



WeBIOPATR 2025

**The Tenth International WEBIOPATR
Workshop & Conference
Particulate Matter: Research and Management**

**Abstracts of Keynote Invited Lectures
and Contributed Papers**

Milena Jovašević-Stojanović,

Alena Bartoňová,

Duška Kleut and Danka B. Stojanović, Eds

“Vinča” Institute of Nuclear Sciences

National Institute of the Republic of Serbia

University of Belgrade

Belgrade 2025

ABSTRACTS OF KEYNOTE INVITED LECTURES AND CONTRIBUTED PAPERS

The Tenth WeBIOPATR Workshop & Conference


Particulate Matter: Research and Management

WeBIOPATR 2025

26th – 28th November 2025

Belgrade, Serbia

Editors

Milena Jovašević-Stojanović 

Alena Bartoňová 

Duška Kleut  and Danka B. Stojanović 

Publisher

“Vinča” Institute of Nuclear Sciences-
National Institute of the Republic of Serbia-University of Belgrade
Dr Slavko Dimović, Director
P.O.Box 522
11001 Belgrade, Serbia

Printed by

Vinča Institute of Nuclear Sciences –
National Institute of the Republic of Serbia – University of Belgrade

Number of copies

100

ISBN: 978-86-7306-179-5

Vinča Institute of Nuclear Sciences –
National Institute of the Republic of Serbia – University of Belgrade
www.vin.bg.ac.rs

*Abstracts of Keynote Invited Lectures and Contributed Papers from the 10th International WeBIOPATR Workshop & Conference (c) 2025 by Milena Jovašević-Stojanović, Alena Bartoňová, Duška Kleut and Danka Stojanović (eds.) is licensed under Creative Commons Attribution-NonCommercial 4.0 International. To view a copy of this license, visit <https://creativecommons.org/licenses/by-nc/4.0/>
This licence requires that reusers give credit to the creator. It allows reusers to distribute, remix, adapt, and build upon the material in any medium or format, for noncommercial purposes only.*

SCIENTIFIC COMMITTEE

Aleksandar Jovović, Serbia

Alena Bartoňová, Norway

Antonije Onjia, Serbia

Dikaia Saraga, Greece

Griša Močnik, Slovenia

Ivan Gržetić, Serbia

María Cruz, Spain

Milena Jovašević-Stojanović, Serbia

Miloš Davidović, Serbia

Saverio de Vito, Italy

Selahattin Incecik, Turkey

Simone Barreira Morais, Portugal

Zoran Mijić, Serbia

Zoran Ristovski, Australia

Zorana Jovanović-Andersen, Denmark

Renata Kovačević, Serbia

ORGANIZING COMMITTEE

Alena Bartoňová, Norway

Andrej Šoštarić, Serbia

Anka Cvetković, Serbia

Bojana Petrović, Serbia

Bojan Radović, Serbia

Branislava Matić, Serbia

Danka Stojanović, Serbia

Duška Kleut (Secretary), Serbia

Lidija Marić-Tanasković, Serbia

Maja Jovanović, Serbia

Maja Nikolić, Serbia

Milena Jovašević-Stojanović, Serbia

Miloš Davidović, Serbia

Mirjana Perišić, Serbia

Željko Ćirović, Serbia

CONFERENCE TOPICS

1. Atmospheric Particulate Matter - Physical and Chemical Properties

- i. Sources and formation of particulate matter
- ii. Particulate matter composition and levels outdoors and indoors
- iii. Environmental modeling
- iv. Nanoparticles in the environment

2. Particulate Matter and Health

- i. Exposure to particulate matter
- ii. Health aspects of atmospheric particulate matter
- iii. Full chain approach
- iv. COVID-19 and particulate matter

3. Particulate Matter and Regulatory Issues

- i. Issues related to monitoring of particulate matter
- ii. Legislative aspects
- iii. Abatement strategies

Organizers:
“Vinča” Institute, Serbia
NILU, Norway

*The 10th WeBIOPATR Workshop and Conference,
Particulate Matter: Research and Management, WEBIOPATR 2025
is supported by:*

*EC Horizon Europe Framework Program for Research and Innovation, area “Spreading excellence
and widening participation”, WeBaSOOP project (2022-2025) coordinated by “Vinča” Institute,
Grant agreement number 101060170*

Ministry of Science, Technological Development and Innovation, Republic of Serbia

PREFACE

Dear Colleagues,

Welcome to the 10th WeBIOPATR Conference, to be held at the Faculty of Mechanical Engineering, University of Belgrade, Serbia, 26.–28.11.2025.

Since 2007, the WeBIOPATR conferences and workshops are organized every second year to create a forum for Serbian and Western-Balkan experts and air pollution stakeholders, to inform each other about state of knowledge in atmospheric research in Serbia and internationally, and to explore opportunities and barriers to reduce air pollution and especially, particulate matter (PM) towards safer levels.

Since the first conference, we have learnt much about the levels and negative effects of PM in Serbia and Western Balkan. The the air pollution burden in Serbia and in Belgrade has been reduced, in line with increased compliance with Serbian and European legislation. Our common quest is however not over, ambient pollution must further be reduced, bringing both the outdoor and the indoor levels towards safer levels.

New challenges have arisen. New health-relevant metrics for PM have been established, and embedded in legislation, bringing with them further requirements for monitoring and assessment systems. New technologies are used across all observing platforms. Low-cost air quality sensors are now used in research and assessment as well as to raise awareness of air pollution in the society. Digitalization and Artificial Intelligence allow us to combine non-traditional data sources, and we can e.g., generate better emission estimates and precise finely time- and space resolved concentration fields that help us to develop targeted mitigation strategies. European Research Infrastructures are supporting harmonized methods and tools to generate, store and access research data on atmosphere, for the benefit of the wider scientific community and the society.

This year's event brings to you over 50 key-notes, lectures and posters, touching upon the new developments and demonstrating the solid basis research in Serbia rests on. The conference is supported by the European Union co-funded project WeBASOOP (2022-2025, Grant agreement ID: 101060170, <https://webasoop.org>), by the Ministry of Science, Technological Development and Innovation of Serbia, by „Vinca“ Institute, Serbia, and by NILU, Norway.

We are grateful to you, the participants, and to our sponsors, for the opportunity to meet here in Belgrade. The Book of Abstracts would not be possible without the unrelenting efforts of our co-editors who brought the abstracts to a common standard and without the language editing performed by Dr Simon Smith, to whom we would like to extend out sincere thanks.

Welcome and have a stimulating and productive time!

Milena Jovašević-Stojanović and Alena Bartoňová

Belgrade and Kjeller, November 2025

TABLE OF CONTENTS

1. ENVIRONMENTAL TOXICOLOGY METHODS	11
1.1. FROM SOURCE TO CELL: CHEMICAL DRIVERS OF <i>IN VITRO</i> RESPONSES IN OSLO'S AIR POLLUTION.....	13
1.2. SOURCE APPORTIONMENT OF PM ₁₀ OXIDATIVE POTENTIAL DURING THE WEBASOOP CAMPAIGNS IN BELGRADE	14
1.3. INVESTIGATING OXIDATIVE POTENTIAL OF PARTICULATE MATTER FROM AN URBAN SAMPLING STATION IN OSLO (NORWAY).....	15
1.4. LINKING CHEMICAL SOURCES TO OXIDATIVE POTENTIAL: SOURCE-RESOLVED ASSESSMENT OF PM _{2.5} IN URBAN MELBOURNE, AUSTRALIA.....	16
2. HEALTH ASPECTS OF ATMOSPHERIC PARTICULATE MATTER I	17
2.1. HEALTH EFFECTS OF PM _{2.5} : OVERVIEW OF LATEST EVIDENCE AND CLIMATE CHANGE IMPLICATIONS	19
2.2. PARTICULATE MATTER EXPOSURE AND CARDIOVASCULAR RISK – A REVIEW	20
2.3. HIGH-RESOLUTION SPATIAL ASSESSMENT OF PARTICULATE MATTER-RELATED MORTALITY BURDEN IN THE LISBON METROPOLITAN AREA	21
2.4. PERTUSSIS IN POST COVID-19 TIME: AIRBORNE OR RESPIRATORY DROPLET TRANSMISSION DISEASE	22
2.5. CHRONIC HEALTH RISK ASSESSMENT OF PM _{2.5} IN THE URBAN CORE OF NOVI SAD, SERBIA	23
3. INDOOR PARTICULATE MATTER	25
3.1. MONITORING INDOOR ENVIRONMENT IN SCHOOLS AND WHAT CAN WE LEARN BY ASKING OCCUPANTS?.....	27
3.2. PARTICULATE MATTER IN PRIMARY SCHOOL CLASSROOMS: EFFECTS OF OCCUPANCY.....	28
3.3. PM _{2.5} LEVELS INSIDE TRAINS: A JOURNEY THROUGH SUMMER AND WINTER SEASONS	29
3.4. AIR QUALITY AND THERMAL COMFORT MEASUREMENTS IN OFFICE ENVIRONMENTS in Bor, SERBIA (2023-2024).....	30
3.5. INDOOR AIR QUALITY IN COMMERCIAL CENTRES – IS THERE A CONNECTION WITH HEALTH OF EMPLOYEES?	31
3.6. PORTABLE AIR PURIFIERS: AN OVERVIEW OF THEIR BENEFITS IN INDOOR AIR QUALITY IMPROVEMENT	32
4. MANAGEMENT AND PARTICLE CHARACTERIZATION	33
4.1. IMPLEMENTATION OF SUPERSITES FOR MONITORING NOVEL AIR QUALITY METRICS	35
4.2. AIR QUALITY MONITORING IN THE CITY OF BELGRADE	36
4.3. EVALUATING WILLINGNESS-TO-PAY TO MITIGATE PAIN AND SUFFERING CAUSED BY AIR POLLUTION.....	37
4.4. REAL-WORLD CASE STUDY OF PM QUANTIFICATION AND CHEMICAL COMPOSITION OF VEHICLE EMISSIONS IN A LISBON ROAD TUNNEL	38

4.5. SEASONAL ANALYSIS OF PARTICLE NUMBER CONCENTRATIONS AND SOURCES OF POLLUTION AT ADA MARINA SUPERSITE IN THE CITY OF BELGRADE	39
5. HEALTH ASPECTS OF ATMOSPHERIC PARTICULATE MATTER II	41
5.1. THE VALUE OF PAN-EUROPEAN OBSERVATIONS FOR THE CHARACTERIZATION OF ATMOSPHERIC AEROSOL PARTICLES: EXPERIENCE FROM THE EUROPEAN PROJECTS FOCI AND RI-URBANS.....	43
5.2. MODELLING ATMOSPHERIC TRANSPORT OF AEROSOLS	44
5.3. EMBEDDING LOCAL INVENTORIES IN CHEMISTRY-TRANSPORT MODELLING PIPELINES	46
5.4. DAILY HIGH-RESOLUTION SURFACE PM _{2.5} ESTIMATION OVER EUROPE BY ML-BASED DOWNSCALING OF THE CAMS REGIONAL FORECAST.....	47
5.5. SECONDARY ORGANIC AEROSOL FORMATION FROM THE AROMATIC HYDROCARBON PRECURSORS	48
6. SOURCE APPORTIONMENT OF PARTICLES I	49
6.1. SOURCE APPORTIONMENT OF CARBONACEOUS AEROSOL IN BELGRADE	51
6.2. COMPARISON OF SA FOR BOR IN THE CAMPAIGNS 2009-2010 AND 2019.....	52
6.3. SOURCE APPORTIONMENT OF PM ₁₀ IN BOR FROM THE WEBASOOP CAMPAIGN – PRELIMINARY RESULTS.....	53
6.4. SOURCE APPORTIONMENT OF PM ₁₀ IN BELGRADE CITY FROM THE WEBASOOP PROJECT – PRELIMINARY RESULTS.....	54
6.5. SOURCE APPORTIONMENT IN THE CITY OF BELGRADE AT ADA MARINA URBAN BACKGROUND SITE.....	55
7. SOURCE APPORTIONMENT OF PARTICLES II	57
7.1. SOURCES OF URBAN PM _{2.5} IN THE MAIN CITIES OF THE ENLARGEMENT REGION	59
7.2. PARTICULARITIES OF SOURCE APPORTIONMENT FOR EUROPEAN NORTHERNMOST MOSCOW MEGACITY	60
7.3. COMBINING PM ₁ AND PM ₁₀ LONG TIME SERIES FOR AN ENHANCED PMF SOURCE APPORTIONMENT	61
7.4. CHEMICAL SPARSITY IN BAYESIAN RECEPTOR MODELS FOR AEROSOL SOURCE APPORTIONMENT	62
7.5. SOURCE APPORTIONMENT OF FINE PARTICULATE MATTER AT AN URBAN BACKGROUND LOCATION IN WESTERN SLOVENIA: LOCAL VS REGIONAL CONTRIBUTIONS	64
8. PARTICULATE MATTER IN THE ENVIRONMENT	65
8.1. TOWARDS LOCAL CLIMATE INTERVENTIONS: COOLING AND SHADING TECHNOLOGIES TO SAVE THE GREAT BARRIER REEF.....	67
8.2. ASSESSING THE ENVIRONMENTAL IMPACT OF BIOMASS BURNING AEROSOLS ON AIR QUALITY AND MARINE ECOSYSTEMS IN THE ADRIATIC COASTAL ZONE	68
8.3. THE INFLUENCE OF SIMULATED THUNDERSTORM CONDITIONS ON POLLEN RUPTURING ..	69
8.4. PROPOSED ADVANCES IN THE CANADIAN RESPIRATORY PROTECTION STANDARD	70
8.5. ABSORPTION COEFFICIENT AND HEATING RATE OF BLACK CARBON AND MINERAL DUST ACROSS DIFFERENT MEDITERRANEAN SITES	71

8.6. CARBONACEOUS FINE AEROSOL IN SARAJEVO, BOSNIA AND HERZEGOVINA: ELEVATED CONCENTRATIONS AND HIGHLY POLLUTED WINTER EPISODES.....	72
8.7. TRANSPORT-RELATED AIR POLLUTION AT THE LISBON CRUISE TERMINAL: INTEGRATING PARTICULATE MATTER, BLACK CARBON AND ULTRAFINE PARTICLES INTO URBAN AIR QUALITY MONITORING	74
9. SENSORS AND SENSOR NETWORKS.....	75
9.1. METROLOGY FOR AIR QUALITY SENSOR NETWORKS: SELECTED INSIGHTS FROM THE FUNSNM PROJECT.....	77
9.2. FEDERATED LEARNING ENABLES FAST DEPLOYMENT OF PERVASIVE LOW-COST PARTICULATE MATTER SENSOR NETWORKS.....	78
9.3. CHARACTERIZING URBAN AIR POLLUTION-LAND USE RELATIONSHIPS USING LOW-COST SENSOR NETWORKS: A HIGH-RESOLUTION SPATIAL ANALYSIS IN LISBON.....	79
9.4. ON THE POSSIBILITIES FOR BLACK CARBON SENSOR VIRTUALISATION.....	80
9.5. PM _{2.5} REMOTE SATELLITE DATA RELATION WITH REFERENT AND LOW-COST SENSOR NETWORK DATA IN FOUR CITIES IN SERBIA.....	81
10. POSTER SESSIONS.....	83
10.1. ABSENCE OF EFFECTIVE INSTITUTIONAL PUBLIC HEALTH ACTION OF MONITORING B(a)P IN PM ₁₀ AT URBAN MEASURING POINTS IN SERBIA.....	85
10.2. ASSOCIATION BETWEEN OCCUPATIONAL EXPOSURE TO AIR POLLUTION AND REPRODUCTIVE OUTCOMES IN FEMALE WORKERS.....	86
10.3. USE OF AIRQ+ SOFTWARE IN ASSESSING HEALTH IMPACT OF EXPOSURE TO AIRBORNE PARTICLES IN SMEDEREVO, SERBIA	87
10.4. SPATIAL STRUCTURE AND PARTICULATE MATTER AS KEY DRIVERS OF BENZENE CONCENTRATION VARIABILITY IN EUROPE.....	88
10.5. SEM/EDS ANALYSIS OF INDOOR PM ₁₀ PARTICLES IN SECONDARY SCHOOL IN BOR, SERBIA	89
10.6. AEROSOL VERTICAL PROFILES OVER BELGRADE FROM GROUND-BASED AND SATELLITE LIDAR OBSERVATIONS.....	91
10.7. BENZO[a]PYRENE AMBIENT CONCENTRATION IN BELGRADE, SERBIA: LEVELS, HUMAN EXPOSURE AND HEALTH RISK.....	92
10.8. THE IMPACT OF WET SEPARATOR AND FLUE GAS CONDENSER ON THE EMISSION AND FRACTIONAL DISTRIBUTION OF PARTICULATE MATTER FROM BIOMASS BOILER.....	93
10.9. COMPOSITION AND LEVELS OF PARTICULATE MATTER AND NANOPARTICLES IN SLEEPING ENVIRONMENTS OF LISBON DWELLINGS: PRELIMINARY RESULTS OF THE HYPNOSAIR PROJECT	94
AUTHOR INDEX.....	97

1. ENVIRONMENTAL TOXICOLOGY METHODS

1.1. FROM SOURCE TO CELL: CHEMICAL DRIVERS OF *IN VITRO* RESPONSES IN OSLO'S AIR POLLUTION

E. Longhin, T. Honza, J. Froment, E. McFadden, A. M. Hudcová, C. Hak, K. E. Yttri, E. Rundén-Pran

The Climate and Environmental Research Institute NILU

eml@nilu.no

Air pollution and exposure to particulate matter (PM) pose a major global health burden, contributing to cardiovascular diseases, lung cancer, respiratory illnesses, and other adverse outcomes. PM consists of a complex mixture of solid and liquid particles varying in size, composition, and origin. While it is well established that reducing PM concentrations improves public health, evidence indicates that not all particle types exert the same toxic effects. Numerous studies emphasize that the physical and chemical characteristics of PM, such as oxidative potential and the presence of bioactive chemical compounds, are key determinants of its health impact.

Nordic environments offer a unique and distinctive case for studying PM, shaped by factors such as widespread use of electric vehicles, extensive residential wood burning during winter, road abrasion from studded tires, and the application of road salting for ice control. In addition, transboundary air pollution from continental Europe contributes noticeably to the PM burden.

The present study investigates the toxicity and chemical profiles of PM in Oslo to enhance understanding of its health impacts and sources. The research involved a year-long sampling campaign of PM₁₀ (particles with aerodynamic equivalent diameter < 10 µm) and PM₁ (aerodynamic equivalent diameter < 1 µm) at the urban background site Sofienbergparken (Oslo), combining chemical and toxicological analyses. Toxicity assessments included evaluation of cell viability, reactive oxygen species (ROS) formation, and release of pro-inflammatory markers in a human cell model. Chemical composition and source apportionment analyses were also conducted to identify the main contributors to PM levels. Finally, correlations between chemical component emission sources, and toxic responses were explored. The assessments highlighted the diverse toxicological potential of PM depending on the size fraction and sampling period. Preliminary results suggest that ROS formation in cells exposed to PM₁₀ correlate with mineral and road dust sources, while in PM₁-exposed cells mostly correlate with markers of biogenic secondary organic aerosol (SOA). Inflammatory markers showed some correlation with SOA and bacterial endotoxins.

This research highlights the importance of long-term monitoring and integrated approaches that combine chemical analyses, modelling, and toxicology to improve understanding of PM effects and guide future air quality regulations.

1.2. SOURCE APPORTIONMENT OF PM₁₀ OXIDATIVE POTENTIAL DURING THE WEBASOOP CAMPAIGNES IN BELGRADE

M. Jovanović (1), B. Petrović (1), M. Davidović (1), S. Stevanović (2), K. E. Yttri (3), A. Alastuey (4), A. Bartonova (3), M. Jovašević-Stojanović (1)

(1) VIDIS centre, Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia, (2) School of Engineering, Deakin University, VIC, 3216 Australia (3) NILU, 2027 Kjeller, Norway, (4) Institute of Environmental Assessment and Water Research, (IDAEA-CSIC), Barcelona, Spain
majaj@vin.bg.ac.rs

Particulate matter (PM) is one of the key indicators used to assess air quality. However, PM mass alone does not fully capture the potential adverse effects of air pollution, as lower PM mass concentrations do not necessarily correspond to reduced health risk (Weichenthal et al., 2024). One of the primary mechanisms associated with PM-related health effects is the formation of reactive oxygen species (ROS) in the respiratory tract and the resulting imbalance in the body's oxidative defense system. Consequently, the oxidative potential (OP) of PM represents an important parameter for characterizing its toxicological properties.

In this study, a one-year PM₁₀ measurement campaign was conducted in an urban environment to identify the dominant emission sources and evaluate their contributions to the oxidative potential of airborne particles. PM₁₀ filter samples were collected at an urban background site (Ada Marina) in Belgrade (Serbia) from June 2023 to May 2024. Comprehensive chemical analyses were performed, including organic carbon (OC) and elemental carbon (EC), trace metals, major inorganic ions, and selected organic tracers. The OP of PM₁₀ was evaluated using the ascorbic acid (AA) and dithiothreitol (DTT) assays (Calas et al., 2018; Dominutti et al., 2025). Source apportionment was conducted using Positive Matrix Factorization (PMF) to identify the emission sources and quantify their contributions to ambient PM₁₀. Subsequently, multiple linear regression (MLR) was applied to estimate the contribution of each PM₁₀ factor derived from PMF to the measured OP values.

PMF resolved seven factors representing dominating sources: biomass burning (BB), long-range transport and road-salt/local combustion (NaCl/COMB), mineral dust (MD), PBAP, BSOA_{Isoprene}, ammonium sulfate ((NH₄)₂SO₄), and mixed traffic/industry (TRA/IND) (Petrovic et al. 2025). The average PM₁₀ concentration during the study was approximately 24 µg/m³, with slightly higher levels during the heating season (27 µg m⁻³). Annual mean OP values were 1.28 nmol/min/m³ for OP^{DTT} and 1.38 nmol/min/m³ for OP^{AA}, both showing higher activity in the heating season. The MLR reproduced OP values well, with R² = 0.90 for OP^{DTT} and R² = 0.76 for OP^{AA}. Clear seasonal patterns were observed. During the non-heating period, BSOA_{Isoprene} and PBAP were the major contributors to OP, while (NH₄)₂SO₄ and TRA/IND sources contributed moderately across both seasons. In contrast, BB was the dominant contributor to OP during the heating season, followed by the mixed long-range transport and road-salt/local combustion factor for both assays. Overall, the results highlight pronounced seasonal contrasts: combustion sources dominated OP in winter, while secondary and biological sources dominated during warmer months.

ACKNOWLEDGEMENTS

The author acknowledges the funding provided by the Vinca Institute of Nuclear Sciences through the grants by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Theme no 1002501 and EC Horizon Europe WeBaSOOP project "Research Reinforcing in the Western Balkans in Offline and Online Monitoring and Source Identification of Atmospheric Particles", GA 101060170.

REFERENCES

- Calas, A., et al. 2018. Comparison between five acellular oxidative potential measurement assays performed with detailed chemistry on PM₁₀ samples from the city of Chamonix (France). *Atmospheric Chemistry and Physics* 18(11): 7863-7875.
- Dominutti, P.A., et al. 2025. An interlaboratory comparison to quantify oxidative potential measurement in aerosol particles: challenges and recommendations for harmonisation, *Atmos. Meas. Tech.*, 18., 1, pp. 177-195.
- Petrovic, B., Alastuey, A., Yttri, K.E., Pandolfi, M., Bartonova, A. and Jovasevic-Stojanovic, M. 2025. Source apportionment of PM₁₀ in Belgrade city from the WeBaSOOP project – Preliminary Results. Presented at WeBIOPATR conference 2025., <https://www.vin.bg.ac.rs/webiopatr/2025/services-2/>.
- Weichenthal, S. et al. 2024. Epidemiological studies likely need to consider PM_{2.5} composition even if total outdoor PM_{2.5} mass concentration is the exposure of interest. *Environmental Epidemiology*, 8(4), e317.

1.3. INVESTIGATING OXIDATIVE POTENTIAL OF PARTICULATE MATTER FROM AN URBAN SAMPLING STATION IN OSLO (NORWAY)

J. Froment (1), T. Honza (1), A. M. Hudcovova (1), C. Hak (2), K. E. Yttri (3), E. M. Longhin (1)

(1) Department of Environmental Chemistry and Health Effects, NILU, Kjeller, NORWAY, (2) Department of Urban Environment and Industry, NILU, Kjeller, NORWAY, (3) Department of Atmosphere and Climate, NILU, Kjeller, NORWAY

ifro@nilu.no

ifro@nilu.no

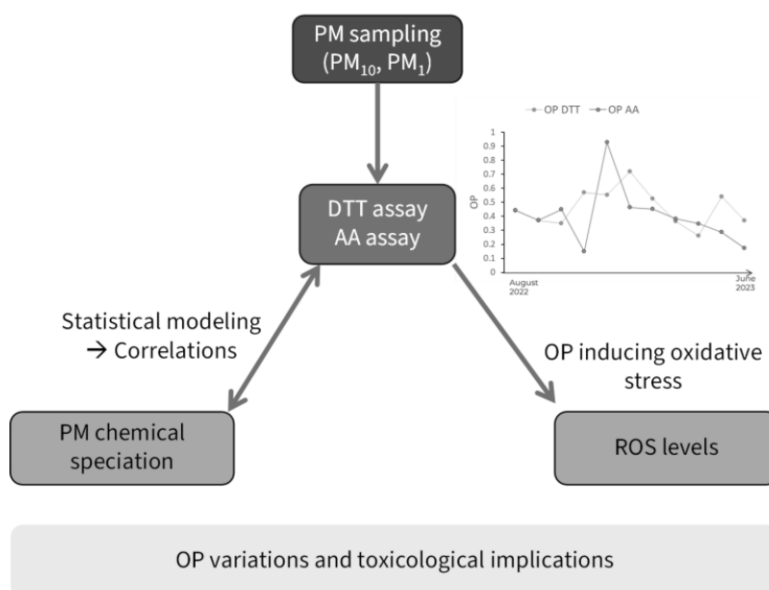
Air pollution poses a significant global threat to human health, underscoring the need for reliable and high-throughput assays to investigate toxicity mechanisms and effects. Exposure to air pollutants can disrupt cellular balance, leading to oxidative stress and subsequent health issues. Oxidative potential (OP) assays are used to evaluate the ability of airborne particulate matter (PM), or other environmental samples, to generate or catalyse the production of reactive oxygen species (ROS), which in turn can lead to oxidative stress.

In this study, we assessed the OP of PM₁₀ and PM₁ collected between August 2022 and July 2023 in a park located in central Oslo (Norway). This urban background site provides PM samples representative of real-world exposure scenarios for the local population. Both daily and monthly PM samples were analysed. Two acellular assays were used to assess temporal variations in OP: the dithiothreitol (DTT) assay and the ascorbic acid (AA) assay. These assays capture different oxidation mechanisms associated with chemical species present in ambient air PM.

The OP of all samples (166 daily samples and 11 monthly) will be presented alongside chemical speciation of the PM samples. Statistical modelling using Elastic Net Regressions showed that DTT oxidation was positively correlated with organic tracers, such as galactosan and levoglucosan, while AA oxidation was more strongly associated with inorganic species, including copper, potassium, and magnesium. The potential sources of the observed toxicity inferred from the modelling will be discussed.

In addition, ROS formation within human lung cells was assessed using the A549 in vitro cellular model, coupled with the cell-based 2',7'-dichlorofluorescein diacetate (DCFH-DA) assay. Differences in responses between the cellular and the acellular assays, as well as the potential contribution of biogenic components (specifically bacterial endotoxins), will be discussed.

Overall, this study will provide insight into the levels and drivers of oxidative potential in an urban Nordic environment contributing to a better understanding of PM toxicity and its sources.



1.4. LINKING CHEMICAL SOURCES TO OXIDATIVE POTENTIAL: SOURCE-RESOLVED ASSESSMENT OF PM_{2.5} IN URBAN MELBOURNE, AUSTRALIA

S. Iram (1), R. Fedele (2) S. Stevanović (1)

(1) School of Engineering, Deakin University, Geelong, 3216, Australia, (2) Environment Protection Authority Victoria, EPA Science, Macleod, 3085, Australia
s223015208@deakin.edu.au

The oxidative potential (OP) of particulate matter (PM) has become an important measure of aerosol toxicity, yet there are less data available connecting emission sources to OP in urban areas of the Southern Hemisphere. This study provides a year-long characterisation of PM_{2.5} OP in Melbourne, Australia, combining acellular assays results with receptor-based source attribution to quantify source-specific contributions to particle-induced redox activity. PM_{2.5} samples were collected from May 2021 to May 2022 at two urban locations situated 2 km apart and examined using dithiothreitol (DTT), ascorbic acid (AA), and dichlorodihydrofluorescein (DCFH) assays to elucidate unique reactive oxygen species (ROS) generation pathways. Positive Matrix Factorisation (PMF), executed by the Environment Protection Authority Victoria (EPA), yielded source contributions that were subsequently associated with OP by multilinear regression (MLR).

