Session 3: Poster Session A (Aircraft, marine and other non-road sources), Poster

Particle Emissions from Small Jet Engine fueled with SAF

H. Yamada[1], T. Kaneko[1]

[1]Tokyo Denki University Graduate School

Effects on Sustainable Aviation Fuel (SAF) mixed with traditional Jet fuel (Jet A1) on particle number emissions over 10 nm and those over 23 nm have been evaluated with a small gas turbine engine which maximum out put is 210 N. The tested engine was small conpared with gas turbine engine used for aircraft, however NOx and particle number emissions factor of tested engine were almost the same level with those of actual aircraft jet engines.

As for SAF, Hydrotreated Esters and Fatty Acids (FEFA) and Catalytic Hydrothermolysis Jet (CHJ) were tested. HEFA consists mainly of parafine and no aromatics are contained. On the other hands, CHJ contains aromatics over 20 %. In all experiments, SPN10 emissions were quite higher than SPN23 suggesting particle emitted from Jet engine were mainly below 23 nm. SPN10 emissions with SAF were lower than that with normal Jet A-1 fuel. Degree of reduction with FEFA was higher than that with CHJ. Emissions of SPN10 with 50% FEFA were 25 to 50% lower than that with normal Jet A-1.

NOx emissions were not affected changing fuels in this study.

Soot masses were below detection limits in all experiments.

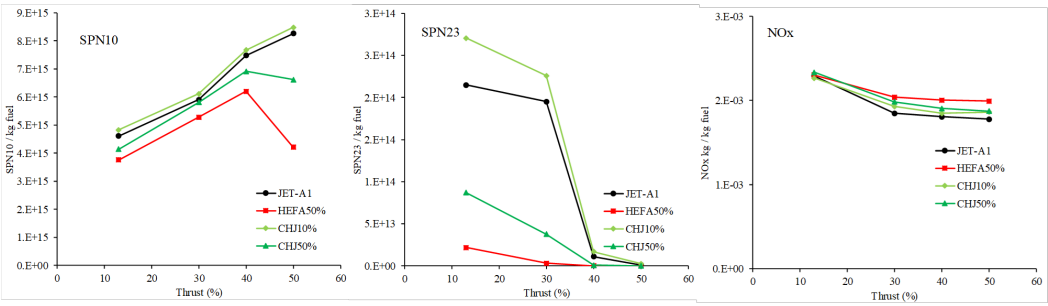


Fig.1 SPN10, SPN23 and NOx emission with 100% Jet A-1, 50% HEFA, 10% CHJ and 50% CHJ with various thrust.

This research was performed by the Environment Research and Technology Development Fund (JMEERF20245005) of the Environmental Restoration and Conservation Agency provided by Ministry of the Environment of Japan.

Advancements in Aircraft Engine Measurement: The New SR Technics Test Cell Emission Monitoring System

T. Schripp[1], M. Alig[1], J. G. Bell[1], J. Edebeli[1], M. Stähelin[1], F. Siegerist[2], T. Rindlisbacher[3]

[1]Center for Aviation, Zurich University for Applied Sciences (ZHAW), [2]SR Technics Switzerland AG, Kloten, [3]Federal Office of Civil Aviation (FOCA)

Aircraft engine emissions have become a prominent research focus in recent years, extending beyond just carbon dioxide emissions. Significant advancements have been achieved in measurement technologies, certification processes, and a deeper understanding of the impacts of different fuel compositions. Nevertheless, conducting comprehensive test bench, field, and flight measurement campaigns on aircraft engines is highly expensive. This results in emission data beyond the standard emission profiles, typically provided by manufacturers, being scarce. Additionally, testing new measurement methods on real aircraft engine exhaust is rarely feasible due to these costs and logistical challenges.

Since 2010, SR Technics has supported development of new global aircraft gas turbine emission standards by installation of prototype emission measurement systems in their engine test cells, where engines are checked after maintenance and overhaul. SRT is set to commission a new state-of-the-art test cell for the latest aircraft engines, including lean-burn engines and last generation geared turbofan (GTF) engines, at the start of 2025. This test cell is equipped with a permanent probe installed in the exhaust tunnel, enabling continuous monitoring of engine emission performance without interfering with the essential performance measurements. The exhaust gases are analysed using a measuring system designed for continuous operation, which builds upon the existing “Swiss Mobile Aircraft Emission Measurement System” (SMARTEMIS). The system provides detailed data on various emission factors, including particle size distribution (measured via SMPS) and soot mass (measured via Aethalometer). It also measures critical combustion gases such as carbon dioxide (CO2) and nitrogen oxides (NOx) with high time resolution over the full engine thrust range.

The sophisticated experimental setup offers unique opportunities for in-depth studies on the variability of emission data from freshly serviced engines and the emission characteristics of modern engines beyond engine emission certification. It facilitates the investigation of new measurement methods, such as toxicological studies and research into aerosol aging, and volatile particle emissions, using real aircraft engine emissions.

This innovative approach not only enhances our understanding of emissions from modern aircraft engines, which will feed into atmospheric science, but also paves the way for more comprehensive testing of new technologies aimed at reducing environmental impact. By continuously monitoring and analyzing emissions in real-time, researchers can gather invaluable data to inform future regulatory standards and technological advancements in the aviation industry.

This work is supported by the Swiss Federal Office of Civil Aviation in the framework of the project “ADVISAR”.

Characterization and control of ash from diesel engine exhaust

A. Apilainen[1], K. Lehtoranta[2], H. Vesala[3], Y. Ge[4]

[1]Transport Emission Control, VTT Technical Research Centre of Finland Ltd, Espoo, Finland, [2]Transport Emission Control, VTT Technical Research Centre of Finland Ltd, [3]Nuclear decommissioning and waste management, VTT Technical Research Centre of Finland Ltd, [4]Advanced materials for nuclear energy, VTT Technical Research Centre of Finland Ltd

1. Introduction

Ship emissions, particularly fine particulate matter ($PM_{2.5}$), have a negative impact on air quality and pose serious health risks. This study examines whether a diesel generator can produce particulate emissions similar to those of a marine engine and the possibility to use the generator in further research related to diesel particulate filters (DPF). The primary goal of the study was to characterize the ash produced by the diesel engine. Diesel exhaust ash is a non-combustible residue resulting from the combustion of diesel fuel, lubricating oil, and engine wear.

2. Materials and methods

In the experimental part of the study, exhaust ash was generated using a diesel generator running on DMB fuel (a distillate marine fuel blend) mixed with ash-forming lubricating oil. The quantity and quality of ash was measured. The physical properties and the chemical composition of the exhaust ash were analyzed using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy-dispersive X-ray spectroscopy (EDS). Additionally, gas emissions, soot levels, and particle number concentration and distribution were measured.

3. Results

The analysis found that using lubricating oil doped fuel increased the number of particles in the exhaust gas. Morphological studies identified various particle types, including nano-sized fuel particles, spherical lubricating oil particles containing calcium and agglomerated soot particles. Adding lubricating oil to the fuel reduced soot emissions presumably because the metal compounds in the oil facilitated the combustion of soot particles. Based on findings the properties of the particles generated by the diesel generator resemble to those obtained with marine engines using similar fuels.

4. Conclusions

The study highlights that fuel composition significantly impacts particulate emissions and their characteristics. The research suggests that diesel generators can be used in place of large ship engines for future studies on ash production and its effects on DPF. Additionally, the study poses an opportunity for developing more precise methods to measure ash concentration directly from exhaust gases, which could help predict DPF maintenance needs and optimize regeneration events.

Experimental investigation of ultrafine particle loss through flow splitters, flow fittings, and coiled tubes typically used in aircraft nvPM sampling systems

F. Lidstone-Lane[1], P. Williams[1], A. Lea-Langton[1], M. Johnson[2]

[1]University of Manchester, [2]Rolls-Royce

It is estimated that 16,000 premature deaths are caused by aviation emissions annually[1]. In response to the growing concerns of aircraft emissions, the regulators have introduced a global nvPM emissions reporting standard to regulate the emitted concentrations of nvPM. The standard is relevant for all in-production and new gas turbine engines above 26.7 kN[2].

Due to the harsh environment at the aircraft engine exit, long sampling tubing is used to transport the exhaust sample to the measurement instruments. Transporting the nvPM sample through the long sampling tubes results in large nvPM losses, which can be described by many aerosol loss mechanisms[3].

To combat the effect of nvPM loss on the final reported measurements, various design and correction methodologies are used, which are outlined in the system design requirements[2] and recommendations[4]. One example requirement refers to the permissible bend angle (coiling) of a tube, which should not exceed 10 times the internal diameter of the tubing, as is assumed to mitigate particle losses through bent tubes[5]. However, limited research has been conducted to validate this requirement for typical particle sizes observed for aircraft nvPM (below 100 nm in mobility diameter). The same can be said about other elements in the system, such as flow fittings (unions, valves, etc..) and flow splitters.

This study aims to experimentally quantify the particle losses through coiled tubes, flow fittings, and flow splitters typically used for aircraft nvPM measurements for particle size ranges and flowrate values observed within aircraft nvPM sampling and measurement systems. Using the experimental results and comparing them against the regulatory used diffusional loss model, an assessment of the potential additional particles losses that these elements may pose in nvPM sampling systems was determined.

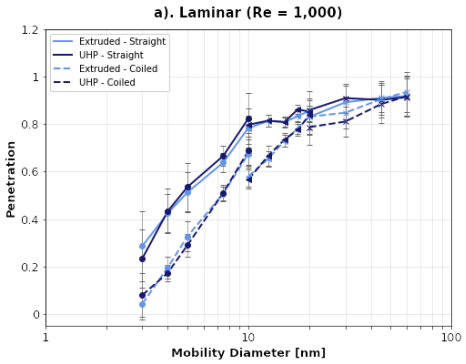


Figure.1: Particle penetration through ¼" OD straight and coiled tubes.

It was determined that generally flow fitting did not results in additional losses; however, there was some indication that additional particle losses were caused through flow splitters and coiled tubes. Interestingly, even when the tubes were coiled less than the limited proposed by regulations (stated above), additional particle losses were observed, on average 12%, for laminar flow (Figure.1). This result could indicate that there are some additional unquantified particle losses in nvPM sampling systems.

[1] Quadros, F, D, S. et al. Environ. Res. Lett. **2020.** 15(10)
[2] ICAO. Annex 16 – environmental protection – volumen II – aircraft emissions. **2023.** 5th Edition
[3] Hinds, W, C. Aerosol technology: properties, behaviour, and measurement of airborne particles. **2022.** 3rd Edition
[4] SAE International. ARP 6320. **2018**
[5] Kulkarni, P. et al. Aerosol measurement: principles, techniques, and application. **2011.** 3rd Edition

Tracing Aviation Impacts on Air Quality: PM Chemical Composition and Source apportionment near Zürich airport

S. Mishra[1], B. T. Brem[1], Z. C. Decker[2], J. G. Slowik[1], P. A. Alpert[1], M. Ammann[1], A. S. Prevot[1], M. Bauer[1], S. M. Tinorua[1], M. Götsch[3], J. Sintermann[3], M. G. Beer[1]*

[1]PSI Center for Energy and Environmental Sciences, 5232 Villigen PSI, Switzerland, [2]NOAA CSL & Cooperative Institute for Research in Environmental Sciences (CIRES), Boulder, CO, USA, [3]AWEL, Amt für Abfall, Wasser, Energie und Luft, 8090 Zürich, Switzerland

Aircraft emissions significantly contribute to particulate matter (PM) and ultrafine particles (UFP) during takeoff, landing, taxiing, and idling, negatively impacting air quality near airports. With air traffic projected to increase by 4.2% annually, doubling pre-pandemic levels by 2040 (IATA, 2023a), the environmental and health implications are serious. Airports contribute to both primary and secondary PM, affecting air quality up to 18 km downwind from major airports like LAX (Hudda et al., 2012).

The Aviation Plume PROPeRtIes AT Point of Exposure (APPROPRIATE) project at Zürich Airport seeks to address these environmental and health concerns. It combines lab experiments, test cell studies, and field campaigns to better understand the impact of aviation on air quality and public health. A key part of the project was an intensive, month-long measurement campaign in fall 2022, conducted at a site in Kloten, about 1 km east of the airport (downwind side). The site was equipped with advanced suite of gas- and aerosol-phase measuring instruments like LTOF-AMS, EESI, and VOCUS to analyze emissions from aircraft engines.

The LTOF-AMS detected non-refractory PM, including organics, nitrate, sulfate, ammonium, and chloride. Initial AMS results revealed organic fragments, indicating the presence of aircraft oil, specifically in the m/z 85 to m/z 71 ratio, for which values above 0.66 have been suggested to reflect oil emissions (Yu et al.,2012). These results suggest that airport emissions impact local air quality considerably. The multi-instrument approach, will enhance source apportionment analyses and provide a clearer picture of airport emissions in this region.

This work was supported by the Swiss Federal Office of Civil Aviation (SFLV 2020-080). We acknowledge the support from ZHAW, EMPA, Frithjof Siegerist (SRTechnics), and the City of Kloten.

IATA. (2023a). Global Outlook for Air Transport - A local sweet spot.

Hudda N, Fruin SA. International Airport Impacts to Air Quality: Size and Related Properties of Large Increases in Ultrafine Particle Number Concentrations. Environ Sci Technol. 2016 Apr 5;50(7):3362-70. doi: 10.1021/acs.est.5b05313. Epub 2016 Mar 14. PMID: 26971965.

