WeBIOPATR 2021

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

Abstracts of Keynote Invited Lectures and Contributed Papers

Milena Jovašević-Stojanović,

Alena Bartoňová,

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Vinča Insitute of Nuclear Sciences

Vinča, Belgrade 2021

ABSTRACTS OF KEYNOTE INVITED LECTURES AND CONTRIBUTED PAPERS

The Eighth WeBIOPATR Workshop & Conference

Particulate Matter: Research and Management

WeBIOPATR 2021

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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
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3. **Particulate Matter and Regulatory Issues**
    i. Issues related to monitoring of particulate matter
    ii. Legislative aspects
    iii. Abatement strategies

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PREFACE

Dear Colleagues,

Welcome to the 8th WeBIOPATR Conference, to be held at the premises of the Vinca Institute of Nuclear Sciences, Serbia, 29.11.–1.12.2021, as a combination of online and face-to-face event.

The International Workshop and Conference, Particulate Matter: Research and Management – WeBIOPATR is a biennial event held in Serbia since 2007. The conference addresses air quality in general and particulate matter specifically. Atmospheric particulate matter arises both from primary emissions and from secondary formation in the atmosphere. It is one of the least well understood local and regional air pollutants, has complex implications for climate change, and is perhaps the pollutant with the highest health relevance. It also poses many challenges to monitoring.

By WeBIOPATR, we aim to link the research communities with relevance to particulate matter with the practitioners of air quality management on all administrative levels, in order to facilitate professional dialogue and uptake of newest research into practice. The workshops usually draw an audience of about 70 and attract media attention in Serbia. It enjoys support of the responsible authorities, Ministry of Education, Science and Technological Development, Ministry of Health, Ministry of Environment, and the Serbian Environmental Agency whose sponsorship is indispensable and gratefully acknowledged. We also enjoy support of international bodies such as the WHO.

The 1st WeBIOPATR Workshop was held in Beograd, 20.-22. May 2007, associated with a project funded by the Research Council of Norway. The 2nd workshop was held in Mećavnik, Serbia, 28.8.-1.9.2009. WeBIOPATR2011 was held in Beograd 14.-17.11.2011 and for the first time, included a dedicated student workshop. WeBIOPATR2013 was held in Beograd 2.-4.10. 2013. It covered the traditional PM research and management issues, discussions on how to encourage citizens to contribute to environmental governance, and how to develop participatory sensing methods. WeBIOPATR2015 was held in Beograd 14.-16.10. 2015. Dedicated sessions were devoted to sensor technologies for air quality monitoring, utilizing information and input from the EU FP7 funded project CITI-SENSE (http://co.citi-sense.eu) and the EU COST action EuNetAir (www.eunetair.it). WeBIOPATR2017, the 6th conference, was held in Beograd 6.-8.9. 2017, with a wider than before Western Balkan participation. The 7th WeBIOPATR2019 was held 1.-4.10. 2019 at the Mechanical Faculty, University of Belgrade. It has attracted a record of over 50 contributions, and brought together scientists from 12 countries, documenting that the issues of atmospheric pollution, with their wide implications for climate change, human health and ecosystem services, are no less important today. This year's event will be with similar number of contributions that have been accepted.

In the past two years, all our lives were affected by the COVID-19 pandemic. We have adapted our ways of life and work – and now we hope that the new format of the conference will be a success, for the participants physically present as well as for those who will participate online.

We are very grateful to our unrelenting national and international partners for their financial and scientific support for this event. In addition, WeBIOPATR2021 is supported by the VIDIS project, https://vidis-project.org/, funded by the EC H2020 Framework Programme for Research and Innovation, area “Spreading excellence and widening participation”. VIDIS (2020-2023) is coordinated by Vinca Institute, Grant agreement number 952433.

Welcome to Vinca and online and have a stimulating and productive time!

Milena Jovašević-Stojanović and Alena Bartoňová

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1. INDOOR, VENTILATION, PROTECTION

1.1 COVID-19, PARTICLES IN THE AIR AND VENTILATION

Lidia Morawska
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Respiratory infections are considered an inescapable part of daily life, and very little has been done so far to control them. Every year acute respiratory illnesses, such as colds and influenza infections strike, sicken millions, kill thousands and cause economic loses of billions of dollars. The COVID-19 pandemic has demonstrated how unprepared the world has been to address the basic question: How can we minimise the risk of airborne infection transmission for any respiratory viruses in a countless number of buildings where most of the population spends a substantial fraction of the day. There is little doubt that the way we design, operate, and maintain our buildings influences transmission. We need a profound change in how we view this risk and how we apply science, building engineering solutions and public health policies to reduce it. In doing this we need to consider all other requirements, including comfort and the control of indoor air quality, and energy-efficiency in the context of local climate and outdoor air quality. The presentation will explore how to turn this vision into a reality.