A distinct assay hierarchy was identified (DTT > AA > DCFH), with Site-2 consistently demonstrating elevated OP levels compared to Site-1, indicating a greater impact from high-traffic corridors. Seasonal patterns varied by assay: DTT reached its maximum in winter due to biomass combustion, AA increased in autumn following heightened metal mobilisation, while DCFH exhibited relative stability, with occasional rises during photochemically driven secondary aerosol events in summer. Weak correlations between OP and PM_{2.5} mass (R²=0.24–0.32) confirm the influence of PM_{2.5} composition on OP.

OP exhibited the strongest correlation with OC (r=0.52–0.77) and transition metals (Fe, Cu; r=0.34–0.65), highlighting the interplay between organic redox cycling and metal-catalysed Fenton chemistry. Site-specific differences were apparent: Site-1 demonstrated episodic winter events primarily characterised by biomass combustion, while Site-2 exhibited a consistent traffic influence with contributions from multiple sources. Episodic high-OP events on 10 July and 23 May 2021 exhibited simultaneous enhancement across all assays, suggesting chemically complex composition abundant in both organics and metals.

MLR analysis identified biomass burning and traffic emissions were the primary contributors to intrinsic oxidative potential (OP_m), while secondary aerosols and crustal dust affected extrinsic oxidative potential (OP_v). Biomass burning was the primary contributor to OP, representing approximately 30–35% of DTT and AA activity, during winter, influenced by increased levels of organic carbon (OC), and potassium. Traffic-related emissions, identified by elemental carbon (EC), copper, and iron from exhaust and brake wear, accounted for 15–20% to OP, with a more pronounced impact observed at Site-2. Secondary nitrate and aged organic aerosol, resulting from atmospheric processing, contributed to 20–30% of OP, notably affecting summer DCFH responses.

This study presents the initial integrated evidence of OP-source apportionment in Australia, indicating that OP is significantly influenced by emission source profiles and atmospheric ageing, rather than by particle mass. The findings validate the use of OP as a relevant air quality metric for exposure assessment and provide a framework for connecting source-resolved OP to toxicological outcomes. Future research will broaden this methodology to include cellular reactive oxygen species and viability assays to assess biological alignment with chemical OP metrics.

REFERENCES

- Kim, J-A., Jeong, S., Lim, S., Choi, Y., Kim, H., and Lee, M. 2025. Oxidative potential of urban PM_{2.5} in relation to chemical composition: Importance of fossil-driven sources, *Environment International*, 198, 109424.
- Campbell, S.J., Barth, A., Chen, G.I., Tremper, A.H., Priestman, M., Kalberer, M., and Green, D.C. 2024. High time-resolution quantification of PM_{2.5} oxidative potential at a Central London roadside supersite, *Environment International*, 193, 109102.

2. HEALTH ASPECTS OF ATMOSPHERIC PARTICULATE MATTER I

2.1. HEALTH EFFECTS OF PM_{2.5}: OVERVIEW OF LATEST EVIDENCE AND CLIMATE CHANGE IMPLICATIONS

Z. Jovanovic Andersen

Department of Public Health, University of Copenhagen, Copenhagen, Denmark

vlq961@sund.ku.dk

Air pollution remains the world's leading environmental threat to health, and second leading risk factor for mortality and morbidity, after high blood pressure, contributing to an estimated 7.9 million deaths in 2023, the vast majority from non-communicable diseases such as heart disease, stroke, lung disease, diabetes, and dementia (State of Global Air 2025). For the first time, dementia-related impacts to mortality are included, attributing over 625,000 deaths and nearly 12 million healthy years of life lost to air-pollution exposure. 95% of air pollution attributable deaths in adults over the age of 60 are due to noncommunicable diseases like chronic obstructive pulmonary disease (COPD), dementia, diabetes, heart disease, and lung disease. 1 in 2 of COPD deaths, 1 in 4 of heart disease deaths, and 1 in 6 of diabetes deaths are attributed to air pollution, highlighting NCD prevention potential of reduction of air pollution. 36% of the world's population is exposed to levels of PM_{2.5} pollution above the least stringent interim target of 35 µg/m³, and almost everyone remains exposed to levels above WHO guideline for PM_{2.5} of 35 µg/m³. Fine particulate matter (PM_{2.5}) exposure remains widespread, with more than a third of the global population living above even the least stringent WHO interim target. The burden is disproportionately concentrated in low- and middle-income countries, where both exposure is higher and access to healthcare is more limited. Climate change worsens air pollution by increasing the conditions that form harmful pollutants and by amplifying natural pollution sources. Rising temperatures speed up the chemical reactions that create ground-level ozone, while more frequent heat waves and stagnant air trap pollutants near the surface. Wildfires—made more intense and frequent by hotter, drier climates—release massive amounts of fine particulate matter (PM_{2.5}). Increasing number of sand- and dust storms will pose new challenges from exposure from coarse particles. Changes in rainfall, wind patterns, and drought can also reduce the atmosphere's ability to disperse pollutants. Together, these effects create a feedback loop where climate change and air pollution reinforce each other, increasing risks to human health. Latest results from EXHAUSTION multi-city European project, showed that short-term exposure to extreme heat and air pollution simultaneously, pose especially harmful combination, increasing risk of dying in patients with cardiorespiratory diseases (EXHAUSTION). Reduction of air pollution remains urgent planetary and human health priority for governments across the globe, as it will reduce burden of NCDs, and help mitigate impacts of climate change on health.

REFERENCES

<https://www.stateofglobalair.org/resources/report/state-global-air-report-2025>
<https://www.exhaustion.eu/>

2.2. PARTICULATE MATTER EXPOSURE AND CARDIOVASCULAR RISK – A REVIEW

S. Alves (1,2), J. Vaz (1), A. Fernandes (1), P. Molés (2)

(1) *Research Centre for Active Living and Wellbeing (LiveWell), Instituto Politécnico de Bragança, 5300-253 Bragança, Portugal,* (2) *Universitat de Jaume I, Unitat Predepartamental d'Infermeria, AV. Sos Baynat, s/n 12071 Castelló de la Plana, Spain*
adilia@ipb.pt

Exposure to particulate matter is a growing public health concern due to its strong association with respiratory and cardiovascular diseases (World Health Organization, 2022). Firefighters face a significant cardiovascular risk due to repeated exposure to particulate matter from smoke, ashes, and combustion by-products (Fabian et al., 2014), combined with disrupted sleep, physical-emotional strain, and extreme heat (Bralewska et al., 2024). Most research only focuses on acute events during active firefighting, neglecting the long-term effects of chronic particulate matter exposure on their cardiovascular health (Esteves et al., 2024).

This study reviews the association between long-term occupational exposure to particulate matter and cardiovascular risk in firefighters. A literature search was conducted using recent publications indexed in PubMed, CINAHL, Cochrane and Web of Science. Literature in English, published from January 2015 to December 2025, was included.

Research after the World Trade Center disaster found a strong link between higher exposure levels to particulate matter and increased cardiovascular events like heart attacks and strokes, even after adjusting for traditional risk factors (Cohen et al., 2019). Studies on wildland firefighters indicated that PM₄ exposure from smoke significantly raises the lifetime risk of cardiovascular disease, with risks increasing with career length and incident frequency (Navarro et al., 2019). There is also evidence of a dose-dependent relationship between firefighting exposure and atrial fibrillation, indicating the combined effects of inhaled pollutants and occupational stress (Vanchiere et al., 2022). Short-term PM_{2.5} exposure can lead to temporary blood pressure spikes, while chronic exposure contributes to sustained hypertension (Clementi et al., 2019). These findings emphasise the causal role of particulate matter exposure in cardiovascular issues and highlight the need for long-term monitoring and preventive measures for high-risk groups like firefighters. Future research should focus on addressing the gaps in long-term monitoring and exposure assessment to better understand cardiovascular risks associated with particulate exposure.

This work is supported by national funds from FCT – Fundação para a Ciência e a Tecnologia, I.P., under the project/support UID/6157/2025 and the grant 2025.03902.BD.

REFERENCES

- Bralewska, K., Bralewski, A., Wolny, P., and Chyliński, B. 2024. Size-resolved particulate matter inside selected fire stations and preliminary evaluation of the effectiveness of washing machines in reducing its concentrations. *Scientific Reports*, 14(1), 1–13.
- Clementi, E. A., Talusan, A., Vaidyanathan, S., Veerappan, A., Mikhail, M., Ostrofsky, D., Crowley, G., Kim, J. S., Kwon, S., and Nolan, A. 2019. Metabolic Syndrome and Air Pollution: A Narrative Review of Their Cardiopulmonary Effects. *Toxics*, 7, Page 6, 7(1), 6.
- Cohen, H. W., et al. 2019. Long-term Cardiovascular Disease Risk Among Firefighters After the World Trade Center Disaster. *JAMA Network Open*, 2(9), e199775.
- Esteves, F., Slezakova, K., Madureira, J., Vaz, J., Fernandes, A., Morais, S., do Carmo Pereira, M., Teixeira, J. P., and Costa, S. 2024. Firefighters' Occupational Exposure in Preparation for Wildfire Season: Addressing Biological Impact. *Toxics*, 12(3), 201.
- Fabian, T. Z., Borgerson, J. L., Gandhi, P. D., Baxter, C. S., Ross, C. S., Lockey, J. E., & Dalton, J. M. 2014. Characterization of Firefighter Smoke Exposure. *Fire Technology*, 50(4), 993–1019.
- Navarro, K. M., Kleinman, M. T., Mackay, C. E., Reinhardt, T. E., Balmes, J. R., Broyles, G. A., Ottmar, R. D., Naher, L. P., & Domitrovich, J. W. 2019. Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. *Environmental Research*, 173, 462–468.
- Vanchiere, C., Thirumal, R., Hendrani, A., Dherange, P., Bennett, A., Shi, R., Gopinathannair, R., Olshansky, B., Smith, D. L., and Dominic, P. 2022. Association Between Atrial Fibrillation and Occupational Exposure in Firefighters Based on Self-Reported Survey Data. *Journal of the American Heart Association*, 11(7), 22543.
- World Health Organization. 2022. Ambient (outdoor) air pollution. Fact Sheets. [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health)

2.3. HIGH-RESOLUTION SPATIAL ASSESSMENT OF PARTICULATE MATTER-RELATED MORTALITY BURDEN IN THE LISBON METROPOLITAN AREA

F. Abedian Aval (1), S. Atace (1), B. Nemati (1), B. T. Silva (1), D. Lopes (1), P. Cirne (3), V. Martins (2), A. I. Miranda (1), H. Relvas (1)

(1) CESAM & Department of Environment and Planning, University of Aveiro, 3810-193 Aveiro, Portugal

(2) Centro de Ciências e Tecnologias Nucleares (C2TN) & Department of Nuclear Sciences and Engineering (DECN), Instituto Superior Técnico, Universidade de Lisboa, 2695-066 Bobadela-LRS, Portugal

(3) Instituto de Telecomunicações, University of Aveiro 3810-193 Aveiro, Portugal

F.Abedian@ua.pt

Exposure to ambient particulate matter (PM_{2.5} and PM₁₀) is recognised as one of the main environmental risk factors for premature mortality in Europe. Numerous studies have shown that long-term exposure to PM_{2.5} leads to substantial avoidable deaths, particularly in densely populated urban regions (Khomenko et al., 2023; McDuffie et al., 2021; Relvas et al., 2022; Yu et al., 2023, 2024). The Lisbon Metropolitan Area (LMA), home to 2.87 million residents across 18 municipalities, faces persistent air quality challenges due to traffic emissions, industrial activities, and regional transport of pollutants (Relvas et al., 2022, 2025). This study aims to provide a high-resolution spatial assessment of the mortality burden attributable to particulate matter exposure in the LMA.

High-resolution pollution concentration fields were generated using geostatistical interpolation techniques at a 1 km × 1 km grid scale, based on continuous hourly PM measurements from the regional air quality monitoring network. Population exposure was estimated through area-weighted spatial allocation algorithms integrating the 2021 Census demographic data. Health impact assessment was performed using concentration–response functions implemented in the WHO AirQ+ tool (v2.2). Mortality estimates were spatially disaggregated at both municipal (n = 18) and parish (n = 203) levels.

The findings reveal significant spatial heterogeneity in PM-related mortality across the LMA, with distinct geographical clustering of environmental health burdens. The results show strong inter-urban variability in source-specific contributions, underscoring the need for geographically targeted emission reduction measures focusing on dominant sectoral sources. This study represents the most spatially detailed evaluation of air pollution–related mortality conducted for the LMA to date. The proposed high-resolution modelling framework enhances the identification of vulnerable sub-populations and supports evidence-based policymaking. It also advances the full-chain assessment from emissions characterization to health outcomes, offering actionable insights for reducing the particulate matter disease burden in alignment with the revised European Air Quality Directive.

ACKNOWLEDGEMENTS

CESAM (UIDP/50017/2020 + UIDB/50017/2020 + LA/P/0094/2020) and C2TN (UIDB/04349/2020). Special thanks to FCT/MCTES for the research contract awarded to Helder Relvas (<https://doi.org/10.54499/2021.00185.CEECIND/CP1659/CT0026>) and ODESSA (<https://doi.org/10.54499/2024.07293.IACDC>).

REFERENCES

- Khomenko, S., Pisoni, E., Thunis, P., Bessagnet, B., Cirach, M., Iungman, T., Barboza, E. P., Khreis, H., Mueller, N., Tonne, C., de Hoogh, K., Hoek, G., Chowdhury, S., Lelieveld, J., and Nieuwenhuijsen, M. 2023. Spatial and sector-specific contributions of emissions to ambient air pollution and mortality in European cities: a health impact assessment. *The Lancet Public Health*, 8(7), e546–e558.
- McDuffie, E. E., Martin, R. V., Spadaro, J. V., Burnett, R., Smith, S. J., O'Rourke, P., Hammer, M. S., van Donkelaar, A., Bindle, L., Shah, V., Jaeglé, L., Luo, G., Yu, F., Adeniran, J. A., Lin, J., and Brauer, M. 2021. Source sector and fuel contributions to ambient PM_{2.5} and attributable mortality across multiple spatial scales. *Nature Communications*, 12(1), 3594.
- Relvas, H., Lopes, D., and Armengol, J. M. 2025. Empowering communities: Advancements in air quality monitoring and citizen engagement. *Urban Climate*, 60, 102344.
- Relvas, H., Lopes, D., Ferreira, J., Silva, A., Rafael, S., Lopes, M., Almeida, S. M., Martins, V., Diapouli, E., Korhonen, A., Hänninen, O., Lazaridis, M., and Miranda, A. I. 2022. Scenario analysis of strategies to control air pollution. *Urban Climate*, 44, 101201.
- Yu, W. et al., 2024. Estimates of global mortality burden associated with short-term exposure to fine particulate matter (PM_{2.5}). *The Lancet Planetary Health*, 8(3), e146–e155.
- Yu, W., Ye, T., Zhang, Y., Xu, R., Lei, Y., Chen, Z., Yang, Z., Zhang, Y., Song, J., Yue, X., Li, S., and Guo, Y. 2023. Global estimates of daily ambient fine particulate matter concentrations and unequal spatiotemporal distribution of population exposure: a machine learning modelling study. *The Lancet Planetary Health*, 7(3), e209–e218.

2.4. PERTUSSIS IN POST COVID-19 TIME: AIRBORNE OR RESPIRATORY DROPLET TRANSMISSION DISEASE

E. Ristanović, N. Djordjevski, S. Atanasievska Kujović, V. Protić-Dokić

Military Medical Academy, University of Defence, Belgrade, Serbia

elizabetha.ristanovic@yma.mod.gov.rs

Bordetella pertussis is a Gram-negative respiratory strictly human bacterial pathogen, and the causative agent of highly contagious acute whooping cough (pertussis), characterized with paroxysmal coughing spasm as well as broad spectrum of manifestations depending on the host immune status and age including post tussive emesis and reduced pulmonary capacity (Trainor et al, 2015). The chain of bacterial transmission and survival in the environment is not clear, while its natural reservoirs and hosts are still unknown (Nieves and Heininger, 2016). Although there is evidence that *B. pertussis* transmission occurs via aerosolized respiratory droplets, experimental studies on baboons has also documented airborne transmission (Warfel et al, 2012). Despite relatively high vaccination rates worldwide, the disease remains endemic in human population. During the COVID-19 pandemic, a decline was observed in reported cases due to stringent health measures and social distancing. In the post-COVID period, there was evidence of the rapid rise of acute respiratory disease incidence including pertussis (Locht, 2025). The aim of the study is to analyse the presence of *B. pertussis* in hospitalized post-COVID patients with lower respiratory tract infections (LRTI). We have detected *B. pertussis* DNA in sputum of 2.63% (1/38) post COVID patients with LRTI in the 2023-2025 period. The PCR positivity was followed with later IgG seropositivity. Other respiratory pathogens such as *Legionella pneumophyla*, *Streptococcus pneumoniae* and *Haemophilus influenzae* are more frequently detected in LRTI patients in a hospitalized environment. It is also necessary to consider that the incidence of *B. pertussis* infection is usually higher in LRTI patients who are not hospitalized due to lower severity of symptoms (Hladchenko et al, 2025). The weakened immune defence after viral infection enabled a suitable environment for proliferation of secondary bacterial pathogens including *B. pertussis*. The inflammatory response to SARS-CoV 2 influences the natural immune response, as well as Th1/Th2 balance decreasing the post-vaccination immunity to *B. pertussis* that could explain the appearance of disease in post-COVID era (Wang et al, 2024). The virus also could change and affect the local microbiome, thus enabling conditions for *B. pertussis* colonization. The complete understanding of host-pathogen interactions, as well as pertussis transmission will improve treatment strategies and lead to the further improvement of specific vaccines for efficient prevention of pertussis spread.

REFERENCES

- Hladchenko, O. I., Dybas, I. V., and Nadruga, A. B. 2025. Evolution of clinical manifestations of whooping cough in children in the post-covid-19 pandemic period. *World of Medicine and Biology*, 21(92), 048-052.
- Locht, C. 2025. Pertussis before, during and after Covid-19. *EMBO Molecular Medicine*, 17(4), 594-598.
- Nieves, D. J., and Heininger, U. 2016. *Bordetella pertussis*. *Emerging Infections* 10, 311-339.
- Trainor, E. A., Nicholson, T. L., and Merkel, T. J. 2015. *Bordetella pertussis* transmission. *Pathogens and disease*, 73(8), ftv068.
- Wang, H., et al., 2024. Post-COVID-19 pandemic changes in pertussis incidence among patients with acute respiratory tract infections in Zhejiang, China. *Frontiers in Microbiology*, 15, 1448997.
- Warfel, J. M., Beren, J., and Merkel, T. J. 2012. Airborne transmission of *Bordetella pertussis*. *The Journal of infectious diseases*, 206(6), 902-906.

2.5. CHRONIC HEALTH RISK ASSESSMENT OF PM_{2.5} IN THE URBAN CORE OF NOVI SAD, SERBIA

S. Dmitrašinić, M. Brborić, S. Čojbašić, M. Turk Sekulić, J. Radonić

Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia

dmitrasinovic@uns.ac.rs

Air pollution represents one of the leading global environmental threats, with fine particulate matter (PM_{2.5}) being the dominant contributor to chronic respiratory and cardiovascular morbidity and mortality (Chen et al., 2024; Al-Kindi et al., 2020). In Serbia, where mixed heating (solid fuels and thermal power plants) and traffic emissions dominate, long-term exposure to elevated PM_{2.5} levels poses substantial health risks (Health Effects Institute, 2022). This study provides a detailed seasonal and spatial assessment of PM_{2.5} concentrations and associated chronic health risks for pedestrians in the urban core of Novi Sad. The aim was to quantify exposure differences between winter and summer seasons and to evaluate potential population-specific health risks based on age and gender.

Measurements were conducted using low-cost particulate sensors PMS7003, deployed at seven representative urban microenvironments characterized by different emission profiles, including high-traffic intersections, residential heating zones, and areas influenced by heating from thermal power plants. Each sensor underwent collocation with the national reference monitoring station operated by the Serbian Environmental Protection Agency for calibration, following scaling methods that improved sensor reliability and reduced error metrics. The chronic health risk was estimated through the lifetime average daily dose (LADD) and hazard quotient (HQ) (Gruszecka-Kosowska, 2020; Ilenić et al., 2024).

The results demonstrated strong seasonal contrast in PM_{2.5} levels. During winter, concentrations ranged from 23.11 to 43.03 µg/m³, frequently exceeding the WHO daily guideline value of 15 µg/m³. The highest values occurred in dense residential neighbourhoods using mixed heating (wood, coal, and gas) combined with nearby traffic corridors, where 24-hour concentrations peaked above 60 µg/m³. In contrast, summer levels were notably lower (11.06–17.07 µg/m³) but still exceeded guidelines near heavily trafficked intersections and active construction sites. Spatial analysis indicated that areas heated by centralized district systems (thermal power plants) showed lower winter concentrations (~23 µg/m³) compared to mixed-heating residential zones (~43 µg/m³). The winter HQ values exceeded 3 for most age categories, confirming a substantial chronic exposure risk, while summer HQs ranged from 1.1 to 1.9. The highest HQ values were recorded among males aged 30–59 years (HQ = 3.8–5.6) and elderly pedestrians (>60 years, HQ = 3.7–5.5), reflecting combined effects of prolonged exposure and higher inhalation rates. Female HQs followed similar spatial patterns, with slightly lower mean values (2.1–4.5). Locations near traffic-dense corridors and solid-fuel heating exhibited the greatest cumulative exposure potential, whereas areas with district heating and better air circulation demonstrated reduced risk.

The findings of this study underscore the urgent need for targeted mitigation strategies to reduce localized PM_{2.5} emissions, such as the modernization of residential heating systems and the development of low-emission transport corridors. These efforts should be supported by an integrated approach involving continuous air quality monitoring, stricter environmental regulations, and long-term epidemiological studies to refine health risk assessments.

REFERENCES

- Al-Kindi, S. G., Brook, R. D., Biswal, S., and Rajagopalan, S. 2020. Environmental determinants of cardiovascular disease: lessons learned from air pollution, *Nature Reviews Cardiology* 17(10), 656–672.
- Chen, F., Zhang, W., Mfarrej, M. F. B., Saleem, M. H., et al. 2024. Breathing in danger: Understanding the multifaceted impact of air pollution on health impacts, *Ecotoxicology and Environmental Safety* 280, 116532.
- Gruszecka-Kosowska, A. 2020. Human health risk assessment and potentially harmful element contents in the cereals cultivated on agricultural soils, *International Journal of Environmental Research and Public Health* 17(5), 1–16.
- Health Effects Institute. 2022. Trends in Air Quality and Health in the Republic of Serbia: A State of Global Air Special Report, Boston, MA, ISSN 2578-6881.
- World Health Organization. 2019. Health Impact of Ambient Air Pollution in Serbia: A Call to Action, WHO Regional Office for Europe, Copenhagen, Denmark.

3. INDOOR PARTICULATE MATTER

3.1. MONITORING INDOOR ENVIRONMENT IN SCHOOLS AND WHAT CAN WE LEARN BY ASKING OCCUPANTS?

A. Bartonova, B. A. Høiskar, M. F. Fredriksen
Stiftelsen NILU, POB 100, N-2027 Kjeller Norway
aba@nilu.no

In Norway, approximately every 7th inhabitant spends at least 12% of time in school buildings, as a student/pupil, teacher, or other member of staff. In Norway, Section 9A-1 and Chapter 12 of the Education Act state that all students have the right to a physical and psychosocial environment that promotes health, well-being and learning, and that this includes a good indoor climate. Compliance is generally kept track of through municipal inspections or the health and safety reporting which however only requires reporting if problem arises. Question arises, where can the school authorities and stakeholders get information about the IEQ.

In Norway, of the nearly 3000 schools for children aged 6-19, more than 75% of the school buildings have a ventilation system (Inneklimaeksperten et al., 2025), and thus in theory, some objective information about IEQ is available. In practice, the ventilation systems do not report data to the users – data is used solely to adjust the operations of the systems. In recent years, a number of schools installed independent low-cost sensors in classrooms, and can check several parameters including temperature and CO₂, the two most common indicators, in a dedicated portal of the sensor provider. This situation is not satisfactory: additional installation requires resources and significant effort if the data is to be used for systematic reporting.

In Europe, requirements on indoor environmental quality in school buildings vary, and only approximately 10 European countries develop systematic IEQ data collection for schools, few of them periodic (Scutaru et al., 2025). Previous projects such as Sinphonie (Kephalopoulos et al., 2020) have tried to develop guidelines, but these were not taken up nationally or internationally. And yet, as many as 1 in 11 children aged 0-19 are reported to suffer from asthma (Zhou and Tang, 2025), and the effects on students of IEQ are well described (Brink et al, 2022).

We propose a school monitoring system that utilizes technological advances in real-time IEQ monitoring and reporting to deliver a comprehensive system that can serve all school stakeholders, including pupils and students, or the school leadership and the technical personnel. The system serves as an awareness raising tool, a decision support system (Alam et al., 2025) and feedback and reporting tool. It has been co-created with school stakeholders and piloted in four schools, but its implementation requires much higher digital connectivity than that available routinely, e.g., access to data from ventilation systems.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Norway. It is a collaboration between NILU, NTNU Trondheim, Norwegian Asthma and Allergy Association and Oslo Municipality, with contributions from schools (Bratteberg and Øyra (Volda Municipality, Brannfjell and Kuben (Oslo municipality)), insurance company KLP, and companies AirTHINGS ASA, Schneider Electric Norway, Johnson Controls Norway and GK Inneklima.

REFERENCES

- Alam, A.G., Bartonova, A., Høiskar, B.A. 2025. Predicting the student's perceptions of multi-domain environmental factors in a Norwegian school building: Machine learning approach. *Building and Environment*, vol. 280, 113144.
- Brink, H.W. et al 2022. A systematic approach to quantify the influence of indoor environmental parameters on students' perceptions, responses, and short-term academic performance. *Indoor Air*. 2022;32:e13116.
- Inneklimaeksperten, 2025, Frisk Luft i Skolen: Nøkkelen til Sunnere Barn - Inneklimaeksperten, accessed 13.11.2025.
- Scutaru, A.M and Bartonova, A. 2025. Comprehensive review of existing knowledge on indoor air quality and the dust, ETC HE working paper, forthcoming, available from the authors.
- Kephalopoulos, S. 2020. SINPHONIE - Schools Indoor Pollution and Health Observatory Network in Europe database on chemical and biological pollutants. European Commission, Joint Research Centre (JRC) [Dataset] PID: <http://data.europa.eu/89h/155ec478-2052-4b7e-982c-b14574c94c9d>, accessed 13.11.2025.
- Zhou, W., Tang, J. 2025. Prevalence and risk factors for childhood asthma: a systematic review and meta-analysis. *BMC Pediatr* 25, 50.

3.2. PARTICULATE MATTER IN PRIMARY SCHOOL CLASSROOMS: EFFECTS OF OCCUPANCY

R. Coelho (1), C. Peixoto (1), G. Hatem (2,3), A.M. Faria (2,3), J. Madureira (2,3), J. P. Teixeira (2,3), M.C. Pereira (1), K. Slezakova (1)

(1) LEPABE-ALiCE, Faculty of Engineering, University of Porto, Portugal, (2) Environmental Health Department, National Institute of Health Dr. Ricardo Jorge, Porto, Portugal, (3) EPIUnit-Institute of Public Health, University of Porto, Porto, Portugal

slezakok@fe.up.pt

Ensuring proper IAQ in classrooms is essential for the health, well-being, and performance of students and teachers (Sadriazadeh et al., 2022). Classrooms often have up to four times higher occupancy than offices, and both indoor and outdoor factors can significantly affect air quality, impacting students' health and performance (Sadriazadeh et al., 2022; Wargocki et al., 2020). To develop effective IAQ management strategies and safeguard the well-being and academic success of all school occupants, a comprehensive understanding of these factors and their interplay is required. Thus, this study aimed to evaluate the levels of particulate matter in the indoor air of primary school classrooms.

IAQ was continuously monitored in ten primary schools (S1–S10) from January to October 2024, over one week in four classrooms per school. A detailed survey characterized each school's physical parameters and surroundings, including location, urbanization, nearby emission sources, infrastructure, green/blue spaces, and potential noise sources. Indoor spaces were assessed for layout, building materials, heating and ventilation systems, ergonomics (furniture, electronics, decoration, and consumer products), and relevant occupant behaviors. Particulate matter was measured in real time using a Lighthouse Handheld Particle Counter (model 3016 IAQ; Lighthouse Worldwide Solutions, Fremont, USA), simultaneously for six particle size fractions (300 nm – 10 µm) at a 1-minute interval.

The results showed that school-average PM₁₀ concentrations ranged from 55 to 95 µg/m³ (mean 198 µg/m³), while corresponding PM_{2.5} levels were 8.4–32 µg/m³ (mean 14 µg/m³). Fine particles contributed 7–29% of the coarse particle fraction. PM₁₀ levels consistently (1.1–4.0 times) exceeded the national health protection threshold of 50 µg/m³. Student occupancy mainly affected coarse particles, increasing concentrations by 1.1–2.7 times when classrooms were occupied, whereas PM_{2.5} concentrations showed minor changes of 0.3–0.7 times.

