internal structure variations with fuel aromatics inside the cylinder of a diesel engine

S. Kook[1]

[1]The University of New South Wales, Sydney, Australia

Aromatics are important in maintaining fuel stability and lubricity but have a negative impact of increased soot formation in a diesel engine. This study systematically evaluates the fuel aromatics impact on soot formation in a diesel engine by applying thermophoresis-based direct particle sampling. In a running optical diesel engine, the sooting regions are identified via high-speed luminosity imaging and planar laser-induced incandescence (PLII) imaging. The soot particles are sampled on a carbon-coated grid securely held up at the tip of a probe mounted on the piston-bowl wall. The sampled particles are imaged using both a standard transmission electron microscope (TEM) and high-resolution TEM for visual inspection and statistical analysis of key morphology parameters (Figure 1). This method is used for custom-made fuels with 4%, 14% and 24% aromatic content with minimal variations in other physical and chemical properties. From soot luminosity and PLII images, the soot distribution and development pattern are found not to change due to fuel aromatics. However, a higher aromatic fuel shows earlier soot inception and higher growth rate, leading to higher peak soot and increased remaining soot at the end of main combustion event. Detailed analysis of sampled soot particles shows carbon layers within the soot primary particles grow more for a higher aromatic fuel, which forms more mature, graphitised internal structures. The increased soot formation for a higher aromatic fuel is closely linked to increased soot aggregates size. Both the TEM images and size distribution plots indicate significantly enhanced soot aggregation caused by higher aromatics.

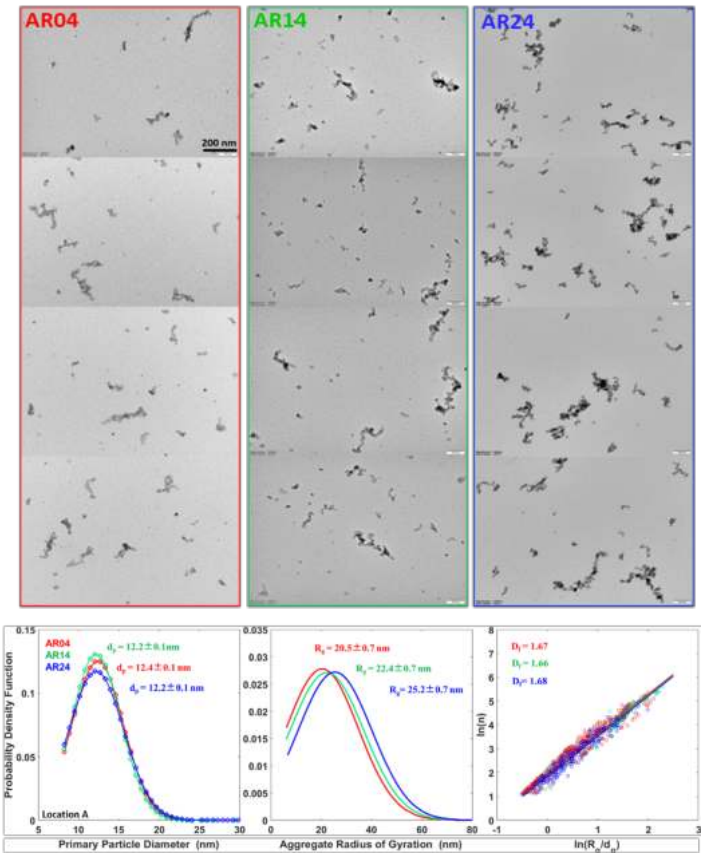


Figure 1 TEM images of soot particles sampled directly from the flames in a diesel engine running on fuels with 4, 14 and 24% aromatics (top) and size distributions of soot primary particles and aggregates as well as the fractal dimension (bottom)

A Critical Analysis of COVID-19 with Special Emphasis to Air Quality and its Consequences

T. Khan[1], A. LAWRENCE[2]*

[1]Integral University, Lucknow, India, [2]Isabella Thoburn College, Lucknow,India

SARS-CoV-2, also known as COVID-19 has taken over the world. The deadly virus causes serious respiratory infections in humans. A number of researches are ongoing to contain the spread of the virus. The aim of this review is to assess the impact of air pollution and environmental factors which may influence the transmission of the disease. This study is aimed to review and analyse various dimensions related to SARS-CoV-2, including its origination, structural features, mode of spread, clinical symptoms and the effect of air pollution in relation to the spread of the virus and the status of in air quality during the lockdown. Air pollutants induce oxidative stress in the airways initiating an inflammatory response and facilitating release of inflammatory cells and mediators (cytokines, chemokines, having a negative effect on the respiratory system. Transmission of the SARS-CoV-2 may be facilitated by the airborne particulate matter. The air quality in cities like New Delhi and Wuhan has been constantly degrading. During the SARS outbreak in China affected patients were more likely to succumb if they belonged to areas of high air pollution. Evidences have suggested that the spike in air pollution may exacerbate the number of infections and the improved air quality during the lockdown period may somewhat influence the faster recovery rate. Positive effect of lockdown on the overall air quality has also been analyzed. Diverse environmental factors like temperature, humidity and air pollution have also acted as contributing factors for the facilitated spread of the infection, or at least in making people more vulnerable to it which makes it an issue of considerable attention in developing countries like India, due to the high air pollution levels in megacities. In developing countries like India, the spread of the virus may be influenced by ambient air pollution, because pollution has been proven to accelerate respiratory illnesses including COVID-19.