Z. Yu, S. C. Herndon, L. D. Ziemba, M. T. Timko, D. S. Liscinsky, B. E. Anderson, et al. Identification of Lubrication Oil in the Particulate Matter Emissions from Engine Exhaust of In-Service Commercial Aircraft, Environmental Science & Technology 2012, Vol. 46 Issue 17, Pages 9630-9637

Optimizing the Aethalometer source apportionment model through multi-site comparison

A. Gregorič[1,2], M. Ivančič[1], C. Franchina[3], I. J. Brecelj[1], B. Alfoldy[1], M. Rigler[1]*

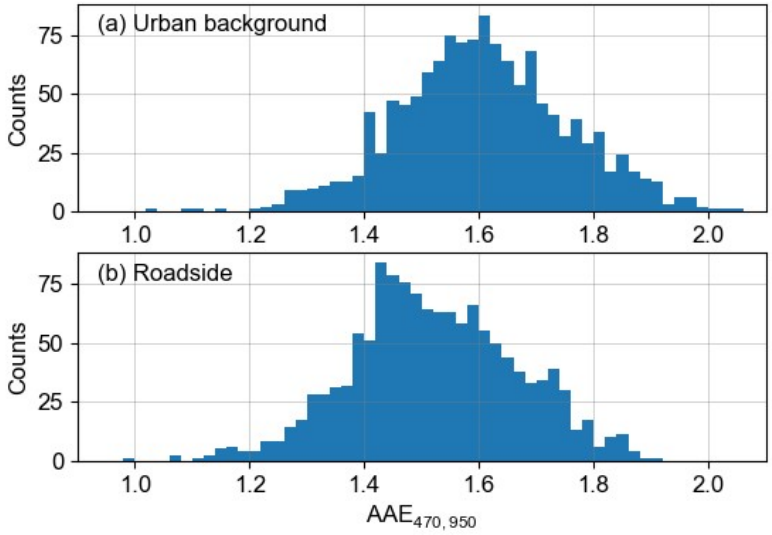
[1]Aerosol d.o.o., Ljubljana, Slovenia, [2]Center fo Atmospheric Research, University of Nova Gorica, Slovenia, [3]University of Milano-Bicocca, Milan, Italy

The Aethalometer source apportionment model [1] has been a valuable tool for several years in determining the contributions of solid fuel (SF) and liquid fuel (LF) to equivalent Black Carbon (BC) concentrations. This model utilizes the wavelength dependence of the absorption coefficient measured by Aethalometers (AE33, AE36, or AE36s, Aerosol Magee Scientific), alongside pre-defined values of the absorption Ångström exponent (AAE) specific to each source. Typically, the AAE for LF is around 1, while the AAE for SF varies based on combustion efficiency and wood type.

A key requirement of the model is a stable source-specific AAE pair, making it appropriate for BC source apportionment in urban settings. It is essential to optimize the AAE pair for each location to accurately reflect the unique optical properties of both fuel sources. Various methods and biomass burning tracers have been employed in this optimization process so far [2], [3].

In this study, we propose an alternative method that compares source-specific BC measurements taken simultaneously at different sites within the same city, varying distances from traffic emissions. The optimization of BC source apportionment was conducted at four measurement sites in y, utilizing a 1-year dataset. BC_{SF} is homogeneously distributed across all locations, while BC_{LF} contribution varies based on the proximity to the traffic source.

The method yields a source-specific AAE pair without a need for additional costly off-line filter analysis, and thus a more accurate source apportionment in the investigated area.



[1] J. Sandradewi *et al.*, 'Using Aerosol Light Absorption Measurements for the Quantitative Determination of Wood Burning and Traffic Emission Contributions to Particulate Matter Using Aerosol Light Absorption Measurements for the Quantitative Determination of Wood Burning and Traffic', *Environ Sci Technol*, vol. 42, no. 9, pp. 3316–3323, 2008, doi: 10.1021/es702253m.

[2] G. W. Fuller, A. H. Tremper, T. D. Baker, K. E. Yttri, and D. Butterfield, 'Contribution of wood burning to PM10 in London', *Atmos Environ*, vol. 87, pp. 87–94, 2014, doi: 10.1016/j.atmosenv.2013.12.037.

[3] P. Zotter *et al.*, 'Evaluation of the absorption Ångström exponents for traffic and wood burning in the Aethalometer-based source apportionment using radiocarbon measurements of ambient aerosol', *Atmos Chem Phys*, vol. 17, no. 6, pp. 4229–4249, 2017, doi: 10.5194/acp-17-4229-2017.

Particle Number Size Distribution in Istanbul Atmosphere

Ü. A. Şahin[1*], M.S. Coşgun[1],C. Ayvaz[1], Z. Çolak[1], B. Onat[1], B.U.Ayvaz[1], S.L. Kuzu[2], G.Güllü[3], R.M. Harrison[4,5]

[1]Department of Environmental Engineering, Engineering Faculty, Istanbul University-Cerrahpaşa, Istanbul, Türkiye

[2]Department of Environmental Engineering, Construction Faculty, Istanbul Technical University, Istanbul, Türkiye

[3]Department of Environmental Engineering, Engineering Faculty, Hacettepe University, Ankara, Türkiye

[4]School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, UK

[5]Department of Environmental Sciences, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia

[*]ulkualver@iuc.edu.tr

Particle numbers (PN) between 10 to 400 nm were measured in the atmosphere of urban background in Istanbul using a NanoScan SMPS during three weeks in four seasons. PN measurement was performed for the first time in Turkiye and Istanbul in this study. TSI nano scanning mobility particle sizer (NanoScanSMPS 3910) with dryer was used to measure PN in the size range 10-400 nm. The average number counts and contributions of each PN fraction (Nucleation: <30 nm, Aitken: 30-100 nm, Accumulation: 100-400 nm) are given in Figure 1. The average total PN levels were $5.7\times10^3 \pm 2.4\times10^3$ ≠/cm^3. Generally, the winter and spring time PN levels were slightly higher than in the autumn and summer. The average contribution of ultrafine particles (UFPs) to the total numbers is 77 % with higher values in spring and lowest in autumn. But their contribution to volume is the highest in winter and summer (< 25%). According to published studies, UFP contributions in this study are higher than the Asian cities ˜49 % [1] and approximately same or slightly lower in European cities >80 % [2]. Wu and Boor [3] analysed the particle number size distribution (PNSD) around the globe and reported that the PNSD in Europe, North America, Australia, and New Zealand are dominated by UFP, while in Asia they are dominated by the substantial contribution from the accumulation mode.

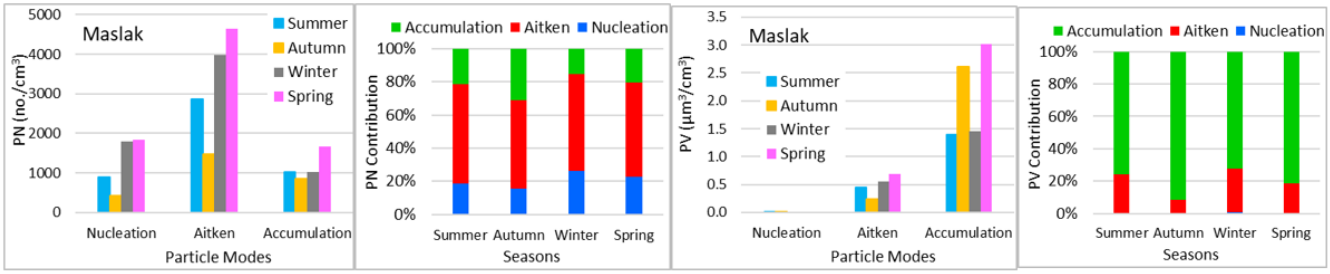


Figure 1: Particle numbers in the nucleation, Aitken and accumulation modes at the traffic site in Istanbul.

This study was funded by Scientific Research Projects Coordination Unit of Istanbul University-Cerrahpasa (FBA-2024-36086) and by the Scientific and Technical Research Council of Türkiye (TUBITAK 122Y079).

[1] Şahin, Ü.A., et al. Atmos. Chem. Phys. **2022**, *22*, 5415–5433.
[2] Vu, T.V., et al., Atmos. Environ. **2015**, *122*, 114–132.
[3] Wu, T. and Boor, B. E., Atmos. Chem. Phys. **2021**, *21*, 8883–8914

Source Apportionment of Light-Absorbing Carbonaceous Aerosols in Blantyre, Malawi Using Locally Derived Absorption Ångström Exponent Values

S. Vijay[1], H. Chilunga[2], L. Schöbitz[1], E. Tilley[1]

[1]Global Health Engineering, Department of Mechanical and Process Engineering, ETH Zürich, Zürich, 8092, Switzerland, [2] Department of Computer Science and Information Technology, Malawi University of Business & Applied Science, Blantyre, 265, Malawi

Light-absorbing carbonaceous (LAC) aerosols, particularly black carbon (BC), pose significant health and climate risks. In sub-Saharan Africa (SSA), LAC sources remain understudied, limiting effective mitigation strategies. This study presents the first source apportionment of LAC aerosols in Malawi, utilizing locally determined Absorption Ångström Exponent (AAE) values to distinguish between fossil fuel and biomass burning emissions. We first conducted controlled field experiments to establish AAE thresholds for local pollution sources. Fossil fuel-related emissions (vehicular: 1.07±0.14, plastic burning: 1.30±0.08, synthetic textiles: 1.17±0.05) had AAE values closer to 1, while biomass burning sources (garden waste: 1.92±0.10, cardboard: 1.90±0.45, firewood: 1.78±0.04) had values closer to 2. A statistically significant difference ($p < 0.01$) allowed us to propose source-specific AAE thresholds: <1.29 for fossil fuels, >1.63 for biomass burning, and 1.29–1.63 for mixed sources. Using these thresholds, we conducted source apportionment of eBC concentrations obtained from mobile and stationary monitoring in Blantyre between May and August 2023. Mobile monitoring across eight settlements and highways revealed eBC concentrations ranging from 2.4 to 9.9 μg m□³ in settlements and 11.3 μg m□³ on highways. Stationary monitoring recorded mean eBC levels of 4.1 ± 4.1 μg m□³ in planned and 3.6 ± 2.6 μg m□³ in unplanned settlements. Biomass burning contributed 7%–47% of total eBC, while fossil fuel emissions accounted for 9%–73%, with variations across locations. Blantyre's eBC levels were higher than those reported in most European cities and comparable to some major SSA urban centers, underscoring the region's air quality challenges. The study emphasizes area-specific interventions and demonstrates a transferable source apportionment methodology for diverse urban contexts globally.

Development of perovskite-based catalyst for the elimination of pollutants such as VOC, CO and PM emitted by wood stoves

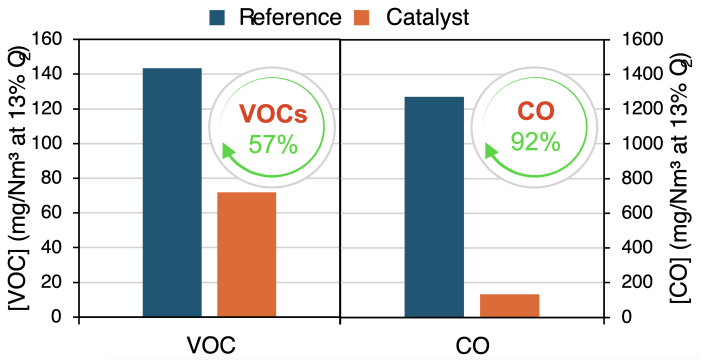
L. Garin[1,2], C. Hiernaux[1,3], T. Barakat[2], B. Su[1,3]*

[1]Laboratory of Inorganic Materials Chemistry (CMI), University of Namur, Namur, Belgium, [2]Stuv S.A., Floreffe, Belgium, [3]Namur Institute of Structured Matter (NISM), University of Namur, Namur, Belgium

Background and motivation. With the increase in global human activity, air pollution levels are reaching dangerous thresholds, leading to 6.7 million premature deaths/year worldwide. Pollutants include notably CO, VOCs and PM, which are primarily emitted by wood combustion in wood stoves used for residential heating. Because of its efficiency and cost-effectiveness, catalytic oxidation has emerged as a promising solution for the degradation of these pollutants into less harmful products such as CO_2 and H_2O. Perovskite-based catalysts are favorable for this purpose due to their oxygen vacancy properties and redox capacity [1,2]. In addition, the incorporation of alkali cations within the structure promotes the oxidation of soot, which is difficult to remove due to its solid form and complex composition [3,4]. Finally, combining perovskite with a ZSM-5 zeolite already effective would considerably improve the catalyst's overall performance in degrading pollutants emitted by wood stoves. This research project focuses on the development of a perovskite-based catalyst whose properties are optimized for soot oxidation, with which a zeolite previously tested and shown to be effective in degrading gaseous pollutants would be combined.

Materials and methods. $La_{1-x}K_xMnO_3$ perovskite was synthesized using the classical citrate sol-gel method. Metal nitrates were used as precursors and were mixed in appropriate proportions in distilled water, with an amount of citric acid equivalent to the metal cations. After dissolution of the reagents, NH_4OH (35%) was added to the solution until the pH reached 7. The solution was then evaporated to dryness at 90°C, and the resulting product, after grinding, was calcined at 800°C for 4 hours. The zeolite-based catalyst was deposited on a ceramic substrate specifically used for catalytic testing on wood stoves, using the wet impregnation method

Results and discussion. The perovskite-based catalyst was successfully synthesized, according to XRD results. Its textural and morphological properties were determined by N_2 physisorption and SEM analysis and are in agreement with the results found in the literature (S_{BET} = 5-15 $m^2.g^{-1}$, no porosity and irregular shape). The zeolite catalyst converts the CO and VOCs emitted by wood combustion by 92% and 57% respectively.



[1] Royer, S. et al. *Chemical Reviews*. **2014**, 114(20), 10292–10368.
[2] Zhu, J. et al. *ACS Catalysis*. **2014**, 4(9), 2917–2940.
[3] Legutko, P. et al. *ACS Catalysis*. **2023**, 13(5), 3395–3418.
[4] Mei, X. et al. *Cuihua Xuebao/Chinese Journal of Catalysis*. **2019**, 40(5), 722–732.