In general, these results emphasise the need for IAQ management strategies to mitigate potential health risks and ensure safe and comfortable learning environments.

This work was financially supported by PTDC/CTA-AMB/3040/2021 (doi 10.54499/PTDC/CTA-AMB/3040/2021) by FCT-MCTES through national funds. Additional support was provided through LA/P/0045/2020 (ALiCE), UIDB/00511/2020-UIDP/00511/2020 (LEPABE), UIDB/04750/2020 (EPIUnit), LA/P/0064/2020 (ITR), and fellowships 2022.11261.BD and 2024.02722.BDANA

REFERENCES

- Sadriazadeh, S., Yao, R., Yuan, F., Awbi, H., Bahnfleth, et al. 2022. Indoor air quality and health in schools: A critical review for developing the roadmap for the future school environment, *Journal of Building Engineering* 57, 104908.
- Wargocki, P., Porras-Salazar, J. A., Contreras-Espinoza, S., and Bahnfleth, W. 2020. The relationships between classroom air quality and children's performance in school, *Building and Environment* 173, 106749.

3.3. PM_{2.5} LEVELS INSIDE TRAINS: A JOURNEY THROUGH SUMMER AND WINTER SEASONS

A. C. T. Silva, P. T. B. S. Branco, F. G. Martins, S. I. V. Sousa
LEPABE, ALiCE, Faculty of Engineering, University of Porto, Porto, Portugal
up201605702@edu.fe.up.pt

Literature has shown that public transport users face poor indoor air quality (IAQ) conditions when travelling, particularly during rush hours, which poses a huge risk to human health (Motlagh et al., 2021). Particulate matter with an aerodynamic diameter smaller than 2.5 µm (PM_{2.5}), usually referred to as fine particles, is particularly dangerous since it has the capability to be retained in the pulmonary alveolus, thus increasing the risk of cardiovascular and respiratory diseases (Xing et al, 2016). Therefore, monitoring in public transport is a first essential step towards the prevention of PM_{2.5} accumulation and its related consequences. Hence, this study aimed to evaluate PM_{2.5} inside trains over two different seasons in Portugal. PM_{2.5} was measured using one research-grade instrument (1-min log intervals) for a total of 96 trips (mean trip duration of approximately 55 min) during two consecutive weeks in both summer and winter seasons, covering rush and non-rush hours (6:00 am - 8:30 pm). Relative humidity was also monitored (1-min log). An urban/suburban train route was chosen for monitoring, and the air conditioning system of the train was always automatically on, with possible manual adjustment by the train driver. A portable apparatus was used to carry the monitoring instrument, placed in the seating area of the central train carriage with the air inlet at seating passengers breathing height (~1 m above the floor). PM_{2.5} concentrations collected inside the train were compared with the IAQ reference limit values from the Portuguese legislation for indoors (buildings) and with WHO guidelines for indoor environments. Overall, the mean PM_{2.5} levels in the train were 18.2 µg/m³ during summer and 19.0 µg/m³ in winter. Moreover, levels during the summer season were similar between rush (17 µg/m³) and non-rush hours (18.7 µg/m³), while levels during rush hour (22.7 µg/m³) were slightly higher compared to non-rush hours (17.6 µg/m³) in the winter season. Despite the similarity in the mean levels, some differences were found in the PM_{2.5} pattern when comparing the analogous trips monitored in the two seasons. Thus, during the first week of monitoring (afternoons), higher levels were noticed in the last two trips of the day (including the rush hour trip) during the winter season, potentially associated with the increase of the relative humidity with the dusk. Moreover, in the second week (mornings) some trips registered lower levels in the winter season than in summer. PM_{2.5} concentrations surpassed the reference limit values in the Portuguese legislation by 17% in summer and 21% in winter and the WHO guidelines by 55% and 44% in summer and winter, respectively. In sum, some differences in the fine particles pattern were observed between the same trips monitored in the two different seasons, although the overall mean PM_{2.5} concentrations of each season were similar in absolute number. Future work should focus this analysis on other important particulate matter fractions, namely ultrafine and the chemical composition analysis.

ACKNOWLEDGMENTS

This work was financially supported by LA/P/0045/2020 (ALiCE), UIDB/00511/2020 and UIDP/00511/2020 (LEPABE), funded by national funds through FCT/MCTES (PIDDAC). This work was supported by FCT – Fundação para a Ciência e Tecnologia, I.P. by project reference 2022.11772.BD and DOI identifier <https://doi.org/10.54499/2022.11772.BD>. This work was supported by FCT - Fundação para a Ciência e Tecnologia, I.P. by project reference 2022.05461.CEECIND/CP1733/CT0011 and DOI identifier <https://doi.org/10.54499/2022.05461.CEECIND/CP1733/CT0011>.

REFERENCES

- Motlagh, N. H., Zaidan, M. A., Fung, P. L., Lagerspetz, E., Aula, K., Varjonen, S., Siekkinen, M., Rebeiro-Hargrave, A., Petäjä, T., Matsumi, Y., Kulmala, M., Hussein, T., Nurmi, P., and Tarkoma, S. 2021. Transit pollution exposure monitoring using low-cost wearable sensors. *Transportation Research Part D: Transport and Environment*, 98, 102981.
- Xing, Y. F., Xu, Y. H., Shi, M. H., and Lian, Y. X. 2016. The impact of PM_{2.5} on the human respiratory system. *J Thorac Dis*, 8(1), E69-74.

3.4. AIR QUALITY AND THERMAL COMFORT MEASUREMENTS IN OFFICE ENVIRONMENTS IN BOR, SERBIA (2023-2024)

V. Tasić (1), V. Kamenović (1), R. Kovačević (1), B. Radović (1), N. Mišić (2), I. Zlatković (1)

(1) Mining and Metallurgy Institute Bor, Bor, Serbia,

(2) University of Niš, Faculty of Occupational Safety, Niš, Serbia

visa.tasic@irmbor.co.rs

This paper presents an analysis of indoor air quality and thermal comfort in an office environment at the Mining and Metallurgy Institute Bor, based on continuous monitoring performed in 2023 and 2024. Measurements of carbon dioxide (CO₂) concentration, temperature, and relative humidity were conducted using low-cost sensors and portable monitoring systems. The analysis aims to evaluate ventilation efficiency and thermal comfort conditions during working hours, in accordance with international standards ISO 7730 (ISO, 2005), ASHRAE 55 (ANSI/ASHRAE, 2020) and EN 16798-1 European Committee for Standardization, 2019). The subjective perception of the indoor environment defines the level of comfort experienced by occupants. Environmental comfort comprises several components: air quality, thermal comfort, visual comfort, and acoustic comfort. Indoor air quality significantly affects human health, concentration, and work performance. The concentration of CO₂ is commonly used as an indicator of ventilation efficiency and, consequently, of indoor air quality (Tasić, V., et al., 2023).

Table 1. Air quality and thermal comfort determined by the analysis of hourly averaged values of temperature (T), relative humidity (RH), and CO₂ concentration in the office during the 2023–2024 period (HS – heating season, NHS – non-heating season)

Time period	Air quality category				Satisfactory thermal comfort
	I	II	III	IV	
	%	%	%	%	%
2023 (whole year)	78.1	11.8	9.1	1.0	63.2
2024 (whole year)	82.9	11.9	4.8	0.4	53.4
2023 HS	74.5	14.7	10.2	0.6	59.2
2024 HS	91.2	5.4	3.4	-	53.4
2023 NHS	81.4	9.7	7.6	1.3	61.2
2024 NHS	74.6	18.4	6.2	0.8	53.5

The analysis indicates that satisfactory air quality (categories I and II) was achieved for over 90% of working hours, while thermal comfort was maintained for approximately 50–60% of the time. These findings emphasize the importance of maintaining adequate ventilation and thermal control measures to achieve optimal indoor environmental quality throughout the year.

ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia, Grants No. 451-03-136/2025-03/200052 and No. 451-03-136/2025-03/200017. This work was co-funded by the Center for the Promotion of Science, under the auspices of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract № 1383/24).

REFERENCES

- American Society of Heating, Refrigerating and Air-Conditioning Engineers. 2020. ANSI/ASHRAE Standard 55-2020: Thermal environmental conditions for human occupancy.
- European Committee for Standardization. 2019. EN 16798-1:2019: Energy performance of buildings — Ventilation for buildings — Module M1-6. CEN.
- International Organization for Standardization. 2005. ISO 7730: Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.
- Tasić, V., Kamenović, V., Radović, B., Mišić, N., Zlatković, I. 2023. Merenje kvaliteta vazduha i termalnog komfora u kancelarijama primenom low-cost senzora i monitora, Bakar, Vol.48., 1, 43-52. (in Serbian).

3.5. INDOOR AIR QUALITY IN COMMERCIAL CENTRES – IS THERE A CONNECTION WITH HEALTH OF EMPLOYEES?

M. Nikolić, A. Stanković

Faculty of Medicine, University of Niš, Niš, Serbia

mani@ni.ac.rs

Potential health effects from occupational exposure to indoor air pollutants in commercial buildings have been investigated since the 1990s, after the peak of the shopping mall boom and the beginning of their global spread (Sterling et al., 1991; Backman, Haghghat, 1999.). It was concluded that individuals who work in these buildings suffer from sick-building-related symptoms: irritation of eyes, nose, throat, and skin, respiratory ailments, headaches, dizziness, confusion, and unusual odour or taste sensations - that occur during occupation of the building but diminish when these persons leave these buildings (Gomzi et al., 2007). It can cause substantial disruption of people's work performance, considerable loss of productivity, increased absenteeism and increased staff turnover (Subri et al., 2024.). However, very few studies have been conducted on the assessment of the indoor working environment and its effect on employee's health in the context of Serbia. Therefore, this study aimed to determine the prevalence of SBS symptoms and its associated factors among employees in commercial centres.

A cross-sectional study of employees from two commercial centres in the city of Niš (Serbia) was performed. We examined 1152 employees (886 females, 293 males, mean age 32.13±8.06 years, by using the MM-40 EA questionnaire developed by Andersson and his colleagues in Örebro, Sweden (Anderson et al., 1993) This questionnaire has five parts. The first part of the questionnaire includes general background data (age, sex, smoking status, educational level, duration of employment in the current job); the second one deals with physical environment factors at working place; the third one explains psychological and social factors at workplace; the fourth part of the questionnaire includes medical history of allergic diseases of the employees and the last one contains questions about work-related symptoms. In this paper, we present only the data from the first, second and fifth part of the questionnaire. Collected data included environmental problems and symptoms during the last three months. All the symptoms were divided into: general symptoms (fatigue, heavy-headedness, headaches, nausea/dizziness, concentration problems), mucosal-irritation symptoms (itching, burning or irritation of the eye, irritated, stuffy or runny nose, hoarse, dry throat and cough), and facial-skin symptoms (dry or flushed facial skin, itching/scaling scalp or ears, dry hands and itching red skin). The questionnaire was modified by adding one question "Do you think that your health problems have been attributed to the physical work environment?". Possible answers were: "yes, often" (every week) ", "yes, sometimes", and "no, never". The average number of work-related symptoms per person – Building symptom index (BSI) was also calculated. Results show that 83.7% of employees reported symptoms concerning the working environment. Frequently reported symptoms were fatigue, while facial-skin symptoms occurred more rarely. Binary logistic regression demonstrated that very low room temperature, dry air, static electricity, and noise were identified as important factors for the occurrence of the high symptoms score.

In conclusion, the results indicated that employees in commercial centres had an elevated prevalence of building-related symptoms. These finding indicated a need for urgent educational initiatives of sick building syndrome for workers in non-industrial workplace. It is very important to point this problem and to begin with a systematic supervision of the working conditions and the workers' health at the non-industrial working places.

ACKNOWLEDGMENTS

The authors would like to thank the Ministry of Education, Science and Technological Development of Republic of Serbia (Grant No: 451-03-136/2025-03/200113) for financial support.

REFERENCES

- Andersson, K, Stridh, G, Fagerlund, K.I., Larsson B. 1993. The MM-questionnaires – A tool when solving indoor climate problems. Department of Occupational and Environmental Medicine, Örebro University Hospital, Örebro, Sweden.
- Backman, H, Haghghat, F. 1999. Indoor-air quality and ocular discomfort. *J Am Optom Assoc.* 70, 309-16.
- Gomzi M, Bobic J, Radosević-Vidaček B, Macan J, Varnai VM, Milković-Kraus S, Kanceljak-Macan B. Sick building syndrome: psychological, somatic, and environmental determinants. 2007. *Arch Environ Occup Health.* 62, 147-55
- Sterling, T.D, Collett. C, Rumel, D.1991. A epidemiologia dos "edificios doentes" [Epidemiology of "sick buildings"]. *Rev Saude Publica.* 25, 56-63.
- Subri, M.S.M, Arifin, K, Sohaimin, M.F.A.M, Abas, A. 2024. The parameter of the Sick Building Syndrome: A systematic literature review. *Heliyon.* 10, e32431.

3.6. PORTABLE AIR PURIFIERS: AN OVERVIEW OF THEIR BENEFITS IN INDOOR AIR QUALITY IMPROVEMENT

B. Petrović, (1,2), D. Vukelić (1), M. Ćurčić (1), A. Buha Đorđević (1), D. Đukić-Ćosić (1), B. Antonijević (1), Z. Bulat (1)

(1) Department of Toxicology “Akademik Danilo Soldatović” University of Belgrade – Faculty of Pharmacy, Serbia, (2) Institute Vinča, University of Belgrade, Belgrade, Serbia
bojana.petrovic@vin.bg.ac.rs

Increased concern over adverse health effects of air pollution has led to more frequent inquiries to healthcare professionals about risks and prevention. Despite their key role in disease prevention, the World Health Organization found that healthcare professionals lack sufficient knowledge about air pollutants and face a shortage of guidelines and recommendations. Therefore, our study aimed to review studies examining effectiveness and health benefits of air pollution reduction using the most frequent enquiry - portable air purifiers (PAPs).

Two electronic databases were searched to conduct this narrative review: PubMed and Scopus databases. Keywords searched were “particulate matter AND (portable air cleaners OR portable air purifiers) AND effectiveness”. Inclusion criteria were original English language articles from 2000-2025 focused on residential facilities and portable units. Only studies examining PM reduction were considered. Additional references were identified through manual search following the initial literature review.

PAPs showed a reduction in PM_{2.5} concentration in the range of 22.6-92.0% in homes with the use of PAPs using filtration technology (Cheek et al. 2021). However, the amount of reduction depended on many factors, such as ventilation behaviours, both outdoor and indoor PM_{2.5} concentration, different activities (cooking, cleaning, smoking) and proper maintenance of the devices. If filters are not properly maintained and replaced, the PAPs will lower their effectiveness in air filtering, and may even become a source of pollution e.g., a source of endotoxin. While PAPs are working, bacteria may accumulate on the filters, together with particles, where they may be exposed to mechanical stress from the high-speed air flow which may lead to an increase in endotoxin concentrations (Niu et al. 2020). The use of PAPs indoors and its connection with a decrease in cardiovascular and respiratory health symptoms was examined in many studies. In the study of Allen et al. (2011) the connection between PM_{2.5} decrease, and endothelial function based on parameters of inflammation and oxidative stress was examined. They found lower levels of IL-6 and CRP in participants' serum while parameters of oxidative stress were not significantly changed where PAPs operated in homes. In the study by Shao et al. (2017) significant reduction in IL-8 values was observed in 35 participants during a 4-week observational intervention trial. However, overall improvement in lung function, blood pressure, and heart rate variability were not observed probably because of the short follow-up of participants. When it comes to vulnerable population groups, children, especially with asthma, represent a focus group. The study of Jia-Ying et al. 2021 examined the effect of the air purifying treatment for six consecutive months in asthmatic males younger than 18 years old. However, the results showed that there was no statistical difference in inflammation levels between the filtration and non-filtration groups. While indoor PM levels were reduced, evidence on health benefits of air purifiers remains limited, partly due to short study durations that may miss long-term effects. Before recommending their use, the cost of purchase, maintenance, and operation should be addressed. Since some PAPs may generate harmful by-products, this information should be considered too. For all these reasons source-oriented control remains the most effective strategy. In the end but most importantly, reducing PM exposure requires coordinated efforts across individuals, healthcare providers, and government.

REFERENCES

- Allen, R. W., Carlsten, C., Karlen, B., Leckie, S., Van Eeden, S., Vedal, S., et al. 2011. An air filter intervention study of endothelial function among healthy adults in a woodsmoke-impacted community, *American Journal of Respiratory and Critical Care Medicine* 183(9), 1222-1230.
- Cheek, E., Guercio, V., Shrubsole, C., and Dimitroulopoulou, S. 2021. Portable air purification: Review of impacts on indoor air quality and health, *Science of the Total Environment* 766, 142585.
- Jia-Ying, L., Li-Li, O., Jing, M., Xin-Yuan, L., Li-Min, F., Hai-Cheng, L., et al., 2021. Efficacy of air purifier therapy for patients with allergic asthma, *Allergologia et Immunopathologia* 49(5), 16-24.
- Niu, M., Shen, F., Zhou, F., Zhu, T., Zheng, Y., Yang, Y., et al, 2020. Indoor air filtration could lead to increased airborne endotoxin levels, *Environment International* 142, 105878.
- Shao, D., Du, Y., Liu, S., Brunekreef, B., Meliefste, K., Zhao, Q., et al. 2017. Cardiorespiratory responses of air filtration: a randomized crossover intervention trial in seniors living in Beijing: Beijing Indoor Air Purifier Study (BIAPSY), *Science of the Total Environment* 603, 541-549.

4. MANAGEMENT AND PARTICLE CHARACTERIZATION

4.1. IMPLEMENTATION OF SUPERSITES FOR MONITORING NOVEL AIR QUALITY METRICS

A. Alastuey, J. Cortés, M. García Marlés, M. Pandolfi, M. Monge-Azemar, X. Querol
Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, 08034, Spain
andres.alastuey@idaea.csic.es

The recent EU Ambient Air Quality Directive 2024/2881 (EU 2024) highlights the need to further investigate new AQ metrics, such as ultrafine particles (UFP), ammonia (NH₃), black carbon (BC) and the oxidative potential (OP) of the particulate matter. According to the new AQ directive, these pollutants of emerging concern must be measured at monitoring supersites at both rural background locations, and urban background locations, in order to support scientific understanding of their effects on human health and the environment. Each Member State shall establish at least one monitoring supersite per 10 million inhabitants at an urban background location. Member States whose territory is more than 10 000 km², shall establish at least one monitoring supersite per 100 000 km² at a rural background location. To ensure that air pollution information is representative and comparable across the EU, it is important to use standardized measurement techniques and common criteria for the number and location of stations used to assess ambient air quality. Where international, CEN or national reference measurement methods or CEN technical specifications are available, these may be used. Where no standardized method exists, Member States may use their own methods in accordance with the requirements of the directive, bearing in mind the objectives of the measurements. Where appropriate, monitoring should be coordinated with the EMEP monitoring strategy and measurement programme and the Aerosol, Cloud and Trace Gas Research Infrastructure (ACTRIS). This presentation outlines the requirements for implementing the new supersites, as well as their implications, limitations, and added value.

REFERENCES

EU, 2024. Directive 2024/2881/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, Off. J. EU; <https://eur-lex.europa.eu/eli/dir/2008/50/oj..>

4.2. AIR QUALITY MONITORING IN THE CITY OF BELGRADE

A. Šoštarić, A. Cvetković

Institute of Public Health of Belgrade, Belgrade, Serbia

andrej.sostaric@zdravlje.org.rs

Air quality monitoring in Belgrade has been conducted for over 70 years and continues to be an ongoing activity. In 1952, measurements were carried out at only two sites. Today, the local and national monitoring networks operate over 40 monitoring locations, including 36 automatic stations. Data from these automatic stations are updated hourly. Based on near real-time data, the Air Quality Index is calculated and published online, together with health recommendations and pollutant concentrations.

Both networks rely on standard reference methods accredited by the Accreditation Body of Serbia, ensuring that the collected data are of high quality (accurate and precise) and comparable with results from other monitoring networks. In addition to routine measurements defined by the officially adopted Air Quality Monitoring Programme, extended measurements are performed at selected monitoring stations in collaboration with scientific institutions. These activities allow for characterization of pollutants not included in the Programme, providing a more comprehensive understanding of air quality and offering opportunities for capacity building with advanced instrumentation.

Results consistently show that suspended particulate matter is the most prominent air pollutant in Belgrade. Consequently, particular attention is devoted not only to monitoring their mass concentrations but also to analysing their chemical composition.

REFERENCES

Air Quality Monitoring Program for the Territory of Belgrade, 2024–2025.

Air Quality Monitoring Program for the Territory of Belgrade, 2022–2023.

Air Quality Protection Law, Official Gazette of the Republic of Serbia, No. 51/2025.

Directive (EU) 2024/2881 of the European Parliament and of the Council of 23 October 2024 on ambient air quality and cleaner air for Europe (recast).

Regulation on Establishing the Air Quality Monitoring Program in the National Network, Official Gazette of the Republic of Serbia, 2011.

4.3. EVALUATING WILLINGNESS-TO-PAY TO MITIGATE PAIN AND SUFFERING CAUSED BY AIR POLLUTION

J. Soares, H. Relvas, P. Roebeling

Department of Environment and Planning, University of Aveiro, Portugal

joana.estebainha@ua.pt

Air pollution presents a complex global challenge, affecting both human health and the environment (Chen et al., 2024). Existing literature tends to focus either on the economic costs of air pollution or on its associated mortality levels, often excluding intangible impacts, such as pain, suffering, or reductions in quality of life. This study aims to address this gap and estimate the public's willingness to pay (WTP) to reduce the impacts of air pollution, particularly focusing on the emotional and physical suffering associated with it. Using the Contingent Valuation Method (CVM) with a combination of the Double-Bounded Dichotomous Choice (DBDC) and the Open-Ended (OE) formats, this study analyses how individuals value air quality improvements in the Aveiro district in Portugal. A choice-based survey was developed to collect sociodemographic data, assess participants' awareness regarding air pollution and evaluate their personal experience with its health effects. The survey presented two hypothetical government programs: one promoting the transition to electric vehicles and another promoting air purification technologies in households. Results indicated that many respondents believe that the responsibility for addressing air pollution should primarily lie with the government and major polluters. Among those willing to contribute financially, higher values were observed for Program 1 (with an estimated mean WTP of 25.19€/person/month) in comparison to Program 2 (with an estimated mean WTP of 22.11€/person/month). Probit regression models further revealed that income, education level, environmental awareness and personal experience with pollution are statistically significant determinants of WTP. Overall, the study concludes that individuals' willingness to pay for air pollution mitigation is influenced not only by socioeconomic factors such as monthly income or education, but also by personal experiences with pollution-related health and emotional impacts. These findings reinforce the importance of designing environmental policies that address not only environmental improvements but also public trust and context-specific perceptions of air pollution.

REFERENCES

Chen, F., et al.. 2024. Breathing in danger: Understanding the multifaceted impact of air pollution on health impacts. *Ecotoxicology and Environmental Safety*, 280.

4.4. REAL-WORLD CASE STUDY OF PM QUANTIFICATION AND CHEMICAL COMPOSITION OF VEHICLE EMISSIONS IN A LISBON ROAD TUNNEL

A. Nunes (1), S.M. Almeida (1), T. Moreno (2) and V. Martins (1)

(1) *Centro de Ciências e Tecnologias Nucleares (C2TN) & Department of Nuclear Sciences and Engineering (DECN), Instituto Superior Técnico, Universidade de Lisboa, 2695-066, Bobadela-LRS, Portugal*

(2) *Institute of Environmental Assessment and Water Research (IDÆA-CSIC), 08034 Barcelona, Spain*
alexandra.nunes@ctn.tecnico.ulisboa.pt

Road tunnels provide a controlled microenvironment ideal for studying traffic-related particulate emissions (Pio et al, 2013). This research presents a real-world case study designed to quantify and characterize the particulate matter (PM) emissions and their chemical composition inside a road tunnel in Lisbon, complemented by background measurements at a monitoring station. The controlled tunnel atmosphere facilitates the isolation of vehicular sources, allowing a precise profile of elemental and carbonaceous components in emitted aerosols (Cunha-Lopes et al, 2023). The campaign was conducted using samplers fitted with quartz microfiber filters, collecting PM at scheduled intervals to capture representative daily traffic patterns. Elemental composition was determined by Inductively Coupled Plasma Atomic Emission Spectroscopy and Mass Spectrometry (ICP-AES/MS), while organic carbon (OC) and elemental carbon (EC) were quantified via thermal-optical analysis.

Temporal concentration trends mirrored the tunnel's traffic intensity. The lowest PM₁₀ levels appeared during early morning hours (2:30–3:30), correlating with minimal vehicular flow, whereas the highest masses were detected during the evening rush hour (17:00–18:00). Even during periods of light traffic, PM₁₀ concentrations inside the tunnel consistently exceeded those recorded at the background site, confirming the tunnel's function as a pollutant reservoir. Chemical analysis revealed a dominant contribution from EC under high traffic volumes, primarily reflecting combustion emissions from diesel vehicles and incomplete fuel oxidation. OC exhibited more moderate fluctuations, remaining relatively higher at the background station, suggesting stable input from biogenic and secondary organic aerosol sources. Trace metals such as Cu, Fe, and Zn were enriched within the tunnel atmosphere, indicative of brake and tyre wear. These findings corroborate the growing influence of non-exhaust components, which have become crucial emission sources in modern vehicle fleets increasingly reliant on improved combustion systems. The chemical fingerprint of tunnel PM reflects the integrated impact of fleet diversity, fuel types and operational behaviours. The study evidence that PM₁₀ concentrations follow pronounced diurnal variations linked to traffic intensity, and that the accumulation effect inherent to tunnel infrastructure amplifies pollutant concentration levels. Chemical profiling substantiates that EC and metal elements serve as reliable markers of vehicular combustion and mechanical wear processes. These results advocate targeted emission-reduction policies at tunnel exits and within urban traffic corridors. Furthermore, the observed chemical composition contrasts between the tunnel and background environments emphasize the effectiveness of controlled tunnel studies for validating vehicular emissions. The outcomes strongly support a transition toward sustainable transportation strategies, including the expansion of low-emission zones, improvement of public fleets and cycling infrastructure, integrated with urban planning, to promote more efficient mobility, safety and enhanced traffic control in densely populated urban areas.

ACKNOWLEDGEMENTS

This work was supported by the Portuguese Foundation for Science and Technology (FCT) through the project iMPact (reference 2022.03600.PTDC; DOI: 10.54499/2022.03600.PTDC) and the contract CEECIND/04228/2018.

REFERENCES

- Cunha-Lopes, I., Alves, C. A., Casotti Rienda, I., Lucarelli, F., Diapouli, E. et al. 2023. Characterisation of vehicle emissions in a road tunnel environment. *Science of the Total Environment*, 899, 164607.
- Pio, C. A., Mirante, F., Oliveira, C., Matos, M., Caseiro, A., Oliveira, C. et al. 2013. Size-segregated chemical composition of aerosol emissions in an urban road tunnel in Lisbon, Portugal. *Atmospheric Environment*, 73, 513–525.

4.5. SEASONAL ANALYSIS OF PARTICLE NUMBER CONCENTRATIONS AND SOURCES OF POLLUTION AT ADA MARINA SUPERSITE IN THE CITY OF BELGRADE

D. B. Stojanović (1), Ž. Čirović (1), M. Davidović (1), M. Garcia-Marlès (2), N. Perez (2), A. Alastuey (2), M. Jovašević-Stojanović (1)

(1)VIDIS centre, Vinča Institute of Nuclear Sciences-National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia

(2)Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, Spain

dankas@vin.bg.ac.rs

Ultrafine particles (UFPs), defined as particles with diameters below 100 nm, are of particular interest in environmental health due to their deep penetration into the respiratory system (Leikauf et al., 2020). According to the new World Health Organisation Air Quality Guidelines (WHO, 2021), UFP concentration is identified as an important air quality metric. This study provides a comprehensive analysis of the diurnal and seasonal variations in total particle number concentrations (PNC) and UFP particle number size distribution (PNSD) at Belgrade's urban background Ada Marina site. Data was collected using a Mobility Particle Size Spectrometer (MPSS TSI 30XXX, range 10–400 nm), and other equipment for conventional pollutant measurements at Ada Marina site.

This study compares the concentrations of PNC and UFP, along with pollution sources, between the heating and non-heating seasons. Measurements were in the period of February to September 2024, while the heating season officially runs from October 15th to April 15th. As anticipated, average PNC levels are higher during the heating season, reaching a peak of 17,908 cm⁻³, with elevated values in the afternoon and evening. In the non-heating season, the highest concentration recorded is 15,214 cm⁻³, occurring between 9:00 a.m. and 1:00 p.m. The morning and evening peaks are mainly caused by rush-hour traffic emissions. Also, we calculated average PNC for nucleation, Aitken and accumulation modes, obtaining 2,924 cm⁻³, 5,864 cm⁻³, and 1,848 cm⁻³, respectively. These concentrations are in the same range as those registered in the large nearby cities, such as Athens, Budapest and others (Trechera et al., 2023).