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1.2 APPLYING AEROSOL SCIENCE TO THE CURRENT NEEDS: PARTICLE REMOVAL EFFICIENCY OF FACE MASKS DURING THE COVID-19 PANDEMIC

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At the onset of the Covid-19 pandemic, the world faced a dire lack of PPE, and in particular face masks. As studies quickly demonstrated, the SARS-CoV-2 virus primarily spreads through droplets (aerosols) that are released when breathing, talking, and coughing. Therefore, masks are the first line of protection to slow the spread of the virus. They act as a barrier against the dispersion of droplets and at the same time protect the wearer against the aerosols already present in the surrounding air.

In spring 2020, we started investigating different properties of face masks and improvised protection equipment with a special focus on the particle removal efficiency. We used a scanning mobility particle sizer to measure the number concentration of a standard aerosol powder passing through a mask mounted on a manikin head in a special chamber. The results show high filtration efficiency of FFP2, FFP3, and certified surgical masks for all sizes of tested particles, while protection efficiency of washable masks depends on their constituent fabrics (Pogačnik Krajnc et al., 2021).

Furthermore, we have demonstrated that ionizing radiation (both gamma and electron beam) can be used for emergency sterilization of FFP2 and FFP3 masks, provided that the respirators are recharged afterwards (Pirker et al., 2021).

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1.3 PERSONAL PROTECTION AGAINST AIRBORNE PARTICULATE MATTER

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The Covid-19 pandemic has driven much change – with great impact on the public and healthcare workers in terms of use of facial coverings ("masks") for both control of exhaled material and respiratory protection. But there are many points where assumptions and misunderstanding about products used in these roles have contributed incorrect selection and use, and poor protection of the wearer. An overview of the factors which contribute to respirator effectiveness in terms of design, function, selection and usage is provided.

Even when appropriate respiratory protective equipment is available, sometimes it is not used because of failure to recognise the hazards in the environment, indicating that better understanding and acceptance of the nature of respiratory hazards is also important to ensure individual protection.

Types of Protective Device Respirators have been used historically to address defined needs in workplaces: they are subject to regulatory approval to national or international standards and have protocols for selection and use. The pandemic has driven use of devices by the general public and workers who have historically not used protective equipment. Surgical or cloth masks so used are not traditionally classed as respirators, and are not subject to the same standards selection, fit or usage guidance, so new expectations are created which need better definition for acceptance in the future.

Design The utility and effectiveness of a facial covering or respirator can be summarized by the "3Fs" which encompass the essential items for minimizing the hazard to the wearer from inhaled airborne matter:

Filtration: the material from which the product is constructed must be capable of efficient filtration for the size range and type of hazardous particles. There are multiple mechanisms by which particles are filtered, and respirator filters demonstrate minimum efficiency at a certain size range – which is used for testing in approval standards. The filtration mechanisms are effective on all types of particle: there is no difference between biologically active and inert matter, liquids or solids.

Fit: a good fit to the face is necessary to ensure that as much inhaled and exhaled air as possible passes through the filtering area of the product. Effective securing mechanisms and shaping of the facepiece is necessary. Fit testing during selection and fit checking methods for each use are employed to verify this.

Function: to be effective, the product must not impose excessive physiological burden on the wearer by making it too difficult to breathe, not become too uncomfortable and allow the wearer adequately to perform functions necessary for their work – such as communication. Design without incorporation all three of these capabilities will not adequately protect the wearer.

Selection Beyond adequate design, the proper protection of individuals depends on selection of a device appropriate to the hazard – which means assessment of the risk of exposure, along the nature of the hazard, assessment of concentration – which may be measured, or may employ a semi-quantitative control banding process-based consideration of generation and ventilation rates. Sometimes the most protective respirator for an exposure may not be the most obvious or generic choice.

Use and Maintenance Adoption of appropriate practices for training, use, recognition of performance limitations and adherence to maintenance requirements provided by the manufacturer are important factors in ensuring safe use and adequate protection of the respirators

Standards Performance standards organised nationally or internationally set out minimum criteria for the manufactured capabilities of respirators. Selection and use provide requirements for the user to maximize their safety and protection. New national and international standards have recently been published better classify capabilities and define performance requirements.

