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

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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.

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

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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.

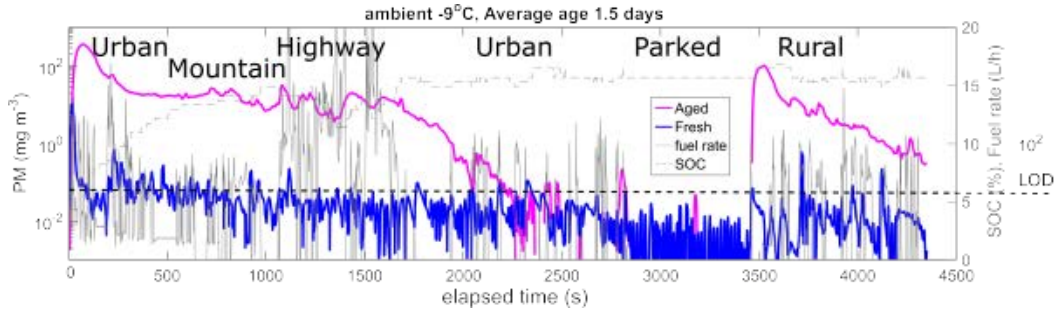

Figure 1. The fresh and aged PM_1 of a PHEV passenger car over a simulated RDE driving cycle.

AKNOWLEDGEMENTS

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

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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.

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Assessing the effect of thermal conditions on emissions of tobacco heating systems

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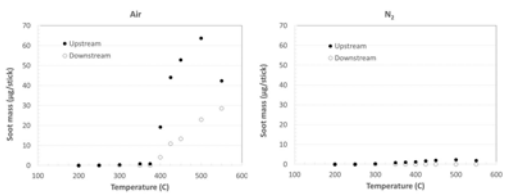
Inhalation of tobacco smoke remains a critical global public health concern, as it is associated with numerous severe health issues. Conventional cigarettes (CCs), which produce smoke, are the most widely used tobacco product. However, in recent years, heated tobacco products (HTPs), which produce liquid-based aerosols by heating tobacco instead of combusting it, have gained traction as potentially less harmful alternatives.

HTPs heat tobacco below combustion temperatures (~300 °C), avoiding the combustion-related formation of solid soot particles and producing lower levels of harmful chemicals, such as PAHs and VOCs. However, HTP aerosols still contain toxicants, albeit at reduced concentrations. Unlike CCs, where incomplete combustion at high temperatures generates solid soot particles, HTPs predominantly undergo non-combustive processes, such as low-temperature pyrolysis and evaporation, producing aerosols of liquid droplets. Mass loss versus temperature evolution studies via Thermogravimetric Analysis (TGA), often coupled with Mass Spectrometry, have been used for analysing the thermal degradation of materials such as tobacco. With TGA, the characteristic temperatures for the onset of specific reactions can be defined [1]. Most studies have concurred that for tobacco biomass, 400 °C represents a critical threshold temperature, below which no significant differences are observed between experiments conducted in air and nitrogen. Beyond this temperature, however, variations in the experimental trends began to emerge, indicating oxygen-limited conditions.

A definitive indicator of the onset of combustion is the formation of soot particles [2]. However, no comprehensive characterisation of HTP mainstream soot particle emissions as a function of temperature has been conducted up to the present study. The study's methodology focuses on evaluating the emissions and thermal processes of heated tobacco products (HTPs) using a custom experimental tobacco heating device (expTHD) based on the IQOS 3 DUO system. Tobacco sticks were heated across a temperature range (200–550 °C) to investigate the onset of combustion and particulate emissions. Advanced equipment, including a catalytic stripping (CS) system, was used to remove volatile compounds and isolate solid particles. The experimental setup featured multiple dilution stages, advanced particle measurement tools, and an inert atmosphere chamber to simulate oxygen-free conditions. Data collection included the total particle number (TPN), concentration of particles with diameter 80 nm (PN80), soot mass, and gas concentrations (CO, CO□). Tests under both ambient and inert conditions were conducted upstream and downstream of the CS.

Combustion was observed to begin at 400 °C under ambient conditions, as evidenced by exothermic reactions, increased CO/CO□ ratios, and solid soot particle formation, while inert conditions prevented combustion entirely. Below this threshold, thermal degradation processes, such as evaporation and pyrolysis, dominated. The use of the CS system allowed for clear differentiation between liquid and solid aerosol fractions, highlighting its importance in identifying combustion and understanding aerosol dynamics. These findings align with prior research on tobacco biomass and offer a robust framework for analysing emissions and improving HTP design to reduce harmful outputs. This study emphasises the interplay of multiple thermal processes and provides a foundation for further research into alternative heating profiles and tobacco products.