When comparing pollution sources between the heating and non-heating seasons, the same sources are identified—biomass burning, nucleation, traffic, and the urban diffuse source—although their relative contributions differ, as expected. Higher concentrations, mainly for particles with diameters in the range 20–80 nm were registered in the heating period. Also, there is also a smaller difference in concentrations of larger particles, indicating that the reasons for higher concentrations in winter can be biomass burning as well as low thickness of boundary layer. At night, the lowering of the boundary layer height leads to higher concentrations of precursors necessary for nucleation, increasing the concentration of particles (Li et al., 2023).

ACKNOWLEDGMENT

This research was funded by: The European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Education, Science and Technological Development of the Republic of Serbia under GA 451-03-136/2025-03/200017.

REFERENCES

- Leikauf, G.D.; Kim, S.-H.2020. Jang, A.-S. Mechanisms of Ultrafine Particle-Induced Respiratory Health Effects. *Exp Mol Med*, 52, 329–337.
- Li, Q. Q. et al. 2023. Review on main sources and impacts of urban ultrafine particles: Traffic emissions, nucleation, and climate modulation. *Atmospheric Environment: X*, 19, 100221.
- Trechera, P., et al. 2023. Phenomenology of ultrafine particle concentrations and size distribution across urban Europe. *Environ. Int.* 172, 107744.
- WHO, 2021. WHO global air quality guidelines: particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization.

5. HEALTH ASPECTS OF ATMOSPHERIC PARTICULATE MATTER

5.1. THE VALUE OF PAN-EUROPEAN OBSERVATIONS FOR THE CHARACTERIZATION OF ATMOSPHERIC AEROSOL PARTICLES: EXPERIENCE FROM THE EUROPEAN PROJECTS FOCI AND RI-URBANS

M. Pandolfi (1), A. Alastuey (1), M. García Marlés (1), M. Savadkoohi (1), J. Rovira (1), H. Navarro-Barboza (2), O. Jorba (2), J. Yus-Díez (3), T. Petäjä (4), X. Querol (1)

(1) Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, 08034, Spain

(2) Barcelona Supercomputing Center (BSC), Barcelona, 08034, Spain

(3) Center for Atmospheric Research, University of Nova Gorica, Vipavska 11c, Ajdovščina, 5270, Slovenia

(4) Institute for Atmospheric and Earth System Research/Physics (INAR), Faculty of Science, University of Helsinki, Helsinki, Finland

marco.pandolfi@idaea.csic.es

Pan-European observations play a crucial role in advancing our understanding of atmospheric aerosol particles and their impacts on air quality, climate, and human health. By integrating harmonized measurements across diverse environments—from urban centers to remote regions—these coordinated efforts provide a comprehensive view of aerosol sources, composition, and dynamics at the continental scale (e.g. Rovira et al., 2025; Savadkoohi et al., 2023, 2024; Navarro-Barboza et al., 2025; Garcia-Marlès et al., 2024). Projects such as FOCI (Non-CO₂ Forcers and their Climate, Weather, Air Quality and Health Impacts) and RI-URBANS (Research Infrastructures Services Reinforcing Air Quality Monitoring) exemplify the value of this approach. They connect research infrastructures and operational networks, bridging the gap between advanced scientific observations and policy-relevant applications. Through shared methodologies, intercomparisons, and open data, these initiatives enhance consistency and reliability in aerosol characterization, support the development of improved air quality models, and strengthen Europe's capacity to address transboundary pollution and climate challenges collaboratively.

REFERENCES

- Garcia-Marlès, M. et al. 2024. Source apportionment of ultrafine particles in urban Europe, *Env. Int.*, 194.
- Navarro-Barboza, H. et al. 2025. Characterization of brown carbon absorption in different European environments through source contribution analysis, *Atmos. Chem. Phys.*, 25, 2667–2694.
- Rovira, J. et al. 2025. A European aerosol phenomenology – 9: Light absorption properties of carbonaceous aerosol particles across surface Europe, *Env. Int.*, 195.
- Savadkoohi, M. et al. 2023. The variability of mass concentrations and source apportionment analysis of equivalent black carbon across urban Europe, *Env. Int.*, 178.
- Savadkoohi, M. et al. 2024, Recommendations for reporting equivalent black carbon (eBC) mass concentrations based on long-term pan-European in-situ observations, *Env. Int.*, 185.

5.2. MODELLING ATMOSPHERIC TRANSPORT OF AEROSOLS

S. Eckhardt, N. Evangeliou

NILU, Kjeller, Norway

sec@nilu.no

Aerosols are key components of the Earth's climate system and important for air quality and health (IPCC, 2021). Their concentrations vary strongly in space and time depending on emission sources, atmospheric transport, and removal processes. Due to atmospheric lifetimes of up to several weeks, aerosols can be transported over long distances influencing regions far from their source. Here we show examples that investigate aerosol source-receptor relationships using the Lagrangian particle dispersion model FLEXPART (Stohl et al., 1998; Pisso et al., 2019), focusing on black carbon (BC) as a tracer for combustion-related aerosols. In addition to present-day analyses, studies cover up to 150 years of aerosol transport, including deposition to Arctic ice cores (Eckhardt et al., 2023).

FLEXPART is a Lagrangian particle dispersion model that simulates the transport and removal of tracer particles in the atmosphere. It is driven by ECMWF meteorological data (ERA-5 or operational analyses) and accounts for advection, turbulence, convection, dry and wet deposition, and gravitational settling. The model allows both forward simulations (from sources to receptors) and backward simulations (from receptors to potential sources). Each particle represents a fraction of mass, enabling the calculation of source-receptor relationships (SRRs) that quantify the sensitivity of receptor concentrations to emissions in different regions. FLEXPART also includes parameterizations for different aerosol types such as dust, sea salt, and microplastics (Evangelou et al., 2020). To constrain emissions, FLEXPART can be coupled with atmospheric inversion techniques, where modelled sensitivities are combined with observations to refine emission estimates (Stohl et al., 2009). Such inversion frameworks have been applied successfully in several studies, e.g., for greenhouse gases and aerosols over China (Mengwei et al., 2023) and during the COVID-19 lockdown period (Evangelou et al., 2021). At NILU, FLEXPART-based SRR products are routinely generated for several European monitoring stations as part of ACTRIS (Aerosol, Clouds, and Trace Gases Research Infrastructure; Laj et al., 2020), providing tools for the interpretation of observed aerosol composition and variability.

FLEXPART successfully reproduces observed BC concentration patterns at multiple European stations. Major contributors to BC levels include domestic heating, traffic, and other combustion sources. The model captures long-range transport events, including wildfire plumes, that elevate background aerosol concentrations far from source regions. Backward simulations identify source areas and their seasonal variability, while age-class analyses provide insights into the atmospheric residence time and transformation of aerosols. Historical modelling studies further reveal how ice core observations in the Arctic can be used to reconstruct emission inventories over the past 150 years (Eckhardt et al., 2023).

Aerosols transported over long distances can substantially influence regional and local air quality. FLEXPART, in combination with observational data and inversion frameworks, provides a powerful tool to trace aerosol origins and constrain emissions. The integration of FLEXPART-based tools within ACTRIS ensures standardized access to SRR products and supports the interpretation of in-situ aerosol measurements. Such analyses are crucial for improving emission inventories, interpreting site observations and understanding the evolving role of both natural and anthropogenic aerosols in the Earth system as well as human health-related challenges.

REFERENCES

- Eckhardt, S. et al. 2023. Black carbon in the Arctic: 150 years of atmospheric transport and deposition recorded in ice cores. *Nature*, 621, 123–129.
- Evangelou, N., Grythe, H., Klimont, Z., Heyes, C., Eckhardt, S., Lopez-Aparicio, S., and Stohl, A. (2020). Atmospheric transport and deposition of microplastics in Europe: A model study. *Environmental Pollution*, 267, 115597.
- Evangelou, N., et al. 2021. Changes in atmospheric composition during the COVID-19 lockdown inferred from FLEXPART-based inversions. *Atmospheric Chemistry and Physics*, 21, 4453–4470.
- IPCC 2021. *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
- Laj, P., et al. 2020. The European Research Infrastructure ACTRIS: Consolidating and expanding aerosol, cloud, and trace gas observations for Earth system research. *Bulletin of the American Meteorological Society*, 101(8), E1365–E1400.
- Mengwei, X., et al. 2023. Top-down estimation of aerosol emissions in China using FLEXPART inversion constrained by observations. *Atmospheric Chemistry and Physics*, 23, 10543–10562.

- Pisso, I., et al. 2019. The Lagrangian particle dispersion model FLEXPART version 10.4. *Geoscientific Model Development*, 12, 4955–4997.
- Stohl, A., et al. 1998. Validation of the Lagrangian particle dispersion model FLEXPART against large-scale tracer experiment data. *Atmospheric Environment*, 32(24), 4245–4264.
- Stohl, A., et al. 2009. An analytical inversion method for determining regional and global emissions of greenhouse gases: Sensitivity studies and application to halocarbons. *Atmospheric Chemistry and Physics*, 9, 1597–1620.

5.3. EMBEDDING LOCAL INVENTORIES IN CHEMISTRY-TRANSPORT MODELLING PIPELINES

D. Chubarov

Airvoice, Belgrade, Serbia
dima.chubarov@airvoice.global

Open source chemistry-transport models are used for air pollution forecasting on a regional scale using meteorological fields produced by regional weather forecasting models and global emission databases for anthropogenic emissions. Many cities have compiled local emission inventories to drive air pollution forecasting. We present preliminary results from an ongoing project to develop a regional air quality forecasting model with the goal to achieve a level of accuracy that allows for scenario assessment of the effectiveness of traffic management policies to reduce air pollution.

After including local emission inventory for road transport we observed higher variability between different locations within the city in agreement with ground observations. The forecast accuracy for PM_{2.5} also improved compared to the baseline case based on global emission inventory. Next steps in the adaptation of the model would involve developing local temporal disaggregation functions for annual emissions based on the historical air pollution monitoring data.

ACKNOWLEDGMENTS

This work is carried out within the framework of "Clean Air Better Life" (CABL) initiative by the Confederation of Indian Industry (CII).

REFERENCES

- Beig, G., Pakhi, Neha, S. 2017. Emission Inventory of Ahmedabad, Institute of Tropical Meteorology Special Scientific Report SAFAR-Ahmedabad-2017-C.
- Mailler, S., Menut, L., Khvorostyanov, D. et al. 2017. CHIMERE-2017: from urban to hemispheric chemistry-transport modeling, *Geoscientific Model Development* 10, 2397–2423.

5.4. DAILY HIGH-RESOLUTION SURFACE PM_{2.5} ESTIMATION OVER EUROPE BY ML-BASED DOWNSCALING OF THE CAMS REGIONAL FORECAST

S. Shetty (1,2), P. D. Hamer (1), K. Stebel (1), A. Kylling (1), A. Hassani (1), T. K. Berntsen (3), P. Schneider (1)

(1) NILU, Kjeller, Norway (2) SatSure Analytics, Bengaluru, India (3) University of Oslo, Oslo, Norway
ps@nilu.no

We introduce a machine learning framework entitled S-MESH (Satellite- and ML-based Estimation of Surface air quality at High resolution) that can generate daily 1 km maps of surface PM_{2.5} across Europe by downscaling the Copernicus Atmosphere Monitoring Service (CAMS) regional 24-h PM_{2.5} forecast with machine learning (Shetty et al., 2025). The approach integrates satellite aerosol optical depth and modelled meteorological predictors in a stacked XGBoost pipeline trained against in-situ monitoring data, balancing coverage, resolution, and computational efficiency. Performance is demonstrated for 2021–2022 over the European domain and evaluated against both the raw CAMS forecast and the CAMS regional reanalysis. Validated against station observations, S-MESH achieves a mean absolute error (MAE) of 3.54 $\mu\text{g m}^{-3}$, improving on the CAMS forecast (MAE = 4.18 $\mu\text{g m}^{-3}$; $\approx 15\%$ reduction) and approaching the reanalysis (MAE = 3.21 $\mu\text{g m}^{-3}$). Mean bias (MB) is substantially reduced ($-0.3 \mu\text{g m}^{-3}$ for S-MESH vs $-1.5 \mu\text{g m}^{-3}$ for the reanalysis). Importantly, at higher concentrations of $>20 \mu\text{g m}^{-3}$ S-MESH better captures pollution peaks, with MB = $-7.3 \mu\text{g m}^{-3}$ compared with $-10.3 \mu\text{g m}^{-3}$ for the reanalysis ($\approx 29\%$ less underestimation), thereby improving representation of severe episodes that are most relevant for exposure assessment and public-health applications. The model also tracks day-to-day variability more closely, reaching a temporal relative absolute error of 5% versus 10% for the re-analysis. This supports its use in time-sensitive analyses such as near-real-time exposure modeling. Spatial evaluation shows particular improvements in the eastern portion of the study area, where wintertime residential heating contributes to elevated PM_{2.5}, which is often underestimated by the re-analysis. Here S-MESH yields higher, more realistic concentrations consistent with the observed patterns. Overall, using a fusion of chemical transport forecasts with satellite and meteorological information in a computationally efficient ML approach, S-MESH delivers continent-scale, daily, kilometre-resolution PM_{2.5} fields with high accuracy, thus making it well suited for health impact assessments, policy evaluation, and urban-scale applications where both spatial detail and timeliness are critical.

REFERENCES

Shetty, S., Hamer, P. D., Stebel, K., Kylling, A., Hassani, A., Berntsen, T. K., and Schneider, P. 2025. Daily high-resolution surface PM_{2.5} estimation over Europe by ML-based downscaling of the CAMS regional forecast, *Environmental Research*, 264, 120363.

5.5. SECONDARY ORGANIC AEROSOL FORMATION FROM THE AROMATIC HYDROCARBON PRECURSORS

I. G. Bejan

Department of Chemistry, Faculty of Chemistry and Integrated Centre of Environmental Science Studies in the North Eastern Region, ICI-CERNESIM “Alexandru Ioan Cuza” University of Iasi, 11 Carol I, 700506 Iasi, Romania

iustinian.bejan@uaic.ro

The atmosphere is a complex system composed of gas-phase compounds and particulate matter. Aromatic hydrocarbons (AHs) are widely distributed in the atmosphere and originate from both natural and anthropogenic activities. Major anthropogenic sources include vehicle exhaust, industrial and residential combustion, petrochemical and refinery operations, as well as emissions from the plastics, dye, and solvent industries. Biomass and waste burning also contribute significantly (Clavert et al., 2002). Although natural sources are less significant, forest fires, oceanic and microbial activity, and emissions from plants and trees under stress can also release aromatic compounds into the atmosphere (Finlayson-Pitts and Pitts, 2000).

Atmospheric aerosols from biogenic and/or anthropogenic emissions affect significantly visibility, quality of air and climate. They can scatter and absorb solar radiation, producing both direct and indirect radiative effects. The effect on human health including respiratory and cardiovascular diseases, asthma, and respiratory tract cancers depends on the composition of aerosols and its toxic and carcinogenic properties (Seinfeld and Pandis, 2012). Aromatic compounds are major precursors of secondary organic aerosols (SOA). SOA from aromatic precursors plays a crucial role in urban atmospheric chemistry, local and regional climate forcing and public health (Al-Naiema et al., 2020). Once released in the atmosphere, AHs react with atmospheric radicals forming successive generations of gas-phase oxidation products. The formation mechanisms and yields of these potential SOA precursors are often investigated through controlled simulation chamber experiments (Bejan et al., 2020).

This study aims to investigate the potential formation of the secondary organic aerosols from the direct photolysis and OH radical initiated oxidation of aromatic compounds. The investigations were performed in different sized simulation chambers mostly under simulated solar radiation. FTIR (Fourier Transform Infrared Spectroscopy) was the main technique used to evaluate concentrations of gas-phase precursors while SMPS (scanning Mobility Particle Sizer) has been employed to monitor the SOA size distribution. The experiments in this study were performed in synthetic air (296 ± 3 K and 1013 mbar).

These investigations on the SOA formation from different aromatic compounds were focused on yields dependency on the SOA precursors. The studied aromatics containing different substituent groups ($-\text{CH}_3$, $-\text{OH}$, $-\text{CH}=\text{CH}_2$, $-\text{NO}_2$, $-\text{OCH}_3$, etc.), affect reactivity towards OH radicals and SOA yields. All SOA formation experiments were fitted using the Odum model considering one major component for the partition between gas and particle phase.

ACKNOWLEDGEMENT

Authors acknowledge the grant support offered by PN-IV-P8- 8.3-PM-ROFR-2024- 0178 (NaOH) and the SIDNER project (Cod SMIS: 337821), project PR/NE/2024/P1/RSO1.1/1/2 – RDI INFRASTRUCTURES.

REFERENCES

- Al-Naiema, I.M., Offenberg, J.H., Madler, C.J., Lewandowski, M., Kettler, J., Fang, T., Stone, E.A. 2020. Secondary Organic Aerosols from Aromatic Hydrocarbons and their Contribution to Fine Particulate Matter in Atlanta, Georgia, *Atmospheric Environment*, 223, 117227.
- Bejan, I., Olariu, R.I., Wiesen, P. 2020, Secondary Organic Aerosol Formation from Nitrophenol Photolysis under Atmospheric Conditions, *Atmosphere*, 11(12), 1346.
- Calvert, J., Atkinson, R., Becker, K.H., Kamens R., Seinfeld, J., Wallington, T, and Yarwood, G. 2002. *The Mechanisms of the Atmospheric Oxidation of Aromatic Hydrocarbons*; Oxford University Press: New York, NY, USA.
- Finlayson-Pitts, B.J. and Pitts, J.N.J. 2000. *Chemistry of the Upper and Lower Atmosphere*. Academic Press, Cambridge.
- Seinfeld, J.H. and Pandis, S.N. 2012. *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*. John Wiley & Sons, Hoboken.

6. SOURCE APPORTIONMENT OF PARTICLES I

6.1. SOURCE APPORTIONMENT OF CARBONACEOUS AEROSOL IN BELGRADE

S. M. Platt (1), M. Davidović (2), A. Bartonova (1), Ž. Čirović (2), S. Eckhardt (1), N. Evangeliou (1), H. Gundersen(1), M. Jovanović(2), M. Jovašević-Stojanović (2), G. Močnik (3), B. Petrović (2), P. Schneider (1), K. E. Yttri (1)

(1) NILU, Kjeller, Norway, (2) VIDIS centre, Vinca Institute of Nuclear Sciences- National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, (3) Center for Atmospheric Research, University of Nova Gorica, Ajdovščina, Slovenia

sp@nilu.no

Carbonaceous aerosol measurements are scarce in South-Eastern Europe, despite their large health and climate impacts. We present the first year-round source apportionment of carbonaceous aerosol at the urban-background site Ada Marina (Belgrade) combining offline filter analyses, online multi-wavelength aethalometer data, and transport modelling.

PM₁₀ filters were analysed for elemental carbon (EC), organic carbon (OC), and organic tracer species including levoglucosan. Contributions to EC and OC from biomass burning, primary biological aerosol particles, and fossil fuel combustion were derived from the measured tracers. Secondary organic carbon (SOC) was derived as the residual fraction after the tracer-based source apportionment. Online equivalent black carbon (eBC) was derived from absorption at 880 nm and separated into liquid- and solid-fuel fractions using both an optimised aethalometer model and a novel ensemble non-negative matrix factorisation (NNMF) approach. Source attribution was validated against offline tracer-based results and FLEXPART backward modelling using high-resolution gridded residential and non-residential emission inventories.

Annual mean eBC and PM₁₀ were below EU limits, but above WHO guidelines, and above the revised EU air quality directive future limit values. All methods identified residential wood combustion (RWC) as the dominant wintertime source. Enhanced brown-carbon absorption and a strong correlation between secondary OC and biomass-burning EC suggest a major anthropogenic SOC component from RWC. FLEXPART simulations show regional transport from Serbia and the Pannonian Basin during pollution episodes, with high correlation between modelled residential emissions and observed EC and levoglucosan, underscoring the policy relevance of RWC as a lever for targeting residential combustion mitigation, since high model skill allows evaluation of mitigation measures.

Carbonaceous aerosol in Belgrade is dominated by fossil-fuel emissions for most of the year and by residential wood combustion in winter. The new NNMF method yields physically consistent results and can provide additional information on spectral characteristics or replace the conventional aethalometer model. Substantial RWC emission reductions could help achieve compliance with future EU PM₁₀ limits and WHO air-quality guidelines, especially if a major fraction of SOC is also from this source.

REFERENCES

- Lee, D. D. and Seung, H. S. 1999. Learning the parts of objects by non-negative matrix factorization, *Nature*, 401, 788–791.
- Yttri, K. E., Bäcklund, A., Conen, F., Eckhardt, S., Evangeliou, N., Fiebig, M., Kasper-Giebl, A., Gold, A., Gundersen, H., Myhre, C. L., Platt, S. M., Simpson, D., Surratt, J. D., Szidat, S., Rauber, M., Tørseth, K., Ytre-Eide, M. A., Zhang, Z., and Aas, W. 2024. Composition and sources of carbonaceous aerosol in the European Arctic at Zeppelin Observatory, Svalbard (2017 to 2020), *Atmos. Chem. Phys.*, 24, 2731–2758.
- Zotter, P., Herich, H., Gysel, M., El-Haddad, I., Zhang, Y., Močnik, G., Hüglin, C., Baltensperger, U., Szidat, S., and Prévôt, A. S. H. 2017. 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.*, 17, 4229–4249.

6.2. COMPARISON OF SA FOR BOR IN THE CAMPAIGNS 2009-2010 AND 2019

R. Kovačević (1), B. Radović (1), V. Tasić (1), T. Apostolovski-Trujić (1), M. Janošević (1), M. Nikolić (2), M. Jovašević-Stojanović (3)

(1) Mining and Metallurgy Institute Bor, Serbia, (2) Faculty of medicine, University of Nis, Serbia,

(3) Vidis Centre, Vinca Institute of Nuclear Sciences- National Institute of the Republic of Serbia, University of Belgrade, Serbia
renata.kovacevic@irmbor.co.rs

Between 2010 and 2018, RTB Bor complex implemented its most extensive modernization program in decades. Key achievements include the construction of a completely new flash smelter, incorporating a flash furnace, converter units, a waste-heat boiler, redesigned gas-handling systems, new electrostatic and baghouse filtration, and a new main stack. In parallel, RTB complex completed the construction of new Sulfuric Acid Plant with modern absorption towers, cooling systems, and gas pipelines dedicated to SO₂ capture and conversion. Within the same industrial zone, RTB complex also modernized the Anode Casting Plant, partially upgraded the Copper Electrolysis Plant, renewed technological water-cooling infrastructure, improved energy systems, and removed several obsolete buildings.

To assess the effect of the reconstruction on air pollution, a second source apportionment PMF5.0 study was conducted using PM₁₀ samples collected in 2019 in the city park located near the RTB industrial complex. The results were compared with the data of first SA PMF5.0 study from 2010.

The optimal PMF solution showed six factors for second SA PM₁₀ study. The first factor is significant for Cd, As, Bi, Pb, Mo, Se, Cu, Zn and Sn and accounted for 80.4, 80.0, 78.7, 71.7, 66.3, 63.2, 61.8, 60.6 and 50.5% of their modelled concentrations, respectively. Copper, arsenic, lead, and cadmium appear to be the best indicators of smelter impacts because emissions are relatively rich in these metals. These species are formed during the melting of copper concentrate in a smelting furnace, so the factor is marked as Flash Smelting furnace. Despite the fact that a high percentage of these metals is present in this source, the total contribution of the smelter to the mass of PM₁₀ is only 10.3%.

The second source marked as Industrial dust makes the largest contribution to PM₁₀ mass of 43.1%. Moderate contributions of many species including Ni (29.1%), Cl⁻ (28.8%), NO₃⁻ (27.6%), Cr (22.1%), Ba (18.7%), Mn (14.9%), Sn (13.9%) and Fe (13.2%) occurred in this factor.

The third factor describes secondary aerosol with significant percent contributions to NH₄⁺ (73.89%) and non-sea sulphate (nss-SO₄²⁻) (57.9%). This source marked as Secondary sulphate contributed 22.1% to PM₁₀ mass in total.

The fourth factor is characterised by large contributions to Al (90.8%), Mn (57.7%), Na (55.8%) with moderate amounts of Mg (44.5%), Ba (29.0%) and Sr (26.5%). The factor is marked as Resuspension from tailing because most of these species are thought to bring wind from the tailings located behind the smelter and plant in the mining complex. The remaining two factors with significantly smaller contributions are Fuel combustion (3.5%) and Converter line (2.4%).

REFERENCES

Kovačević, R., Radović, B., Manojlović, D., Urošević, T., Apostolovski-Trujić, T., Tasić, V., Jovašević-Stojanović, M. 2024. Determining the PM₁₀ pollution sources near the Copper smelter in Bor, Serbia. *Atmosphere* 15(12), 1948.

6.3. SOURCE APPORTIONMENT OF PM₁₀ IN BOR FROM THE WEBASOOP CAMPAIGN – PRELIMINARY RESULTS

B. Radović (1), R. Kovačević (1), B. Petrović (2), A. Alastuey (3), K.E. Yttri (4), M. Pandolfi (3), A. Bartonova (4), M. Jovašević-Stojanović (2)

(1) Mining and Metallurgy Institute Bor, Serbia, (2) Vidis centre, Vinca Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia, (3) Institute of Environmental Assessment and Water Research, (IDAEA-CSIC), Barcelona, Spain, (4) NILU, Norway

bojan.radovic@irmbor.co.rs

Air pollution is global challenge with significant impacts on both climate and human health (Manisalidis et al. 2020). Rapid urbanization and industrialization have supported economic development but have also intensified environmental pollution (Zafar et al. 2020). The town of Bor, Serbia, is widely recognized for its extensive copper deposits, which are among the largest in Europe (Serbula et al., 2013). The Mining-Metallurgical Complex Bor is considered the primary source of environmental pollution in the region, due to emissions from the copper smelter, open pits, tailing ponds and associated industrial activities (Serbula et al., 2015).

Here we present a preliminary source apportionment of PM₁₀ based on a one-year measurement campaign at an urban-industrial site (City Park) in Bor.

PM₁₀ was collected every second day (midnight to midnight) using low volume samplers (Flow rate: 2.3 m³ h⁻¹). Chemical characterization included analysis of organic carbon (OC) and elemental carbon (EC), elements, inorganic ions, and organic tracers. Positive Matrix Factorization (PMF 5.0) was applied to the PM₁₀ chemical composition dataset to identify the major sources and quantify their contribution to PM₁₀ mass.

PMF resolved eight factors: secondary inorganic aerosol (SIA), city dump combustion particles (CD COMB), industrial dust (INDD), biomass burning (BB), smelter emissions (SMELTER), mineral dust (MD), primary biological aerosol particles (PBAP), and biogenic secondary organic aerosol from isoprene oxidation (BSOA_{Isoprene}). Secondary inorganic aerosols were dominated by NO₃⁻, SO₄²⁻ and NH₄⁺. Approximately half of the OC and EC were attributed to the city dump factor, while the remaining portion was associated with residential wood burning (BB factor) and the smelter source. Two distinct industrial sources were identified: smelter emissions, characterized by As, Cd, Pb, and Se, and industrial dust enriched in Cu. Mineral dust showed high contributions from crustal elements, such as Al, Fe, Ca, and Ti. The PBAP factor was defined by sugars and sugar alcohols, and BSOA_{Isoprene} by 2-methyltetrols.

This study provides a scientific basis for air-quality management in Bor. The results can support the identification of priority emission sectors, be of support for mitigation strategies, and guide public health protection measures.

ACKNOWLEDGMENTS

This research was funded by: The European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Education, Science and Technological Development of the Republic of Serbia under GA 451-03-136/ 2025-03/200052 and GA 451-03-136/2025-03/200017.

REFERENCES

- Manisalidis, I., Stavropoulou, E., Stavropoulos, A., and Bezirtzoglou, E. 2020. Environmental and health impacts of air pollution: a review. *Frontiers in public health*, 8, 14.
- Serbula, S. M., Kalinovic, T. S., Kalinovic, J. V., and Ilic, A. A. 2013. Exceedance of air quality standards resulting from pyro-metallurgical production of copper: a case study, Bor (Eastern Serbia). *Environmental earth sciences*, 68(7), 1989-1998.
- Šerbula, S. M., Ćivković, D. T., Radojević, A. A., Kalinović, T. S., and Kalinović, J. V. 2015. Emission of SO₂ and SO₄²⁻ from copper smelter and its influence on the level of total s in soil and moss in Bor and the surroundings. *Hemijska industrija*, 69(1), 51-58.
- Zafar, A., Ullah, S., Majeed, M. T., Yasmeen, R. 2020. Environmental pollution in Asian economies: does the industrialisation matter?. *OPEC Energy Review*, 44(3), 227-248.