Ultrafine particle Exposure from different heating stoves and Fuels in Homes: A Case Study in Guildford, United Kingdom

A. T. Kuye[1], P. Kumar[1,2]

[1]Global Centre for Clean Air Research (GCARE), School of Sustainability, Civil and Environmental Engineering, University of Surrey, Staghill Reception, Guildford, Surrey, [2]BInstitute for Sustainability, University of Surrey, Guildford GU2 7XH, Surrey, United Kingdom

Traditional heating stoves emit high concentrations of particulate matter ($PM_{2.5}$) to the environment. Efforts to address these concerns have led to the development of improved wood stoves designed to burn wood more efficiently and emit less $PM_{2.5}$. However, while these stoves succeed in reducing $PM_{2.5}$ emissions, studies have shown that they may inadvertently increase the emissions of ultrafine particles (UFPs) (particles ≤ 100 nm), which are even smaller and can cross biological barriers, potentially entering the bloodstream and causing other health impacts. This study evaluates the effects of five different solid fuel types under the improved wood-burning stoves and open fireplaces on indoor air quality (IAQ). We evaluated indoor exposure levels to UFP, $PM_{10,}$ $PM_{2.5}$, black carbon (BC), and carbon monoxide (CO) across five non-smoking households in Guildford, United Kingdom, using handheld monitors placed in a common living area where a stove was located during the winter months. Each household was equipped with a different type of commercially available wood stove (eco-design, multifuel eco-design, clear skies stage (v), and open fireplace) used for four different fuel types: seasoned wood (SW), kiln-dried wood (KDW), smokeless coal (SC), and wood briquette (WB). Exposure profiles of the room occupants showed that the fuel type, room volume, stove type, and average burning time were the major factors influencing the IAQ levels, combined with inadequate ventilation. Open-fire stoves showed the highest exposure concentrations, followed by multifuel eco-design, eco-design, and clear skies stage (v) stove types. During the burning periods, real-time indoor median (interquartile range) for UFP (3.6 (5.8) $\times 10^4$ # cm^{-3}), $PM_{2.5}$ (38.4 (65.5) µg m^{-3}), PM_{10} (89.6 (89.0) µgm^{-3}) and BC (1.7 (3.6) µg m^{-3}). As expected, it was highest for an open fireplace. Among the improved stoves, the multifuel eco-design stove used as a primary heat source has the highest exposure concentration: UFP (2.2 (4.9) $\times 10^4$ # cm^{-3}), $PM_{2.5}$ (14.2 (16.9) µg m^{-3}), PM_{10} (37.9 (45.9) µgm^{-3}) and BC (1.5 (2.3) µg m-3)—followed by eco-design and clear skies stage (v) stoves. Wood briquettes showed the highest exposure concentrations, followed by smokeless coal, kiln-dried wood, and seasoned wood types. For example, manufactured fuels (wood briquettes) during the burning period increased $PM_{2.5}$ and UFP concentrations by 4- and 1.5-times, respectively, compared to seasoned wood. The mean CO concentration was 3.1 ppm for an open fireplace, which was below the 24-hour average World Health Organisation (WHO) guideline value of 7 ppm. The space with the smaller volume (<40 m^3) and the highest burning duration increased pollutant exposure by 2- and 3-times compared with their larger-volume counterparts (>50 m^3). Also, all the homes have low Air Changes per Hour (ACH) (<1.2 h^{-1}) to allow the accumulation of indoor pollutants. Our findings indicate that residential wood burning using solid fuels significantly increases short-term exposure to elevated concentrations of air pollutants, including ultrafine particles (UFP), PM2.5, black carbon (BC), and carbon monoxide (CO), posing potential health risks to occupants. These results underscore the importance of prioritising health-focused strategies when considering wood burning as a heating option in a domestic setting.

Aged emissions of passenger cars studied with an oxidation flow reactor (DOFR)

A. Arffman[1], M. Nikka[1], E. Laakkonen[1], K. Kylämäki[2], T. Rönkkö[2], W. Honkisz[3], P. Bielaczyc[3], J. Topinka[4], T. Červená[4], H. Timonen[5], M. Aurela[5], S. Saarikoski[5], A. Järvinen[6], P. Aakko-Saksa[6]*

[1]Dekati Ltd. (Kangasala, Finland), [2]Tampere University (Tampere, Finland), [3]Bosmal Ltd. (Bielsko Biala, Poland), [4]IEM Institute of Experimental Medicine (Prague, Czech Republic), [5]Finnish Meteorological Institute (Helsinki, Finland), [6]VTT Technical Research Centre of Finland Ltd. (Espoo, Finland)

Secondary particle emissions of vehicles are increasingly important aspect for the human health and environment as the primary particle emissions have been efficiently cut down during last two decades by introducing particle filters to vehicles after treatments. In this study, we used a new commercially available OFR called Dekati Oxidation Flow Reactor (DOFR) for ageing passenger car emissions on a chassis dynamometer and in low idle conditions. The DOFR has a design similar to the previously introduced Tampere University Secondary Aerosol Reactor (TSAR) by Simonen et al. [1] using OH-radical as the main oxidizer. The first part of the study was to use the combination of DOFR reactor and the sampling unit to measure the fresh and aged emissions over simulated RDE driving cycle on a chassis dynamometer at Bosmal Ltd. emission laboratory. In the second part, the emissions of cars running in low idle after the cold start and with warmed up engines were compared. The exhaust ageing inside the DOFR was also modelled with a simple time dependent model based on the model presented by Li et al. [2].

The idle engine measurements showed that tested gasoline vehicles could produce 1 to 4 orders of magnitude more SA mass compared to the primary mass with a cold engine. An example of chassis dynamometer measurement results is shown in Figure 1. The aged emissions were found to be orders of magnitude higher than the fresh emissions during the urban, mountain, highway, and rural driving simulation parts.

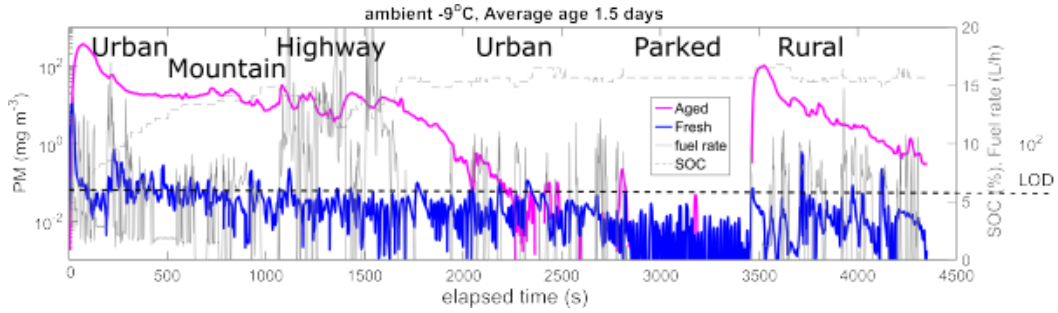


Figure 1. The fresh and aged PM_1 of a PHEV passenger car over a simulated RDE driving cycle.

AKNOWLEDGEMENTS

This work was supported by the European Union's Horizon Europe research and innovation programme under grant agreement No 01096133 (PAREMPI: Particle emission prevention and impact: from real-world emissions of traffic to secondary PM of urban air).

[1] Simonen, P., Saukko,E., Karjalainen, P., Timonen, H., Bloss, M., Aakko-Saksa, P., Rönkkö,T., Keskinen, J., Dal Maso, M., **2017** Atmos. Meas. Tech., 10, 1519–1537.

[2] Li, R., Palm, B., B., Ortega, A., M., Hlywiak, J., Hu, W., Peng, Z., Day, D., A., Knote, C., Brune, W., H., de Gouw, J., A., Jimenez, J., L. **2015** The Journal of Physical Chemistry A 119 (19), 4418-4432.

GPF for Passenger Cars - VERT knowledge prior to AeroSolfd 2020

J. Czerwinski[1], A. Mayer[1], T. Lutz[1], L. Rubio[1], L. Larsen[1], P. Comte[2]

[1]VERT-Association, Aemetstraße 3, CH-8166 Niederweningen, [2]Berner Fachhochschule, Technik und Informatik TI, Abgasprüfstelle (AFHB), CH-2560 Nidau

Particle number concentration (PN) in exhaust gas from vehicles and in the ambient air relates to the ultrafine particles (UFP) below 500nm, which are recognized and legally limited in several countries as a toxic and carcinogenic pollution component.Nuclei of metals, ashes as well as organics contribute considerably to the ultrafine particle size fractions and thus to the particle number concentration.

The exhaust gas filtration is increasingly applied worldwide to reduce significantly this pollution, both on Diesel- (DPF) and on gasoline- (GPF) engines. In recent years, the EU has awarded research projects that deal with the possibilities of retrofitting gasoline vehicles with GPF. Together with various partners, VERT is working on an EU project, AeroSolfd, in which the suitability and efficiency of GPF for retrofitting the gasoline vehicle fleet was demonstrated.

This poster (presentation) shows the earlier research activities of VERT/AFHB and some of the results that were largely confirmed in the current work.

The most important things to note are that:

- the gasoline vehicles with MPI can emit a considerable amount of PN.
- with the GPF's from previous decade it is possible to lower the emissions below the actual European limit value of 6.0 x 1011#/km.
- the retrofitted, non catalyzed, add-on-GPFs as well as the 4WC work durably and with no problems in the real world application.

On-road measurement of all Euro 7 gaseous emissions from motorcycles using a rider-worn portable FTIR analyzer

M. Vojtisek-Lom[1,2], M. Pechout[1], L. Dittrich[3,4], F. Mejdr[4], V. Liska[1], V. Vobr[1], M. Kotek[1]

[1]Department of Vehicles and Ground Transport, Czech University of Life Sciences in Prague, [2]Institute of Experimental Medicine of the Czech Academy of Sciences, [3]Department of Mechatronics and Computer Engineering, Technical University of Liberec, [4]CreaTech, Ohnistany, Czech Republic

Fourier-transform infra-red (FTIR) spectrometers have been commonly used to analyze engine exhaust for gaseous pollutants, many of which are precursors to secondary aerosols. Several FTIR have been adopted, including three by this group, for the use in moving vehicles, which is challenging due to the effects of vibrations on precision multipath low-volume optical cells used to achieve a fast response time.

In this work, a Bruker Matrix FTIR with a 5-meter heated cell and liquid nitrogen cooled MCT detector, providing spectra at 5 Hz and 0.5 cm^{-1} optical resolution with a t_{90} time response under 2 seconds, has been extensively modified into a road-ready, self-contained 70x35x35 cm, 35 kg package including heated sampling line, filter and pump, consuming <300 W when operating at -9°C ambient temperature. For motorcycle tests, the FTIR has been fitted into an in-house fabricated external frame backpack worn by the motorcycle rider, with bulk of the weight resting on the motorcycle passenger seat.

Absorption spectra of exhaust have been collected during on-road operation from a range of L-category vehicles, including 50cc mopeds, enduro bikes and quads at ambient temperatures 0-30°C, and analyzed for all gaseous pollutants set to be regulated under Euro 7 - greenhouse gases CO2, CH4 and N2O; reactive nitrogen species NO, NO2, NH3; and reactive gases CO and formaldehyde, with an option to analyze ex-post for additional gases. Exhaust flow has been calculated from measured fuel injector pulse width or using a speed-density method. The validation of on-road FTIR instruments typically consists of parallel measurement with reference instruments in the laboratory for all measured pollutants and on the road for those pollutants that can be reliably measured on the road. A set of validation data, including dynamic chassis dynamometer tests on a variety of vehicles at -9 to +35°C, showing a reasonable correlation with several reference instruments, will be presented and discussed.

Funded by Horizon Europe project 101056777 LENS, L-vehicles Emissions and Noise Mitigation Solutions.

Session 3: Poster Session A (Health effects), Poster

Systematic review and meta-analysis on short-term concentrations of ambient ultrafine particles and natural, cardiovascular and respiratory mortality

M. Bergmann[1,2], P. Haddad-Thoelke[1], H. Jeong[1], R. Kappeler[3,4], H. Altug[1], H. Boogaard[5], M. Kutlar Joss[3,4], Y. Lim[2], S. Loft[2], Z. J. Andersen[2], B. Hoffmann[1]

[1]Institute of Occupational, Social, and Environmental Medicine, Centre for Health and Society, Medical Faculty and University Hospital, Heinrich Heine University Düsseldorf, Germany , [2]Section of Environmental Health, Department of Public Health, University of Copenhagen, Copenhagen, Denmark, [3]Swiss Tropical and Public Health Institute, Allschwil, Switzerland, [4]University of Basel, Basel, Switzerland, [5]Health Effects Institute, Boston, MA, United States

BACKGROUND: Ambient ultrafine particles (UFP, <100 nm) are suspected to cause adverse health effects independent from larger particle fractions. Accordingly, there is increasing interest in their health effects. This paper describes a systematic review and meta-analysis of studies investigating the association of short-term concentrations of UFP with natural, cardiovascular, and respiratory mortality.

METHODS: We systematically searched for epidemiological studies published between January 2011 and December 2024 in the databases PubMed and LUDOK and added studies from before 2011 from a previous review. We assessed heterogeneity and risk of bias and performed random-effects meta-analysis when at least four estimates were available.

RESULTS: We identified 21 studies in total, with 17, 17, and 15 studies on natural, cardiovascular, and respiratory mortality, respectively. Meta-analytic summary estimates were 1.000 (95% CI: 0.993, 1.007), 0.996 (0.990, 1.002) and 1.005 (0.979, 1.032) for natural, cardiovascular, and respiratory mortality, respectively, per 10,000 pt/cm^3 increase in UFP at lag 0, which had most available estimates. Overall, associations were non-significant and close to null across most lags. We found heterogeneity in UFP monitoring and lag reporting.

CONCLUSION: The number of studies on the association between short-term UFP concentrations and mortality has increased substantially in the last years. However, the current evidence does not clearly support an association between short-term concentrations of UFP and mortality. Future studies should improve and harmonize UFP monitoring to improve investigation of health effects and inform policymaking.

Air Toxic Emissions And Potential Impacts from Industrial Complex And Port Operation in A Harbor City in Taiwan

J. TSAI[1], P. YEH[2]

[1]Professor, [2]Master

The potential health impact on community in the vicinity of industrial complex and port caused by air toxics has been concerned by the public in Taiwan. Taiwan EPA (2020) monitored the ambient concentrations of VOCs and particle-bound heavy metals in the industrial complex in Kaohsiung City and presented a significant impact. This research had been conducted to evaluate the potential impacts on the nearby community caused by multiple air toxics from various sources in the Linhai industrial complex and Kaohsiung port in the industrial city in southern Taiwan. Several species of air toxics, including benzene, formaldehyde, 1,3-butadiene, vinyl chloride, arsenic, and diesel particulate matter (DPM), from various sources in the industrial complex and port operations had been designed as target air toxics.

Emission inventory of target air toxics from industrial sources, port operation activities, ships, and inland transportation were estimated by activities and emission factors. The Gaussian dispersion model (AEDMOD) was applied to simulate the airborne concentration of each target air toxics. Residential inhalation risk was evaluated by following the guideline released by Taiwan EPA which had been revised from the OEHHA protocol (2015). Potential impacts on residents was evaluated at each grid based on model simulation results.

Emission estimation of target air toxics from all sources indicated that 1,3-butadiene and DPM were dominantly emitted from port activities and on-road transportation. Benzene was mainly emitted from stationary sources and on-road transportation. Formaldehyde, vinyl chloride and arsenic were dominantly emitted from stationary sources in the industrial complex. Airborne concentrations of target air toxics by AERMOD simulation indicated that there were several hot spots in the vicinity of industrial complex and port. The concentration of benzene, formaldehyde, 1,3-butadiene, vinyl chloride and arsenic in the community were dominantly affected by stationary sources. The airborne concentrations of DPM in the communities were dominantly influenced by port activities and on-road transportation.