Soot mass per stick under ambient (left) and inert (right) conditions.

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[2] Torero Cullen, J., Kärkelä, T., & Tapper, U., J. Anal. Appl. Pyrolysis, 2024, 179, 106478. https://doi.org/10.1016/j.jaap.2024.106478

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

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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.

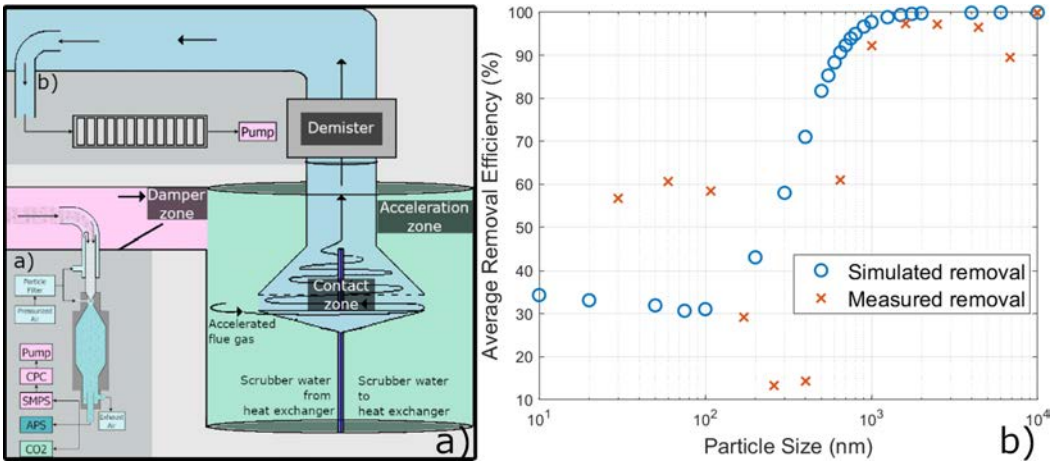

Figure 1: a) Schematic sketch of scrubber and particle sampling. b) Particle removal according to aerodynamic size, comparison between measurements and simulation model.

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Characterization and control of ash from diesel engine exhaust

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[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.

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

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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.

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

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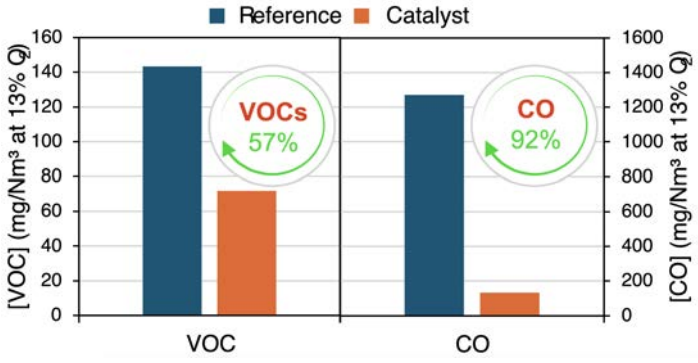
Background and motivation. With the increase in global human activity, air pollution levels are reaching dangerous thresholds, leading to 6.7 million premature deaths/year worldwide. Pollutants include notably CO, VOCs and PM, which are primarily emitted by wood combustion in wood stoves used for residential 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.



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

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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.

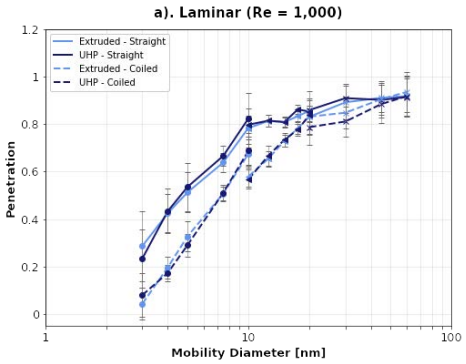

Figure.1: Particle penetration through ¼" OD straight and coiled tubes.

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.

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GPF for Passenger Cars - VERT knowledge prior to AeroSolfd 2020

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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.

Material Characterisation of vehicle-emitted fine and ultrafine particles

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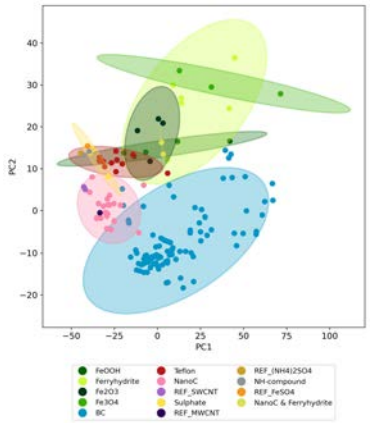
This paper summarises some relevant features of Raman spectra recorded on samples of micro- and sub-micro particulate emitted by both light-duty and heavy-duty vehicles. The particulate samples were collected from tailpipe exhaust in internal combustion engine vehicles in dedicated chassis-dyno driving 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.