Single-cell sequencing reveals spatio-temporal and material specific cellular perturbation patterns in the lungs of nanoparticle exposed mice

C. Voss[1,3], M. Ansari[2,4], I. Angelidis[2], C. Mayr[2], M. Strunz[2], H. B. Schiller[2], T. Stöger[1]*

[1]Dynamics of Pulmonary Inflammation, iLBD/CPC, Helmholtz Center Munich, Germany., [2]Systems Medicine of Chronic Lung Disease, iLBD/CPC, Helmholtz Center Munich, Germany. , [3]Mechanism of Neonatal Chronic Lung Disease, Ludwig-Maximilians-University, Munich, Germany. , [4]Institute of Computational Biology, Helmholtz Center Munich, Germany

Many rodent studies focus on the global pulmonary response to nanomaterial exposure. Cellular key players orchestrating specific downstream event initiation or leading to long-term consequences are still unknown. Recapitulation of these *in vivo* toxicological findings *in vitro* (IVIV) is a major challenge of the current nanotoxicology community. Mimicking adverse outcome pathways for chronic pulmonary effects in vitro is of great importance, especially in line with the 3R strategy and the development of NAMs (new approach methodologies) in nano-hazard assessment. In this study, we investigated lungs instilled with carbon nanoparticles (CNPs), double walled carbon nanotubes (DWCNTs) and multi-walled carbon nanotubes (MWCNTs) with single-cell RNA sequencing technology. Instillation doses of CNPs, DWCNTs and MWCNTs were chosen to result in a comparable level of inflammatory response measured by the neutrophil numbers in BAL fluid at 12h. Neutrophilia persisted over 6d for all NMs but not LPS. After 28d, neutrophil numbers were further reduced but did not reach base levels of sham controls. With scRNAseq we identified over 30 different pulmonary cell types represented in our dataset. Global differential gene expression patterns already indicate a strong involvement of the bronchial epithelium for all treatments and time points, however, the temporal patterns were surprising. CNPs and DWCNTs for instance elicit an increasing, time-dependent response in club/ciliated cells peaking at 28d. Also MWCNTs induce gene expression changes in the bronchial compartment at 12h which is mainly replaced at 6d by orchestrating monocytes and macrophage populations. This was also evident in cell communication network analyses showing functional interactions of bronchial epithelium with matrix- and lipofibroblasts at 12h and a remarkable role for classical monocytes to modulate the inflammatory response in later time points. Furthermore, all NMs and particularly MWCNTs cause alveolar epithelial type 2 cell injury marked by elevated Lipocalin 2 (Lcn2) release over 28d. Lcn2 is mainly regulated in activated AT2s for all treatments, in contrast neutrophils only express elevated Lcn2 levels after LPS and CNTs. Additionally, MWCNTs rapidly (12h) and efficiently induce an intermediate epithelial cell state recently identified for their important role in epithelial regeneration ($Krt8^+$ ADI cells [1]). These ADI however do not contribute to the inflammatory resolution as at 6d ADI cannot be detected, instead, cells expressing markers of (re-)activated AT2s highly appear, indicating a cycle of inflammatory stimuli by MWCNTs. Alveolar macrophage cell death was identified as key initiating event for DWCNTs and MWCNTs, not for CNPs, long term toxicity. Experiments are ongoing to further substantiate the hypothesis of lysosomal destabilization.[2] Giant monocytic/macrophage-like cells are already visible at d6 after instillation, especially for MWCNTs and persist up to day 28 indicating granuloma formation to remove CNTs efficiently. The major role of monocytes orchestrating the long term signaling events is therefore to be studied in detail. Further analysis of specific cell-cell communication is currently ongoing based on intricate connectome analysis. This comprehensive dataset will, for the first time, facilitate mimicking of acute and chronic inflammatory processes by identifying new AOP key events for *in vitro* testing strategies.

[1] Strunz, M., et al. Nature Communications, 2020. **11**(1): p. 3559.

[2] Zhu, W., et al. Proceedings of the National Academy of Sciences, 2016. **113**(44): p. 12374-12379.

Portable exhaust toxicity system: A concept of a portable air-liquid interface cell exposure system for laboratory and on-road assessment of exhaust toxicity

M. Vojtisek-Lom[1], M. Pechout[2], T. Cervena[3], P. Rössner[3]

[1]Czech Technical University in Prague, [2]Czech University of Life Sciences in Prague, [3]Institute of Experimental Medicine of the Czech Academy of Sciences

Due to discrepancies between legislative metrics for and health effects of particulate matter, and between laboratory tests and real driving, health-relevant metric applicable to real driving conditions are being sought to evaluate the effects of emerging legislation, technologies and fuels. Models of human lung air-liquid interface have been recently explored to simulate effects of exposure to the whole exhaust. In this study, a compact exposure system, utilizing commercially available inserts with 3D in-vitro model of human lung cells, has been designed and fabricated in-house with the vision of mobile use, minimizing size and power consumption. Preliminary tests were done on a Euro 6 direct injection spark ignition engine operating at speeds and throttle positions corresponding to the WLTC cycle. A sample of diluted exhaust was taken from two systems offering dynamic variation of dilution ratio to account for variable exhaust flow: a proportional sampling gravimetric system and from a rotating disc diluter. The highest particle losses – around 40 % - were in a membrane humidifier, a part of the effort to maintain incubator conditions of 37 C, 80-95 % relative humidity and around 5 % CO_2 at the cells. Two types of cell cultures have been exposed over a period of 5 days, with daily exposure consisting of two runs of WLTC, first with a cold start, active cooling of the engine for two hours, and two additional runs of WLTC, with acceptable rate of cell survival. The compact design and choice of components offers a promise for implementation during common laboratory tests and also on the road.

Real time *in vivo* investigation early alveolar neutrophil dynamics during ventilator-assisted nanoparticle inhalation

M. Rehberg[1], Q. Liu[1], O. Schmid[1], T. Stöger[1]

[1]ILBD/CPC, Helmholtz-Zentrum München

Inhalation of nanoparticles (NPs) can induce a pro-inflammatory response of the lung, characterized by the influx of neutrophilic granulocytes into the airspace. However, the spatio-temporal events taking place in the early phase of NP induced neutrophil recruitment from the pulmonary microvasculature to the alveolar compartment remain largely elusive.