The results of potential carcinogenic risk assessment indicated that there were 11 communities, with distance < 1 km to the industrial complex or port, should be put on the hot spot list. Among these communities, there were 9 communities which were with distance less than 200m to the industrial complex or port. The maximum potential cancer risk at the hot spot was approximate 10^{-04}. The potential carcinogenic risk at these communities were dominantly caused by DPM, 1,3-butadiene, and benzene. The results also indicated that DPM was the critical air toxic in the vicinity of industrial complex and port.

[1] Taiwan EPA, Report No. EPA-109-FA1203-A163, 2020. (In Chinese)

[2] TEPA, Taiwan HAP Emission Data, 2021. (In Chinese)

[3] OEHHA, Consolidated Table of OEHHA / CARB Approved Risk Assessment Health Values. 2020.

Memories of Asbestos: Health hazards due to Toner / Emissions from Laser printers and Copiers

H. Krüger[1,2]

[1]Nano-Control, International Foundation, Zum Hägerdorn 13, 27318 Hoya, Germany, [2]Heike.krueger@nano-control.org

Introduction & Background

The voluntary nano-Control, International Foundation, building on the legacy of the citizens' initiative ITG, has been addressing the critical issue of indoor air protection for nearly 30 years—a matter of great importance, as we spend over 90% of our lives indoors. International studies confirm that fine dust, including emissions from toner-based laser printers, poses serious health risks.

nano-Control is committed to raising awareness, conducting research, and mitigating the risks associated with indoor particulate matter pollution, particularly from toxic emissions produced by laser printer devices. The foundation also provides support to individuals affected by these risks.
Over the past 25 years, nano-Control has documented reports from 4,000 individuals, primarily in Germany, who believe their health issues originate from exposure to ultrafine emissions from laser printers and copiers. Many of these individuals have spent more than a decade searching for answers to their chronic health problems, with some now facing severe illness.

Self-reported Symptoms Associated With the Use of Printer and Photocopier Machines: Results From the Nano-Control, International Foundation Survey

Laser printers release billion of micro- and nanoplastic particles per printing page, contributing to indoor air pollution with metallic and ultrafine particles. These particles can cross blood-lung&brain-barrier.
The statutory mission of nano-Control, International Foundation is to initiate and oversee medical, scientific, and technical research projects. In 2024, a **systematic analysis of anonymized reports from over 2,000 individuals** (collected 1999–2010) revealed significant health impacts among workers exposed to laser printer emissions, (technicians, operators, and office workers) Reported health issues e.g. respiratory diseases (90%), allergies (70%), asthma/COPD (15%), cardiovascular and neurological disorders, gastrointestinal issues, metal allergies, and some cancers. Notably, half of the workers experienced acute respiratory and skin symptoms that improved during weekends or holidays but worsened upon returning to work, highlighting workplace exposure as a key factor. **Visible toner dust** was strongly associated with chronic fatigue, bronchial hyperreactivity, asthma/COPD, and cardiovascular disease, with statistically significant correlations. Health risk warrant further investigation of causes.
Journal of Occupational and Environmental Medicine 66(11):p 891-902, November 2024. | DOI: 10.1097/JOM.0000000000003197

Results

Ensuring high standards of indoor air quality is vital to protecting public health, reducing exposure to harmful pollutants, and eliminating inhalable endocrine-disrupting chemicals, including PFAS and other toxic substances.
Findings reveal that toner and emissions from laser printers and copiers can contain heavy metals, volatile organic compounds, polycyclic aromatic hydrocarbons, PFAS, and ultra-toxic substances like DBT and TBT, as also documented these ingredients in toner patents. Studies show that toners exhibit genotoxic and cytotoxic effects, damaging and destroying human lung cells. Toner particles have been identified in lung cells and submesothelial tissue.

$PM_{2.5}$ Bound PAHs: Seasonal TEQ Analysis and ILCR Based Health Risk Profiling of a rapidly growing urban city

S. Dwivedi[1], A. Lawrence[1,2]*

[1]Department of Chemistry, Isabella Thoburn College, Lucknow, India, [2]Alfred_lawrence@yahoo.com

The current study investigates the concentration and seasonal variations of $PM_{2.5}$ and its bound polycyclic aromatic hydrocarbons (PAHs) across industrial, commercial, and residential microenvironments in a rapidly growing capital urban city of South Asian precinct for three major seasons. Winter recorded the highest $PM_{2.5}$ concentrations, particularly in industrial areas (286.91 ± 37.34 µg/m³ outdoors, indoor/outdoor ratio 0.664), followed by commercial (246.93 ± 37.49 µg/m³, I/O 0.662) and residential environments (113.54 ± 10.31 µg/m³, I/O 0.878). Summer and monsoon seasons exhibited comparatively lower concentrations, with monsoon showing the least levels (industrial outdoors: 76.83 ± 8.37 µg/m³, I/O 0.577). Indoor/outdoor ratios across seasons and environments indicate varying infiltration rates, with residential areas demonstrating a significant indoor dominance during summer (I/O 1.09). Further, evaluation of toxicity of PAHs was done using TEQ. TEQ was found to highest for BaP in all seasons and for all microenvironments. It ranged between 0.012-6.5. Other PAHs reported with high TEQ values included InP, BKF, BbF and BaA in indoor as well as outdoor. Moreover, ILCR values were evaluated. According to the results, the ILCR values were significantly higher for all the PAHs in all the three microenvironments, but in particular were more noticeable in industrial microenvironment. During winter season, at industrial microenvironment, ILCR values were notably higher for the 1-3 years age group compared to older age groups. For instance, the ILCR value for 1-3 years is 149.9, which drops significantly as the age increases. Across all PAHs, there is a general decreasing trend in ILCR values with increasing age. This indicates that younger children are at higher risk due to higher exposure levels or higher susceptibility. The current research highlights critical seasonal and spatial variations in PM2.5 and PAH levels, revealing severe health risks, especially for young children in industrial areas. It underscores the industrial sector's role in pollution and the urgent need for targeted interventions. The findings provide valuable insights for improving urban air quality and protecting public health in rapidly growing South Asian cities.

Keywords: Indoor air Quality, PAHs, $PM_{2.5}$, TEQ, ILCR.

Properties and Health Impact of Inhalable-Retainable Ultrafine Particles from Combustion (Exhaust-UFPs), Indoor Combustion (Indoor-UFPs) and Solar-thermally Aged Tire-Wear Particles (TWP-UFPs)

P. A. Sermon[1,1]

[1]Brunel University

Carbon [1] particle retention in lungs can be modelled [2] and then followed in pathways through the body [3] affecting human health [4].
Here the characterization of UFPs from combustion (land machinery, portable power generators, vehicles, marine engines, jet engines; Exhaust-UFPs), indoor combustion (candles, natural gas hobs, and wood burning stoves) and solar-thermal aging of tire-wear particles (TWP-UFP) is reported using TEM, SEM-EDX, XRF, XRD, Raman (sp2:sp3) FTIR and TPO methods.
In inhalation-exhalation profiles measured by real time (10ms) mass spectrometry, it is noted that (Figure 1a) that O_2 (red), H_2O (blue) and CO_2 profiles are as expected, but NO_2 profiles reflect an unexpected biomarker exhalation. Interestingly, there is an 80% retention of UFPs (see Figure 1b).
This needs following up with different ages, genders, health characteristics.
It is hoped that ongoing research will defines mechanisms, pathways, destinations and effects of these UFPs.

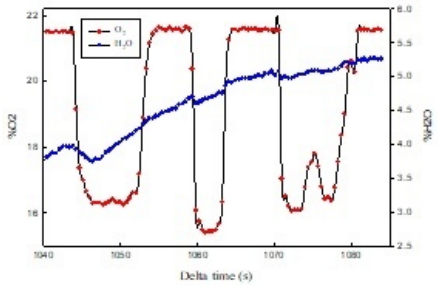


Figure 1a. O_2 and H_2O inhalation-exhalation profiles for a 79 year old

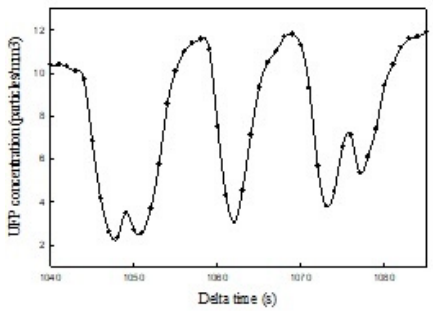


Figure 1b. UFP inhalation-exhalation profiles for a 79 year old

This abstract has NPC25-TWP and NPC25-Health relevance.

[1] K Ganguly, D Ettehadieh, S Upadhyay, S.Takenaka, T Adler, E Karg, F Krombach, WG Kretling, H Schulz, G Schmid, T Stoeger Partic.Fibre Toxicol 2017,14,AR19
[2] VS Grytting, T Skuland, J Ballangby, M Refsnes, M Lag, J Overvik, E Mariussen Toxicol.Vitro 2024,98,AR105841
[3] YD Shag, R Chen, R Bai, JY Tu, L Tian Nanoimpact 2021,22,AR100322
[4] JC Chow,G Watson Nat.Res.Sust.Dev.Ecol.Haz 2007,99,619

CFD model for particle removal and heat recovery in centrifugal wet scrubber.

W. Thelin[1], L. Lin[1]

[1]Linnaeus University, Department of built environment and energy technology

During biomass combustion, two aerosol modes are typically generated: coarse particles with a peak around 3 µm and fine particles with a peak around 100 nm. Both these modes are harmful for human health. Coarse particles are easily collected by cyclones, but fine particles require different removal methods. Wet scrubbers are effective for larger particles, but their efficiency is generally low for fine particles due to the greenfield gap. This low efficiency gap occurs when particles are too small for removal through inertial impaction but too large for removal through Brownian diffusion. However, recent research shows that high heat transfer and vapor condensation in scrubbers can significantly increase removal efficiency even in these ranges [1]. Our research investigates particle removal in a centrifugal wet scrubber using a CFD (Computational Fluid Dynamics) simulation model and onsite measurements. The scrubber, connected to a 3 MW grate-fired biomass furnace, is described in [2], along with process data for model validation regarding heat recovery. Flue gas particles were sampled before and after the scrubber, see Fig. 1. Measurements were taken with cascade impactors (no dilution needed) and with an Aerodynamic Particle Sampler (APS) and Scanning Mobility Particle Sizer (SMPS) coupled with a Condensation Particle Counter (CPC), where dilution with pressurized air was controlled using a CO_2-meter, see Fig. 1a. The onsite measurements showed particle removal of around 40 % for submicron particles and close to 100 % for coarse particles. These particle measurements were also used to validate the simulation model. Our model predicts heat recovery with less than 4 % error and particle removal with less than 4 % error for particles larger than 1 µm and 2 % error for submicron particles. Although total removal is well predicted by the model, it is clear from Figure 1b that the model does not follow the same trend as measured at the facility. This is likely due to particle growth through coagulation inside the scrubber. In an upcoming paper, we show how particle growth of only a few nanometers can distort the removal efficiency curve like this while only marginally increasing total removal. The CFD-model show great promise as a tool for further investigating particle removal in wet scrubbers. However, to better account for particle growth, another function will be developed to simulate particle coagulation.

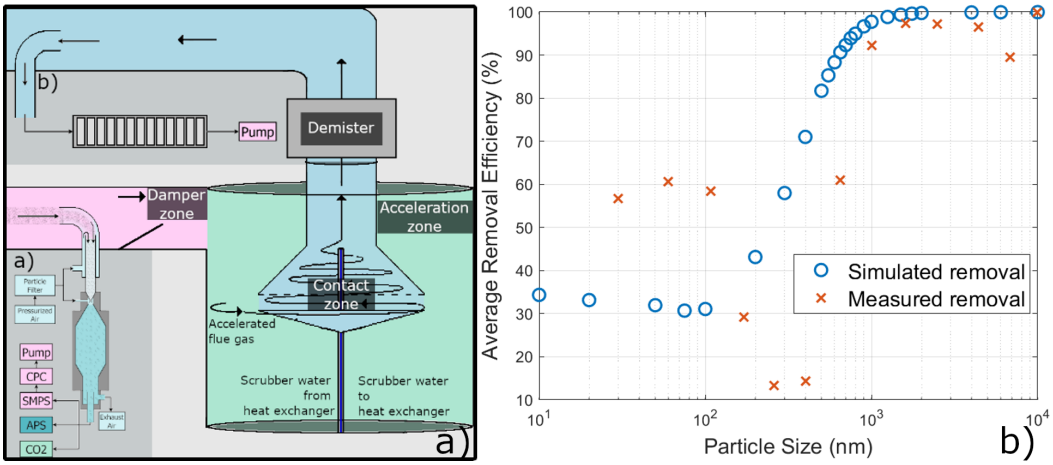


Figure 1: a) Schematic sketch of scrubber and particle sampling. b) Particle removal according to aerodynamic size, comparison between measurements and simulation model.

[1] Y. Feng, Y. Li, L. Cui, L. Yan, C. Zhao, and Y. Dong, *Energy, 2019,* 171, 1193-1205
[2] W. Johansson, J. Li, and L. Lin, *Applied Thermal Engineering, 2023,* 219, 119454

Detecting diesel exhaust particles in lung cells using lock-in thermography

R. He[1], A. . Moreno-Echeverri[1], A. Petri-Fink[1,2], B. Rothen-Rutishauser[1]

[1]University of Fribourg, Fribourg, Switzerland, [2]Chemistry Department, University of Fribourg, Fribourg, Switzerland

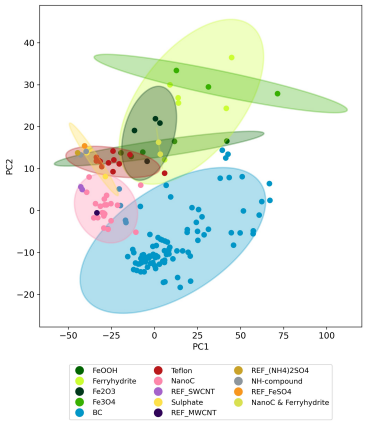
Diesel exhaust particles (DEPs) can deposit on the respiratory epithelial surface upon inhalation, with fractions entering cells in the epithelial tissue via endocytic pathways. The cellular burden of internalized particles is important for dose-response relationships in the cells using *in vitro* approaches. However, rapid, non-destructive methods to detect DEPs in cells are still challenging and not well established. This study explores a non-destructive particle detection technique, *i.e.,* lock-in thermography (LIT), which measures the thermal signature produced by an absorbing sample (*e.g.,* carbon-based particles) illuminated by light. In this study, standard DEPs (SRM2975) were used to optimize LIT parameters, with a wavelength of 525 nm at a stimulation frequency of 1 Hz identified as optimal for detection. Human epithelial lung A549 cells were grown for 4 days and then exposed to DEPs at concentrations ranging from 0 to 8 µg/mL for 24 hours, followed by extensive washing with PBS (> 4 times) before LIT measurement. LIT successfully detected thermal signals of DEPs in the cell layer at concentrations as low as 1 µg/mL, with signal intensity increasing with exposure concentration. Transmission electron microscopy (TEM) further confirmed DEP internalization into cells. Our results demonstrate that LIT is a rapid, sensitive, and non-destructive method for detecting internalized DEPs in cells. Further studies are ongoing to detect carbon-based particle internalization in animal and human lung tissues.