1.4 THE ROLE OF MICROCLIMATE IN THE FORMATION OF INDOOR AIR POLLUTION

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Indoor air quality plays a key role in assessing people's quality of life, as a large proportion of people spend up to 22 hours a day indoors. So people are exposed to indoor air almost all day long. People in developed countries spend much more time indoors. Recently, employers are paying more and more attention to ensuring the well-being of employees, as it affects the quality and productivity of their work (Indoor air.., 2018; Andrejiova et al, 2012). Ensuring an appropriate working environment on the part of employers ensures both sustainable social and economic links. Well-being can be affected by various parameters of the indoor environment, in addition to the microclimate, they can be - lighting, noise level, various odors. However, one of the primary indicators of comfort or discomfort in an indoor environment is thermal comfort or discomfort (Flimel et al, 2018).

Gas stations are selected as the object of the research, which are already objects of increased danger with much higher environmental risks. Based on the above, the topic was chosen to provide an in-depth understanding of the formation of the indoor microclimate and its possible effect on accumulation of different aerosols in an environment that is considered to be potentially unhealthy for humans.

The paper provides an overview of the factors influencing the microclimate of gas stations, the existing measurement results and the methodology used to obtain these measurements. Repeated microclimate measurements were performed at several gas stations in Riga, Latvia. Measurements were performed in autumn, winter and spring of 2018 - 2019. The obtained results on indoor air temperature and relative humidity changes were compared with the data of the National Meteorological Centre on the data of the same period in the outdoor environment. This measurement methodology was chosen because the determination of aerosol contamination is relatively expensive and complicated, but microclimate measurements are easy to perform and are also regulated by work safety legislation. The analysis of the obtained results has also been performed with the aim to assess the current situation and develop recommendations for its improvement.

Preliminary results show that the indoor microclimate is exposed to the effects of outdoor climate, meteorological conditions, indoor parameters, variability in the number of customers, as well as the complex influence of all these parameters, the influence of indoor microclimate on accumulation of aerosols in building is also visible. Further research is required in this regard across Latvia and EU as a whole.

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2. LOW-COST SENORS

2.1 PM LOW-COST SENSORS CALIBRATION IN THE WILD: METHODS AND INSIGHTS FROM AIRHERITAGE PROJECT

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PM low-cost sensors based on OPCs are gaining momentum for their availability and easy of integration (Alfano et al., 2021). Recent works reports that their accuracy is significantly affected by environmental factors wether different particulate sources and composition may severely affect the factory calibration performance (Reese et al., 2017). AirHeritage project, aimed to participatory and distributed AQ sensing, rely on low cost PM sensors for enabling crowdsensing approach and densify the sparse fixed network of regulatory analysers (AirHeritage Website, 2020).

In particular, the ENEA MONICA device (De Vito et al., 2021) is based on an array of three electrochemical sensors, namely Alphasense A4 class NO2, O3, and CO sensors plus a Plantower PMS7003 sensor. The latter comes with two different on-house factory calibration targeting two different deployment scenarios and binned particle counts.

During two field campaigns we tested several tenth of nodes, collocating them with regulatory grade analyzers, courtesy of Campania Regional Environmental Protection Agency. The campaigns have been implemented during Winter 2020/2021 and Summer 2021 each time deploying 30 MONICA devices each of them for at least three weeks. Data have been collected using a Raspberry Pi3 used as a Bluetooth Low Energy Datasink relying on a Python 3 script for data management and storage. Data have been recorded using remote Restful APIs on a ad-hoc NOSQL database for future uses (MongoDB). Thus, we obtained a large dataset enabling us to compare different approaches to PM sensors calibration as well as to use gathered data for PM concentration mapping in the highly complex urban scenario of a densely inhabited Italian town. Multivariate calibration algorithms including MultiLinear Regression and shallow neural networks(5 tansig hidden layer, 1 linear output) have been developed and tested relying on different features.

Performance and their variance have been captured using MAE, MRE, CRMSE and R^2.

One of the key results is the improvement of estimation accuracy which have been obtained using particle counts as input feature as opposing to both in house calibrations and its correction.

Finally, the calibrated nodes have been used for AQ participated mapping using opportunistic measurement coming from several citizens which have shared data captured during uncontrolled measurement sessions in Summer 2021. This keynote will report the primary findings of this endeavour, providing insights on best practice for PM sensors calibration and usage in the field.