To visualize and measure in real-time the cellular pulmonary innate immune response simultaneously with NP dynamics, we apply state of the art intravital microscopy (IVM) on the alveolar region of the murine lung, in combination with ventilator-assisted inhalation of nebulized NP aerosols.

This novel approach enables the study of (sub-)cellular dynamic events, which were inaccessible up to now.

Carboxyl Quantum-Dots (cQDs, 20 nm diameter) - which served as fluorescent model NPs - became visible within seconds after the onset of inhalation of 2.8 µm cQD suspension droplets and accumulated as distinct fluorescent spots at the alveolar walls. Already at 45 min after inhalation, a deposited NP dose of 16 cm^2/g (geom. surface area of NPs / mass-lung), determined by quantitative fluorescence measurements, elicited an increase in neutrophil numbers (immunolabeled with fluorescent anti-Ly6-G) in the area of observation, as compared to the control group. Neutrophils preferentially arrested in microvessels in close proximity to the NPs, where they exhibited a probing/crawling behavior. The number of alveolar localized neutrophils, i.e. after trans-endothelial and trans-epithelial migration, was significantly increased 60 min upon NP inhalation, compared to the control group, receiving vehicle. Interestingly, we frequently observed alveolar localized neutrophils with ingested NPs. This observation may point towards a contribution of neutrophils in the alveolar clearance of NPs. In addition, our results suggest a specific immune function of cells of the alveolar walls in response to NPs, including crosstalk with microvascular endothelium, facilitating rapid and site-specific recruitment of neutrophils.

Predicting the permeation of PAHs and nanoparticles through biological cells

A. Violi[1]

[1]University of Michigan

v id="enc-abstract" class="abstract-content selected">
One of the main issues related to the health effects of pollutants is their ability to cross biological cells, i.e. the transport through a physiological cellular membrane. The behavior of nanoparticles in a biological matrix is a very complex problem that depends not only on the type of nanoparticle but also on its size, shape, phase, surface charge, chemical composition, and agglomeration state.

In this paper, we introduce a theoretical model that predicts the average time of entry of nanoparticles in lipid membranes, using a combination of molecular dynamics simulations and statistical approaches. The model identifies four parameters that separate the contributions of nanoparticle characteristics (*i.e.*, size, shape, solubility) from the membrane properties (density distribution). This factorization allows the inclusion of data obtained from both experimental and computational sources, as well as a rapid estimation of large sets of permutations in membranes. The robustness of the model is supported by experimental data carried out in lipid vesicles encapsulating graphene quantum dots as nanoparticles.

The new model, named LDA, is applied to the permeation of PAHs through various membranes, and to the study of small molecules crossing the viral envelope of the SARS-CoV-2.

Given the high level of interest across multiple areas of study in modulating intracellular targets, and the need to understand and improve the effects of nanoparticles and to assess their effect on human health (*i.e.*, cytotoxicity, bioavailability), this work contributes to the understanding and prediction of interactions between nanoparticles and lipid membranes.

Characterization of oxidative potential and toxicology in vitro study of fine and ultrafine PM generated by smoke grenades shots

V. Martin de Lagarde[1], T. Rogez[1], F. Cazier-Dennin[2], D. Dewaele[2], M. Janona[1], F. Cazier[2], C. Monteil[1], C. Corbière[1]

[1]University of Rouen Normandy, Health Department - ABTE EA4651 ToxEMAC, Rouen, France, [2] University of Littoral Côte D'Opale, Centre Commun de Mesures, Dunkerque, France

Pyrotechnic smokes are widely used for civilian and military applications: protection, security, festivity, obscuring or signaling. Particulate air pollution is a major public health concern and smokes combustion induces intense particulate matters pollution episodes. There are multiple types of smokes with various initial compositions, but there is a lack of data on chemicals produced after combustion and their toxic effects.

In this study, we evaluated the toxicity of particles of two different smokes, a red signaling smoke (RSS) and an hexachloroethane-based obscuring smoke (HC-OS) by measuring their oxidative potential (OP) and by exposing a 3D model of primary human pulmonary cells (NHBE) grown at the Air-Liquid-Interface to suspended particles. OP was examined with the dithiothreitol (DTT) and the antioxidant (acid ascorbic) depletion assays. Cytotoxicity (MTT, cell cycle, ATP production) as well as pro-inflammatory and antioxidant genes expression (RT-qPCR) were explored after 24h of exposure (RSS and HC-OS) and after 24h of recovery for RSS particles exposure.

Physico-chemical characterization of particles was previously studied and revealed that particles were smaller than 1 µm diameter; therefore particles are capable to penetrate deep into the airways after inhalation. Furthermore, RSS particles were more organic (quinones and polycyclic aromatic hydrocarbons) than HC-OS particles that were mainly metallic. Indeed, we noticed a higher metal content (133 282 µg/g) especially in Al (106 000 µg/g) and Fe (12 100 µg/g) compared to RSS particles (12 035 µg/g). Results showed (Mean +/- SD) that DTT was significantly depleted by RSS (73.7% +/- 1.1) and HC-OS (42.0% +/- 0.1) particles at the highest dose of exposure (50 µg/cm^2) but acid ascorbic was only depleted by HC-OS (42.3% +/-1.3). Both particles were not cytotoxic but genes expression was altered and was dependent on particles type. Particles from RSS (50 µg/cm^{2}l) but not from HC-OS significantly increased superoxide dismutase 1 (SOD1, 1.48 +/-0.10) and 2 (SOD2, 1.32 +/-0.06) and heme oxygenase-1 (HO-1, 8.32 +/-2.5) expression. Both particles significantly induced NADPH quinone oxidoreductase-1 (NQO-1, 6.35+/-0.6 with S1, 1.73+/-0.1 with S4) and IL-8 expressions (2.11+/-0.3 with RSS, 1.79+/-0.4 with HC-OS) whereas the catalase expression was unchanged. After 24h of recovery, genes expression were back to normal (SOD1, SOD2, HO-1), stayed significantly increased (NQO-1, IL-8) or remained unchanged (Catalase).