Material Characterisation of vehicle-emitted fine and ultrafine particles

S. Valentini[1], C. Ferrarese[1,2], D. Manara[1], D. Mehn[1], A. Valsesia[1], J. Ponti[1], N. E. Fonseca Gonzalez[2], G. Schirinzi[1], G. Martini[1]*

[1]European Commission, Joint Research Centre (JRC), Via Enrico Fermi 2749, Ispra, Italy, [2]ETSI Minas y Energía, Universidad Politécnica de Madrid, c/Rios Rosas 21, 28003, Madrid, Spain

This paper summarises some relevant features of Raman spectra recorded on samples of micro- and sub-micro particulate emitted by both light-duty and heavy-duty vehicles. The particulate samples were collected from tailpipe exhaust in internal combustion engine vehicles in dedicated chassis-dyno driving tests performed at the European Commission's Joint Research Centre Vehicle Emission Laboratories [1], both under standardised type-approval conditions and under extended driving conditions, including high speed, varied ambient temperatures, different simulated altitudes and diesel particulate filter regeneration. Various compounds of carbon are identified by Raman spectroscopys. Black carbon mostly consisting of defective graphite crystals constituted the main component of exhaust-emitted particulates. However, different species were also observed, including amorphous and highly-crystalline graphite and non-carbonaceous species, such as iron oxides, sulphates and nitrogen compounds. More rarely occurring species were identified with the help of Principal Component Analysi. This statistical approach permits the identification of clusters of Raman spectra from different vehicle types, fuels and injection technologies. Some sub-micrometric ordered carbon structures were detected, mostly when particulate samples were collected directly at the vehicle tailpipe and not diluted in a constant volume sampler system. These sub-micrometric structures were assigned to Multi-Wall Carbon Nanotubes based on further material characterisation performed by Transmission Electron Microscopy. The current research confirms that the chemical nature of exhaust particulate emissions can be conveniently approximated with black carbon in the majority of the cases. However, one should not neglect the possible formation of different, and possibly hazardous, chemical species in combustion processes. Nano-structured particles, although more challenging to characterize, can result to be highly dangerous for human health and harmful for the environment. Figure 1 reports example clusters identified in the Principal Component Analysis performed in this work on a broad database of Raman spectra measured on exhaust particulate emitted by Diesel, gasoline liquefied petroleum gas, compressed natural gas and hydrotreated vegetable oil (HVO) fuel.



[1] European Commission, Joint Research Centre, Valverde Morales, V., et al., European Market Surveillance of Pollutant Emissions from Internal Combustion Engine Vehicles, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/191638, JRC138842

Diffusion-charging based sensors for ambient air quality measurements

M. Fierz[1], J. Bussmann[1], M. Hügi[1], P. Küry[1], D. Meier[1], L. Zuber[1]

[1]Naneos particle solutions

Ultrafine particles are suspected to be particularly health-relevant due to their small size, which allows them to penetrate deeply into the lung, and to cross cellular barriers that larger particles cannot cross. So far however, regulations usually only consider particle mass, with PM10 and PM2.5 being widely measured, and corresponding limit values are in place. Ultrafine particles (UFP) in ambient air have so far only been measured optionally for research purposes. This is about to change though with new WHO recommendations asking for specific UFP measurements, ideally with size resolution; and in particular with a new EU directive which mandates UFP measurements of particle number concentration (PN) and particle size distributions (PSD). Reliable and well-known instruments to measure these two new metrics exist; the condensation particle counter (CPC) for PN, and the mobility particle size spectrometer (MPSS) for PSD. These instruments will also be used to implement the new EU directive. However, this directive asks for a very low geographic coverage: one measurement site must be implemented for each 5 million inhabitants. If we translate this to a country like Switzerland, it would need only two sites measuring UFPs to fulfil the new directive - which is obvioulsy far too little to gain any understanding of the spatial distribution of UFP. This low coverage is rather absurd, since UFPs are know to be very inhomogenously distributed compared to PM-based metrics. One reason for the currently low mandated spatial coverage is the complexity and cost of the instruments used. To understand UFP and their spatial distribution better, instruments are needed which are cheaper, easier to operate, and which can be operated outside of traditional measurement stations. Diffusion-charging based instruments can fulfil these requirements, as they are far smaller, consume less power, need no working fluid and can work within a large range of operating temperatures. At naneos, we have developed two diffusion-charging based devices for ambient air monitoring:

1) The Partector 2 was originally designed for easy handheld UFP measurements, e.g. in workplaces. It was not intended for longer-term deployments, and certainly not for 24/7 ambient monitoring for long periods (e.g. 1 year) without service. However, some of our customers started using it for such measurements, and we have since started our own testing of the Partector 2 Pro at different measurement sites in Switzerland where the PSD is measured with conventional MPSS systems. The first such measurements were started in mid-2023, and by now, we have 6 Partector 2 devices measuring at 3 different sites: Zürich, Payerne and Jungfraujoch.

2) For the EU project Net4Cities we developed an entirely new low-cost OEM sensor which only measures lung-deposited surface area (LDSA). LDSA is not among the newly mandated metrics for UFP, but there are toxicological and animal studies showing that it might represent health effects better than either particle number or particle mass. From an instrumentation perspective, LDSA instruments are much simpler than diffusion-charging based particle number measurements such as the Partector 2, and therefore they are cheaper, less prone to failure, and also far more robust, leading to much lower total cost of ownership. One can therefore deploy a far larger number of such devices in far more places to study UFP than when using traditional instruments.

We have also designed an ambient enclosure which accepts either the Partector 2 or the low-cost OEM sensor, and comes with internet connectivity, so both systems can be installed anywhere where mains power is available, e.g. on a lamp post, rather than needing a climatized measurement station. We will present comparisons of our devices vs MPSS and CPCs, and some of the issues found in the field with our sensors, and measures taken to improve the Partector 2 for longer term monitoring.

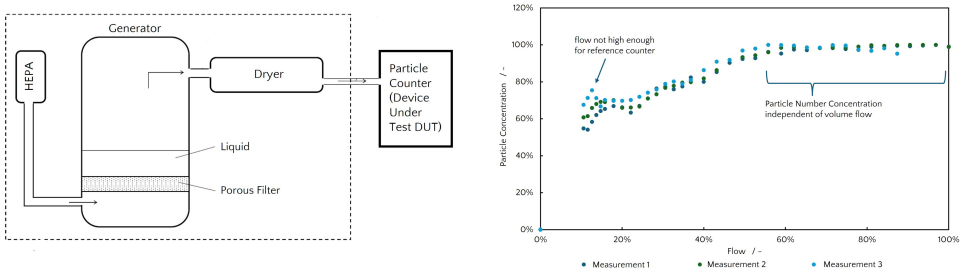
Usage of porous filter and salt solutions for the generation of constant particle concentrations

P. Schwanzer[1], P. Seifert[1], K. Hartkopf[1]

[1]Scale MT GmbH

>**Keywords:** #Calibration #Particle Counter #CPC and DC #DailyCheck #Nanoparticle

Porous filters with defined pore sizes are used in a wide range of technical applications. ISO 4793:1980 specifies classes for the pore sizes, therefore there are well established industrial processes to produce high quality structures with defined pore sizes. In our study we are using a porous structure immersed in a liquid while an air stream is flowing through the porous structure. Gas bubbles of a defined size distribution are formed by the pores and burst on the surface of the liquid. Fine droplets are created in the air steam above the liquid reservoir. If that liquid contains additives, like minerals (for example salt) these droplets can be dried to create solid ultrafine particles of a defined size distribution, depending on the pore size used in the porous filter. Now these particles can be detected with a particle counter (DUT).



For our study we are varying the gas volume flow through the porous structure and observe the generated particle number concentration the DUT is reporting. It turns out that there is a wide window of volume flow, where the particle number concentration is independent of the volume flow and that the generated particle concentration is repeatable, as the sizes of the generated bubbles above the porous structure are uniform for these gas velocities passing the porous structure. Figure 2 shows the generated particle number concentration as a function of volume flow through the porous structure.

Applications and outlook

A weak point of particle counters is that it is very complex to check their function. To ensure that the reading of PN counters is correct, a complex laboratory setup with a particle generator and a reference counter is required. Unlike gas analyzers, that can be checked with a span gas bottle, particle counters can only be checked with a HEPA filter on a daily basis, to find leaks. Real calibrations are usually performed on an annual basis and errors are only recognized after the data collection, so that measurement results become unusable when errors are found. With the porous filter generator we found a very easy and simple way to check particle counters before the measurement is performed on-site (patent pending DE 102024139698.9). As the porous filter generator doesn't need its own compressed air supply or pump, it is an easy and cheap tool for checking the DUT counter before the measurement takes place on site. With switching valves this check can be performed fully automated. Choosing the right geometry and pore size, a suitable generator can be designed for every possible PN measurement application.

Synthesis and characterization of thin films for sensing Bioaerosols

A. Bhatnagar[1], J. Masih[2], R. Kumar[3]

[1]Department of Chemistry,Dayalbagh Educational Institute,Agra,282005,India, [2]Department of Chemistry, Wilson College, Mumbai, 400007, India, [3]Department of Chemistry, Dayalbagh Educational Institute, Agra, 282005, India

Abstract:

Detection of biological components in ambient air is a difficult challenge as the methods are cumbersome and time taking. Hence, the development of fast and accurate methods of detection and identification systems for biological components in the environment is of paramount importance in the recent scenario of the infection and spread of pathogens. For that we are synthesizing and characterizing the material which will be used as a tool for making prototype for microbial biosensor which will be of low cost, efficient, highly sensitive and versatile. ZnO electrodes in the form of thin films were prepared with different layer coatings and later characterized to see the biosensing properties so that biosensors for monitoring and measurements of bioaerosols in the environment can be fabricated. These thin films have been prepared using sol-gel method and characterization were investigated by various techniques such as FE-SEM, UV-VIS and XRD. The electrical behavior of the electrode has also been studied and plotted into I-V curve, ranging from -1 to 1 V which shows the fluctuation in current on applying voltage. It is predicted that 2- layer thin films carry more current which makes it suitable for biosensing application compared to 5-layer films on applying bias. This is because if the 5-layer coating becomes too thick, it might suffer from higher resistance therefore reducing current flow.

Keywords: *Ambient environment, bioaerosols, biosensors, nanomaterial*

Corresponding author: *E-mail address:* rkschem@rediffmail.com

Real-world implementation of an optoacoustic Black Carbon Sensor for Ship Emissions Measurement

N. Kousias[1,2], L. Haedrich[3], J. S. Nielsen[4], M. Levin[4], F. Braestrup[4], I. Raptis[1], U. Stahl[3], V. Ntziachristos[3]*, L. Ntziachristos[1]*

[1]Aristotle University of Thessaloniki, Department of Mechanical Engineering, Thessaloniki 54636, Gree, [2]Maurus Oy, Suvantokatu 13, 33100 Tampere, Finland, [3]Technical University of Munich, School of Medicine, Chair of Biological Imaging, 80333 Munich, Germa, [4]FORCE Technology, Park Alle 345, DK-2605 Brøndby, Denmark

Black Carbon (BC) is a byproduct of combustion of carbon-containing fuels, that is defined partly by its strong light absorption properties [1]. It contributes significantly to climate change [2], while it also has adverse effects on human health [3]. Currently, new legislation for BC emissions from ships in the Arctic, is being discussed by the International Maritime Organization. Absorption based techniques that can quantify BC are required for on-board monitoring. Optoacoustics, aka Photoacoustics, is one such promising candidate technology.

We have previously developed a low-cost optoacoustic sensor [4]. A portable version of this sensor was installed on-board a RoRo ferry that was transporting passengers and cargo in the Baltic Sea. The ferry was powered by four medium speed 4-stroke main engines, it was equipped with SCR catalysts, and it was operating on MGO fuel. A diluter was used to provide a sample from one of the main engines to the sensor, while an AVL MSS and an AVL Smokemeter were used as references.

The results of the campaign show that the sensor is suitable for BC monitoring of ships. It was able to monitor the BC mass concentration from the exhaust stack with very good agreement to the MSS. The Smokemeter seems to consistently overestimate BC emissions. Insight on required sampling protocols was also gained. Stable BC concentrations were observed during cruising, as expected. During maneuvering (close to the port) we noticed rapid and very large peaks of BC which can only be captured by continuous measurements. The use of a dilution cycle or long averaging (typically employed by filter-based instruments) should be avoided for accurate emissions estimation.

Acknowledgements
This work was supported by the EU's Horizon 2020 programme under grant agreement No 862811 (RSENSE).

[1] A. Petzold *et al.*, *Atmos. Chem. Phys.*, vol. 13, no. 16, pp. 8365–8379, 2013.
[2] T. C. Bond *et al.*, *J. Geophys. Res. Atmos.*, vol. 118, no. 11, pp. 5380–5552, 2013.
[3] World Health Organization, "Health effects of black carbon," 2012.
[4] A. Stylogiannis, et al., *Sensors (Switzerland)*, vol. 21, no. 4, pp. 1–14, 2021.

Urban Air Quality Monitoring with the AVL UltraFine Particle Monitor: Measurement Campaigns and Key Findings

G. Wimmer[1], J. Murg[1], C. Cresnoverh[1], R. Davok[1], A. Pein[1], B. Tschofenig[2]

[1]AVL List GmbH, Graz, Austria, [2]Amt der Steiermärkischen Landesregierung, Graz, Austria

Ultrafine particles (UFPs, <100 nm) are a significant concern in urban air quality due to their potential adverse health effects. The AVL UltraFine Particle Monitor (UFPM) has been developed to meet the requirements of EN 16976, ensuring high precision in ambient UFP monitoring. This study presents measurement results from long-term urban monitoring campaigns conducted in Graz and Vienna, Austria, providing insights into spatial and temporal variations of UFP concentrations. Results indicate a strong correlation between traffic activity and UFP levels, with concentration peaks observed during morning and evening rush hours. Notably, Graz exhibits ~60% higher UFP concentrations compared to Vienna, attributed to differences in topography, urban structure, and prevailing wind conditions. High-resolution measurements during New Year's Eve further highlight the need for real-time monitoring to capture rapid fluctuations caused by transient events such as fireworks. These findings emphasize the importance of continuous UFP monitoring for urban planning and public health assessments. The AVL UFPM, independently calibrated and ACTRIS-compatible, demonstrates its capability as a robust tool for regulatory and research applications in air quality management.