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2.2 SCHOOLS FOR BETTER AIR QUALITY: CITIZENS-BASED MONITORING, STEM EDUCATION, AND YOUTH ACTIVISM IN SERBIA *UNICEF IN SERBIA*

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In 2021 UNICEF, with financial support from the Government of Norway, is initiating awareness raising and experimental collection of real-time air quality data in a total of 46 schools in Central and South-West Serbia, situated in 15 local self-governments. To enhance children's learning and awareness through STEM education and to measure real-time air quality at the micro locations where children spend most of their time - at school sites, low-cost air quality sensor devices are introduced in the selected schools. Each of the devices (nodes) developed by the Internet Society of Serbia[1] contains: Laser Particle Sensor (PLANTOWER Technology) for detection of PM1, PM 2.5 and PM10; Digital Gas Sensor for Sulfur dioxide; Digital Gas **Sensor** for Nitrogen Dioxide; PCB board with: ESP32 microcontroller, RGB LED, buttons, voltage converters and a USB-C port on the board itself (manufacturer: JLCPCB); 3D printed box. At each location, three devices are installed, which means that the network consists of 135 devices. Additional devices (5-10) are installed at the Vinča Institute of Nuclear Sciences for continuous testing**.** A system of additional two components is further designed: IoT (Internet of Things) platform and website. The IoT Platform is created to ingest, store, and display data on air-pollution. The platform will also support basic visualizations, displaying PM, NO2 and SO2 concentration on a selected time scale. The IoT platform will be open-sourced, and API will be available for accessing data via external sources. The public website will display real-time air-quality data at school sites, and make collected data available to citizens. The Vinča Institute for Nuclear Sciences will conduct quality assurance of the device and data by establishing protocols for testing and calibration of sensors and monitoring data streams on IoT platform received from the air quality sensors device network. This experimental approach will therefore contribute to establishing further evidence on the utility of low-cost sensor devices in multiple micro-locations and offer solutions for managing data quality of a large network of unofficial air quality measurement devices. It will also help facilitate teachers' decision-making around daily school activities based on indicative pollution levels and increase children's awareness and knowledge to create future positive change in social norms and behaviours, as well as policies over the long-term.

[1] A non-profit association active in the field of Internet communication and technologies (https://www.isoc.rs/about-us/?lang=en).

2.3 ASSESSING AIR POLLUTION FROM WOOD BURNING USING LOW-COST SENSORS AND CITIZEN SCIENCE

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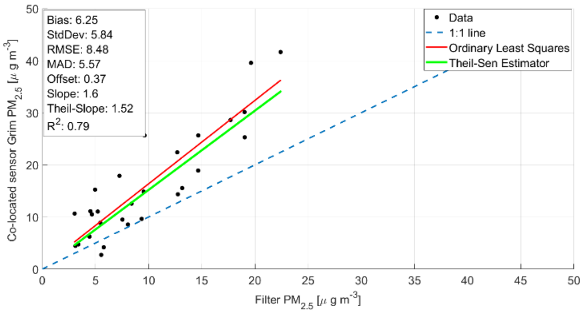
Summary This study aims to investigate how data from low-cost sensors mounted at residents' households can complement official monitoring and modelling of air quality and provide new information on local pollutant concentrations, in this case, from residential wood burning. For this study we engaged with 20 citizens that mounted a low-cost sensor monitoring PM2.5 in their houses from December 2021. Additionally, a Kleinfiltergerät (KFG) providing measurement of fine particle mass concentration (PM2.5) was installed in the garden of one of the houses for a period of 4 weeks from 21 January to 3 February 2021 and 17 February to 2 March 2021. The comparison between the KFG and the low-cost sensor shows a good agreement with a coefficient of correlation of 0.8 for PM2.5 daily averages. The study shows that citizen-contributed data, when data quality routines are in place, can contribute to in-situ environmental monitoring in urban environments.

Introduction Conventional monitoring systems as reference stations can provide accurate and reliable pollution data in the urban environment, but only in single points. This data can be complemented using air quality models to provide the spatial distribution of pollutants. However, to do so, air quality models rely on emission inventories that, specially at local scale, suffer from many uncertainties. In this study, we investigated how citizen science observatories and low-cost sensor technologies can contribute to fill in existing gaps in pollution monitoring at high spatial and temporal resolution.