6.4. SOURCE APPORTIONMENT OF PM₁₀ IN BELGRADE CITY FROM THE WEBASOOP PROJECT – PRELIMINARY RESULTS

B. Petrović (1), A. Alastuey (2), K.E. Yttri (3), M. Pandolfi (2), A. Bartonova (3), M. Jovasević-Stojanović (1)

(1) VIDIS centre, Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, (2) Institute of Environmental Assessment and Water Research, (IDAEA-CSIC), Barcelona, Spain, (3) NILU, Norway
bojana.petrovic@vin.bg.ac.rs

To improve air quality and reduce adverse health effects of particulate matter (PM), comprehensive monitoring and source identification are essential. The aim of this study is to provide reliable source apportioned data that support the development of effective mitigation measures (Hopke et al, 2016). A one-year PM₁₀ sampling campaign (June 2023 – May 2024) was conducted at an urban background site (Ada Marina) within the recreational area of Ada Ciganlija, Belgrade (Serbia). Aerosol filter samples were collected every second day (midnight to midnight) using low volume samplers (2.3 m³ h⁻¹). Chemical analysis included organic carbon (OC) and elemental carbon (EC), 27 elements, 4 ions, and 12 organic tracers. Positive Matrix Factorization (PMF 5.0) was applied to the PM₁₀ composition data to identify major sources and quantify contributions to the PM₁₀ mass. The first factor resolved was biomass burning, explained by monosaccharide anhydrides, K, and OC, typical markers of wood combustion (Liu et al, 2025), was the dominant source, contributing 21% of PM₁₀. The NaCl/COMB factor, representing a combination of NaCl from regional (marine) and local (road salt) origin and seasonal combustion, was dominated by Na, NO₃⁻ and Cl⁻. Increased Na was associated with air masses from the North Atlantic, the Mediterranean, and the North Sea, as well as intensive road salting during a January 2024 snow episode in Belgrade. Contributions of EC and levoglucosan indicate mixed fossil fuel and biomass combustion influences in winter. This factor contributed the least to PM₁₀ mass, 9%. The MD factor exhibited strong crustal signatures and contributed 17% to PM₁₀. Diagnostic ratios (Na/Al = 0.14 and K/Al = 0.27) (Moreno et al, 2006) and footprint sensitivity analysis point to Northern Africa as the source region, consistent with a Saharan dust episode in March 2024. The PBAP factor, characterized by sugars and sugar alcohols, accounted for 10% of PM₁₀. BSOA_{Isoprene}, identified by 2-methyltetrols, also contributed 10%. Both biological factors were prominent during the warm, non-heating season. The (NH₄)₂SO₄ factor contributed 18% to PM₁₀, dominated by NH₄⁺ and SO₄²⁻, reflecting a persistent regional secondary aerosol background. The mixed TRA/IND factor, characterized by EC, Fe, Sb, Cu, Sn, Mn, Pb, V, Cd and As, typically associated with tailpipe emissions, non-exhaust traffic emissions, coal combustion, and industrial processes (Pandolfi et al., 2016), represented 15% of PM₁₀. Its OC/EC ratio (2.5) exceeded the typical primary traffic value (OC/EC ~ 1 in PM₁₀ at urban background sites; Pio et al. 2011), indicating combined contributions from non-exhaust emissions and secondary organic aerosol mixed with primary emissions.

ACKNOWLEDGMENTS

This research was funded by: The European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Education, Science and Technological Development of the Republic of Serbia under GA 451-03-136/2025-03/200017.

REFERENCES

- Hopke, P. K. 2016. Review of receptor modeling methods for source apportionment. *Journal of the Air & Waste Management Association*, 66(3), 237-259.
- Liu, X. et al., 2025. Source apportionment of PM₁₀ based on offline chemical speciation data at 24 European sites. *npj Climate and Atmospheric Science*, 8(1), 255.
- Moreno, T., et al. 2006. Geochemical variations in aeolian mineral particles from the Sahara–Sahel Dust Corridor. *Chemosphere*, 65(2), 261-270.
- Pandolfi, M., et al. 2016. Trends analysis of PM source contributions and chemical tracers in NE Spain during 2004–2014: a multi-exponential approach. *Atmospheric Chemistry and Physics*, 16(18), 11787-11805.
- Pio, C. et al. 2011. OC/EC ratio observations in Europe: Re-thinking the approach for apportionment between primary and secondary organic carbon. *Atmospheric Environment*, 45(34), 6121-6132.

6.5. SOURCE APPORTIONMENT IN THE CITY OF BELGRADE AT ADA MARINA URBAN BACKGROUND SITE

Ž. Ćirović (1), D. B. Stojanović (1), M. Garcia-Marlès (2), N. Perez (2), A. Alastuey (2), M. Jovašević-Stojanović (1)

(1) VIDIS Centre, Vinca Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia (2) Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, Spain
zeljko.cirovic@vin.bg.ac.rs

Particulate matter is widely known as a significant air pollutant due to its proven detrimental impact on human health (WHO_2024). Ultrafine particles (UFP) are defined as particles with diameters smaller than 100 nm and there is the evidence that they have notable health effects (Leikauf et al, 2020). While larger particles have higher mass concentrations, smaller particles tend to have lower mass concentrations but higher particle number concentrations (PNC) and larger surface areas, which may contribute to more significant adverse health effects (Oberdörster et al, 2005). Thus, identifying the sources of UFP is essential for formulating effective mitigation strategies. Quantifying the contributions of sources can be done by particle number size distribution (PNSD) which is measured by calculating UFP for specific size ranges (Trechera et al, 2023).

This study apportioned the sources of PNSD by analyzing the data collected between February and September 2024, about two months of heating and four months of non-heating season at Ada Marina, urban background site, recreation complex, in the city of Belgrade, the capital of Serbia. The particle sources were analyzed using positive matrix factorization (PMF) of PNSD along with equivalent Black Carbon (eBC), as well as key air pollutants like PM₁₀, PM_{2.5}, O₃, SO₂, NO, NO₂ and NO_x. The source profiles, derived using the EPA PMF5 software, were analyzed with consideration for potential regional and local sources. It was also taken into account that air pollutant levels, including particulate matter fractions, fluctuate over time, influenced by a combination of emission rates and meteorological conditions (Trechera et al, 2023, Garcia-Marlès et al, 2024). Seven factors were identified: local nucleation and nucleation growth, urban diffuse source, biomass burning and three traffic sources including the mixed sources which includes other contributions. Wind directions indicate the influence of local as well as non-local sources. Traffic was the main factor accounting for 54 % of total emissions with low wind speeds from the east sector, indicating the local origin related to the main roads. Local nucleation and nucleation growth account for 24 % of total emissions and are originated mainly from the west sector. Conducting this type of study over longer periods can be highly valuable for investigating the health effects of ultrafine particles and for identifying the most appropriate emission-reduction measures.

ACKNOWLEDGMENTS

This research was funded by: The European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Education, Science and Technological Development of the Republic of Serbia under GA 451-03-136/2025-03/200017.

REFERENCES

- Garcia-Marlès, M., et al. 2024. Source apportionment of ultrafine particles in urban Europe. *Environ. Int.*, 194, 109149.
- Leikauf, G.D. et al. 2020. Mechanisms of Ultrafine Particle-Induced Respiratory Health Effects. *Exp Mol Med*, 52, 329–337.
- Oberdörster, G. Oberdörster, E., Oberdörster, J. 2005. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. *Environ. Health Perspect.*, 113(7), 823-839.
- Trechera, P., et al. 2023. Phenomenology of ultrafine particle concentrations and size distribution across urban Europe. *Environ. Int.*, 172, 107744.
- WHO, 2024. Ambient (outdoor) air pollution, 2024. Fact sheet, WHO, [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).

7. SOURCE APPORTIONMENT OF PARTICLES II

7.1. SOURCES OF URBAN PM_{2.5} IN THE MAIN CITIES OF THE ENLARGEMENT REGION

C.A. Belis, A. Kona, P. Thunis, E. Pisoni, S. Zauli-Sajani, A. De Meij, A. Rey-Pommier, F. Pekar

European Commission Joint Research Centre Via E. Fermi, Ispra, VA, Italy

claudio.belis@ec.europa.eu

Many European cities suffer the impact of air pollution and PM_{2.5} is mainly responsible for adverse health effects including premature deaths and morbidity (EEA, 2024). The countries involved in the EU Enlargement Policy (e.g. Western Balkans, Ukraine, etc.) are at different steps of aligning their legislation with the European body of laws (*EU Acquis*), including provisions concerning Environment and Climate (Chapter 27). For instance, the current EU limit values are not always met in the Western Balkans (Belis et al., 2024) and the total premature deaths attributable to PM_{2.5} in the main cities of this region in 2019 were between 4 600 and 5 300 (Belis et al., 2023). In the same year, 43 000 premature deaths were reported in Ukraine (Belis et al., 2025).

A critical barrier to effective action at the city level lies in the limited available data to support the choice of cost-effective strategies within the geographical area under the jurisdiction of the policy-maker. To support local authorities in dealing with this challenge, the present study focuses for the first time on the PM_{2.5} sources in the main cities from the entire Enlargement region (118), providing city specific source allocation information in terms of sector and spatial dimensions based on 2022 annual PM_{2.5} concentrations. The study area has been subdivided in three regions with spatial continuity: Western Balkans, Ukraine and Moldova, and Türkiye and Georgia.

The “Screening for High Emission Reduction Potentials for Air quality” tool (SHERPA), developed by the Joint Research Centre to quantify the origins of air pollution in cities and regions (Thunis et al., 2016; Pisoni et al., 2019), was deployed to quantify the spatial and source allocation of PM_{2.5} concentrations in 32 urban areas from the Western Balkans, 40 in Ukraine and Moldova and 46 in Türkiye and Georgia. In terms of spatial dimension, five distinct scales were defined: “core city”, “greater city”, country, transboundary and external. While the sectorial apportionment of PM_{2.5} quantified the impact from anthropogenic activity sectors (residential heating, road transportation, agriculture, industry, shipping and others not included in the previous sectors), and from natural sources, to the total PM_{2.5} concentration in each city.

In the Western Balkans, 22% of the annual PM_{2.5} concentrations derive from one city, plus the surrounding greater city, and the share rises to 38% in Ukraine and Moldova and to 30% in Türkiye and Georgia. The share of population in urban areas in which the city’s own emissions are the highest ranges between 51% and 79%, depending on the region. These figures highlight the role of the local emissions and consequently the importance of actions taken at the city level.

Regarding the sectorial contribution, residential heating is the largest contributor to PM_{2.5} pollution in many urban areas. This source accounts for 40% of total PM_{2.5} in the Western Balkans, while its role falls to 23% in Ukraine and Moldova and to 31% in Türkiye and Georgia. Industrial emissions have higher impact in Ukraine and Moldova (34%), followed by Türkiye and Georgia (27%) and the Western Balkans (22%).

REFERENCES

- Belis, C.A., Djatkov, D., Dobricic, S., De Meij, A., Kolarević, S., Arias Navarro, C., Wojda, P., Jones, A., Lamy, M.-C., Porcel Rodriguez, E., Marinov, D. and Lettieri, T. 2024. Status of Environment and Climate in the Western Balkans, Publications Office of the European Union, Luxembourg
- Belis, C.A., Matkovic, V., Ballocci, M., Jevtic, M., Millo, G., Mata, E., Dingenen, R.V., 2023. Assessment of health impacts and costs attributable to air pollution in urban areas using two different approaches. A case study in the Western Balkans. *Environment International* 182, 108347.
- Belis, C.A., Petrosian, A., Turos, O., Maremhuka, T., Morhulova, V., Kona, A., Djatkov, D., Caudullo, G., Ceccherini, G., Beck, P.S.A., San-Miguel, J., Arias Navarro, C., Wojda, P., Jones, A., Hanke, G., Mariani, G. and Carravieri, A., 2025. Status of Environment and Climate in Ukraine, Publications Office of the European Union, Luxembourg.
- EEA, 2024. Briefing no. 21/2024, Harm to human health from air pollution in Europe: burden of disease status, 2024.
- Pisoni E., Thunis P., Clappier A., 2019. Application of the SHERPA source-receptor relationships, based on the EMEP MSC-W model, for the assessment of air quality policy scenarios, *Atmospheric Environment: X*, Volume 4, 100047.
- Thunis, P., Degraeuwe, B., Pisoni, E., Ferrari, F., Clappier A., 2016. On the design and assessment of regional air quality plans: The SHERPA approach, *Journal of Environmental Management*, 183, 952-958.

7.2. PARTICULARITIES OF SOURCE APPORTIONMENT FOR EUROPEAN NORTHERNMOST MOSCOW MEGACITY

O. Popovicheva (1), M. Chichaeva (2), N. Kosheleva (2), N. Kasimov (2)

(1) *Scobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow*

(2) *Faculty of Geography, Lomonosov Moscow State University, Moscow*

olga.popovicheva@gmail.com

Identification of sources responsible for observed particulate pollution levels is crucial for protection of public health in megacities, because high population density and socioeconomic activities result in numerous emission sources. In a northern megacity, peculiar climatological characteristics related to heating system operation, high levels of fuel consumption and population activity make it an important issue for assessment by advanced aerosol characterization. This is the first source apportionment study performed for Moscow, where a centralized gas-fuelled heating system operates during cold seasons. Biomass and coal are not used in the residential sector, unlike other European megacities (Popovicheva et al., 2024).

PM₁₀ sampling was carried out during the spring of 2018, and autumn and winter of 2019-2020 at the Aerosol Complex of Moscow State University, classified as urban background site. Samples were analysed for (i) major and trace elements by ICP-MS, ICP-AES and XRF, (ii) OC and EC by thermo-optical transmittance method, and (iii) major ionic species by IC. PM₁₀ concentrations were measured by TEOM 1400a. Chemical mass balance, polar plots, positive matrix factorization (PMF), trajectory clustering were employed for characterizing aerosol speciation, identifying meteorological influence and source origin, and apportioning contributions from each source. PM₁₀ concentrations were higher during spring associated with soil re-suspension after the snow cover melted, followed by autumn and winter. Varied distinctive aerosol speciation was associated with seasonality. Soil dust increases in spring and decreases in summer; K⁺ acts as a marker of fires in spring as well as for the domestic biomass burning in the region around the megacity in autumn and winter. Secondary aerosol components always dominate over all other inorganic ion species. Salt components (Na⁺ and Cl⁻) are attributed to de-icing agents used in road management.

Emission sources in this northern megacity pose the several specific peculiarities: they reflect the impact of a centralized heating supply fuelled by natural gas and winter road management. SO₄²⁻ concentrations are more comparable with values in European regional background sites than with cities where wood and petroleum coke/fuel oil are widely used for residential heating and power generation. The low temperature and solar radiation in Moscow do not support intensive photochemical processes of secondary inorganic aerosol formation. City dust is a major factor in spring, dominated by re-suspended soil, road dust, and construction; the last of these is because of rapid development during the last decade in the Moscow conurbation. Traffic encompasses emissions derived from exhaust and non-exhaust of vehicles, demonstrating a high contribution of road dust highly mixed with mineral dust. The contribution of the secondary aerosol sources shows strong seasonality driven by nitrate, with a low impact in spring and a high one in winter. The continuous operation of gas-fuelled centralized heating systems support secondary aerosol formation during the cold period, indicating an opposite trend of this source compared with southern cities where photochemical processes cause maximum impact in the warm seasons. BB daily contributions reveal pronounced levels in autumn, a distinction from European and Asian cities where emissions from BB remain a major driver of winter-time aerosol pollution due to use of biomass for residential heating. Trace elements in the industrial factor indicate the impact of metal manufacturing plants. All of the mentioned factors are influenced by long-range transport from western, northern, and southern populated and industrialized regions surrounding the megacity. De-icing is a major source of the ubiquity of road salt aerosols with no negligible impact in autumn and summer because of the different mobility and remobilization of salts.

No critical issues about aerosol atmospheric pollution were observed, in comparison to large European and Canadian cities (Zappi et al., 2023), despite Moscow being one the most populated metropolitan areas over Europe and the world. This work was supported by the Russian Science Foundation (project no. 19-77-30004II).

REFERENCES

- Popovicheva, O., Diapouli, E., Chichaeva, M., Kosheleva, N., Kovach, R., Bitukova, V., Eleftheriadis, K. and Kasimov, N. 2024. Aerosol Characterization and Peculiarities of Source Apportionment in Moscow, the Largest and Northernmost European Megacity. *Science of The Total Environment*, 170315.
- Zappi, A., Popovicheva, O., Tositti, L., Chichaeva, M., Eremina, I., Kasper-Giebl, A., Tsai, Y.I., Vlasov, D. and Kasimov, N. 2023. Factors Influencing Aerosol and Precipitation Ion Chemistry in Urban Background of Moscow Megacity. *Atmospheric Environment*, 294,119458.

7.3. COMBINING PM₁ AND PM₁₀ LONG TIME SERIES FOR AN ENHANCED PMF SOURCE APPORTIONMENT

J. Cortés, A. Alastuey, M. Pandolfi, C. Reche, N. Perez, M. López, K. Glojek, X. Querol

Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, 08034, Spain.

joaquim.cortes@idaea.csic.es

A study has been conducted into the contribution of sources to PM₁ and PM₁₀ levels at the Palau Reial urban background station in Barcelona, north-eastern Spain, for the period 2014-2024. Complete chemical characterization was carried out on 24-hour samples of PM₁ (1000 samples) and PM₁₀ (1365 samples), collected every 1-3 days.

Trends in chemical composition were studied using OpenAir from R Studio, revealing a clear decrease in SIA, EC and specific tracer metals, while mineral matter, marine aerosol and OC showed no clear trend. The contribution of PM₁ and PM₁₀ sources, as well as the coarse fraction (PM_{coarse} = PM₍₁₀₋₁₎), was estimated using the positive matrix factorization (PMF) receptor model developed by the EPA, based on days with simultaneous PM₁ and PM₁₀ sampling. Applying PMF to the PM₁ and PM_{coarse} fractions identified 9 sources contributing PM₁₀: six of which contribute to PM₁ and seven to coarse PM with four common to both fractions. These results are an improvement on those obtained when applying PMF to PM₁₀ alone, as the separation allowed an additional source contributing to coarse PM to be detected.

Trends in the contributions of the identified sources show a decrease in the contribution of some anthropogenic sources, primarily traffic, heavy fuel oil combustion, and industry. While these sources have shown a continuous decline due to mitigation policies adopted by the European Union over the years, a more pronounced decline has been observed due to the cessation of activities during the pandemic. Other sources, such as mineral matter and marine aerosols, have not shown a clear trend in the chemical profiles of the identified sources. PMF was applied over four-year periods, and no significant variation in the profiles was observed.

7.4. CHEMICAL SPARSITY IN BAYESIAN RECEPTOR MODELS FOR AEROSOL SOURCE APPORTIONMENT

M. Via (1), J. Demšar (2), Y. Hao (3), M. Manousakas (3),(4), A. Rusanen (5), J. Jiang (6), S. K. Grange (7), J-L. Jaffrezo (8), V. Dinh (8), G. Uzu (8), G. Močnik (1), and K. R. Daellenbach (4)

(1) Center for Atmospheric Research, University of Nova Gorica, Ajdovščina 5270, Slovenia (2) Faculty of Computer and Information Science, Tržaška Cesta 25, 1000 Ljubljana, Slovenia (3) Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland (4) Environmental Radioactivity Aerosol Tech. for Atmospheric Climate Impacts, INRaSTES, National Centre of Scientific Research “Demokritos”, Ag. Paraskevi, 15310, Greece (5) Atmospheric Composition Research, Finnish Meteorological Institute, 00101 Helsinki, Finland (6) School of Ecological and Environmental Sciences, East China Normal University, 200241, Shanghai, China (7) Climate and Environmental Physics, Physics Institute, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland (8) University of Grenoble Alpes, CNRS, INRAE, IRD, Grenoble INP, IGE, Grenoble 38000, France
marta.viagonzalez@ung.si

The Positive Matrix Factorisation (PMF) algorithm (Paatero and Tapper, 1994) has been the most widely used receptor model for a long time and has only recently been challenged with new methodologies. The novel Bayesian auto-correlated matrix factorization method (BAMF, Rusanen et al. 2024) integrates an auto-correlation term emulating real-world pollutant sources time evolution has produced higher accuracy compared to PMF. However, both PMF and BAMF struggle to provide well-separated profiles manifested as mixed time series contributions. A sparsity-handling algorithm named horseshoe (HS) regularization has been applied to BAMF in order to improve profile determination. The horseshoe application pushes some parameters to be close to zero and others to have large values (Piiroinen and Vehtari, 2017). The BAMF+HS method reduces the dimensionality of the problem by suppressing the non-significant species for each profile. The resulting profiles are expected to be less noisy and better representing the nature of the atmospheric pollution sources. Hence, the outcoming time series, which have been reported to be very sensitive to profiles adjustment, are expected to improve substantially. Figure 1 shows the effect of BAMF+HS (in orange) compared to the regular BAMF (in blue) and the PMF (in green) on a toy dataset, consisting on an oversimplified dataset with very sparse profiles. The BAMF+HS results show contributions pushed to zero, making the profiles closer to the truth (in black) with respect to the less sparse results of BAMF and PMF. This same comparison has been carried out on realistic synthetic datasets for 5 different sites to show the effectiveness of sparsity introduction into source apportionment. Four of these synthetic datasets were created from CAMx model outputs and reference profiles to make them challenging for the models, the other one was created from a more simplistic random walks approach. Preliminary results show better profile accuracy and a more balanced overall solution when the horseshoe prior is implemented in the model.

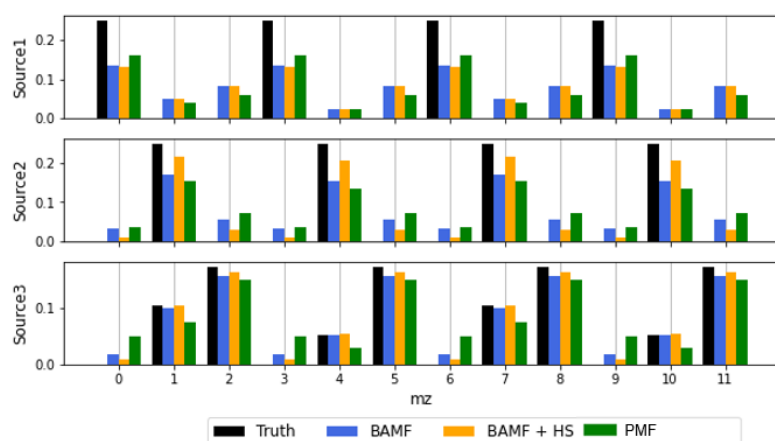


Figure 1. Comparison to truth of source apportionment profiles resulting from three different receptor models for a toy dataset.

ACKNOWLEDGEMENTS

This work is supported by the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie Postdoctoral Fellowship Programme, SMASH co-funded under the grant agreement No. 101081355. The SMASH project is co-funded by the Republic of Slovenia and the European

Union from the European Regional Development Fund. K.R.D. acknowledges support by SNSF Ambizione grant PZPGP2_201992.

REFERENCES

- Piironen, J., and Vehtari, A. 2017. Sparsity information and regularization in the horseshoe and other shrinkage priors.
- Rusanen, A. et al. 2023. A novel probabilistic source apportionment approach: Bayesian auto-correlated matrix factorization. *Atmospheric Measurement Techniques Discussions*, 1-28.
- Paatero, P., and Tapper, U. 1994. Positive matrix factorization: A non-negative factor model with optimal utilization of error estimates of data values. *Environmetrics*, 5(2), 111-126.

7.5. SOURCE APPORTIONMENT OF FINE PARTICULATE MATTER AT AN URBAN BACKGROUND LOCATION IN WESTERN SLOVENIA: LOCAL VS REGIONAL CONTRIBUTIONS

I. Stavroulas (1), K. Glojek (1), J. Yus-Díez (1), P. Makorič (1), M. Via (1), L. Drinovec (1), A. Gregorič (1,2), M. Rigler (2), B. Chazeau (3), M. Manousakas (3), A.S.H. Prevot (3) and G. Močnik (1)

(1) Center for Atmospheric Research, University of Nova Gorica, Ajdovščina, Slovenia, (2) Research and Development Department, Aerosol d.o.o, Ljubljana, Slovenia, (3) Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland

iason.stavroulas@ung.si

Air pollution poses a significant risk for human health. Specifically, exposure to airborne particulate matter (PM) is linked to 7-8 million premature deaths annually on a global scale, being the top greatest environmental health risk. Since stricter guidelines have been proposed by the WHO regarding population exposure to PM and given the recently revised EU air quality directive, monitoring and characterization of PM, especially in largely under-represented areas, such as south-eastern Europe, is imperative for forming adequate mitigation strategies.

An eight-month intensive field campaign was designed in order to characterize the chemical properties, sources and processing of fine particulate matter in Nova Gorica, a city numbering roughly 25000 inhabitants situated in western Slovenia. The measuring site is located at an urban background location with the campaign starting on November 17, 2023 and finishing on June 16, 2024. In this context, a comprehensive set of high temporal resolution measurements derived from an array of online instrumentation was performed. Non-refractory submicron aerosol (nr-PM₁) chemical composition was recorded with an Aerosol Chemical Speciation Monitor (ACSM), Black Carbon (BC) concentrations were monitored with a 7-wavelength aethalometer (AE33) while trace metal contribution was quantified through an online XRF analyser (Xact 625i). Meanwhile, standard meteorological parameters were recorded and air mass back trajectories were calculated using the HYSPLIT trajectory model. Positive Matrix Factorization utilizing the multilinear engine (ME-2) was performed to the organic aerosol (OA) mass spectra, effectively identifying OA sources using the SoFi Pro software package (Canonaco et al., 2021). The aethalometer model (Sandradewi et al, 2008) was implemented, apportioning eBC to its traffic related (BC_{tr}) and biomass burning (BC_{bb}) combustion components. Links to prevailing meteorology and air mass origin were explored through non-parametric wind regression (NWR) and Potential Source Contribution Function (PSCF) analysis respectively.

OA were found to be the dominant species in PM₁ throughout the campaign contributing 53% during the cold months of the campaign, with characteristic night-time peaks linked to wood combustion, and 54% during the warm season showing a less pronounced diurnal variability. Nitrate was the second most important contributor during the cold season (21%), giving its place to sulphate for the warm season (24%) highlighting a seasonal contrast in prevailing sources affecting the site. Furthermore, significant concentrations of trace metals, especially Al were recorded throughout the campaign, pointing to local smelting activity. OA source apportionment results, point to four OA factors, of which two were primary OA, namely a Hydrocarbon-like OA (HOA) factor, related to local traffic exhibiting a typical bimodal diurnal trend with peaks during the morning and afternoon rush hour, and a biomass burning OA factor (BBOA) with enhanced contributions during night-time linked to residential heating, persisting through a significant part of the warm season. Moreover, two secondary components were identified. A more oxidized oxygenated OA factor (MO-OOA) was related to long range transported pollution from activity in the Po valley and shipping emissions in the Adriatic, while a less oxidized (LO-OOA) component correlated with biomass burning tracers, pointing to secondary processes related to wood combustion. Biomass burning was found to be a dominant source, contributing 56% to eBC and close to 50% to OA, when both the primary and secondary component identified are taken into account during the cold season, clearly guiding elevated concentrations recorded at the site.

REFERENCES

- Canonaco, F., et al. 2021. A new method for long-term source apportionment with time-dependent factor profiles and uncertainty assessment using SoFi Pro: application to 1 year of organic aerosol data, *Atmos. Meas. Tech.*, 14, 923–943.
- Sandradewi, J., et al. U., 2008. Using Aerosol Light Absorption Measurements for the Quantitative Determination of Wood Burning and Traffic Emission Contributions to Particulate Matter. *Environ. Sci. Technol.* 42, 3316–3323.

8. PARTICULATE MATTER IN THE ENVIRONMENT

8.1. TOWARDS LOCAL CLIMATE INTERVENTIONS: COOLING AND SHADING TECHNOLOGIES TO SAVE THE GREAT BARRIER REEF

Z. Ristovski

Queensland University of Technology, Australia

z.ristovski@qut.edu.au

Local extreme temperature anomalies are becoming increasingly frequent and severe, driving catastrophic impacts such as mass coral bleaching, polar ice melt, flooding, wildfires, and heat-related mortality. While global decarbonisation efforts are essential, a low-carbon economy remains decades away, and planetary-scale geoengineering solutions are still in early trials, facing legal and ethical challenges. These approaches cannot address the immediate threats posed by regional climate extremes.

This presentation explores local climate interventions as a near-term strategy, focusing on cooling and shading technologies developed under the Reef Restoration and Adaptation Program (RRAP) to protect the Great Barrier Reef. RRAP is a world-leading initiative combining marine science, engineering, and environmental management to trial innovative solutions such as coral seeding, water quality improvements, and localized cooling systems, aiming to enhance reef resilience and buy time for global climate action. The cooling technologies developed under RRAP aim to reduce heat stress on corals during marine heatwaves, which are the primary driver of mass bleaching events.