Because of their different chemical composition, smoke particles produced many different reactive species, which can be detectable by the two OP assays. Indeed, the reaction of DTT assay is mainly associated with organic components, which may explain the higher depletion by RSS particles. On the contrary, acid ascorbic depletion is generally attributed to metals corresponding to HC-OS depletion. Our study demonstrated that NHBE exposure to different military smoke particles triggered an adaptive antioxidant response that was reversible for RSS particles and lead to inflammatory response but without cytotoxicity. This study improves the knowledge of the toxicity of pyrotechnic mixtures like smoke particles to assess human health risk.

Keywords: smokes particles, oxidative potential, Air-Liquid Interface exposure, primary human pulmonary cells, antioxidant and inflammatory responses

In vitro toxicity of airborne emissions from combustion of graphene nanoplatelet-enabled epoxy nanocomposites

W. Netkueakul[1,4], S. Chortarea[2], H. Li[1,4], G. Qiu[1,4], M. Jovic[3], S. Gaan[3], T. Buerki-Thurnherr[2], P. Wick[2], J. Wang[1,4]

[1]Institute of Environmental Engineering, ETH Zurich, 8093, Zurich, Switzerland, [2]Particles-Biology Interactions Lab, Empa, Swiss Federal Laboratories for Materials Science and Technology, 9014, St. Gallen, Switzerland, [3]Additives and Chemistry Group, Advanced Fibers, Empa, Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, 9014, Switzerland, [4]Laboratory for Advanced Analytical Technologies, Empa, Swiss Federal Laboratories for Materials Science and Technology, 8600, Dübendorf, Switzerland

Combustion is one of the processes occurring at the material's end of life. The combustion process can release the embedded nanoparticles from the nanocomposite's matrix and might transform the nanoparticle's properties[1]. An increasing use of graphene nanoplatelets (GNPs) as an additive in commercial products raises concerns about the potential risks of the released particles, especially human exposure to airborne fraction of the released GNPs since inhalation is one of the major exposure routes. Despite many studies about the release of nanoparticles induced by combustion [2], [3], the hazard assessment of the GNPs released from the combustion is still limited. Therefore, this study aims to characterize the particulate and gaseous emissions from the combustion of neat epoxy (EP) and GNP-enable epoxy composite (EP-GNP) and evaluate the biological effects of the emissions on human alveolar epithelial cells (A549) cultivated at air-liquid interface for up to 96 h after the combustion exposure. The particle modal sizes of the emissions from both EP and EP-GNP were in the respirable range of 4 µm. We found volatile organic compounds and polycyclic aromatic hydrocarbons (PAHs) in the soots and gases from the emissions. After the treatment with the emissions from both EP and EP-GNP, the quantification of lactate dehydrogenase suggested no adverse effects on cell membrane integrity. Cells treated with the emissions from EP-GNP, but not EP, showed a significant reduction in mitochondrial activity at 24 h time point. However, this effect was transient and values recovered to those of filtered air controls after 96 h. Release of the inflammatory chemokines/cytokines MCP-1 and GM-CSF was increased at 24 h time point after exposure to both EP and EP-GNP, while the values were dropped to control levels at 96 h. Expression of CYP1A1 gene, associated with metabolic activation of PAHs, strongly increased with exposure to both EP and EP-GNP at both time points. Exposure to EP-GNP emissions caused slightly higher CYP1A1 expression at 24 h than exposure to EP emissions. Our results reveal potential enhanced toxicity from GNP nanofillers, which should be considered in future risk assessment studies and the safe design and use of GNP-enabled nanocomposites.

This work was supported by the EU Horizon 2020 Framework Graphene Flagship GrapheneCore2 (grant n°785219) and Swiss National Science Foundation (SNF) (grant number 310030_169207).

[1] J. Wang, L. Schlagenhauf, A. Setyan, *J. Nanobiotechnology*, **2017**, 15 (1), 15.
[2] C. Watson-Wright, D. Singh, P. Demokritou, *NanoImpact*, **2017**, 5, 29–40.
[3] J. P. Coyle et al., *Part. Fibre Toxicol.*, **2020**, 17 (1), 40.

MetroPEMS: Metrology for portable emission measurement systems. Project goals and preliminary findings

J. Saturno[1], A. Nowak[1], D. Worton[2], M. Schakel[3], R. Pettinen[4], V. Ebert[1]

[1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany, [2]National Physical Laboratory, Teddington, United Kingdom, [3]VSL Dutch Metrology Institute, Delft, The Netherlands, [4] VTT Technical Research Centre of Finland Ltd., Espoo, Finland

Nitrogen oxides and particulate matter emitted by vehicles are among the most important components of urban and suburban air pollution. They are associated to multiple damages to human health, to negative impacts on agricultural yields, and particulate matter emission, which is dominated by black carbon, has important effects on climate change by acting as a negative radiative forcer. Therefore, controlling vehicle exhaust emission has been in the agenda of regulatory bodies around the world since the last decades and significant progress has been achieved in reducing emission by the introduction of stricter regulations and controls. However, the type approval (TA) of light duty vehicles (LDV), traditionally done in dynamometer test benches has proven not to be representative for real driving conditions. In order to tackle this issue, real driving emission (RDE) tests have been introduced by legislation since 2017 in Europe.