Seeded Growth of Silver Nanoparticles by Heterogeneous Condensation in a Tandem Silver Particle Generator Setup

V. Berger[1], P. Bauer[1], E. Sorani[1], H. Schulz[1], A. Boises[1,2], J. Swanson[1,3]

[1]Catalytic Instruments GmbH & Co.KG, 83026 Rosenheim, Germany, [2]Stanford University, 440 Escondido Mall, Stanford, United States, [3]Minnesota State University, Mankato, MN 56001, United States

The calibration of CPCs and DMAs needs monodisperse, singly charged, spherical particles (Wiedensohler et al., 2018; EN 16976:2024). A common way to generate these using silver is the evaporation condensation method described by Scheibel and Porstendörfer (Scheibel et al., 1983). Silver is evaporated at temperatures around 1100 °C. The silver vapor nucleates to particles when cooling down. When generating sufficiently high concentrations of particles, agglomeration of these particles generates larger, fractal-like particles. To obtain spherical particles, these agglomerates need to be sintered, i. e. reheated to temperatures in the range of 400 to 700 °C (Ku et al., 2006; Zihlmann et al., 2014; Tuch et al., 2016; Berger et al., 2024). Sintering reduces electrical mobility diameter by approx. 70 % (Zihlmann et al., 2014), as the low-density agglomerates are compacted into solid spheres. The significant reduction in size makes it challenging to achieve spherical silver particles larger than 100 nm (Berger et al., 2024), as agglomerates with an electrical mobility diameter larger than 300 nm are needed. An alternative approach for the generation of spherical silver nanoparticles has been presented (Zihlmann et al., 2014): Seed particles, generated in a spark discharge generator, are sent through a tube furnace operated at 1210 °C. A crucible filled with silver inside the tube furnace generates silver vapor. In the cooler parts of the tube furnace, the silver vapor heterogeneously condensates onto the seed particles, increasing their size. It has been shown that these particles are spherical, and that particle diameters of up to 104 nm are achievable. In a first step, the work presented here aims at reproducing the results by Zihlmann et al. while using two Silver Particle Generators (SPG) by Catalytic Instruments GmbH & Co. KG, Germany. Figure 1 shows a schematic of the experimental setup.

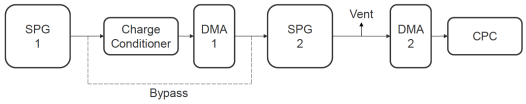


Figure 1: Experimental setup. Silver particles are generated in the first Silver Particle Generator (SPG 1). Optionally, the particles are charge conditioned and size-selected in DMA 1. Subsequently, the aerosol is fed into SPG 2, where silver vapor condenses heterogeneously onto the incoming particles, increasing their size. DMA 2 and the CPC perform particle size distribution scans. The second step is to further investigate the possibilities of this Tandem-SPG (T-SPG) setup. As the SPG is quick in adjusting its operating parameters (temperature, carrier gas flow rate, dilution flow rate), a large field of temperature and gas flow combinations of the two SPGs can be investigated efficiently. Main goals of this investigation are the upper particle size limit of this setup, and whether a monodisperse aerosol can be achieved from polydisperse seeds via supersaturation of silver vapor.

[1] Berger, V., et al., 27th ETH Nanoparticles Conference, Zurich, Switzerland, **2024**.

[2] EN 16976:2024, European Committee for Standardization, Brussels, Belgium, **2024**.

[3] Ku, B. K., et al., Journal of Aerosol Science, **2006**, 37, 452-470.

[4] Scheibel, H. G., et al., Journal of Aerosol Science, 1983, 14:2, 113-126.

[5] Tuch, T., et al., Aerosol Science and Technology, **2016**, 50:4, 331-338.

[6] Wiedensohler, A., et al., Aerosol Science and Technology, **2018**, 52:2, 146-164.

[7] Zihlmann, S., et al., Journal of Aerosol Science, **2014**, 75, 81-93.

Session 7: Poster Session B (Instrumentation), Poster

A Fast Wide Size Range Condensation Particle Counter

Y. Zou[1], J. P. Symonds[1], S. D. Payne[1], M. Tofts[1]*

[1]Cambustion, Cambridge, CB1 8DH, U.K

This study presents a Condensation Particle Counter (CPC) with a wide size detection range and fast time response. A fast time response is useful to reduce scan times in scanning applications and supports real-time monitoring and the study of dynamic processes. CPCs grow particles by condensation until they are large enough to be detected by optical scatter, allowing it to count particles smaller than the minimum detectable size of Optical Particle Counters. However, many CPC models have low detection efficiency of larger particles (>1 µm) due to particle inertial losses in bends and constrictions in the flow pathway.

The presented CPC uses a laminar mixing design, where pre-vapourised working fluid in a stream of filtered air mixes with the sample. This avoids losses of larger and smaller sampled particles in a saturator. The CPC is of a wholly horizontal design to avoid bends; at the design conditions gravitational settling is not significant <10 µm.

The CPC was tested for large particle (>1 µm) counting with condensation aerosols from a Sinclair Le Mer Generator (modified TOPAS SLG-250) using DEHS as a condensate. Below 6 µm particles were size selected with a Cambustion AAC, and a PALAS Welas 1000H aerosol spectrometer was used as number reference, and above 6 µm for size. A TSI 3752 CPC was also used as a comparator and to correct the WELAS counts by examining their overlap. For intermediate sizes, a TSI 3752 was used as a reference, sampling ambient air or an oil aerosol. For small particles (<20 nm) ultrafine sodium chloride aerosols, condensed from a tube furnace, were size selected with a TSI 3085 NanoDMA, while a PALAS Charme electrometer served as a counting reference.

Particle counting results are collated in Fig 1a – the $D_{50,min}$ was measured to be 5 nm, and $D_{50,max}$ was greater than 10 µm. The time response ($T_{90\text{-}10\%}$) was measured to be <40 ms (Fig 1b).

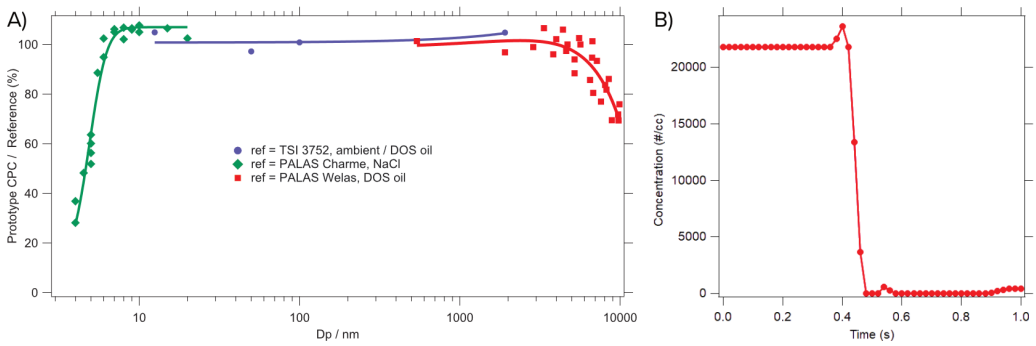


Figure 1: a) Particle counting results over full size range of CPC; b) time response measurement (atmospheric aerosol with HEPA filter added/removed) where each datum is 20 ms.

Session 7: Poster Session B (Instrumentation), Poster

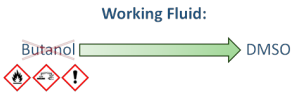
Insights from over two years of using DMSO as working fluid in condensation particle counters

S. Kirchhoff[1,2], O. F. Bischof[3,1], G. Steiner[4], A. Petzold[1,2], U. Bundke[1], P. Weber[1]*

[1]Forschungszentrum Jülich GmbH, Institute of Climate and Energy Systems 3 – Troposphere (ICE-3), Jülich, Germany, [2] Institute of Atmospheric and Environmental Research, University of Wuppertal, 42119 Wuppertal, Germany , [3]TSI GmbH, Particle Instruments, Aachen, Germany, [4]GRIMM Aerosol Technik GmbH, Vordere Aue 4, 06744 Muldestausee, Germany

Condensation particle counters are an indispensable measuring instrument in aerosol research. Nanoparticles suspended in the air, also known as aerosols, pose a potential risk to human health and industrial processes. Precise monitoring is therefore essential in many environments, but also in high-security laboratories or clean rooms in the manufacturing industry. The working principle of condensation particle counters is the vaporisation of a working fluid with subsequent condensation onto the airborne particles. The subsequent growth of the particles means that all particles activated in this way can be counted and a number concentration can be determined.

In order to be used as a working fluid, various characteristics are important, including vapour pressure behaviour at different temperatures. To-date, butanol is the most commonly used working fluid in CPCs event though it is associated with a pungent odour, health risks and flammability. Liquid DMSO (Dimethylsulfoxid) does not have the negative properties mentioned above. DMSO, on the other hand, has a similar vapour pressure curve to butanol, but shifted by an order of magnitude, resulting in significantly reduced consumption for the same particle size activation (Weber, et al., 2023).



DMSO as a working fluid has proven its performance in various experiments and a wide range of working conditions including low pressure environments. After two years of operation, we have gained more experience regarding the tolerance to DMSO of various components used inside CPCs. DMSO was used instead of butanol in three Model 5411 Sky-CPC (Grimm Aerosol Technik, Muldestausee, Germany) and a CPC 3772-CEN (TSI Incorporated, Shoreview, MN, USA) without any modification of the CPC hardware.

We will present our findings and discuss any questions regarding applications and experiences made during multiple test-runs and long-term measurements.

Parts of this work were supported by the FZJ Innovation Fund

Weber, P., Bischof, O. F., Fischer, B., Berg, M., Schmitt, J., Steiner, G., Keck, L., Petzold, A., and Bundke, U., Aerosol Research, 1, 1–12, https://doi.org/10.5194/ar-1-1-2023, 2023.

ROS production of source-specific emissions from combustion, brake, tire and road wear

V. Malmborg[1,2], S. Bengtsdotter[1], M. Gustafsson[3], J. Wahlström[4], J. Pagels[1], K. Dällenbach[5], Y. Lyu[4], U. Vogel[2]

[1]Ergonomics and Aerosol Technology, Lund University, Sweden, [2]The National Research Centre for the Working Environment, Copenhagen, Denmark, [3]Swedish National Road and Transport Research (VTI), Linköping, Sweden, [4] Machine Elements, Lund University, Sweden, [5]Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland

Grouping by similarity is an established method for extrapolating toxicity pathways for chemicals in general and has also been suggested for nanomaterials [1]. Therefore, such grouping may also be a useful approach when considering source specific emissions. This work will quantify acellular ROS production and oxidative potential (OP) of individual particle components from combustion, brake, tire, and road wear. Detailed particle characterization allows grouping by similarity and identification of source-specific markers that will help improve the mechanistic description of particulate ROS and OP. This can support new health policies and emissions legislation. Within the project, aerosol experiments are primarily performed under controlled generation in laboratory and real-scale simulations. Combustion particles were collected from a miniCAST soot generator, an experimental heavy-duty diesel engine fueled with renewable and fossil diesel, and from fire emissions of real-scale compartment fires during simulated arson. Tire and road wear particles were collected from a road simulator set up with summer, winter-friction, and studded winter tires on a cement concrete pavement. Brake emissions were collected from a pin-on-disc tribometer using different pin materials, relevant to the EU and USA, on a grey-cast iron disc. Screening methods for the generation of road emissions without tire particles will be investigated.

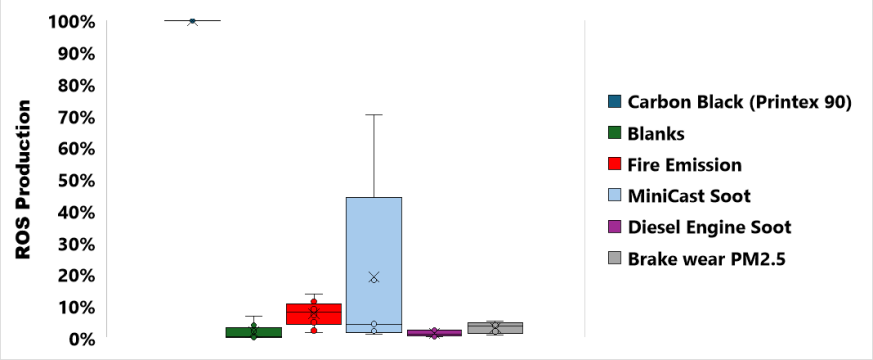


Fig. 1. *ROS production by PM2.5 combustion and non-exhaust particles normalized to Printex 90.*

Particles were collected on Teflon filters and extracted by sonication (3x15 min) in methanol. Fluorescence-based quantification of acellular ROS production was performed with the 2,7- dichlorodihydrofluorescein diacetate ($DCFH_2$-DA) assay. In addition, we plan acellular OP measurements with the dithiothreitol (DTT) assay and a selection of the particle samples will be subject to in vitro and in vivo analysis of relevant toxicological endpoints. We use a well-characterized carbon black nanomaterial (Printex 90, Degussa, DE) with high specific surface area as a positive control, which facilitates further comparison to a broad range of carbon nanomaterials [2]. Preliminary results (Fig. 1) suggest that acellular ROS production per unit mass were of similar magnitude for the tested combustion and traffic-related emissions, but significantly lower than the positive control (1-70%). Future work aims to group particle emissions by similarity with respect to phys-chem characteristics, ROS and OP.

[1] Giusti, A., R. Atluri, R. Tsekovska, A. Gajewicz, M.D. Apostolova, C.L. Battistelli, . . . A. Haase, NanoImpact, 2019. 16, 100182.

[2] V. Malmborg, D.A. Elam, V. Di Battista, J. Rissler, P.A. Clausen, U. Vogel, W. Wohlleben, N.R. Jacobsen, Carbon, 2025. 234, 119997.