8.2. ASSESSING THE ENVIRONMENTAL IMPACT OF BIOMASS BURNING AEROSOLS ON AIR QUALITY AND MARINE ECOSYSTEMS IN THE ADRIATIC COASTAL ZONE

A. Depolo (1), J. Arapov (2), S. Skejić (2), D. Šantić (3), A. Cvitešić Kušan (1), F. Chaux (1), S. Davila (4), G. Močnik (5), C. Alves (6), L. Bubola (7), S. Frka (1)

(1) Division for Marine and Environmental Research, Ruđer Bošković Institute, Zagreb, 10000, Croatia

(2) Laboratory of Plankton and Shellfish toxicity, Institute of Oceanography and Fisheries, Split, 21000, Croatia

(3) Laboratory of Microbiology, Institute of Oceanography and Fisheries, Split, 21000, Croatia

(4) Institute for Medical Research and Occupational Health, Zagreb, 10000, Croatia

(5) Centre for Atmospheric Research, University of Nova Gorica, Ajdovščina, 5270, Slovenia

(6) Centre for Environmental and Marine Studies, University of Aveiro, Aveiro, 3810-193, Portugal

7Aerosol, Ljubljana, 1000, Slovenia

sanja.frka@irb.hr

Climate change scenarios predict a continuous increase in emissions from biomass burning (BB). This calls for a comprehensive assessment of the environmental impact of BB aerosol particles (BBA), especially their chemically reactive organic fraction (BBOA), which changes over time. Understanding these effects in dynamic and vulnerable coastal zones requires collaboration across atmospheric chemistry, modelling, marine science, and toxicology. Therefore, with a holistic, multidisciplinary approach, ADRIAirBURN aims to enhance scientific knowledge on physico-chemical properties of BBA, focusing on BBOA, and how their ageing in the atmosphere affects air quality, human health and the marine environment in coastal zones. The project focuses on the Adriatic coast, prone to extreme fire hazards, where the impact of BB emissions remains largely unknown.

The first phase of the project investigated air quality variability in the Adriatic coastal area during controlled pinewood biomass burning (BB) in April 2025. Aerosol particle up to 2.5 μm ($\text{PM}_{2.5}$), volatile organic compounds, and size-segregated aerosols (0.010–32 μm) were collected and analysed for mass, trace metals, major ions, anhydrosugars and polyols, and organic carbon. Concurrently, meteorological conditions, CO_2 , SO_2 , black carbon (BC), and particle number size distribution were continuously monitored. This dataset enables detailed characterization of BB impacts on coastal aerosol composition and air quality. Additionally, the effects of ambient BB aerosols and model BC material on the growth of marine phytoplankton (as *Emiliania huxleyi*, *Cylindrotheca closterium*, *Melosira nummuloides*, *Synechococcus* sp.) were assessed through controlled laboratory incubations (18 °C, 16 h light/8 h dark) to evaluate species-specific responses to BB aerosol exposure.

This work was supported by Croatian Science Foundation project IP-2024-05-6224 ADRIAirBURN.

8.3. THE INFLUENCE OF SIMULATED THUNDERSTORM CONDITIONS ON POLLEN RUPTURING

S. Venkatesan (1), A. Zare (1), J. Lamont (1), B. Alinaghipour (2), Z. Ristovski (2), S. Stevanovic (1)
(1) School of Engineering, Deakin University, 3216 Waurin Ponds, VIC, Australia, (2) International Laboratory for Air Quality and Health, Queensland University of Technology (QUT), QLD, 4000 Australia
svetlana.stevanovic@deakin.edu.au

Pollen allergies are on the rise globally, with climate extremes contributing to longer and more intense pollen seasons. Under certain conditions in the atmosphere, pollen grains, that are otherwise too large to enter the lower respiratory tract, can fragment into smaller particles that are called subpollen particles (SPPs). SPPs are frequently in respirable size range. Specifically, during thunderstorms, SPPs, can be released at very high amounts, and trigger more severe allergic reactions, intensifying conditions like Thunderstorm Asthma (TA) (Venkatesan et al, 2024).

The exact mechanism behind TA remains unclear. While physical factors such as osmotic and mechanical forces are typically recognised as primary contributors to pollen rupture, emerging evidence highlights the potential role of electrical charges during storm events in influencing this process (Taylor et al, 2004, Venkatesan et al 2025).

This study investigates the role of electrical charges in pollen rupturing during stormy conditions by simulating pollen-charge interactions for wind-pollinated pollen grains from the Lolium (Perennial Ryegrass) family. These simulations were conducted within the house-made, novel 'Environmental Chamber for High Voltage and Oxidative Air Pollutants'(ECHO). Pollen-charge interactions were examined under various voltage differences: static electric fields (10, 20, 30, and 40 kV)/9.5 cm and arcing (31-35 kV)/4.5 cm, replicating the charge regimes within clouds during thunderstorms. The testing procedure for this study involves exposing to varying charge regimes under two conditions of humidity: dry (35 – 40 %) and wet (90-95 % RH) to clearly demarcate the influence of humidity on airborne pollen. Aerosol sampling is done using the aerosol instrumentation which encompasses detection and characterisation of wide range of aerosols with size ranges from 60 nm – 35 µm.

After pollen was introduced between the electrodes, we observed a sudden surge in the concentration of submicronic particles. A sharp increase in particle concentration indicates the onset of pollen fragmentation, triggered by the presence of electrical field. We observed that the extent of rupturing increases with increasing the strength of electric field and that the rupturing increases significantly under high humidity conditions. Following arcing, a sharp surge in particle release occurs, peaking higher and persisting longer at 95% RH, indicating that humidity enhances pollen rupture and aerosolisation. These findings suggest that electric fields and high humidity significantly influence airborne allergen dispersion, with potential implications for respiratory health and environmental studies.

REFERENCES

- Venkatesan, S., Zare, A. and Stevanovic, S. 2024. Pollen and sub-pollen particles: External interactions shaping the allergic potential of pollen, *Sci. Total Environ.*, 926, 171593.
Taylor, P.E. and Jonsson, H. 2004. Thunderstorm asthma. *Current allergy and asthma reports*, 4(5), 409-413.
Venkatesan et al, 2025.. Simulation of pollen–humidity interactions and origin of airborne sub-pollen particles, *Sci. Total Environ.*, 966, 178706.

8.4. PROPOSED ADVANCES IN THE CANADIAN RESPIRATORY PROTECTION STANDARD

S. J. Smith

567 River Ridge Drive, Glenburnie, Ontario K0H 1S0 Canada

sjsmith@kos.net

A national standard for selection, use and care of respirators administered by the Canadian Standards Association (CSA Group) has existed in Canada since 1982. It provides guidance to support regulatory requirements in all workplaces across the country. As well as covering the subjects in its title, the standard addresses management of respiratory protection programmes, training and qualification requirements, fit testing and record-keeping. It is updated periodically: intensive effort has been under way over the last three years towards a new edition, in which it is proposed to introduce new guidance following the experience of the Covid pandemic.

Standards development by CSA Group is undertaken by committees of volunteers with balanced representation from manufacturers, users, academic and industry experts and labour groups. Inputs are provided by users of earlier editions, from relevant new research, and needs arising from emerging hazards and advances in respirator technology are all reviewed in the update process, accompanied by consultation with user groups and subject experts and a period for open public review. The current effort to update the 2018 version is nearing completion.

Selection guidance for respirators for biological aerosols (such as those transmitting Covid) was added in 2011, with a method based on control banding. However, since then, the standard was only rarely referenced in guidance from governments and medical authorities. The current work addresses recent learnings to improve the utility of the standard to improve resilience against infectious disease in the healthcare community and general workplaces.

Key considerations for the current standard update

- Follows the precautionary principle to presume aerosol transmission of infectious disease until disproven: as confirmed by laboratory and field study, Covid and other diseases are transmitted by aerosols, remaining airborne and infectious for periods of time and potentially viable over long distances;
- Aerosol sources: typical respiration-related activities – coughing, sneezing, talking, shouting have been shown to release hundreds of times higher aerosol levels than traditional “Aerosol Generating Medical Procedures”;
- Asymptomatic/pre-symptomatic disease transmission: individuals can release infectious aerosols without showing typical disease symptoms or being aware of their infected state;
- Data from infection surveillance: a weekly national sampling of Canadian hospitals on infection origin for admitted individuals shows that over the last two years, 25 to 50% of people admitted for treatment for Covid acquired the disease in a healthcare facility, showing the need to improve infection control practices;
- Emerging and resurging diseases: advent of new types or strains of infectious disease, and the re-occurrence of known diseases such as measles spread by the respiratory route
- Current users expressed a desire to simplify guidance – yet also to assess more factors contributing to risk;
- Certain non-healthcare workplaces with opportunities for high rates of infection transmission need inclusion.

New features in the standard

- Specific clause to address use of respirators in healthcare to augment current infection control practices;
- Risk analysis protocol for healthcare with “reverse onus” – respirator use is required unless analysis shows that control measures are sufficient to minimize opportunities for infection transmission;
- Specific protocols for workplaces determined to have “elevated exposure to human bioaerosols”, requiring enhanced attention to respirator use during pandemic conditions;
- Revised criteria for respirator selection for biological aerosols in general workplaces – with more factors included in consideration but with a simplified control banding process;
- Simplified set of minimum respirator selection outputs – levels for filtering facepieces/half-facepieces, loose-fitting powered air purifying respirators – with tight-fitting powered air for severe viral diseases.

The standard is still being finalized after public comment. While there was some concern from individuals from an infection control background, it received very favourable review from many experts and respirator users, as well as broad support from medical professionals and labour unions.

8.5. ABSORPTION COEFFICIENT AND HEATING RATE OF BLACK CARBON AND MINERAL DUST ACROSS DIFFERENT MEDITERRANEAN SITES

S. Gautam (1), M. Pandolfi (2), N. Pérez (2), A. Alastuey (2), M. Ivančič (3), A. Gregorič (1,3), I. Ježek Brecelj (3), M. Rigler (3), L. Drinovec (1), J. Yus-Díez (1), G. Močnik (1)

(1) Center for Atmospheric Science, University of Nova Gorica, Ajdovščina, Slovenia (2) Institute of Environmental Diagnostics and Water Research, IDAEA-CSIC, Barcelona, Spain (3) Aerosol d.o.o., Ljubljana, Slovenia
sangita.gautam@ung.si

Black carbon (BC) and Mineral dust (MD) are essential factors in Earth's climate due to their contrasting optical properties and are significant contributors to atmospheric radiative forcing. Mineral dust (MD) accounts for three-quarters of global aerosol mass, yet its net climate effects remain uncertain due to the complex light absorption and scattering at short wavelengths (Kinne et al., 2006; Kok et al., 2023), which challenges the accuracy of climate models. There remain considerable uncertainties about their net contribution (Legg, 2021). The effects of BC and MD on atmospheric heating depend, among other factors, on their mixing state, which is currently not well understood.

We investigated absorption coefficients of MD and BC and their heating rates (HR), varying with location and altitude, at three western Mediterranean background sites: continental Montsec (MSA), regional Montseny (MSY), and urban Barcelona (BCN), all frequently affected by Saharan dust outbreaks. A paired Aethalometer (AE33) (Drinovec et al., 2015) at each station, equipped with a PM₁ and virtual impactor inlets (Drinovec et al., 2020), to separate fine and coarse particles; a Nephelometer to correct scattering cross-sensitivity in filter photometers (Yus-Díez et al., 2021). In both size fractions, a source apportionment model (Massabò et al., 2015) separates dust and BC contributions to absorption, and respective HR are calculated (Ferrero et al., 2018).

Results show pronounced altitude-dependent variations in dust absorption and heating. During dusty summer days, MD absorption at 370 nm reached $2.29 \pm 2.85 \text{ Mm}^{-1}$ at MSA, 1.7 and 6 times higher than MSY ($1.28 \pm 1.22 \text{ Mm}^{-1}$) and BCN ($0.33 \pm 0.48 \text{ Mm}^{-1}$), respectively. MAC values progressively increased with altitude: BCN $0.11 \pm 0.19 \text{ m}^2\text{g}^{-1}$, MSY $0.39 \pm 0.82 \text{ m}^2\text{g}^{-1}$, and MSA $1.05 \pm 1.9 \text{ m}^2\text{g}^{-1}$. The heating rate of MD during dusty periods increased with elevation, indicating that mineral dust at higher altitudes retains stronger absorbing properties due to reduced anthropogenic mixing and less BC coating. Finally, we will also present our results for the HR during dusty events, which show mean values of $0.13 \pm 0.27 \text{ K day}^{-1}$ in the MSA and $0.066 \pm 0.052 \text{ K day}^{-1}$ in the MSY for MD, and $0.29 \pm 0.31 \text{ K day}^{-1}$ in the MSA and $0.53 \pm 0.39 \text{ K day}^{-1}$ in the MSY for BC.

These findings underscore the need to represent altitude-dependent mineral dust absorption and heating rate more accurately in regional climate models. Improved characterization of MD and BC interactions is essential for accurately assessing radiative forcing in Mediterranean and other dust affected regions.

REFERENCES

- Drinovec, L. et al. 2015. The "dual-spot" Aethalometer: an improved measurement of aerosol black carbon with real-time loading compensation. *Atmospheric Measurement Techniques*, 8, 1965–1979.
- Drinovec, L. et al. 2020. A new optical-based technique for real-time measurements of mineral dust concentration in PM₁₀ using a virtual impactor. *Atmospheric Measurement Techniques*, 13, 3799–3813.
- Ferrero, L. et al. 2018. Heating rate of light absorbing aerosols: time-resolved measurements, the role of clouds, and source identification. *Environmental Science & Technology*, 52, 6, 3546–3555.
- Kinne, S. et al. 2006. An AeroCom initial assessment—optical properties in aerosol component modules of global models. *Atmospheric Chemistry and Physics*, 6, 1815–1834.
- Kok et al. 2023. Mineral dust aerosol impacts on global climate and climate change. *Nature Reviews Earth & Environment*, 4, 71–86.
- Legg S. 2021. IPCC. *Climate Change 2021: The Physical Science Basis*.
- Massabò, D. et al. 2015. Multi-wavelength optical determination of black and brown carbon in atmospheric aerosols. *Atmospheric Environment*, 108, 1–12.
- Yus-Díez et al. 2021. Determination of the multiple-scattering correction factor and its cross-sensitivity to scattering and wavelength dependence for different AE33 Aethalometer filter tapes: a multi-instrumental approach. *Atmospheric Measurement Techniques*, 14, 6335–6355.

8.6. CARBONACEOUS FINE AEROSOL IN SARAJEVO, BOSNIA AND HERZEGOVINA: ELEVATED CONCENTRATIONS AND HIGHLY POLLUTED WINTER EPISODES

M. Via (1), B. Chazau (2), A. Gregorič (3), M. Bauer (4), K. Glojek (5), P. Makorić (1), M. Rigler (3), P. Khare (4), L. Folghera (4), L. Williams (6), J. Jayne (6), P. Croteau (6), A. Bijedić (7), E. Omerčić (7), E. Krečinić (7), D. Smajić (7), I. Ahmović (7), G. Močnik (1), J. Slowik (4), K. Dzepina (4), A. S. H. Prévôt (4)

(1) University of Nova Gorica, Ajdovščina, 5270, Slovenia (2) Aix Marseille Univ., CNRS, LCE, Marseille, 13007, France (3) Research and Development Department, Aerosol d.o.o, Ljubljana, 1000, Slovenia (4) Center for Energy and Environmental Sciences, Paul Scherrer Institute (PSI), Villigen, 5232, Switzerland (5) Institute of Environmental Assessment and Water Research (IDAEA-CSIC), Barcelona, 08034, Spain (6) Aerodyne Research, Inc. 45 Manning Rd, Billerica, MA 01821, USA (7) Federal Hydrometeorological Institute of Bosnia and Herzegovina, Sarajevo, 71000, Bosnia and Herzegovina
marta.viagonzalez@ung.si

The Western Balkan region has some of the highest mortality rates attributed to indoor and outdoor air pollution in Europe. The Sarajevo basin in particular becomes a wintertime pollution hotspot, with a complex mixture of airborne particulate matter (PM_{2.5}) (Huremović et al., 2020). Modelling studies suggest energy production, transport activities, and residential combustion are the main drivers of PM_{2.5} in Sarajevo (Belis et al., 2019). However, source apportionment studies of aerosol in the area, including organic aerosol (OA), which is likely its most abundant component, are scarce. The Sarajevo AEROSol Experiment (SAAERO) project took place from Aug 2022 – Mar 2023 and was centred at the supersite in Sarajevo, with an aim to characterize aerosol ambient loadings, composition, sources and health effects. For that objective, among other instrumentation, we deployed an Aerosol Chemical Speciation Monitor (ACSM) and an aethalometer (AE33) for measurements of aerosol composition particularly during high-pollution winter episodes. Source apportionment was conducted for both instruments, providing OA and BC sources, respectively, through Positive Matrix Factorization (PMF, Paatero and Tapper, 1994) and the Sandradewi model (Sandradewi et al., 2008).

ACSM NR-PM₁ campaign average concentration is 30.6 µg·m⁻³ (three times the European legislation annual limit value of 10 µg·m⁻³) with peaks over 200 µg·m⁻³. During the campaign, 72 days exceeded the PM_{2.5} limit values of the European legislation. OA and SO₄²⁻ constituted the majority of the PM mass (Figure 1). SO₄²⁻ concentration was higher during winter, indicating the prevalence of significant sources besides regional transport. The similarities in PM composition between the entire campaign and the winter periods likely a result from the site being located on a hill slope where aerosol from the city centre arrives mixed during boundary layer growth. Preliminary OA source apportionment revealed three main factors: hydrocarbon-like OA (HOA, 15%) solid combustion OA (SCOA, 30%), and oxygenated OA (OOA, 55%) (Figure 1). Black carbon mean concentration over the measurement period was 3.0 µg·m⁻³, with fossil fuel contribution (BCff) accounting for 61% and biomass burning contribution (BCwb) 39%. The maximum monthly contributions of BCff and BCwb, respectively, happened in December 2022 (2.4 µg·m⁻³), and January 2023 (1.7 µg·m⁻³), reaching peak values of 18.3, and 11.7 µg·m⁻³.

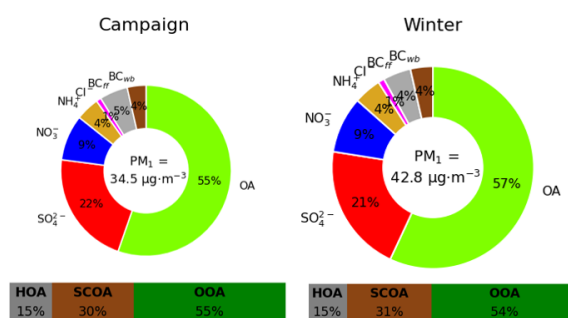


Figure 1. Pie plots of PM₁ composition and bar plots with OA source apportionment.

ACKNOWLEDGEMENTS

MV acknowledges the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie Postdoctoral Fellowship Programme, SMASH co-funded (No. 101081355). The SMASH project is co-funded by the Republic of Slovenia and the European Union from the European Regional Development Fund. SAAERO project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101028909. . Work was

partially funded by the Slovenian Research and Innovation Agency (ARIS) research project (CAEmissionMonitor) L1-4386.

REFERENCES

- Belis, C. A., et al., 2019. Urban pollution in the Danube and Western Balkans regions: The impact of major PM_{2.5} sources.. *Environment International*, 133, 105158.
- Huremović, J., et al. 2020. Analysis of PM₁₀, Pb, Cd, and Ni atmospheric concentrations during domestic heating season in Sarajevo. *Air Quality, Atmosphere & Health*. 13, 965-976.
- Paatero, P., and Tapper, U. 1994. Positive matrix factorization: A non-negative factor model with optimal utilization of error estimates of data values. *Environmetrics*, 5(2), 111-126.
- Sandradewi, J., et al., 2008. Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contributions to particulate matter. *Environmental Science & Technology*, 42(9), 3316-3323.

8.7. TRANSPORT-RELATED AIR POLLUTION AT THE LISBON CRUISE TERMINAL: INTEGRATING PARTICULATE MATTER, BLACK CARBON AND ULTRAFINE PARTICLES INTO URBAN AIR QUALITY MONITORING

C. Gameiro (1), J. Martinho (1), T. Faria (1), M. Manousakas (2), K. Eleftheriadis (2), K. Glojek (3), P. Makoric (3), G. Močnik (3), S. M. Almeida (1)

(1) *C2TN, DECN, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal*

(2) *NCSR DEMOKRITOS Institute of Nuclear and Particle Physics, Agia Paraskevi 15341, Greece*

(3) *University of Nova Gorica, Centre for Atmospheric Research (CRA), Ajdovščina 5270, Slovenia*
catarina.gameiro@tecnico.ulisboa.pt

Air pollution remains a critical environmental and societal concern, largely driven by transport sector emissions, including road, air and maritime traffic (Ducruet et al, 2024; EEA, 2024). Key pollutants include particulate matter (PM₁₀ and PM_{2.5}), Black Carbon (BC) and Ultrafine Particles (UFP) (Karl et al, 2023). Nonetheless, conventional air quality monitoring stations often measure only PM fractions, overlooking BC and UFPs (García-Marlès et al, 2024; Savadkoohi et al, 2024). In line with the World Health Organization 2021 global air quality guidelines and the European Directive 2024/2881 (European Parliament & Council, 2024; WHO, 2021), this study monitored PM, BC and UFP in the vicinity of the Lisbon Cruise Terminal, evaluating the impact of cruises on air quality.

A monitoring station was installed in the Lisbon Cruise Terminal between March and August 2025, equipped with high resolution equipment, namely Optical Particle Sizer (OPS), Aethalometer® AE33 and Scanning Mobility Particle Sizer (SMPS) to continuously measure PM, BC and UFP, respectively.

Results showed lower mean pollutant concentrations than those reported for other European cities, reflecting the influence of wind patterns and Lisbon's coastal location, which favors the inflow of cleaner Atlantic wind masses. Days of low wind speed corresponded to higher pollutant concentrations, evidencing that weak ventilation favors pollutant accumulation. Northern and southwestern winds were associated with higher BC and UFP concentrations, suggesting combined contributions from air and road traffic, industrial activities, and ship operations. The fossil-fuel-related BC fraction was higher than that from biomass burning, further supporting fossil fuels as the main contributor to BC. A weak BC-UFP correlation ($R^2 < 0.20$) pointed to distinct processes originating these pollutants.

These findings highlight the multi-source nature of air pollution in urban areas and support the integration of BC and UFP metrics in air quality monitoring networks, as well as the development of targeted emission-control strategies addressing both land- and sea-based transport sectors.

REFERENCES

- Ducruet, C., Martin, B. P., Sene, M. A., Lo Prete, M., Sun, L., Itoh, H., Pigné, Y. 2024. Ports and their influence on local air pollution and public health: A global analysis, *Science of The Total Environment*, 915, 170099.
- European Environment Agency 2024. Sustainability of Europe's Mobility Systems.
- European Parliament & Council of the European Union 2024. Directive (EU) 2024/2881 of the European Parliament and of the Council on ambient air quality and cleaner air for Europe (recast), *Official Journal of the European Union*.
- García-Marlès, M., Trecehera, P., Liu, X., Petäjä, T., Harrison R., Hopke P., Wiedensholer, A., Alastuey, A., Querol, X. 2024. Guidance Documents on Measurements of Air Quality Advanced Parameters for Air Quality Stakeholders: Ultrafine Particles/Size Distributions, RI-URBANS.
- Karl, M., Ramacher, M. O. P., Oppo, S., Lanzi, L., Majamäki, E., Jalkanen, J.-P., Lanzafame, G. M., Temime-Roussel, B., Le Berre, L., and D'Anna, B. 2023. Measurement and Modeling of Ship-Related Ultrafine Particles and Secondary Organic Aerosols in a Mediterranean Port City, *Toxics*, 11(9), 771.
- Savadkoohi, M., Pandolfi, M., Alastuey, A., Petäjä, T., Putaud, J. P., Favez, O., Querol, X. 2024. Guidance Documents on Measurements & Modelling of Novel Air Quality Pollutants: Black carbon (BC) Determinations, RI-URBANS.
- World Health Organization 2021. WHO global air quality guidelines.

9. SENSORS AND SENSOR NETWORKS

9.1. METROLOGY FOR AIR QUALITY SENSOR NETWORKS: SELECTED INSIGHTS FROM THE FUNSNM PROJECT

M. Davidović (1), M. Iturrate-Garcia (2), M. Jovašević-Stojanović (1), S. Tabandeh (3)

(1) VIDIS Centre, Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia, (2) Federal Institute of Metrology METAS, Switzerland, (3) VTT MIKES, Finland
davidovic@vin.bg.ac.rs

The high temporal and spatial variability of urban air pollution shapes monitoring approaches and their underlying principles. These approaches encompass both traditional and emerging air pollution monitoring at the urban scale: governmental, non-governmental and citizen-science sensor networks, as well as the emerging field of sensor networks metrology, implementing intelligent systems in varying degrees, from node to network level. Various types of sensors are used in monitoring of urban air pollution, spanning a wide cost-accuracy spectrum: from low-cost or soft(virtual) sensors on one end, to the highly accurate reference grade instrumentation in automatic monitoring supersites. The fact that the air quality sensor networks are spatially distributed, and exhibit pronounced gradients and dynamic temporal profile dictates the need for them to be approached and assessed with specialized methods, in order to ensure that sound metrological principles are applied throughout the sensor network. The project 'Fundamental principles of sensor network metrology' - FunSNM, aims to provide solutions and good practice guides for metrology community, with a special focus on sensor networks, including also the highly relevant case of air quality sensor networks. To highlight the importance of this endeavour, one has to keep in mind that sensor networks in general, and air quality sensor networks in particular, are becoming ubiquitous and an inseparable part of smart cities, however, important issues of data quality and trustworthiness, still present challenges to the researcher and stakeholder community.

This work gives a high-level view of the overall goals/structure of the FunSNM project, and proceed to highlight several result/activities of the FunSNM project, focusing on those with contribution of the Vinca Institute (VINS) team of researchers in the context of air quality monitoring networks. One of the first activities was to describe data requirements within the complete lifecycle of the typical air quality network node, as well as data requirements within complete sensor network (data coverage needed for metrics, methods, results reporting, physical modelling, possibility of soft sensor support etc). Following that, METAS and VINS are working on calibration process and laboratory setup for calibration of low-cost sensors, comparison of different calibration models, while also considering the possible effects of interfering air parameters such as e.g. humidity.

Sensor network metrology is an emerging branch of metrology that has the potential to shape the way in which sensor networks data pipelines are approached, drawing insights from different sensor networks and distilling them into practically applicable fundamental principles. It covers the vast metrology landscape going from individual nodes all the way up to the complex interplay of sensor network observations, highlighting new aspects such as self-calibration, co-calibration, drift and anomaly detection, as well as new challenges due to the size and mixed quality of networks.

ACKNOWLEDGMENTS

The project (22DIT02 FunSNM) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States; European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under GA 451-03-136/2025-03/200017

REFERENCES

- Tabandeh, S. et al. 2025. Sensor network metrology: Current state and future directions. *Measurement: Sensors*, 101798.
- Stojanović, D. B. et al. 2024. Data Evaluation of a Low-Cost Sensor Network for Atmospheric Particulate Matter Monitoring in 15 Municipalities in Serbia. *Sensors* 24, 13, 4052.
- Davidović, M., et al. The VIDIS low-cost sensor network deployment in the city of Novi Sad. In *WeBIOPATR 2023: 9th WeBIOPATR Workshop & Conference: Particulate Matter: Research and Management: Abstracts of Keynote Invited Lectures and Contributed Papers*, pp. 28-33. Belgrade: University of Belgrade, Vinča Institute of Nuclear Sciences, 2025.
- Topalović, D. B. et al. 2019. In search of an optimal in-field calibration method of low-cost gas sensors for ambient air pollutants: Comparison of linear, multilinear and artificial neural network approaches. *Atmospheric Environment* 213, 640-658.