Portable emissions measurement systems (PEMS) are used for on-road TA real driving emission of LDVs. The implementation of RDE measurements is complementary to stationary in-laboratory dynamometer test over the current Worldwide Harmonised Light Vehicle Test Procedure (WLTP), from which not-to-exceed conformity factors are defined for nitrogen oxides (NO_x) as well as for particle number (PN). These conformity factors established by the regulation are revised periodically and have been reduced in each revision. Although, the regulations are revised continuously, there are few metrological specifications nor infrastructure available to guarantee SI-traceable calibration of PEMS.

The MetroPEMS project addresses the three key components of a PEMS system: i.e. modules for the determination of (i) NO/NO_2 concentrations and (ii) PN, as well as (iii) exhaust mass flow. By studying existing commercial PEMS devices and comparing the performance of their components with known and fully traceable laboratory standards, the project will develop uncertainty budgets for each of these three key parts. Furthermore, based on these uncertainty budgets, the major contributing elements to the uncertainty of the PEMS device will be identified, and best practices will be developed to improve the underlying factors of these uncertainties and to improve comparability. Based on the deeper understanding of the uncertainty sources, this project will develop and intends to qualify a ‘golden’ PEMS (gPEMS) instrument, which will represent the best available level of accuracy that can be achieved and will use the procedures developed in the project. This qualification will make use of the project’s newly developed gas and particle standards, optical transfer standards, exhaust mass flow standards and metrologically sound calibration procedures. The gPEMS is going to be based on a commercial instrument that will be also validated with available procedures on a chassis dynamometer and constant volume sampler (CVS) system set-up. This will be done in order to maximise knowledge transfer and applicability for end-users.

The MetroPEMS project is creating the metrological capabilities that will provide traceability for PEMS calibration. More information about the project can be found at https://metropems.ptb.de

Potential of portable on-board FTIR analyzers for real driving emissions and chase vehicle monitoring

M. Vojtisek-Lom[1]

[1]Czech Technical University in Prague

This presentation reviews the possibilities of using a mobile, in-vehicle FTIR analyzer as a single on-board instrument for the measurement of exhaust emissions all principal gaseous pollutants of interest, and, in a chase vehicle configuration, for remote check of NOx aftertreatment functionality on individual vehicles. Outdoor air pollution remains one of the leading causes of premature deaths, with particulate matter, nitrogen oxides and tropospheric ozone being of principal concern. Historically, only nitrogen oxide (NO), formed at high temperatures in the combustion chamber, was emitted, with subsequent formation of NO2, and formation of ozone by photodecomposition of NO2, happening after considerable dilution. The beneficial role of NO2 in diesel particle filter regeneration and fast NOx reduction in selective catalytic reduction (SCR) devices has promoted an increased conversion of NO into NO2 in diesel oxidation catalysts, under the assumption that most of the NO2 will be reduced by subsequent aftertreatment. The drive to achieve high NOx conversion rates has lead to both three-way catalysts (TWC) and SCR running close to the limit, leading to NH3 formation in TWC and NH3 slip in SCR. The drive to realize modest savings on operating costs has motivated the SCR functionality, in many cases, to be limited. These developments provide for a strong motivaton to monitor, at a minimum, NO, NO2 and NH3 during a range of operating conditions, including "real- real driving emissions" (real-RDE), defined as emissions in typical everyday operation, both in and out of the boundary set in "real driving emissions" legislation. In addition, the emissions of two potent greenhouse gases, nitrous oxide from SCR and methane from lean NOx traps and methane based fuels, are of additional concern, and should be considered together with CO2 emissions.

The concentrations of all of the mentioned compounds, plus many others, can be inferred from absorption spectra in mid-infrared regions. While CO and CO2 have strong absorption regions with very little interference, resolving the spectra for NO and NO2 requires either removal of nearly all water in the sample or high spectral resolution. Removal of water, however, prevents the measurement of water-soluble compounds NH3 and formaldehyde. FTIR spectrometer, using a Michelson interferometer to produce two infrared beams with variable optical path length difference which pass through a multipass cell filled with exhaust, and a Fourier transform to convert the absorption measured in the space domain to the frequency domain, is advantageous over discrete wavelenghts both due to better signal to noise ratio and due to the fact that optical distortions due to vibrations affect the entire spectra.

Three FTIR instruments have been successfully used, over the last fifteen years, by this group on the road. All have mercury cadmium telluride detectors cooled by liquid nitrogen, 0.2-0.3 liter multipass optical cells with 5-6 meter pathlength, and operate at optical resolution 0.5 cm-1 and around 130 C sample temperature. Examples of validation in the laboratory and on the road and examples of installation on a variety of machines, from small cars to diesel lomocotives, will be presented.

One of the instruments, temporarily mounted in an ordinary highway patrol vehicle, has been used to assess NOx emissions on over 200 heavy-duty diesel trucks in the Czech Republic over one week, offering a practical solution for enforcement agencies to detect suspect NOx high emitters.

Novel, all-in-one apparatus for stable and reproducible generation of atmospherically relevant aerosols using simulated atmospheric aging

A. Keller[1], K. Vasilatou[2]*, P. Specht[1], P. Steigmeier[1], D. M. Kalbermatter[2]

[1]University of Applied Sciences Northwestern Switzerland, 5210 Windisch, Switzerland, [2]Federal Institute of Metrology METAS, 3003 Bern, Switzerland

There is a need for well-defined reference aerosols generated in the laboratory, simulating properties of real ambient aerosols while being stable and reproducible. Ambient aerosols are mixtures of fresh and aged products. Atmospheric photochemical aging influences both physical and chemical properties and should be considered for complex studies as well as everyday applications. Nevertheless, there is no commercial aerosol generator that can mimic this complexity. A possibility is to combine a source of fresh soot particles, e.g. a miniCAST burner, an oxidation flow reactor (OFR) and a carefully controlled dosing system to produce high concentrations (i.e., tens of mg/m^3) of fresh and aged carbonaceous particles in a stable and reproducible manner [1].