Real-time simultaneous measurement of carbon and trace metals in brake wear particles using ICP-TOFMS

H. Hagino[1]

[1]Japan Automobile Research Institute

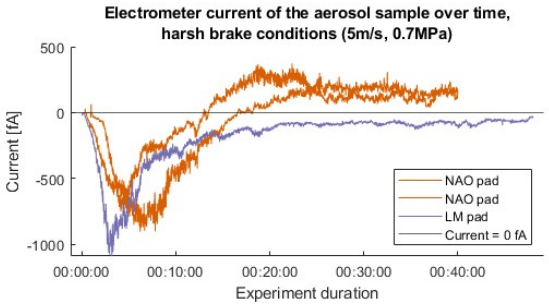
This study was conducted under realistic driving and braking conditions of a currently used brake system, using ICP-TOFMS (Inductively coupled plasma time-of-flight mass spectrometry) to measure elements in brake wear particles in real time. Conventional elemental analysis techniques have mainly focused on samples collected by filters, but the ICP-TOFMS equipped with a counterflow denuder in this study succeeded in real-time elemental analysis of brake wear particles as aerosols. In contrast to elemental analysis, which has mainly focused on metal analysis, this study has enabled simultaneous determination of carbon and metal by accurate mass analysis using ICP-TOFMS. Simultaneous real-time determination of carbon and metal in aerosol particles makes it possible to measure not only brake wear particles, but also tire wear particles, exhaust gas particles, and a wide range of other sample types. This study will be presented on the emission mechanism by comparing brake load, brake wear particle composition, and nanoparticle number size measurements.

Characterization of brake wear particles: influence of pad material and braking conditions on particle charging state

S. Bengtsdotter[1], J. Hoivala[2], Y. Lyu[3], V. Malmborg[1], T. Rönkkö[2], J. Wahlström[3], J. Pagels[1], P. Wacker[1]

[1]Ergonomics and Aerosol Technology, LTH, Lund University, Lund, Sweden, [2]Aerosol Physics Laboratory, Physics Unit, Tampere University, Tampere, [3]Machine Elements, LTH, Lund University, Lund, Sweden

Brake wear particles, generated from the brake pad – disc contact, contribute significantly to particle emissions from vehicle transport, and as the vehicle fleet transitions to electric, heavier, vehicles and alternative fuels, their relative contribution may increase. A recent study suggests that brake wear particles are highly charged, which can affect their atmospheric lifetime and deposition in lungs [1]. Further, determining the charging state of these particles might provide useful information of their initial formation mechanism. This study investigated how brake pad material and braking conditions influence the charging state and electrical properties of brake wear particles. We used a pin-on-disc tribometer to study particles generated from pins from two common brake pad types, low metallic and non-asbestos organic, in contact with a gray cast iron disc. Mild and harsh braking conditions were simulated with a disc speed of 2 and 5 m/s and a contact pressure of 0.6 and 0.7 MPa, respectively. The net charge of the aerosol particles was assessed from electric currents measured with an electrometer. More detailed studies of the charging state were conducted with a scanning mobility particle sizer with and without the bipolar charger (BPC), to compare the electrical mobility distributions of particles with their charge state from the tribological interaction retained to that of particles at bipolar charge equilibrium. We also used a differential mobility analyzer connected to an aerodynamic particle sizer to select particles with a certain, retained, electrical mobility and measure their aerodynamic size distribution. Connecting a BPC to this setup, we could determine the effective density used to convert electric mobility equivalent diameters to aerodynamic equivalent diameters. Additionally, number and mass size distributions were measured across an extensive range of particle sizes. P10 and PM2.5 samples were collected for chemical analysis.



Preliminary results indicate that both brake pad type and braking conditions affect the electrical properties of brake wear particles. For harsh conditions, the electrometer showed a strong negative net charge during the running-in phase, and a pad dependent net charge during steady-state. There was a strong shift in the electrical mobility size distribution measured with and without the bipolar charger, indicating that the particles are highly charged, tentatively around 10-20 charges per particle. The non-asbestos organic pin generated both the highest and lowest mass and number concentrations, during harsh and mild braking conditions respectively. Notably, harsh braking conditions generated a significant increase in nucleation-mode particles.

[1] A.E Thomas, P.S Bauer, M. Dam, V. Perraud, L.M Wingen, J.N Smith, *Proc. Natl. Acad. Sci. U.S.A.,* **2024**, 121, e2313897121.

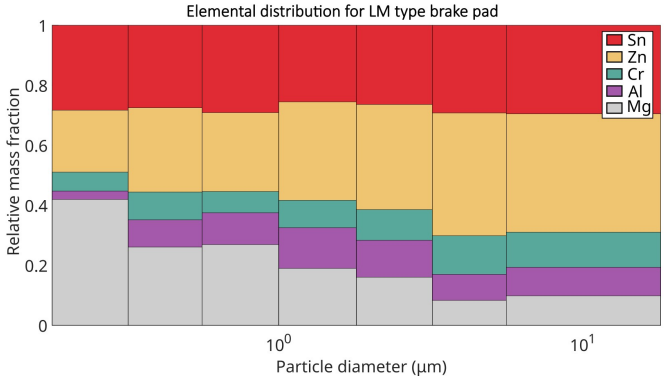
Size-resolved Elemental Analysis of Brake Emissions from Popular Brake Linings.

J. Hoivala[1], S. Bengtsdotter[2], M. Aurela[3], Y. Lyu[4], J. Wahlström[4], S. Saarikoski[3], J. Pagels[2]*, T. Rönkkö[1]*

[1]Aerosol Physics Laboratory, Physics Unit, Tampere University, Tampere, Finland, [2]Ergonomics and Aerosol Technology, LTH, Lund University, Lund, Sweden, [3]Atmospheric Composition Research, Finnish Meteorological Institute, Helsinki, Finland, [4]Machine Elements, LTH, Lund University, Lund, Sweden

Electrification is expected to have an effect on urban air quality as electric vehicles replace traditional internal combustion powered vehicles. Lack of exhaust emissions from electric vehicles is a key component in this exchange. Additionally, electrical vehicles has been found to be heavier than their traditional counter parts and vehicle weight has been reported to increase emitted non-exhaust emissions (NEE) [1]. A common tracer for exhaust emissions, carbon dioxide, is absent in NEE. Finding such component is essential when quantifying importance of NEE in urban air. In their review article Thorpe and Harrison [2] concluded that multiple authors have proposed Cu:Sb ratio could be used as a tracer for brake emissions. Manufacturers have developed new Copper Free brake pads, which will effect the ability of Cu:Sb ratio to be used as a tracer in the future.

In this study, we used a insulated pin-on-disc tribometer for emissions production. Two different brake lining materials were used, Non-asbestos organic (NAO) and Low-metallic (LM). The pin (10mm diameter) was cut from a brake pad ensuring same material as in commercially available brake linings. Similarly, the disc in the system was made of the same material (cast-iron) as actual brake disc, but in smaller scale. Two different conditions were tested, mild (2 m/s, 0.6 MPa) and harsh (5 m/s 0.7 MPa), where both disc speed and contact pressure varied. We used a 13-stage impactor (MOUDI 125R, TSI) to collect filter samples from which elemental composition was analysed with an X-ray fluorescence spectrometer (EDXRF, Epsilon 4, Malvern Panalytical). Simultaneously, we measured with an Aerodynamic Particle Sizer (APS 3321, TSI) to determine size distribution. We found that the relative mass fractions of elements vary with particle size, indicating that the elemental composition of brake-emitted PM2.5 differs from PM10.



This research was conducted as part of NEX-EL project (www.nexel.fi) funded by Business Finland (grant number 8308/31/2022).

[1] A. Simons, International Journal of Life Cycle Assessment, 2016, 1299-1313.
[2] A. Thorpe & R. Harrison, Science of The Total Environment, 2008, 270-282.

Physico-chemical characterization of dust generated by a brake for light-duty vehicle applications

A. Magno[1], B. Apicella[1], F. Catapano[1], S. Di Iorio[1], C. Russo[1], B. Vaglieco[1]

[1]Institute of Science and Technology for Sustainable Energy and Mobility (STEMS) - CNR

It is well documented in literature that the exposure to particle emissions has a severe impact on public health. Emissions from vehicles, including both exhaust and non-exhaust sources, represent the major contribution to ambient particulate matter (PM). In the last years, the adoption of even more stringent regulatory standards has resulted in an effective reduction of the tailpipe emissions from vehicles. The decreasing trend of exhaust emissions has been accompanied by a gradual increase in the proportion of non-exhaust emissions. A significant source of non-exhaust emissions is represented by the brake wear particles generated from the friction between the brake lining and the rotating components [1-2]. The hazardous environmental impact of brake wear particles has also been recognized by the European Commission that has introduced a limit in the next Euro7 vehicle standards. The adverse effects of PM depend on two factors that are the particle size distribution and their chemical composition.

This study addresses both these aspects by investigating the debris generated by the wear of a brake for light duty application from physical and chemical point of view. A characterization of the particles, in terms of number and size was performed under braking profiles typical of urban driving. To this purpose, a proper experimental setup was designed consisting in a box where the brake was enclosed and connected to an inlet tunnel for the entrance of filtered air and an outlet tunnel for the evacuation of the flow. Two different principle-based instruments were used to characterize the particles in a wide diameter range, the EEPS from 5.6 to 560 nm and the OPS from 0.3 to 10 µm. An in-depth investigation of the chemical composition and morphology of brake wear dust, collected at the end of the braking test on the surface of the chamber was carried out through several techniques, including spectroscopic tools, thermogravimetric analysis (TGA), chromatography, morphological and elemental analysis. This methodology was adopted to analyse a representative sample of the dust deposited on the roadside soil and then resuspended in the atmosphere. On-line physical investigation revealed the presence of particles with size varying between 100 and 6000 nm (Figure 1-a). The particle size distribution is characterized by a bimodal evolution with a first pronounced peak at 200 nm and a second mode centered at 1000 nm. Quantification of the inorganic and organic components in the sample (about 85 and 15%, respectively) has been made possible by an EDX analysis of the collected powder and a thermogravimetric analysis in oxidative conditions. The inorganic portion of the sample is primarily made up of iron and iron oxides, as confirmed by XRD, Raman and ICP. Furthermore, SEM images (Figure 1-b) reveal that the smallest particles are "attached" to the surface of the largest ones, most likely due to oxidative wear. These submicron particles may have a greater effect on human health if inhaled. Raman spectroscopy analysis confirms that the samples is manly composed by an aromatic carbon-based part and iron-based part.

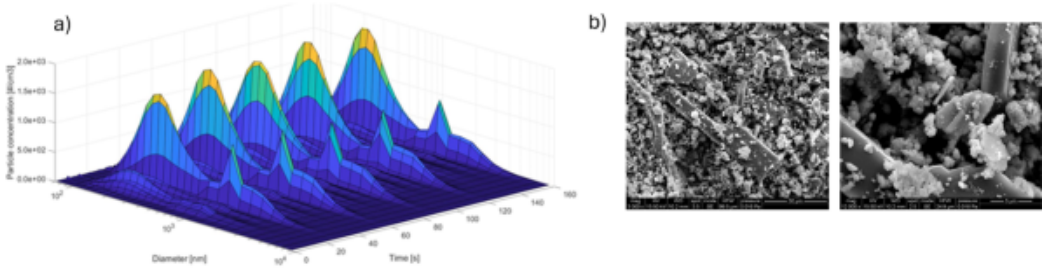


Figure 1.a) Time-resolved particle concentration and size distributions; b) SEM images of debris at two magnifications

[1] Catapano F, Di Iorio S, Magno A, Vaglieco BM. 2024, SAE Tech Pap 2024-24-0041.
[2] Russo C, Gautier di Confiengo G, Magnacca G, Faga MG, Apicella B. Heliyon 2023;9:e20672.

Basic evaluation of brake-emission correlation between chassis dynamometer and brake dynamometer

P. Lienerth[1], K. Kondo[1], D. Soare[1], T. Al-Wasif Ruiz[2], V. Ruiz-Torres[3], E. Barrajón-Catalán[3], C. Barrios[2]*, M. Schröder[1]*

[1]HORIBA Europe GmbH, 61440 Oberursel, Germany, [2]Research Centre for Energy, Environment and Technology (CIEMAT), Avda. Complutense, 40, 28040, Madri, [3]Institute of Research, Development and Innovation in Health Biotechnology of Elche (IDiBE), Universi

Transportation significantly contributes to air pollution, with vehicle emissions playing a major role. The WHO reported 4.2 million deaths in 2019 due to outdoor air pollution, with fine particulate matter being a key factor. A report by the European Environment Agency highlights that non-exhaust emissions (NEE)—from tire, brake, and road wear—now exceed exhaust emissions. The heavier weight of electric vehicles worsens NEE, underscoring the need for effective measurement and mitigation.

The LIFE NEEVE project, funded by the EU's LIFE program under CINEA, aims to develop methods to measure and reduce NEE from brakes, tires, and road interactions. It introduces mobile measurement devices and innovative organoids to assess NEE's effects on human lung and skin cells.

To advance on-board measurement system for NEE we decouple brake emissions from the total NEE on a chassis dynamometer and correlate the measurements with the emissions measured on a brake dynamometer, where the results are also evaluated with respect to the GTR 24 brake emissions testing regulation. Particle number and particulate mass results are supported by particle size distribution scans and evaluation of the toxicology of the filter load through the assessment of cell survival and oxidative stress in skin and lung organoids.

The project establishes a framework for enhancing real-world NEE measurement, supporting regulatory improvements and industrial applications for both combustion and electric vehicles.