9.2. FEDERATED LEARNING ENABLES FAST DEPLOYMENT OF PERVASIVE LOW-COST PARTICULATE MATTER SENSOR NETWORKS

A. M. Elamin (1), I. Erunsal (1), R. Liu (3), W. Hu (3), M. Davidović (2), F. Tian (3), S. De Vito (1)
(1) ENEA, C.R. Portici, Naples, Italy, (2) Vidis centre, Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia, (3) University of Chongqing, Chongqing, China.
saverio.devito@enea.it

Federated learning (FL) is a consolidating distributed machine learning framework allowing delocalized in-edge learning of AI models showing particular suitability for AIoT applications. In this framework, each device or local device group can learn, given appropriate reference values, a local model. At each learning round, local partially-trained models can be fused together in a centralized location or in the cloud, and the resulting model can be sent to the edge again for operation or for a further iteration of the learning task. Many papers explored the trade-offs emerging in this paradigm, but here, we highlight among other advantages, the possibility to learn while operating from the deployment date, the relaxation of data transmission bandwidth and latency requirements, and the increased resilience to cyber attacks to the smart city infrastructure. While low-cost air quality (multi)sensors have nowadays shown their importance for achieving pervasive environmental information, accuracy is still an enduring issue which is particularly costly to achieve. Logistic costs and reference access still pose significant limitations to the deployment of networks comprising a significant number of measuring devices. In-Network calibration, is often obtained through remote stations' reference data. The achieved accuracy is strongly dependent on several factors including closeness to the LCMS deployment site and the similarity between reference and LCMS deployment site conditions (road side, urban background, regional background, etc.). Good accuracy is therefore difficult to obtain. In our opinion, FL could play a positive role in reducing the cost of accuracy goals. Universal or Global calibration is, actually, showing the capability to obtain an acceptable accuracy requiring the collocation of only a limited subset of the device type units. However, it still needs a seasonal collocation time in the first year of deployment. Federated learning could build upon these findings by using a limited number of collocated devices, participating in the calibration model federated learning, in front of hundreds of deployed devices. In fact, it could provide a city-wide continuous learning framework with universal models made available in the first days after initial deployment, making it a faster alternative to universal calibration models. In this contribution we show how a FL model, obtained through implementing the FLOWER framework, can cope with LCMS calibration task needs using a publicly available dataset featuring 30 MONICA™ LCMS devices (10.5281/zenodo.13151960) including Plantower 7003 Optical particle counters. The devices have been co-located with regulatory grade analysers for 3 periods spanning 1.5 year (Winter 2021, Summer 2021, and Winter 2022) in Portici, 7 km south of Naples (Italy) city centre. Specifically, 10 collocated devices have been set apart as calibration learners, providing local calibration models in specific seasons which have been harmonized through the model averaging process of federated learning. The resulting universal federated models have been tested vs. state of the art individual field calibration in order to assess the model quality. It is worth noting that while test devices have been calibrated and tested in the same season, federated learning exploits data and models obtained in a different deployment period (and, subsequently, location). Additionally, a time-wise (sequential time-stratified) and node-wise cross-validated cross validation has been implemented through random selection of the 10 calibration learning devices. Results indicate that the observed performance difference is minimal with respect to the performance variance induced by both the sensors' inherent differences and environmental conditions, with FL approach reaching a 0.61 r^2 assessment on average (MAE=5.65ug/m³) while individual calibration reached a r^2 factor of 0.66 (MAE=5.15ug/m³). In this case, universal federated learning calibration could allow for immediate accurate city-scale data gathering, while providing a continuous update during multiple seasons at a fraction of the cost needed for seasonal recalibration of individual sensors. Though still needing collocation of a fraction of devices, this approach also allows promotion of diversity in the training set providing additional robustness to extreme localized concentrations.

ACKNOWLEDGMENTS: This work has received funding from PON MARTA and PORH2 Italian projects.

REFERENCES

- Beutel D.J. et al., 2020. Flower: A Friendly Federated Learning Research Framework, arXiv:2007.14390
De Vito, S. et al. 2024. Future Low-Cost Urban Air Quality Monitoring Networks: Insights from the EU's AirHeritage Project. *Atmosphere*, 15, 1351.
De Vito, S. et al. 2024. A Global Multiunit Calibration as a Method for Large-Scale IoT Particulate Matter Monitoring Systems Deployments, *IEEE Transactions on Instrumentation and Measurement*, 73, 1-16, Art no. 2501916.

9.3. CHARACTERIZING URBAN AIR POLLUTION-LAND USE RELATIONSHIPS USING LOW-COST SENSOR NETWORKS: A HIGH-RESOLUTION SPATIAL ANALYSIS IN LISBON

S. Ataee , M.Lopes, H. Relvas

CESAM & Department of Environment and Planning, University of Aveiro, 3810-193 Aveiro, Portugal
sinaataee@ua.pt

To assess urban air quality, it is essential to obtain high spatial resolution exposure estimates to characterize intra-urban variability and identify pollution hotspots. Low-cost sensor networks present promising opportunities to supplement regulatory monitoring systems for enhanced particulate matter exposure assessment. However, systematic calibration protocols are crucial for ensuring data quality assurance (Bi et al., 2020). Additionally, emerging spatial analysis techniques enable the integration of air quality measurements from low-cost sensor networks with urban land use characteristics to generate spatially-comprehensive exposure surfaces. (Bagkis et al., 2025; Jain et al., 2021; Wang et al., 2024).

This study employs continuous 2022 measurements of nitrogen dioxide (NO₂), PM₁₀, and PM_{2.5} concentrations gathered from low-cost sensor networks deployed across Lisbon, Portugal. Subsequently, geospatial analysis examines the correlations between observed pollutant concentrations and multiple land use categories, including residential zones, commercial districts, industrial areas, transportation corridors, and green spaces. Spatial regression methods quantify the relationships between land use patterns and pollutant variations, elucidating both direct and spillover effects of urban form on air pollution distributions.

Initial findings reveal clear spatial clustering of heightened pollutant concentrations linked to particular land use categories. The methodology categorizes urban areas demonstrating significant relationships between land use and pollution, offering empirical identification of high-exposure microenvironments that necessitate focused emission reduction measures.

This research advances particulate matter monitoring and management objectives by providing actionable intelligence for geographically-targeted air quality interventions. The low-cost sensor approach enables scalable urban air quality characterization, supporting evidence-based urban planning and sector-specific emission control policies to achieve sustainable air quality improvement in metropolitan environments.

Acknowledgements

The authors would like to acknowledge the support of CESAM (UIDP/50017/2020 + UIDB/50017/2020 + LA/P/0094/2020) and C2TN (UIDB/04349/2020). Also, thanks are due to FCT PhD grant to Sina Ataee (2023.02767.BD). In addition, the special thanks to FCT/MCTES for the research contract awarded to Helder Relvas (<https://doi.org/10.54499/2021.00185.CEECIND/CP1659/CT0026>) and ODESSA (<https://doi.org/10.54499/2024.07293.IACDC>).

REFERENCES

- Bagkis, E., Hassani, A., Schneider, P., DeSouza, P., Shetty, S., Kassandros, T., Salamalikis, V., Castell, N., Karatzas, K., Ahlawat, A., and Khan, J. 2025. Evolving trends in application of low-cost air quality sensor networks: challenges and future directions. *Npj Climate and Atmospheric Science*, 8(1), 335.
- Bi, J., Wildani, A., Chang, H. H., and Liu, Y. 2020. Incorporating Low-Cost Sensor Measurements into High-Resolution PM_{2.5} Modeling at a Large Spatial Scale. *Environmental Science and Technology*, 54(4), 2152-2162.
- Jain, S., Presto, A. A., and Zimmerman, N. 2021. Spatial Modeling of Daily PM_{2.5}, NO₂, and CO Concentrations PM_{2.5} Measured by a Low-Cost Sensor Network: Comparison of Linear, Machine Learning, and Hybrid Land Use Models. *Environmental Science and Technology*, 55(13), 8631-8641.
- Wang, P., Zeng, C., Zhang, W., Lv, T., Miao, X., and Xiang, H. 2024. Investigation of the spatial effects on PM_{2.5} in relation to land use and ecological restoration in urban agglomerations. *Science of Total Environment*, 913, 169665.

9.4. ON THE POSSIBILITIES FOR BLACK CARBON SENSOR VIRTUALISATION

**M. Davidović (1), M. D. Davidović (2), M. Jovanović (1), D. B. Stojanović (1), A. Šoštarić (3),
S. Tabandeh (4), M. Jovašević-Stojanović (1)**

(1) VIDIS Centre, Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Serbia, (2) Department of mathematics, physics and descriptive geometry. Faculty of Civil Engineering, University of Belgrade, Serbia, (3) Institute of Public Health of Belgrade, Serbia, (4) VTT MIKES, Finland
davidovic@vin.bg.ac.rs

Traditionally monitored air quality parameters often do not give a sufficiently detailed and comprehensive picture of air quality, thus limiting the ability of citizens and authorities for informed decision making. For example, reducing PM_{2.5} by the same amount of mass concentration in different places may not deliver the same health benefits, thus highlighting the need for additional metrics. Carbonaceous aerosols concentration in air is an example of one such additional air quality metric, since carbonaceous aerosols are often the largest component of fine particulate matter, yet very diverse, composed of light-scattering Organic Carbon (OC), and light-absorbing Black Carbon, (BC). Presence of BC has negative effects for both, human health and our climate (Novakov et al., 2013). Furthermore, inhalation of BC is associated with health problems including respiratory and cardiovascular disease, cancer, and even birth defects (Janssen et al., 2011, Janssen et al. 2012). However, measuring mass concentration of BC, either using online or offline methods, requires specialized equipment, which is typically not a part of routine regulatory monitoring and BC concentration data is thus not readily available throughout air quality sensor networks. This BC data is typically only available at the specialized monitoring sites, so-called monitoring supersites, where much more comprehensive monitoring is done.

Recently, a concept of virtual or soft sensors has been introduced (Zaidan, Martha Arbayani et al. 2023) as a way of increasing spatial resolution for certain pollutants, by utilizing IoT (low-cost sensors) and AI algorithms. Sensor virtualization is gaining traction in the metrology of sensor networks (Tabandeh, Shahin et al., 2025). By using similar research vision of virtual sensors, we attempt to expand the concept to reference air quality automatic monitoring networks, and to determine to which extent information about BC mass concentration can be statistically inferred for the entire reference grade network, and not just the supersites in the network, where such information is produced by the physical sensors. This paper further explores the initial models presented in (Davidovic et al., 2025) based on multiple linear regression, by further considering different training and test periods for the model development, more specifically, assessing virtual sensor model performance for scenarios with different biomass burning and fossil fuel contribution to black carbon concentrations. Sensor virtualization is a promising technique that can be used to estimate BC concentration, in the absence of specialized monitoring equipment. It is a useful sensor network metrology tool under the condition that the sensor network infrastructure is well developed, and that certain network nodes (supersites or sites conducting additional monitoring campaigns) contain additional information about BC concentration. Under the favourable model training conditions, RMSE as low as $\sim 1 \mu\text{g}/\text{m}^3$ can be achieved.

ACKNOWLEDGMENTS

This work was funded by European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project), project (22DIT02 FunSNM) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States; and the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under GA 451-03-136/2025-03/200017.

REFERENCES

- Novakov, T., et al. 2013. The black carbon story: early history and new perspectives. *Ambio* 42, no. 7, 840-851.
- Janssen, N. A. H., et al. 2011. Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM₁₀ and PM_{2.5}. *Environmental health perspectives* 119, no. 12, 1691-1699.
- Janssen, N. A. H. et al. 2012. Health effects of black carbon, The WHO European Centre for Environment and Health, Bonn, Germany. World Health Organisation Regional Office for Europe, Copenhagen, Denmark.
- Zaidan, M. A. et al. 2023. Virtual Sensors: toward High-resolution air pollution monitoring using AI and IoT. *IEEE Internet of Things Magazine* 6, no. 1, 76-81.
- Tabandeh, S. et al. 2025. Sensor network metrology: Current state and future directions. *Measurement: Sensors*, 101798.
- Davidovic, M. et al. 2025. A Simple Virtual Sensor Approach for Black Carbon Estimation in Sensor Networks, 12th International Conference on Electrical, Electronics and Computer Engineering (IcETRAN).

9.5. PM_{2.5} REMOTE SATELLITE DATA RELATION WITH REFERENT AND LOW-COST SENSOR NETWORK DATA IN FOUR CITIES IN SERBIA

D. Kleut, **Ž. Ćirović**, **D. B. Stojanović**, **M. Davidović**, **M. Jovašević-Stojanović**
*VIDIS Centre, Vinca Institute of Nuclear Sciences, National Institute of the Republic of Serbia,
University of Belgrade, Serbia*
duska@vin.bg.ac.rs

Recent progress in satellite-based remote sensing and the proliferation of low-cost sensors offer promising avenues to complement existing datasets. In particular, satellite-derived aerosol optical depth (AOD) has proven effective in estimating PM_{2.5} concentrations, helping to fill the void left by limited ground-based observations. Numerous statistical models—ranging from machine learning algorithms to geographically and temporally weighted regression techniques—have been developed to quantify the relationship between AOD and PM_{2.5} levels (Lin C. et al, 2020).

This study was conducted in four Serbian cities—Čačak (C), Užice (U), Kosjerić (K), and Novi Pazar (NP)—where PM_{2.5} were measured using a low-cost sensor network and an equivalent Optical Particle Sensor (OPS) installed at automatic monitoring stations that are part of the national air quality monitoring network (SEPA). Measurements from these stations were averaged to daily values to facilitate comparison with data compiled and analyzed for monthly reporting (Stojanović D.B. al, 2024).

In this study, we analyzed daily average PM_{2.5} concentrations from four municipalities, using data from both the national monitoring network (SEPA) and a parallel low-cost sensor (LCS) network, alongside satellite remote sensing data. Specifically, we utilized ECMWF/CAMS/NRT and MODIS/006/MCD19A2_GRANULES datasets, with spatial resolutions of 44,528 m and 1,000 m, respectively, covering the period from May 2022 to June 2023.

Reference concentrations recorded at AMS sites were compared to monthly averages obtained from three separate locations within each city where low-cost particulate matter sensors were deployed and the satellite data. Our previous studies we investigated the low-cost sensor data strong correlation with SEPA measurements in three of four municipalities, except at a rural site with greater distance between sensors. Satellite-derived data aligned with ground measurements to varying degrees, with the strongest correlations occurring during summer and winter. (Ma, Z., et al, 2022, Ćirovic Z. et al, 2025)

This research investigated the index of agreement (IA) which is one of the methods for assessing agreement between quantitative measurements (inter-agreement) on the combined dataset (Jiang et al, 2021). The index of agreement (IA), which normally ranges from 0 to 1, serves as a measure of how closely the sensor/satellite values align with the reference measurements—higher IA values indicate stronger agreement. We have previously considered the IA of the low-cost sensor networks with SEPA where the PM_{2.5} data were showing the index of agreement of around 0.9. (Kleut D. et al, 2023).

Monthly values of the index of agreement of satellite data with the ground-based datasets were obtained using only the dates when the data from both satellites were available. The agreement of both satellite datasets with SEPA was good in the warmer seasons, reaching 0.4-0.9, while in the winter months when PM_{2.5} concentrations reach high values, both satellite datasets compared with both referent and LCS data show low levels of agreement.

ACKNOWLEDGMENT

This research was funded by: The European Union's Horizon Europe Research and Innovation Program under GA 101060170 (WeBaSOOP project) and the Ministry of Education, Science and Technological Development of the Republic of Serbia under GA 451-03-136/2025-03/200017.

REFERENCES

- Lin, C., Labzovskii, L. D., Mak, H. W. L., Fung, J. C. et al., 2020, Observation of PM_{2.5} using a combination of satellite remote sensing and low-cost sensor network in Siberian urban areas with limited reference monitoring. *Atmospheric Environment*, 227, 117410.
- Stojanović, D. B. et al, 2024, Data Evaluation of a Low-Cost Sensor Network for Atmospheric Particulate Matter Monitoring in 15 Municipalities in Serbia. *Sensors*, 24(13), 4052.
- Ma, Z. et al, 2022, A review of statistical methods used for developing large-scale and long-term PM_{2.5} models from satellite data. *Remote Sensing of Environment*, 269, 112827.
- Ćirovic, Z. et al. 2025, Comparative assessment of pm_{2.5} data from remote satellite observations and by the low-cost sensor network in Serbia, *Scientific Research Abstracts. Atmospheric Dust - DUST 2025*, Vol. 15, p. 16.
- Jiang, Y. et al. 2021. On-field test and data calibration of a low-cost sensor for fine particles exposure assessment, *Ecotoxicology and Environmental Safety*, Volume 211, 111958,
- Kleut, D., et al, Level of agreement (variability) of PM₁₀ and PM_{2.5} detected with equivalent v.s. low-cost monitors installed in four municipalities, *WeBIOPATR 2023 Book of Abstracts*, p18, Abs 2.2

10. POSTER SESSIONS

10.1. ABSENCE OF EFFECTIVE INSTITUTIONAL PUBLIC HEALTH ACTION OF MONITORING B(A)P IN PM₁₀ AT URBAN MEASURING POINTS IN SERBIA

B. Matić (1), S. Milanović (2)

(1) *Institute of Public Health of Serbia, Belgrade, Serbia,* (2) *High School of Medicine, Zvezdara, Belgrade, Serbia*

brankicam@batut.org.rs

Polycyclic aromatic hydrocarbons (PAHs) are ranked among the most potent toxic pollutants in the urban environment, as products of incomplete combustion or pyrolysis of organic matter, such as petroleum products (gasoline, diesel), coal or wood. Benzo(a)pyrene is considered the main representative of this group of compounds, with proven cytotoxic, genotoxic, carcinogenic, teratogenic and immunotoxic effects. (IARC, 1989; Zasadowski and Wysocki, 2002; Tang et al, 2008). Landfill fires are an additional source of unexpected PAH emissions (Rykała et al., 2022). The paper aims to indicate the extent of monitoring and concentration of BaP in PM₁₀ particles in 2023 in Serbia, initiating a discussion about the utility of monitoring if no health impact assessment is done with acquired data.

Data used for this cross-sectional study were derived from the Serbian Environment Protection Agency (SEPA), responsible for measurements within the State Network of automatic measuring stations, as well as the Belgrade City Institute of Public Health (IPH), which, in addition to the three State AMSs, are managing a local network of measuring points/stations on the territory of their jurisdiction (Agglomeration Belgrade).

In 2023, BaP was monitored at 61 measuring points, of which 28 were monitored by IPH of Belgrade city, with other 33 distributed in sixteen different urban settlements. The lowest average annual value (0.1 ng/m³) was in Bor (Gradski park), and the highest in Šabac (4 ng/m³). At 24/61 sites, the BaP average annual value exceeded the limit value of 1.0 ng/m³. This indicates a need to approach the exposure to PAHs from the aspect of public health protection of exposed vulnerable groups, due to the nature of their effects (cancerous and endocrine disrupting compounds).

Given the fact that the majority of BaP value exceedances were recorded continuously at the same measuring points, and that the significant impact of these emissions on the health of the exposed population was recognized, this requires a more serious involvement of public health institutions in the systemic risk assessment of these emissions on health in those locations. BaP should be taken into account as a toxic chemical of high public health concern.

REFERENCES

- World Health Organization. Regional Office for Europe. 2021. Human health effects of polycyclic aromatic hydrocarbons as ambient air pollutants: report of the Working Group on Polycyclic Aromatic Hydrocarbons of the Joint Task Force on the Health Aspects of Air Pollution. World Health Organization. Regional Office for Europe <https://iris.who.int/handle/10665/350636>. License: CC BY-NC-SA 3.0 IGO
- Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Vol. 34. Polynuclear Aromatic Compounds. Part 3. Industrial Exposure in Aluminium Production, Coal Gasification, Coke Production and Iron and Steel Founding, IARC, Lyon, 1989.
- Zasadowski, A., Wysocki, A. 2002. Some toxicological aspects of polycyclic aromatic hydrocarbons (PAHs) effects? *Roczn PZH*, 53, (1), 33.
- Tang, D., Kapota, L., Zhou, Z., Kapota, Y., Chen, Y. et al. 2008. Effects of prenatal exposure to coal-burning pollutants on children's development in China. *Environ Health Perspect.*, 116, (5), 674.
- Rykała, W., Fabianska, M.J., Dabrowska, D. 2022. The Influence of a Fire at an Illegal Landfill in Southern Poland on the Formation of Toxic Compounds and Their Impact on the Natural Environment. *Int. J. Environ. Res. Public Health* 19, 13613.

10.2. ASSOCIATION BETWEEN OCCUPATIONAL EXPOSURE TO AIR POLLUTION AND REPRODUCTIVE OUTCOMES IN FEMALE WORKERS

A. Stanković (1), M. Nikolić (1), B. Kocić (2), B. Vuković Mirković (1)

(1) Department of Hygienology, Medical Faculty of Niš, Serbia

(2) Department of Epidemiology, Medical Faculty of Niš, Serbia
aleksandrasei@yahoo.com

Women workers require special protection during pregnancy because the developing embryo is very susceptible to hazardous agents (Ling et al., 2018). Women employed in industries, transportation, or other professions involving consistent exposure to pollutants are especially at risk. Several hazards have been established as risk factors for adverse reproductive outcomes in women such as particulate matter, nitrogen dioxide, ozone and other toxic substances (Simončić et al, 2020; Li et al., 2023; Yuan et al., 2019). The underlying mechanisms include inflammation, oxidative stress, placental dysfunction, and hormonal imbalances, all of which can affect pregnancy maintenance and fetal development (Silva VC et al., 2022).

The objective of this investigation was to estimate the effects of occupational exposure to air pollution during pregnancy on the prevalence of spontaneous abortion.

The study was conducted in the city of Niš during 2018. In this study we evaluated data from a sample of 1155 never-smoking pregnant women, ages 20-40 years, who have lived in part of the town with low concentrations of outdoor air pollutants. According to the responses collected by a questionnaire regarding exposure to occupational air pollution, the interviewees are divided into two groups: the exposed (n = 578) and a control group (n = 577). Pregnant women of both groups do not have symptoms of any cardiovascular or pulmonary diseases, anemia, diabetes and pathological condition of pregnancy. Collecting data on the occurrence of spontaneous abortion was performed by the hospital protocol of subjects.

Exposed female workers had a higher prevalence of spontaneous abortion than non-exposed female workers ($p < 0,01$).

Our results suggest that occupational exposure after and during the pregnancy to air pollution was associated with occurrence of spontaneous abortion.

REFERENCES:

- Li, J., Liu, L., Gu, J., Cao, M., Lei, J., Li, H., He, J. 2023. The impact of air pollutants on spontaneous abortion: a case-control study in Tongchuan City. *Public Health*. 231, 102845.
- Ling, Y.L., Mei, L.Y., Wei, T.T., Zhang, L.L., Lu, L., Yu, W.L. 2018. An investigation of reproductive health in female workers engaged in administrative management. *Zhonghua Yu Fang Yi Xue Za Zhi*, 52(4), 379–383.
- Silva, V.C, Pires, R.C., Silva, H.E.P., Lopes É.M.S. 2022. Exposure to pollution during pregnancy and occurrence of miscarriage. *São Paulo*. 25, 1-21.
- Simončić, V., Enaux, C., Deguen, S., Kihal-Talantikite, W. 2020. Adverse birth outcomes related to NO₂ and PM exposure: European systematic review and meta-analysis. *Int J Environ Res Public Health*. 17(21), 8116.
- Yuan, L., Zhang, Y., Gao, Y., Tian, Y. 2019. Maternal fine particulate matter (PM_{2.5}) exposure and adverse birth outcomes: an updated systematic review based on cohort studies. *Environmental Science and Pollution Research*. 26, 13963–13983.

10.3. USE OF AIRQ+ SOFTWARE IN ASSESSING HEALTH IMPACT OF EXPOSURE TO AIRBORNE PARTICLES IN SMEDEREVO, SERBIA

S. Živković Perišić, B.Matić

Institute of Public Health of Serbia "Dr Milan Jovanović Batut", Belgrade, Serbia

snezana_zivkovic@batut.org.rs

Staying adjacent to steel plants may raise the chance of non-communicable disease (NCD) risk factors for their inhabitants, including cardiovascular diseases (Shhab, et al., 2023). In order to address the issue of harmful effects of air pollution on human health, the World Health Organization (WHO) European Region has developed an AirQ+ software tool for assessing the health risks associated with exposure to criteria air pollutants (WHO, 2020). The aim of this study was to assess impact on health due to PM_{2.5} ambient air exposure of the population of Smederevo (town hosting a steel plant) for the period 2018 to 2023 by using the WHO AirQ+ software Version 2.2 (released in 2023).

Five mortality outcomes were analysed: all-natural causes of death (30+ years), cardiovascular disease (30+), respiratory diseases (30+ years), lung cancer in adults and chronic obstructive pulmonary disease (COPD) in adults (25+ years). Software is freely downloadable from the WHO website (WHO, 2023).

The percentage of mortality according to diagnoses was calculated for mean annual values of PM_{2.5} for the town of Smederevo, which resulted in the highest percentage of average mortality from circulatory diseases (19.2%), while the average values of mortality from lung cancer and COPD (17.8%) and mortality from respiratory diseases were almost identical (17.7%).

It would be of great public health interest for the AirQ+ modeling software to be used by public health authorities and researchers, in order to enhance decisions regarding air quality improvement measures at both local and national levels.

REFERENCES

- Shhab, H., Safaeian A., Khadivi R. 2023. Is Neighborhood with a Steel Factory Associated with Cardiovascular Disease Risk Factors?. *Epidemiology and Health System Journal* 10 (2): 95-99.
- WHO Regional Office for Europe; 2020. Health impact assessment of air pollution: introductory manual to AirQ+. Copenhagen: Licence: CC BY-NC-SA 3.0 IGO <https://apps.who.int/iris/bitstream/handle/10665/337681/WHO-EURO-2020-1557-41308-56210-eng.pdf>
- WHO Regional Office for Europe; 2023. AirQ+ 2.2 software tool for health risk assessment of air pollution free download https://terrance.who.int/internet/euro/airqplus/AirQPlus_v22_Windows.zip

10.4. SPATIAL STRUCTURE AND PARTICULATE MATTER AS KEY DRIVERS OF BENZENE CONCENTRATION VARIABILITY IN EUROPE

I. Đuknić (1), T. Bezdán (1), G. Jovanović (2), A. Stojić (1,2), M. Perišić (1,2)

(1) Singidunum University, Serbia, (2) Institute of Physics Belgrade, Serbia

mirjana.perisic@ipb.ac.rs

Benzene is a toxic volatile organic compound of major environmental and public health concern due to its carcinogenicity and persistence in the atmosphere. Its concentrations are primarily influenced by anthropogenic activities, particularly vehicular traffic, industrial combustion, and fossil fuel use (IARC, 2018). Numerous studies have shown that benzene strongly correlates with particulate matter (PM₁₀) (Radić et al., 2025).

To identify the key environmental and societal determinants of benzene variability, we have applied an AI-based framework to disentangle anthropogenic signals from meteorological conditions, yielding a transparent map of drivers and enabling the identification of environment-specific regimes (Radić et al., 2025). Multisource observations of PM₁₀, CO, NO₂, SO₂, and O₃ are fused with meteorological forcings from the Global Data Assimilation System (GDAS1), as well as the governmental measures (Oxford), mobility (Apple, Google), and epidemiological (Worldometer) indicators that capture exogenous shifts in human activity during the COVID-19 period. The analysis covers 84 monitoring sites across Europe from 15 February 2020 to 10 October 2021. To model nonlinear responses and higher-order interactions, we train a Light Gradient Boosting Machine (LightGBM) regression, tuning its hyperparameters with the population-based Sine-Cosine Algorithm (SCA). The resulting model exhibits strong predictive performance ($R^2 = 0.86$) and high generalization capability. Global contributions were quantified using Incremental Shapley Additive Global Importance (iSAGE), which provides a model-agnostic ranking of predictors, while Shapley Additive Explanations (SHAP) offered local attributions that reveal the response relationships and key interactions.

Analysis of 29,049 daily observations revealed substantial variability among pollutants, reflecting diverse emission sources and atmospheric processes. The iSAGE identified longitude and PM₁₀ as the dominant predictors influencing benzene variability across Europe. Elevated benzene levels occurred in Spain, central and eastern Europe, and southern Greece, whereas lower values characterized western and northern Europe, forming a distinct west-east and north-south gradient linked to differences in emission intensity and atmospheric dispersion. The SHAP analysis further highlighted PM₁₀ as a key amplifying factor in benzene dynamics, revealing a clear positive relationship between PM₁₀ levels and their influence on benzene predictions. Higher particulate matter concentrations were systematically associated with increased benzene levels, indicating that PM₁₀ serves as an effective proxy for combustion-related emissions and particle-bound transport of benzene. The accompanying CO gradient further reinforced this connection, linking high SHAP impacts to combustion-dominated conditions.

The presented approach demonstrates the potential of AI-driven modeling to integrate chemical, meteorological, and socio-epidemiological data for a comprehensive understanding of air pollution dynamics. By combining machine learning, hyperparameter optimization, and explainable AI, the study identifies spatial and particulate matter influences as dominant factors controlling benzene variability across Europe. These findings contribute to advancing regional air quality assessment and establishing a scientific foundation for evidence-based emission and exposure mitigation policies.

FUNDING

The authors acknowledge funding provided by the Institute of Physics Belgrade, through the grant by the Ministry of Education, Science and Technological Development of the Republic of Serbia, as well as by the Science Fund of the Republic of Serbia, Grant No. #7373, Characterizing crises-caused air pollution alternations using an artificial intelligence-based framework – crAIRsis.

REFERENCES

- IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. 2016. Outdoor air pollution. Lyon (FR): International Agency for Research on Cancer. 2016. (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 109.) 1.2, Sources of air pollutants.
- Radić, N., Perišić, M., Jovanović, G., Bezdán, T., Stanišić, S., Stanić, N., Stojić, A. 2025. An AI-Based Framework for Characterizing the Atmospheric Fate of Air Pollutants Within Diverse Environmental Settings. *Atmosphere*, 16, 231-243.

10.5. SEM/EDS ANALYSIS OF INDOOR PM₁₀ PARTICLES IN SECONDARY SCHOOL IN BOR, SERBIA

V. Tasić (1), R. Kovačević (1), B. Radović (1), T. Apostolovski-Trujić (1), M. Živković (2)
(1) Mining and Metallurgy Institute Bor, Bor, Serbia, (2) Institute Vinca, University of Belgrade, Belgrade, Serbia
visa.tasic@irmbor.co.rs

Morphological and chemical characterization of the suspended particles (PM₁₀) collected on PTFE filters in the selected classroom of the "MEŠ" secondary school in the city of Bor, Republic of Serbia, during the heating season, was performed using scanning electron microscopy (SEM) coupled with energy-dispersive X-ray spectroscopy (EDS). The analysis was conducted on individual particles representing different morphologies and contrast levels observed on the filter surface. The accelerating voltage was 20 kV, and the sample was coated with a thin carbon layer to ensure adequate conductivity.