Within the framework of the EMPIR AeroTox project, we have gone a step further toward the miniaturization and automation of the production of ambient-like carbonaceous aerosols. We developed a novel portable aerosol generator equipped with a humidifier, a precursor dosing system and a redesigned micro smog chamber (MSC)[2]. This instrument can produce pure secondary organic matter (SOM) particles or, used in combination with a standard soot generator, particles consisting of a soot core coated with SOM. The physical and chemical properties of the generated particles can be tuned in a simple manner by selecting target values for parameters, such as precursor concentration, humidity, and UV light intensity. This development allows, for the first time, to simulate in the laboratory a wide range of atmospherically relevant carbonaceous aerosols with the use of a single portable instrument. Applications include instrument calibration, filter testing, and health and climate studies. The 18HLT02 AeroTox project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme

[1] M.N. Ess, M. Bertò, A. Keller, M. Gysel-Beer & K. Vasilatou, J. Aerosol Sci., **2021**, under review.

[2] A. Keller & H. Burtscher, J. Aerosol Sci., **2012**, 49, 9-20.

Laser Induced Breakdown Spectroscopy as analytical tool for spectrochemical characterisation of trace elements in Particulate Matter generated from in-use Diesel engine passenger vehicles

R. Viskup[1], E. Alivuk[2], N. De Mecquenem[3], Y. Vereshchaga[1], A. T. Stadler[1], T. Roland[1], A. Weth[1], C. Wolf[1], W. Baumgartner[1]

[1]Institute of Biomedical Mechatronics, Johannes Kepler University, Altenberger Strasse 69, 4040 Linz, Austria, [2]Institute of Analytical Chemistry, Johannes Kepler University, Altenberger strasse 69, 4040 Linz, Austria, [3]University of Bordeaux, Campus Talence, 351 Cours de la Libération, 33400 Talence, France

Abstract: The particulate matter (PM) exhaust emissions generated from Diesel engine driven vehicles are forming significant sources of toxic and metallic nanoparticles into the air and surrounding atmosphere mainly in heavily traffic areas in large metropolitan locations or cities suburbs. Previously, we reported that particulate matter generated from in-use Diesel engine passenger vehicles are chemically composed of different major as well as minor chemical elements. In this research, we apply LIBS - laser induced breakdown spectroscopy technique for qualitative comparative study of trace elements detected in different PM collected from in-use Diesel engine passenger vehicles.

Handheld Emission Particle Counter for testing diesel particle filters of off-road engines

T. Rüggeberg[1], P. Specht[1], P. Steigmeier[1], M. Fierz[2], E. Weingartner[1], H. Burtscher[1]

[1]FHNW/ISE, [2]Naneos

Introduction & Background

In Switzerland, construction machines and other off road diesel engines need to have a diesel particulate filter to minimize the exposure of on-site personnel to carcinogenic diesel soot particles. To test the correct function of these filters at construction sites and other locations, a mobile diesel soot sensor is needed, which is able to measure the particle number concentration of soot particles directly at the exhaust. This sensor has to fulfill the specifications of the Ordinance of the Federal Department of Justice and Police on Exhaust Gas Measuring Devices for Internal Combustion Engines (VAMV SR 941.242). The Aerosol Group of the Institute for Sensors and Electronics at the University of Applied Science and Arts, Northwestern Switzerland (FHNW) developed such a device, the Handheld Emission Particle Counter (HEPaC). The HEPaC is based on the Partector2 by naneos LLC. It has been certified by METAS.

Methodology and Results

The HEPaC is a diffusion charging sensor, consisting of a heavily modified Partector2. The result of the measurement is transferred to a tablet PC to generate protected PDF reports. To avoid problems with condensation or nucleation, the exhaust aerosol enters the sensor via a probe followed by an evaporation tube, which is heated to 195°C. The sensor itself is heated to 55°C. This enables the fulfilment of the tetracontane test, i.e. evaporating at least 95% of 30nm tetracontane particles up to a particle number concentration of 10^5 pt/cm³. The heated evaporation tube is followed by the diffusion charger, which charges the soot particles constantly, followed by a pulsed electrostatic precipitator, switched between two voltage levels. The resulting periodically changing charge induces a pulsed current (fA) on arrival in a faraday cage, which is measured by an electrometer. To control the aerosol flow rate a differential pressure sensor and a nozzle are used in this sensor. When all operational parameters like diffusion current, pulsed precipitator voltage and flowrate are correct, the amplitude of the electrometer current is directly proportional to the particle number concentration of the aerosol. The battery operation time is approximately 3 hours.

Conclusions

The HEPaC is a METAS certified lightweight sensor, which allows mobile and simple measurements of particle number concentrations of construction machines directly at the construction site. The sensor implementation follows the protocol for Swiss regulation SR 941.242. It works up to a number concentration of 5’000’000 particles/cm³ with a CPC like counting efficiency curve. The efficiency versus particle size also fulfills the requirements of the Dutch PTI regulations and the suggestion by PTB for PTI.