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

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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.

Conclusions

nano-Control calls for mandatory rules on indoor air quality and advocates for systamatic control over the installation and operation of toner-based devices, such as laser printers and copiers.

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Self-reported Symptoms Associated With the Use of Printer and Photocopier Machines: Results From the Nano-Control, International Foundation Survey.
J Occup Environ Med. 2024 Nov 1;66(11):891-902. doi: 10.1097/JOM.0000000000003197.

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

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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.

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Optimizing the Aethalometer source apportionment model through multi-site comparison

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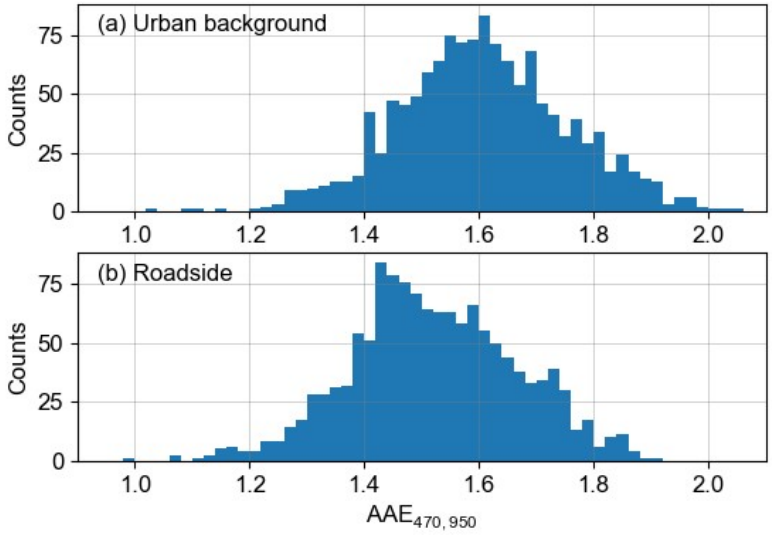
The Aethalometer source apportionment model [1] has been a valuable tool for several years in determining the contributions of solid fuel (SF) and liquid fuel (LF) to equivalent Black Carbon (BC) concentrations. This model utilizes the wavelength dependence of the absorption coefficient measured by Aethalometers (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.



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Particle Number Size Distribution in Istanbul Atmosphere

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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.

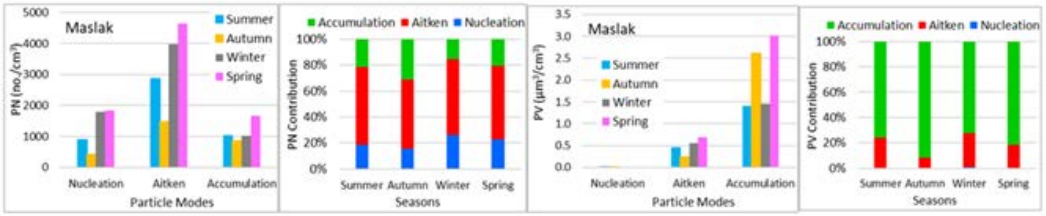

Figure 1: Particle numbers in the nucleation, Aitken and accumulation modes at the traffic site in Istanbul.

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

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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)

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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.

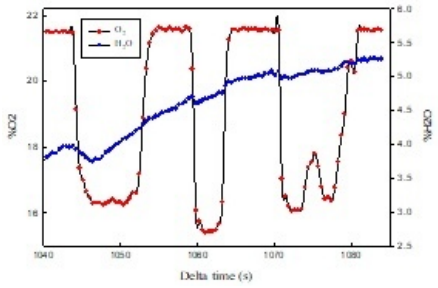

Figure 1a. O_2 and H_2O inhalation-exhalation profiles for a 79 year old

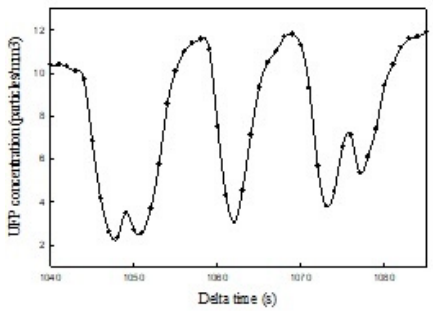

Figure 1b. UFP inhalation-exhalation profiles for a 79 year old

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

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

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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.

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

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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.

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

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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.