Shedding (Synchrotron) Light on Speciation of Metals in Brakes Emissions: a XANES Investigation on Micro- and Nano- Particulates

A. Mancini[1], B. Tsyupa[1,2], I. Carlomagno[3], G. Agostini[4], A. Bonfanti[1]*, U. Olofsson[5]*

[1]Materials Engineering & Laboratories, GCF Research & Development, Brembo NV, Viale Europa 2, 24040 Stezzano, Italy, [2]Department of Chemistry, Materials and Chemical Engineering "G. Natta", Politecnico di Milano, Italy, [3]XRF Beamline, Elettra Sincrotrone Trieste, Area Science Park, 34149 Basovizza (TS), Italy, [4]XAFS Beamline, Elettra Sincrotrone Trieste, Area Science Park, 34149 Basovizza (TS), Italy, [5]Department of Engineering Design, KTH Royal Institute of Technology, 100 44 Stockholm Sweden

Brakes non-exhaust emissions (NEE) are gaining increasing attention in the air quality discussions due to the imminent enforcement of the EURO 7 legislation and the progressive electrification of road mobility. In particular, EURO 7 regulation introduces for the first time in history a limitation on the mass of PM_{10} particles generated by brakes of new passenger cars (PCs) and Light Commercial Vehicles (LCVs) entering the EU market, starting from July 2025. The corresponding legislative process has been sustained in the last decade by significant scientific and technological effort to: *i)* understand mechanisms underlaying the generation of particulates during braking; *ii)* unveil influencing factors leading to different brakes emission levels; *iii)* develop reliable procedures to measure and characterize emissions generated by brake systems; and *iv)* design new automotive brake components able to reduce the particulate emissions. More recently, particular attention has also been paid to the chemical characterization of brakes NEE, since this is pivotal for assessing their toxicological and environmental behavior. At this specific aim, current studies are more frequently focused on unveiling the chemical species composing brakes emissions, which appear more relevant than looking at their elemental composition only. In particular, due to brakes NEE compositional characteristic features, including a dominant content of inorganic compounds, X-Ray Diffraction (XRD) analysis has been proposed and successfully deployed in the last years for evaluating their phase distribution in crystalline fraction. However, in spite of being a convenient tool for the brakes NEE phase composition investigations, XRD probe suffers of two following main drawbacks: *i)* poor detection limits of analytes, especially when limited amount of material is available for the analysis or nanometric particles are investigated; and *ii)* complete insensibility to amorphous materials. Considering the aforementioned reasons, this contribution proposes X-Ray Absorption Near Edge Structure (XANES) as additional analytical probe for widening the field of inorganic compounds speciation in brakes NEE. As case study, authors report on the speciation of Ti, V, Cr, Mn, Fe, Ni, Cu, Zn and Sn -based compounds contained in brakes NEE generated by the coupling of a grey cast iron (GCI) brake disc and ECE R90 low metallic brake pads, representing the current standard of friction pairings in the EU market. Brakes NEE investigated in this study have been collected in both micrometric and nanometric dimensional fractions, during tests carried out at a variable inertia brake dynamometer bench following the most updated guidelines reported in the United Nations Global Technical Regulation (UN GTR) n°24 for laboratory measurements of brake emissions for light-duty vehicles.

Acknowledgments

This work was supported by the European Commission's Horizon 2020 research and innovation program, nPETS (grant agreement No 954377, https://www.npets-project.eu/), aimed at studying the sub-100 nm particles emitted from different transport modes.

Ultrafine Brake Wear Particles in Real-World Scenarios: Morphology and Composition

T. Al-Wasif Ruiz[1], R. Suárez Bertoa[2], J. Sánchez Martín[1], C. Barrios Sánchez[1]*

[1]Research Centre for Energy, Environment and Technology (CIEMAT), Avda. Complutense, 40, 28040 Madrid, Spain, [2]European Commission, Joint Research Centre (JRC), Via Enrico Fermi, 2749, 21027 Ispra (VA), Italy

Non-exhaust emissions, such as brake wear particles, are a growing concern due to their significant contribution to urban particulate matter pollution and associated health risks, particularly from ultrafine particles that can penetrate deeply into the respiratory system [1, 2]. These emissions, influenced by the thermal and mechanical conditions of braking, require further investigation to better understand their environmental and health impacts [3].

This study aims to bridge the gap between laboratory and real-world analyses by developing an innovative approach that combines in situ and off-line particle characterization. On-road tests were conducted with a passenger vehicle under harsh braking conditions (60–120 km/h), achieving disk temperatures of up to 380 °C. Real-time measurements using an Engine Exhaust Particle Sizer (EEPS) revealed significant concentrations of ultrafine particles during high-temperature braking events. Off-line analyses using Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDS) provided detailed insights into the morphology and elemental composition of the particles. Additionally, Transmission Electron Microscopy (TEM) was employed to explore their nanoscale structure.

The results highlight the dependence of particle size and morphology on brake disk temperature, with thermal decomposition processes leading to smoother, more spherical particles at higher temperatures. These findings are particularly relevant for scenarios such as descending steep downhill roads, where prolonged braking heats the system significantly before entering urban areas, amplifying emissions. This work underscores the importance of combining real-time and microscopic analyses to advance the understanding of brake wear particles and their environmental implications

[1] Kelly, F. J., & Fussell, J. C. (2012). Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter. *Atmospheric Environment*, *60*, 504–526. https://doi.org/10.1016/j.atmosenv.2012.06.039

[2] Oberdörster, G., Oberdörster, E., & Oberdörster, J. (2005). Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles. *Environmental Health Perspectives*, *113*(7), 823–839. https://doi.org/10.1289/ehp.7339

[3] Bondorf, L., Köhler, L., Grein, T., Epple, F., Philipps, F., Aigner, M., & Schripp, T. (2023). Airborne Brake Wear Emissions from a Battery Electric Vehicle. *Atmosphere*, *14*(3), 488. https://doi.org/10.3390/atmos14030488

Assessment of Airborne Emissions from Tire Wear: Insights into Ultrafine Particle Distribution

L. Schubert[1,2], G. Steiner[1], D. Heuberger[2], C. Lex[2]

[1]AVL List GmbH, Hans-List-Platz 1, 8020 Graz, [2]Institute of Automotive Engineering - Graz University of Technology, Inffeldgasse 11/II, 8010 Graz

Since tire wear is one of the largest sources of microplastics in the environment today, its measurement and mitigation are of significant public and regulatory interest. Tire wear is regulated in terms of the weight loss of a tire over distance traveled. This is currently the primary focus of the UNECE Task Force on Tyre Abrasion (TFTA). However, the airborne fraction of tire wear is not considered by the TFTA and remains unknown.

Due to the presence of background emissions in real-world driving (brake wear, exhaust emissions, road wear, resuspension), the measurement of tire wear particle emissions is challenging. In this study, an outer drum test bench with an enclosure around the tire was used to measure the tire's airborne emissions in a controlled environment. The total particle number (TPN), solid particle number (SPN), particle masses (PM2.5 and PM10), and the size distribution of the aerosols were measured.

Key findings reveal that a high number of particles were in the ultrafine size range, with particle sizes around 10 nm. The results of the total particle number compared to the SPN indicate that most of these particles were volatile, as the TPN was significantly higher than the SPN.

Finally, this study underscores the need for further research in the field of airborne tire wear particles. This research provides a quantification of airborne tire wear particles according to different metrics, helping to understand the potential impact of ultrafine tire particles on human health.

Solar-Thermal Aging of Tire-Wear Particles (TWP) Affecting Their Properties and Environmental-Health Impacts

P. A. Sermon[1,1]

[1]Brunel University

Tire wear particles [1] are toxic [2] and produced in large amounts per vehicle km. Cross-disciplinary studies [3] show that they vary in size and composition, containing heavy metals. They are components in toxic water-borne motorway run-off. They have passenger polycyclic aromatic hydrocarbons. Here TWPs have been collected from UK motorways.

Their properties are reported as they undergo solar-thermally aging using TEM, SEM-EDX, XRF, XRD, Raman (sp2:sp3), evolved gas analysis, TPO, DSC, TGA and FTIR methods and how these affect their environmental and health impacts in part by the release of nanoparticles (NPs) and ultrafine particles (UFPs).

This abstract is relevant to NPC-25 Focus Event on Tire Wear Particles

[1] MZ Zhang, JC Li, H Yin, X Wang, YC Qin, ZJ Yang, Y Wen, JX Luo, DL Yin, YS Ge, CH Wang, XY Sun, LX Xu Sci.Tot.Environ. 2024,932,AR172760

[2] M Gustafsson, G Blomquist, A Gudmundsson, A Dahl, E Swietlicki, M Bohyard Sci.Tot.Environ. 2008,393,226-240

[3] B Bessagnet, N Allemand, JP Putaud, F Couvidat, JM Andre, D Simpson, E Pisoni, BN Murphy, P Thunis Appld.Sci.Basel 2022,12,AR3623

Reducing Brake Wear Emissions in Public Transport: Insights from the RE_BREATH Project

M. Leonardi[1], M. Besana[1], S. Belotti[1], M. Pagnoni[1], A. Santini[1], V. Semperboni[1], C. Ghezzi[1], G. Perricone[1]

[1]Brembo N.V. Via Stezzano, 87 24126 - Bergamo (BG) Italy

Public transport, particularly buses, plays a crucial role in maintaining good air quality in cities by reducing the number of cars on the road and, consequently, the amount of polluting emissions, including non-exhaust Particulate Matter (PM). Within this context, the LIFE program of the European Commission has co-funded the RE_BREATH project, which stands for Reduction of Brake Wear Emissions in the Transport sector. One of the project's objectives is to improve the understanding of non-exhaust particle emissions generated by public transport braking systems.

The study focuses on collecting comprehensive data on PM10, PM2.5, and finer particles through Particle Number (PN) measurements. While extensive research exists on non-exhaust brake emissions from Light-Duty Vehicles (LDVs) with established measurement protocols, there is a significant gap in focus on Heavy-Duty Vehicles (HDVs). To address these challenges, the study is structured into four distinct phases:

1. Instrumentation and Data Acquisition: This phase involves equipping an HDV with the necessary instruments to collect data and acquire essential mission profile information.
2. Analysis of Mission Profiles: In the study, typical mission profiles of HDVs are analyzed to understand the conditions under which brake wear emissions are generated.
3. Generation of a Representative Dynamometric Bench Procedure: Based on the mission profiles, a dynamometric bench procedure is developed to simulate real-world braking scenarios.
4. Testing Different Materials: Various brake materials are tested to define emission factors for PM (10 and 2.5) and PN, with a focus on the finer fraction of particulates.

The limitations of the study highlight the need for a more diverse dataset to replicate different scenarios, highlighting the potential for further research and refinement. By addressing these shortcomings, the RE_BREATH project aims to contribute to the understanding and reduction of brake wear emissions in public transport.

Particles Size Manipulation: Experimental and Numerical Study

K. Kutsher[1], N. Haikin[2], D. Katoshevski[1]*

[1]Environmental Engineering, Ben-Gurion University of the Negev, Israel, [2]Physics department, NRCN

This study investigates the efficiency of the particle clustering mechanism ("grouping") under oscillatory flow conditions, utilizing fine particle powder as a representative model for environmental aerosols. The experimental setup incorporates flow oscillations and modular geometries to enhance particle interactions. Continuous particle size monitoring and microscopic analysis of captured particles reveal a shift in size distribution, resulting in the formation of larger aggregates [1].

Additionally, numerical simulations identify two key mechanisms influencing particle dynamics: oscillatory flow parameters and Brownian motion. Particles experience oscillatory flow effects depending on their relative positions within the flow wave, leading to convergence in certain regions and dispersion in others. Furthermore, the stochastic nature of Brownian motion, particularly significant for submicron particles, increases the likelihood of particle collisions and contributes to the observed grouping phenomena. The interplay between deterministic oscillatory forces and random Brownian displacements facilitates clustering within the experimental system's residence time.

Overall, particle manipulation offers opportunities to explore and design methods for enhancing filtration efficiency, improving the detection limits of relevant diagnostic systems and segregating and sorting particles for various applications.

[1] Haikin, N., Multanen, V., Lerman, S., Kutsher, J., Vinod, A., Shendalov, S., Tsur, O., Haimson, A., Tadmor, R. and Katoshevski, D., 2025. Increasing particle-size by air-flow modification–An experimental study. *Separation and Purification Technology*, *354*, p.129441.

Minimizing Indoor Infection Risk by Airborne Pathogens with Nanofiltration and Vertical Flow

J. Czerwinski[1,2], H. Burtscher[3]

[1]NanoCleanAir, [2]VERT Scientific Committee, [3]NanoCleanAir

The risk of infection between people can be significantly reduced with targeted vertical flow control in the room and nano-filtration of the recirculated air. This cannot be achieved with any other air purification device or ventilation system.

In the work described, three examples of preventing the risk of infection - a classroom ventilation system, ventilation of an elevator cabin and securing a hospital bed - were physically implemented and evaluated experimentally and numerically.

In addition to the results of these examples, the currently applicable regulations were critically discussed, as well as the difficulties involved in the widespread introduction of the innovations developed.

An Innovative Vertical Airflow System with Ceramic Filters for Reducing Airborne Pathogens in Healthcare Settings

M. Sousa de Almeida[1], A. Mayer[2], J. Frey[3], A. Petri-Fink[4,5], B. Rothen-Rutishauser[4], H. Burtscher[6]

[1]Adolphe Merkle Institute (AMI), University of Fribourg, Chemin des Verdiers 4, 1700 Fribourg, Switze, [2]NanoCleanAir GmbH, Fohrhölzlistrasse 14B, 5443 Niederrohrdorf, Switzerland, [3]Vetsuisse Faculty, University of Bern, 3012 Bern, Switzerland, [4]Adolphe Merkle Institute (AMI), University of Fribourg, Chemin des Verdiers 4, 1700 Fribourg, Switzerland, [5]Department of Chemistry, University of Fribourg, Chemin du Musée 9, 1700 Fribourg, Switzerland, [6]Institute of Aerosol and Sensor Technology, Swiss University of Applied Sciences and Arts Northwestern Switzerland

The COVID-19 pandemic underscored the pivotal role of aerosol transmission in the spread of infectious diseases, highlighting the urgent need for enhanced air quality control in healthcare settings[1,2]. In a previous study we have shown that ceramic wall flow filters can be used for an efficient filtration of the virus surrogate MS2 bacteriophages[3]. This study presents a novel vertical airflow device, which integrates the earlier described ceramic wall flow filters to mitigate the spread of airborne pathogens in hospital environments. Positioned above a patient's bed, the system captures exhaled air, filters it through high-efficiency ceramic filters, and redistributes it beneath the bed. Laboratory evaluations conducted in both small (15 m²) and large (36 m²) rooms demonstrated significant reductions in aerosol spread, with filtration efficiencies up to 95% for salt particles and 87% for MS2 bacteriophages under real-world conditions. The system's performance was further tested in combination with hospital curtains, which, while moderately effective on their own, showed marked improvement when used alongside the device. These findings highlight the system's potential to reduce nosocomial infections by lowering bioaerosol concentrations. The combination of vertical airflow and advanced filtration technology offers a practical and effective approach to safeguarding patients and healthcare workers in hospital settings.

[1] G. Scheuch, *J. Aerosol Med. Pulm. Drug Deliv.*, DOI:10.1089/jamp.2020.1616.
[2] H. Nishiura, H. Oshitani, T. Kobayashi, T. Saito, T. Sunagawa, T. Matsui, T. Wakita and M. Suzuki, , DOI:10.1101/2020.02.28.20029272.
[3] T. Rüggeberg, A. Milosevic, P. Specht, A. Mayer, J. Frey, A. Petri-Fink, H. Burtscher and B. Rothen-Rutishauser, *Aerosol Air Qual. Res.*, DOI:10.4209/aaqr.210224.