Acknowledgement: This project was funded by the BAFU Umwelttechnologieförderung, contract Nr. UTF 601.13.19

In-Use Emission Measurements from Two High-Speed Passenger Ferries Operating in California

C. Frederickson[1], W. Liu[2], M. Villela[1], K. Johnson[1], D. Quiros[2], H. Jung[1]

[1]University of California, Riverside, [2]California Air Resources Board

In 2007, the California Air Resources Board (CARB) adopted an in-use regulation to reduce emissions from Commercial Harbor Craft (CHC), which includes ferries, tug boats, barges, and other vessel categories. After full implementation of the CHC regulation in 2022, many CHC vessels operating in California will be equipped with engines certified to the U.S. Environmental Protection Agency (EPA) Marine Tier 2 or Tier 3 standards. Although the CHC regulation will have achieved substantial emission reductions by accelerating turnover to cleaner engines, no marine engines are originally equipped with diesel particulate filters (DPF) to control particulate matter (PM). Consequently, CHC are expected to remain one of the top three seaport sources of cancer risk due to exposure to diesel PM.

In this study, we measured in-use particulate matter (PM) and gaseous emissions – including carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), and nitrogen dioxide (NO_2) from two high-speed passenger ferries in the San Francisco Bay Area: one equipped with Tier 2 engines with 18,096 hours, the other equipped with Tier 3 marine engines with 6,392 hours at the commencement of the study. Whereas marine engines are certified by United States (U.S.) Environmental Protection Agency (EPA) over the ISO 8178 E3 steady-state cycle, we used Portable Emissions Measurement Systems (PEMS) to measure emissions during normal revenue service, which includes some transient and some steady-state operation. Emissions were below relevant certification limits; average in-use NOx emissions were 4.62 and 3.62 g/bhp-hr for the Tier 2 and Tier 3 engine, respectively, and PM emission were 0.044 g/bhp-hr for the Tier 3 engine. The second vessel, equipped with Tier 3 standards engines, was also equipped with an aftermarket selective catalytic reduction (SCR) and diesel oxidation catalyst (DOC) system. In-use data in this study can be used to further evaluate the need for transient versus steady-state certification test cycles, support emission inventory development, and underscores the complexity of aftermarket control of NOx using SCR.

Fast PN-PTI sensor based on electrical detection and real-time particle size estimation

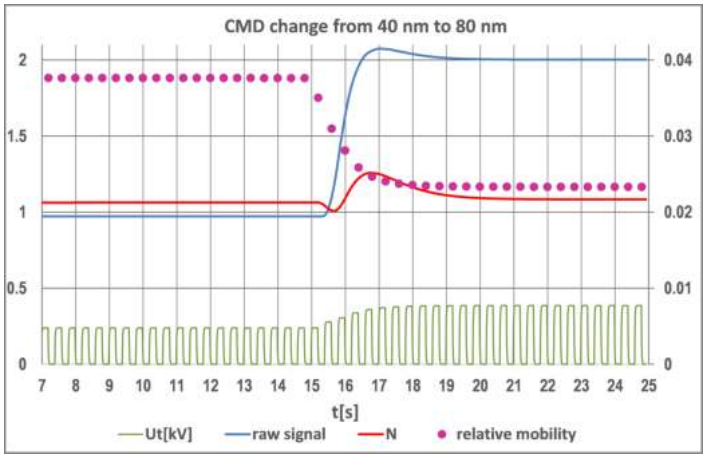
E. Saukko[1], K. Janka[1]

[1]Pegasor Oy, Tampere, Finland

Single channel electrical aerosol measurement instruments used for particle number measurement generally compromise between fast response time and accurate concentration response over a range of particle sizes. The response is typically sensitive to particle size and distribution shape. The size dependency disadvantage is solved by stepping the trap voltage optimally to estimate mean particle size, which is used to compensate for particle size dependency of the concentration measurement[1]. Using the stepping method, however increases the time response and is not suitable for fast transients, such as in automotive emissions.

An advanced measurement scheme has been developed to simultaneously achieve real time size dependency compensation and fast concentration response. The new sensor and measurement method achieves and surpasses number concentration accuracy, repeatability and linearity required for approval and inspection applications. The electrical measurement with a single channel construction is simple and robust and can be used in applications with harsh conditions. The lower particle size cut response function shape can be adjusted to match different application requirements.

The system has been tested with reference aerosols as well as engine exhaust. The concentration measurement time response is ~0.2s, while particle number size response is measured in seconds. The particle size range for the number concentration measurement can be down to 10nm and up to 300nm.



[1] Kauko Janka, Erkka Saukko, US PAT 10760997

Characterization of the ePNC number counter for annual PTI and testing applications

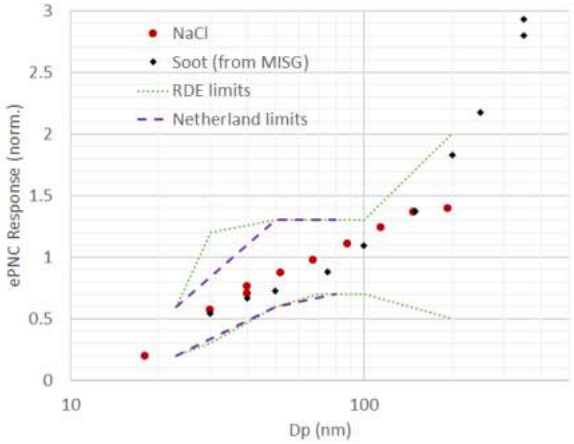
A. Arffman[1], M. Nikka[1], E. Luntta[1], M. Olin[2], P. Karjalainen[2], S. Mikkonen[3]

[1]Dekati Ltd., [2]Aerosol Physics Laboratory, Tampere University, [3]Department of Applied Physics, University of Eastern Finland

Diesel passenger cars sold in the Europe have been forced to use diesel particulate filters (DPF) to comply with particle number (PN) emission limits (Euro 5 standard). The DPF's are an effective way to control the PN and mass emissions, but from the car end-user perspective it is a rather expensive part to replace if it is not functioning properly. Thus, manipulation or removing the DPF is a problem in Europe, and a small number of cars equipped with non-working DPF's produce a majority of the overall emissions [1]. Therefore, European countries are incorporating a new PN measurement for the diesel cars in periodical technical inspection (PTI).