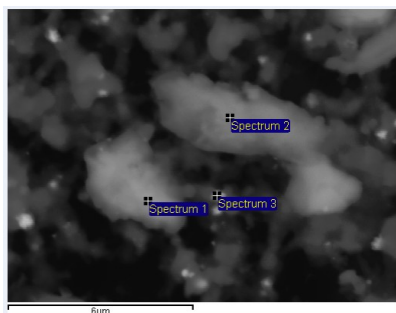


Figure 1. SEM photomicrograph of PM₁₀ particles collected on a Teflon filter

The EDS spectra were quantified using standard ZAF corrections, and results are expressed as weight percentages of detected elements. The results revealed a heterogeneous particle composition reflecting a mixture indoor and outdoor sources. The obtained spectra revealed that the indoor PM₁₀ sample contained particles of both mineral and anthropogenic origin, reflecting a combination of indoor and outdoor sources.

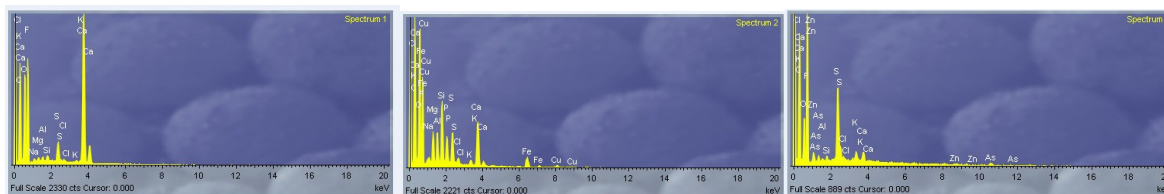


Figure 2. EDX spectra of the first (Spectrum 1), second (Spectrum 2) and third (Spectrum 3) analyzed particle.

The first analysed particle (Spectrum 1, Figure 2) showed a composition dominated by calcium (≈ 29 wt%) and oxygen (≈ 65 wt%), with minor sulfur (≈ 2.5 wt%) and silicon (≈ 0.6 wt%). This composition is typical of calcium-rich mineral dust, primarily calcium carbonate (CaCO₃) or calcium sulfate (CaSO₄), commonly originating from classroom chalk, wall plaster, or other construction materials. Such particles are clearly associated with indoor sources. The second particle (Spectrum 2, Figure 2) exhibited a more complex composition, including oxygen (≈ 58 wt%), silicon (≈ 7.5 wt%), calcium (≈ 8.4 wt%), magnesium (≈ 4.4 wt%), aluminium (≈ 3.7 wt%), phosphorus (≈ 4.0 wt%), sulfur (≈ 4.5 wt%), and iron (≈ 4.7 wt%), with trace elements such as Cu and Zn. These results indicate a mixed aluminosilicate-mineral particle, possibly originating from resuspended soil, road dust, or combustion aerosols. The coexistence of Fe, Zn, and S suggests that the particle may have incorporated anthropogenic material from the ambient air, consistent with the general outdoor pollution pattern in Bor.

In contrast, the third particle (Spectrum 3, Figure 2) was strongly enriched in sulfur (17.8 wt%), lead (13.6 wt%), and arsenic (3.3 wt%), together with oxygen (51 wt%). This composition is typical of metal-rich sulfate particles formed in metallurgical processes, such as copper smelting, and suggests the presence of PbSO₄ and As oxides/sulfates. These particles likely penetrated the indoor environment via air infiltration from outdoor industrial emissions. In summary, SEM/EDS analyses demonstrate that indoor PM₁₀ in the classroom contained both Ca-based particles from indoor activities and metal-bearing particles of anthropogenic origin. The detection of Pb-As-S-rich particles confirms the significant impact of metallurgical emissions on indoor air quality in Bor, even during the winter period when ventilation is reduced.

ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia, Grants No. 451-03-136/2025-03/200052 and No. 451-03-136/2025-03/200017. This work has also been partly funded by the European Union's Horizon Europe Research and Innovation program under grant agreement no.101060170 - WeBaSOOP, "Research Reinforcing in the Western Balkans in Offline and Online Monitoring and Source Identification of Atmospheric Particles."

REFERENCES

Girão A.V., Caputo G., Ferro M.C. 2017. Chapter 6 - Application of Scanning Electron Microscopy–Energy Dispersive X-Ray Spectroscopy (SEM-EDS), Editor(s): Teresa A.P. Rocha-Santos, Armando C. Duarte, Comprehensive Analytical Chemistry, Elsevier, 75, 153-168.

10.6. AEROSOL VERTICAL PROFILES OVER BELGRADE FROM GROUND-BASED AND SATELLITE LIDAR OBSERVATIONS

M. Kuzmanoski (1), J. Kostić (2), Z. Mijić (1)

(1) Institute of Physics Belgrade, National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, (2) Faculty of Physics, University of Belgrade, Belgrade, Serbia
maja.kuzmanoski@ipb.ac.rs

Accurate representation of atmospheric aerosols in climate and air pollution models requires their better characterization. Information on aerosol vertical profiles is essential for improving our understanding of their impact on cloud formation, as well as their role in climate system and air pollution. Lidar systems provide vertical profiles of aerosol optical properties with high vertical resolution. Ground-based lidar measurements provide this information at a single location, whereas satellite-borne lidar provides data over a broader spatial extent. We present case studies of aerosol vertical profiles obtained from ground-based lidar measurements in Belgrade, Serbia and from CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) onboard CALIPSO (Cloud Aerosol Infrared Pathfinder Satellite Observation) during the satellite overpasses in 2018-2020.

We used daytime elastic backscatter measurements at 355 nm from ground-based lidar in Belgrade (Mijić et al., 2023). The aerosol backscatter coefficient was derived from lidar signals averaged over 30-minute intervals closest to the CALIPSO overpass, using the Klett-Fernald retrieval method (Klett, 1981; Fernald, 1984) with an assumed lidar ratio of 50 sr. For comparison, and to assess the spatial representativeness of the ground-based measurements, we used aerosol backscatter coefficient profiles from the CALIOP 5-km Aerosol Profile product (Level 2, Version 4.51). For this purpose, cloud-free aerosol backscatter coefficient profiles from CALIOP that satisfied the quality assurance criteria described by Tackett et al. (2018) were averaged along the satellite ground-track, within a maximum distance between 100 km and 200 km from the ground-based lidar, depending on the case. It should be noted that, due to different wavelengths of ground-based and satellite measurements, this study focuses on a qualitative comparison of aerosol vertical distributions.

The studied cases correspond to influence of different airmasses and diverse aerosol conditions, including those affected by long-range transported aerosols. In all cases, the comparison between ground-based and satellite measurements showed good agreement in the vertical extent and structure of the aerosol layers, indicating large spatial representativeness of ground-based lidar measurements. Aerosol type information from CALIOP, along with airmass backward trajectories and dust model results were used to interpret the observed aerosol vertical profiles.

ACKNOWLEDGEMENTS

MK and ZM acknowledge funding provided by the Institute of Physics Belgrade, through the grant by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia.

REFERENCES

- Fernald, F. G., 1984. Analysis of atmospheric lidar observations: some comments. *Applied Optics* 23, 652-653.
- Klett, J. D. , 1981. Stable analytical inversion solution for processing lidar returns. *Applied Optics* 20, 211-220.
- Mijić, Z., Ilić, L. and Kuzmanoski, M., 2023. Data quality assurance for atmospheric probing and modeling: characterization of Belgrade Raman lidar station. *Contributions of the Astronomical Observatory Skalnaté Pleso* 53, 163-175.
- Tackett, J. L., Winker, D. M., Getzewich, B. J., Vaughan, M. A., Young, S. A. and Kar, J., 2018. CALIPSO lidar level 3 aerosol profile product: version 3 algorithm design. *Atmospheric Measurement Techniques* 11, 4129--4152.

10.7. BENZO[A]PYRENE AMBIENT CONCENTRATION IN BELGRADE, SERBIA: LEVELS, HUMAN EXPOSURE AND HEALTH RISK

A. Cvetković, A. Šoštarić, K. Radusin, N. Vuković, S. Dikanović

Institute of Public Health of Belgrade, Serbia

anka.cvetkovic@zdravlje.org.rs

The exposure to a mixture of Polycyclic Aromatic Hydrocarbons (PAHs) is causally associated with an increased incidence of respiratory and cancer disease according to many studies because of their toxic, teratogenic, mutagenic and carcinogenic properties (Schreiberová et al., 2020). PAHs are mixture of many compounds and the composition of the mixture in ambient air varies in time and space. Among 16 priority EPA PAH, Benzo[a]pyrene (BaP) is considered as carcinogenic to humans and is usually used as an indicator of human exposure to PAHs (Bostrom et al., 2002). According to International Agency for Research on Cancer (IARC), BaP is classified as carcinogenic to humans (Group 1) (IARC, 2012). This paper estimated the long-term temporal variation of BaP in Belgrade in the framework of a local monitoring network that can be used in epidemiological studies on the health effects of ambient BaP exposure.

The analysed data were collected from campaigns conducted at sampling sites representing Belgrade urban settlement zones (4 locations), and municipalities Obrenovac (2 locations) and Lazarevac (1 location). This study aimed to present evaluated data for the period 2009-2013 and 2022 to 2024. PAH-PM₁₀ samples were collected by European reference low-volume sampler (Sven/Leckel LVS3 with flow rates 2.3 m³ h⁻¹). Collected samples were prepared according to an ISO standard (ISO 12884:2000; US EPA) (extraction by mixture of organic solvents in microwave) using Gas Chromatography with Mass Selective Detector and Capillary column RESTEK (40m x 0,18mm x 0,07µm) in SIM mode.

The mean BaP values at all sampling sites have shown seasonal trends and the obtained mean year values were from 0.36 ng/m³ during summer (2023) to 3.05 ng/m³ during winter (2022). The highest concentration of BaP was observed at the suburban/industrial location during the heating season. The concentrations of BaP for collected PM₁₀ during the H season were found to be between 0.13 ng/m³ and 39.65 ng/m³, highest at the urban site. At some locations Benzo[a]Pyrene (BaP) concentrations were above 1 ng/m³ during both seasons. The excess number of lung cancer incidences was calculated in Belgrade each year during the study period (Guerreiro et al., 2016, Porwisiak et al., 2023).

Due to population density, cancer risks are higher in the Belgrade urban settlement than in other cities due to BaP toxicity. Our estimates can be used in epidemiological studies to assess the health effects of BaP exposure at ambient concentrations.

ACKNOWLEDGMENTS

Funding for this work has been provided by the European Union's Horizon Europe Research and Innovation program under grant agreement no.101060170 - WeBaSOOP, "Research Reinforcing in the Western BalkanS in Offline and Online Monitoring and Source Identification of Atmospheric Particles".

REFERENCES

- Boström, C.E., Gerde, P., Hanberg, A., Jernström, B., Johansson, C., Kyrklund, T., Rannug, A., Törnqvist, M., Victorin, K., Westerholm, R., 2002. Cancer risk assessment, indicators and guidelines for polycyclic aromatic hydrocarbons in the ambient air. *Environmental Health Perspectives*, 110, 451-488.
- Guerreiro, C., Horálek, J., De Leeuw, F., Couvidat, F., 2016. Benzo(a)Pyrene in Europe: ambient air concentrations, population exposure and health effects. *Environ. Pollut.* 214, 657–667.
- IARC, 2012. Chemical agents and related occupations. In: International Agency for Research on Cancer (IARC) Monographs on Evaluation of Carcinogenic Risks to Humans, vol. 100F, pp. 111–144.
- Porwisiak, P., Werner, M., Kryza, M., Vieno, M., Holland, M., ApSimon, H., Drzeniecka-Osiadacz, A., Skotak, K., Gawuc, L., Szymankiewicz, K., 2023. Modelling Benzo(a)Pyrene concentrations for different meteorological conditions – analysis of lung cancer cases and associated economic costs. *Environ. Int.* 173, 107863.
- Schreiberová, M., Vlasáková, L., Vlček, O., Šmejdiřová, J., Horálek, J., Bieser, J., 2020. Benzo[a]Pyrene in the ambient air in the Czech Republic: emission sources, current and long-term monitoring analysis and human exposure. *Atmosphere* 11 (9), 955.

10.8. THE IMPACT OF WET SEPARATOR AND FLUE GAS CONDENSER ON THE EMISSION AND FRACTIONAL DISTRIBUTION OF PARTICULATE MATTER FROM BIOMASS BOILER

**D. Todorović (1), M. Obradović (1), A. Jovović (1),
N. Karličić (1), D. Radić (1), R. Karamarković (2), M. Nikolić (2)**

(1) University of Belgrade Faculty of Mechanical Engineering, Belgrade, Serbia, (2) The Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo, Serbia
dtodorovic@mas.bg.ac.rs

This paper presents the results of experimental investigations performed on a 35 kW biomass pellet boiler, aimed at assessing the influence of a wet separator and a flue gas condenser on the total particulate matter (PM) emissions and their fractional distribution. The wet separator and condenser operate as an integrated active condensation system, which primarily enhances the overall boiler efficiency through latent heat recovery, but also contributes to a substantial reduction of solid particle emissions. During the experimental campaign, the gaseous combustion products were continuously monitored using an automatic gas analyser, while the total particulate matter was determined by the isokinetic gravimetric method. For the characterization of particle size distribution, the HT-DLPI+ cascade impactor was employed, enabling classification of airborne particles into 14 size fractions ranging from 16 nm to 10 μm . Since individual biomass-fired heating systems represent one of the dominant sources of PM_{2.5} emissions, the implementation of such technologies is of great importance for improving local air quality and reducing health risks. The findings of this study may serve as a basis for further optimization of small-scale biomass boiler systems equipped with condensation-based emission control technologies.

ACKNOWLEDGEMENT

This research was supported by the Science Fund of the Republic of Serbia, 5959, Active Condensation Hybrid Systems in Biomass Combustion - AC-BC.

10.9. COMPOSITION AND LEVELS OF PARTICULATE MATTER AND NANOPARTICLES IN SLEEPING ENVIRONMENTS OF LISBON DWELLINGS: PRELIMINARY RESULTS OF THE HYPNOSAIR PROJECT

S. Méndez (1), C. Gamelas (1,2), J. Lage (1,3), S.M. Almeida (1), N. Canha (4)

(1) C2TN – Centro de Ciências e Tecnologias Nucleares, Instituto Superior Técnico, Universidade de Lisboa, Portugal (2) Instituto Politécnico de Setúbal, Escola Superior de Tecnologia de Setúbal, Portugal

(3) Escola Superior de Tecnologia de Setúbal, Instituto Politécnico de Setúbal (IPS), 2914-508 Setúbal, Portugal (4) Faculdade de Engenharia, Universidade Lusófona de Humanidades e Tecnologias de Lisboa, Portugal

sergiomendez@ctn.tecnico.ulisboa.pt

Indoor air quality (IAQ) plays a crucial role in human health and well-being, especially during sleep, when essential physiological functions occur. Since people spend approximately one-third of their lives sleeping, bedrooms represent critical microenvironments for long-term exposure. Previous HypnosAir studies revealed that nine out of ten bedrooms in Lisbon exceeded the World Health Organization (WHO) guideline value for PM_{2.5} of 5 µg.m⁻³ during the sleeping period (Canha et al., 2020; WHO, 2021). However, information regarding the chemical composition of particulate matter and the predominant emission sources remains scarce. This study, within the HypnosAir project, aims to characterize the concentrations and composition of particulate matter (PM₁, PM_{2.5}, PM₁₀), black carbon (BC), and ultrafine particles (UPF) in 30 bedrooms across the Lisbon Metropolitan Area (LMA), to evaluate the contribution of indoor and outdoor sources and to estimate their potential impact on personal exposure during sleep.

Between May 2023 and May 2024, a sampling campaign was conducted in 30 dwellings in the LMA, occupied by non-smoking adults sleeping either alone or in couples. Each bedroom was monitored for four consecutive weeknights (Monday–Friday) during the sleeping period (23:00–06:59). Indoor real-time monitoring included: DustTrak DRX 8533 (TSI, USA) for PM₁, PM_{2.5}, and PM₁₀; AE51 (AethLabs, USA) for BC, corrected using the ONA algorithm; Partector Pro Silent (Naneos, Switzerland) for UPF; and TSI 7545 for CO₂, temperature (T), and relative humidity (RH). Gravimetric reference sampling was performed simultaneously using the Silent Sequential Air Sampler (FAI Instruments, Italy) indoors and the Leckel MVS6 (Sven Leckel, Germany) outdoors, collecting PM_{2.5} on Teflon and quartz filters for subsequent chemical analyses (ions, organic and elemental carbon, trace metals). Information regarding occupants' behaviour (window opening/closing) and meteorological conditions was also recorded. Concentration data were corrected using factors obtained from intercomparison studies (Canha et al., 2021).

Preliminary results show that indoor PM_{2.5} concentrations ranged from 3.8 to 25.7 µg.m⁻³, with an overall mean of 9.2 ± 4.4 µg.m⁻³. Outdoor concentrations averaged 9.8 ± 6.6 µg.m⁻³. Only 12.6% of all measurements (12 of 95) complied with the WHO guideline value (5 µg.m⁻³), while 6% exceeded the Portuguese limit of 25 µg.m⁻³ established by Portaria n° 138-G/2021. In 51.7% of the dwellings, the indoor/outdoor ratio (I/O) was >1, indicating a predominant influence of indoor sources, likely related to occupant activity, resuspension of settled dust, or emissions from building materials and furnishings. Mean BC concentrations ranged between 0.6 and 3.8 µg.m⁻³, with peaks coinciding with reduced ventilation. CO₂ levels averaged 872 ± 203 ppm, with exceedances above 1250 ppm for 2% of the monitored time, suggesting inadequate air renewal. Mean nocturnal temperature and relative humidity were 21.8 ± 0.4 °C and 58 ± 10%, respectively, both within ISO 7730 comfort ranges. High variability among dwellings was observed, influenced by seasonality, occupancy, and ventilation habits. Ongoing analyses will assess the chemical composition (organic/elemental carbon, trace metals, and anions) and oxidative potential of collected PM_{2.5} samples.

These results confirm that PM_{2.5} concentrations in sleeping environments of Lisbon frequently exceed international recommendations, even in non-smoking households. Indoor sources substantially contribute to nighttime exposure (I/O >1), emphasizing the need to identify specific sources of BC and UPF to develop mitigation strategies. This study provides the first large-scale dataset on IAQ during sleep in Portugal and highlights the importance of improving nocturnal ventilation and reducing indoor emissions to ensure healthy sleeping conditions. The ongoing HypnosAir analyses will expand these findings by linking IAQ parameters with objective sleep quality indicators, providing valuable input for evidence-based public health policies.

REFERENCES

- Basner, M., et al. 2023. Sleep and environmental noise: implications for health. *The Lancet Public Health*, 8(1), e36–e47.
- Canha, N., Teixeira, C., Figueira, M., and Correia, C. 2021. How Is Indoor Air Quality During Sleep? A Review of Field Studies. *Atmosphere*, 12(1), 110.
- Canha, N., Alves, A.C., Marta, C.S., Lage, J., Belo, J., Faria, T., Cabo Verde, S., Viegas, C., Alves, C., Almeida, S.M. 2020. Compliance of indoor air quality during sleep with legislation and guidelines—a case study of Lisbon dwellings. *Environmental Pollution*, 264, 114619.
- Strøm-Tejsen, P. et al. 2016. The effects of bedroom air quality on sleep and next-day performance. *Indoor Air*, 26(5), 679–686.
- WHO 2021. WHO Global Air Quality Guidelines: Particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization.

AUTHOR INDEX

Author Name	Abstract Number(s)
Abedian Aval, F.	2.3
Ahmović, I.	8.6
Alastuey, A.	1.2, 4.1, 4.5, 5.1, 6.3, 6.4, 6.5, 7.3, 8.5
Alinaghipour, B.	8.3
Almeida, S.M.	4.4, 8.7, 10.9
Alves, C.	8.2
Alves, S.	2.2
Atanasievska Kujović, S	2.4
Andersen, Z. J.	2.1
Antonijević, B,	3.6
Apostolovski-Trujić, T.	6.2, 10.5
Arapov, J.	8.2
Ataee, S.	2.3, 9.3
Bartonova, A.	1.2, 3.1, 6.1, 6.3, 6.4,
Bauer, M.	8.6
Bejan, I. G.	5.5
Belis, C. A.	7.1
Berntsen, T. K.	5.4
Bezdan, T.	10.4
Bijedić, A	8.6
Branco, P.T.B. S.	3.3
Brborić, M.	2.5
Bubola, L.	8.2
Bulat, Z	3.6
Buha Đorđević, A	3.6
Canha, N.	10.9
Chaux, F	8.2
Chazeau, B.	7.5, 8.6
Chichaeva, M.	7.2
Chubarov, D.	5.3
Cirne, P.	2.3
Coelho, R.	3.2
Cortes, J.	4.1, 7.3
Croteau, P.	8.6
Cvetković, A.	4.2, 10.7
Cvitešić Kušen A.	8.2
Ćirović, Ž.	4.5, 6.1, 6.5, 9.5
Ćojbašić, S	2.5
Ćurčić, M	3.6
Daellenbach, K. R.	7.4
Davidović, M.	1.2, 4.5, 6.1, 9.1, 9.2, 9.4, 9.5

Author Name	Abstract Number(s)
Davidović, M. D.	9.4
Davila, S.	8.2
De Meij, A.	7.1
Demšar, J.	7.4
Depolo, A.	8.2
De Vito, S.	9.2
Dikanović, S.	10.7
Dinh, V.	7.4
Djordjevski, N	2.4
Dmitrašinović, S.	2.5
Drinovec, L	7.5, 8.5
Dzepina, K.	8.6
Đukić-Ćosić, D	3.6
Đuknić, I.	10.4
Eckhardt, S.	5.2, 6.1
Elamin, A. M.	9.2
Eleftheriadis, K.	8.7
Evangeliou, N.	5.2, 6.1
Erunsal, I.	9.2
Faria, A.M	3.2
Faria, T.	8.7
Fedele, R.	1.4
Fernandes, A.	2.2
Folghera, L.	8.6
Fredriksen, M. F.	3.1
Frka, S.	8.2
Froment, J.	1.1, 1.3
Garcia Marlés, M.	4.1, 4.5, 5.1, 6.5
Gautam, S.	8.5
Gameiro, C.	8.7
Gamelas, C.	10.9
Glojek, K.	7.3, 7.5, 8.6, 8.7
Grange, S.K.	7.4
Gregorič, A.	7.5, 8.5, 8.6
Gundersen, H.	6.1
Hak, C.	1.1, 1.3
Hao, Y	7.4
Hamer, P. D.	5.4
Hassani, A.	5.4
Hatem, G.	3.2
Hoiskar, B. A.	3.1
Honza, T.	1.1, 1.3
Hu, W.	9.2

Author Name	Abstract Number(s)
Hudecova, A. M.	1.1, 1.3
Iram, S.	1.4
Iturrate-Garcia, M	9.1
Ivančič, M	8.5
Jaffrezo, J-L.	7.4
Janišević, M	6.2
Jayne, J.	8.6
Ježek Brecelj, I	8.5
Jiang, J.	7.4
Jorba, O.	5.1
Jovanović, G.	10.4
Jovanović, M.	1.2, 6.1, 9.4
Jovašević-Stojanović, M.	1.2, 4.5, 5.1, 6.1, 6.2, 6.3, 6.4, 6.5, 9.1, 9.4, 9.5
Jovović, A.	10.8
Karličić, N.	10.8
Kamenović, V.	3.4
Kasimov, N	7.2
Khare, P.	8.6
Kleut, D.	9.5
Kocić, B.	10.2
Kona, A	7.1
Karamarković, R.	10.8
Kosheleva, N	7.2
Kostić, J.	10.6
Kovačević, R.	3.4, 6.2, 6.3, 10.5
Krečinić, E.	8.6
Kuzmanoski, M.	10.6
Kylling, A.	5.4
Lage, J.	10.9
Lamont, J.	8.3
Liu, R.	9.2
Longhin, E	1.1, 1.3
Lopes, D.	2.3
Lopes, M.	9.3
Lopez, M.	7.3
Madureira, J	3.2
Makorič, P	7.5, 8.6, 8.7
Manousakas, M	7.4, 7.5, 8.7
Martinho, J.	8.7
Martins, F. G.	3.3
Martins, V.	2.3, 4.4
Matić, B.	10.1, 10.3
McFadden, E.	1.1

Author Name	Abstract Number(s)
Mendez, S	10.9
Mijić, Z.	10.6
Milanović, S.	10.1
Miranda, A.I.	2.3
Mišić, N	3.4
Močnik, G	6.1, 7.4, 7.5, 8.2, 8.5, 8.6, 8.7
Molés, P.	2.2
Monge-Azemar, M.	4.1
Moreno, T.	4.4
Navarro-Barboza, H.	5.1
Nemati, B	2.3
Nikolić, M.	3.5, 6.2, 10.2
Nikolić, M.	10.8
Nunes, A	4.4
Obradović. M.	10.8
Omerčić, E	8.6
Pandolfi, M.	4.1, 5.1, 6.3, 6.4, 7.3, 8.5
Peixoto, C.	3.2
Pereira, M.C.	3.2
Perez, N.	4.5, 6.5, 7.3, 8.5
Petäjä, T.	5.1
Pekar, F	7.1
Perišić, M.	10.4
Petrović, B.	1.2, 3.6, 6.1, 6.3, 6.4
Pisoni, E.	7.1
Platt, S. M.	6.1
Popovicheva, O	7.2
Prevot, A. S. H.	7.5, 8.6
Protić-Đokić, V.	2.4
Querol, X.	4.1, 5.1, 7.3
Radić, D.	10.8
Radonić, J	2.5
Radović, B.	3.4, 6.2, 6.3, 10.5
Radusin, K.	10.7
Reche, C	7.3
Relvas, H,	2.3, 4.3, 9.3
Rey-Pommier, A.	7.1
Rigler, M	7.5, 8.5, 8.6
Ristanović, E.	2.4
Ristovski, Z.	8.1, 8.3
Roebeling, P	4.3
Rovira, J.	5.1
Rundén-Pran, E.	1.1

Author Name	Abstract Number(s)
Rusanen, A.	7.4
Savadkoohi, M.	5.1
Schneider, P.	5.4, 6.1
Shetty, S	5.4
Silva, A. C. T.	3.3
Silva B. T.	2.3
Skejić, S.	8.2
Slezakova, K	3.2
Slowik, J.	8.6
Smajić, D.	8.6
Smith, S. J.	8.4
Soares, J.	4.3
Sousa, S. L.V.	3.3
Stanković, A.	3.5, 10.2
Stavroulas, I.	7.5
Stebel, K.	5.4
Stevanović, S.	1.2, 1.4, 8.3
Stojanović, D. B.	4.5, 6.5, 9.4, 9.5
Stojić, A.	10.4
Šantić, D	8.2
Šoštarić, A	4.2, 9.4, 10.7
Tabandeh S.	9.1, 9.4
Tasić, V.	3.4, 6.2, 10.5
Teixeira, J.P.	3.2
Thunis, P.	7.1
Tian, F.	9.2
Todorović, D.	10.8
Turk Sekulić, M	2.5
Uzu, G.	7.4
Vaz, J.	2.2
Venkatesan, S	8.3
Via, M.	7.4, 7.5, 8.6
Vukelić, D.	3.6
Vuković, N.	10.7
Vuković Mirković, B.	10.2
Williams, L.	8.6
Yttri, K. E.	1.1, 1.2, 1.3, 6.1, 6.3, 6.4
Yus-Díez, J.	5.1, 7.5, 8.5
Zare, A.	8.3
Zauli-Sajani, S.	7.1
Zlatković, I	3.4
Živković, M.	10.5
Živković Perišić, S	10.3

CIP-Katalogizacija u publikaciji Narodna biblioteka Srbije, Beograd

502.3:502.175(048)

613.15(048)

66.071.9(048)

INTERNATIONAL WeBIOPATR Workshop Particulate Matter: Research and Management (10 ; 2025 ; Beograd)

Abstracts of Keynote Invited Lectures and Contributed Papers / The Tenth International WEBIOPATR Workshop & Conference Particulate Matter: Research and Management, WeBIOPATR 2025, [26th – 28th November 2025 Belgrade, Serbia] ; editors Milena Jovašević-Stojanović ... [et al.]. – Belgrade : Vinča Institute of Nuclear Sciences, 2025 (Belgrade : Vinča Institute of Nuclear Sciences). – 103 str. : ilustr. ; 30 cm

Tiraž 100. –

Str. 5: Preface / Milena Jovašević-Stojanović and Alena Bartoňová. -

Bibliografija uz većinu apstrakata. –

Registar.

ISBN 978-86-7306-179-5

1. International Conference Particulate Matter: Research and Management (10 ; 2025 ; Beograd)

a) Ваздух -- Контрола квалитета -- Апстракти

б) Здравље -- Заштита -- Апстракти

в) Отпадни гасови -- Штетно дејство -- Апстракти

COBISS.SR-ID 180626953