In this study, we introduce and characterize the operation of a new PN sensor for PTI applications called ePNC (Dekati Technologies Ltd) by modelling, and lab- and field-tests. The ePNC is based on the electrical detection of particles, and it operates in reduced pressure conditions (400 mbar). The main components of the sensor are a corona charger and a diffusion collector in a series configuration. The charge carried by particles to the diffusion battery is measured with an electrometer that is used to determine the PN of the sampled aerosol. The analytical and computational fluid dynamics modelling results of the sensor were compared with the measured sensor response as a function of particle size. To apply the sensor for the measurement of primary emissions (dried soot particles) of idling car in a PTI station, it is combined with a sample conditioning unit that removes moisture, subsequently evaporates hydrocarbons condensed onto particles, and reduces the sample pressure below ambient. The conditioning unit was characterized by determining the penetration of monodisperse NaCl and soot particles. The feasibility of the combination of the ePNC and the conditioning unit was investigated by comparing the results against a PMP-type reference measurement with several passenger cars running in idle.

The results show the charging phenomena is controlled by diffusion charging in the ePNC charger, and that the sensor number correlation is only weakly dependent on the particle size in the size range of 20 – 200 nm. Comparison of the sensor with the conditioning unit showed a good correlation with the reference measurement for several diesel and gasoline cars. Small deviations were mostly addressed to slightly deviating detection efficiency curves of the devices.



[1] H., Burtscher, Th., Lutz, A., Mayer, Emiss. Control Sci. Technol. **2019**, 5, 279–287.

Study on the Emission Level of Heavy-duty Vehicles in South Korea according to Real Driving Emission Regulation

S. Jo[1], H. J. Kim[2], S. I. Kwon[2], J. Lee[2], S. Park[3]*

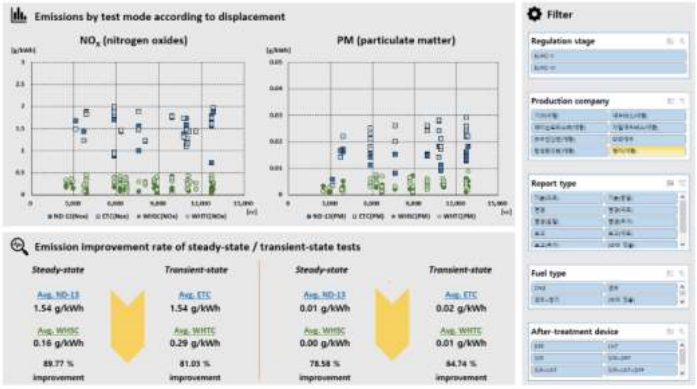
[1]Department of Mechanical Engineering, Graduate School of Chonnam National University, [2] National Institute of Environmental Research, [3]School of mechanical Engineering, Chonnam National University

Nitrogen oxide(NO_X) has a large contribution to the generating of $PM_{2.5}$ by secondary emissions[1], and diesel vehicles, especially heavy-duty, have a large number of emissions of $PM_{2.5}$. In order to improve the exhaust emission emitted from heavy-duty vehicles, emission regulations are increasingly strengthened by introducing real driving emission (RDE) regulations. Meanwhile, numerous emission certification data measured in engine and real road driving tests have been accumulated for heavy-duty vehicles in Korea. So it is necessary to use this to analyze the certification status and the characteristics of exhaust emissions of heavy-duty vehicles according to the emission regulation standards. In this study, a dashboard that can intuitively view the test results was produced for the convenience of analyzing a number of certification data, and emission characteristics were analyzed according to the regulation stage, displacement, vehicle weight, and accumulated mileage.

Fig. 1 shows a dashboard that indicates the rate of change of NO_X and PM emissions according to the change in the emission standard and test mode of the engine certification test in South Korea. As the regulation stage is strengthened from EURO-V to VI, the average NO_X emission of certification data was improved by 89.77% in the steady-state test and 82.01% in the transient test. Additionally, the average PM emission of certification data improved by 78.58% in the steady-state test and 64.74% in the transient-state test.

ACKNOWLEDGEMENT

This study was financially supported by Transportation Pollution Research Center in National Institute of Environmental Research (NIER-2020-04-02-011) and Basic Science Research Program (2019R1A2C1089494) and Korea-India Joint Research Project (2020K1A3A1A19088692) through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (Korea).



[1] Yong Pyo Kim, Min Ju Yeo, Journal of Korean Society for Atmospheric Environment, 2013, 29(4), 369-377.

Measuring and reporting PN and PM values from vehicles with different engines, aftertreatment technologies and fuel types

D. B. Thomas[1], G. S. Sandhu[1]

[1]3DATX Corporation

Accurate measurement of particulate emissions from vehicles is an important step toward the successful abatement of this pollutant from combustion engines. Transient particle mass (PM) and particle number (PN) measurements from multiple measurement systems were compared using an E10 fuelled light-duty GDI vehicle with TWC on chassis dynamometer. The vehicle was tested over various drive cycles, including the US EPA's FTP-75, the LA92, the US06, and the Highway Fuel Economy Test (HWFET). The PM values reported by the 3DATX parSYNC iPEMS are compared against those of a Dekati Mass Monitor (DMM) and AVL Micro Soot Sensor (MSS), while the PN values reported by the parSYNC are compared against those of the AVL Particle Counter (APC) and TSI Engine Exhaust Particle Sizer (EEPS). The matrix method by which the 3DATX parSYNC calculates its values of PN and PM was previously calibrated according to a diesel DPF vehicle, and the results initially presented reflect the difference in the nature of particulate matter emitted from a GDI vehicle. The 3DATX parYSNC particulate matrix is thereby updated for this new engine technology so that the parSYNC reports more representative PN and PM values.