Methodology and Results During winter 2021 we engaged with residents in 3 neighbourhoods in Kristiansand to monitor air pollution using low-cost sensor systems. For this study we employed 20 Airly sensor units monitoring PM10, PM2.5, and PM1. The selection of the sensor system was based on their usability (i.e. easy to be mounted by a regular citizen) and reliability. The Airly sensor systems integrate a Plantower 5003 and showed a correlation of 0.6 against FIDAS optical reference-equivalent for PM2.5 and of 0.8-0.9 for PM1 hourly observations. The sensor does not accurately monitor coarse particles and has a correlation of 0.5 against FIDAS for PM10 (Vogt et al., 2021). During the winter campaign (December to February 2021) we installed a KFG (gravimetric method) measuring PM2.4 over a 24 h sampling interval. The KFG gathered daily average concentrations for 4 weeks. The comparison between the daily average of PM2.5 from the KFG and the Airly unit showed a coefficient of determination of 0.8, a slope of 1.6 and a bias of 6 µg/m3 (Figure 1).



The diurnal pattern of the data collected with the sensors clearly showed two peaks, one in the morning, around 7-8 and one in the evening around 17-20. Those peaks were not picked up by the reference station in Kristiansand, that is located close to a road. However, they were very clear, specially in the afternoon and in the cooler months in the residential areas where wood burning is employed. Pollution levels from PM2.5 were especially high in one of the neighbourhoods that is located in a small valley.

Conclusions Low-cost sensors can complement traditional monitoring methods, providing measurements than can help science and authorities in locations where we do not have reference stations. When data quality limitations and the risk of misinterpretation of the data are reduced, engaging citizens in air quality monitoring using tested and characterized low-cost sensors can meaningfully contribute to the existing urban environmental observations.

Acknowledgement This work was partly supported by NordForsk through the funding to Nordic participatory, healthy and people-centred cities, project number 95326 (http://nordicpath.nilu.no). We acknowledge Jøran Solnes Skaar and Erik Andresen for their help during the installation of the KFG and analysis of the filters. We acknowledge the citizen scientists in Kristiansand that participated gathering data, and specially to Kai Nygaard. Special thanks also to the municipality of Kristiansand and to Solvor B. Stølevik for her help establishing the citizen science observatory in Kristiansand.

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2.4 POTENTIAL FOR USING LOW-COST SENSOR MEASUREMENTS IN OUTDOOR ENVIRONMENTAL QUALITY PARTICULATE MATTER MEASUREMENTS

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Atmospheric particle pollution is one of the main factors in mortality and health risks, resulting in annual deaths of up to 8.9 million people worldwide. Personal PM measurements are informative only at the individual level, but the network of reference stations is not sufficiently dense to provide comprehensive information, so there is an increasing interest in the use of low-cost sensors. However, the key risk factors are related to the reliability of measurements (Bulot et al., 2019).

The sources of particulate pollutants vary, on average: 25% of the smaller particles ($PM_{2.5}$) are estimated to be related to transport effects, 22% to anthropogenic effects of a different nature, 20% to combustion of fuels in households, 18% to biogenic origin and 15% to industrial activities. In urban areas, spatial and temporal distribution is very variable, the effects of meteorological parameters are crucial (Karagulian et al., 2015), and should be monitored in order to explain results and determine potential sources.

Three sensing equipment devices were located in different sites (area of individual buildings, industrial areas and sites affected by intensive traffic) in the medium-sized city of Latvia – Liepaja. Measurements were carried out in 2021 during the winter and summer period to assess the impact of heating processes. The quality control of the results has been performed using data quality control algorithms and parallel measurements using the reference method (gravimetry).

The results have shown that sensor measurements have extremely high usage potential, and are effective in identifying particularly high-pollution episodes that are often short-lived (e.g. local fires). Due to their low cost, such sensors can be deployed sufficiently densely to judge the extent of impacts of local sources of pollution. As a deficiency, sensing equipment may be contaminated, which requires cleaning and monitoring, and sensor measurements have also been shown to produce results 20-30% higher when compared to reference measurements.

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3. SCIENCE – POLICY

3.1 HOW DO WE UNDERSTAND INTERDISCIPLINARITY IN ENVIRONMENT AND CLIMATE RESEARCH: RESULTS FROM A RECENT STUDY IN NORWAY

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The value of interdisciplinary framing for solving research problems of societal importance is broadly accepted. Researchers are thus actively seeking interdisciplinary collaboration – out of necessity (when it is a funding requirement) or out of genuine interest and professional curiosity. A successful development and execution of an interdisciplinary research project has many challenges and barriers. This contribution seeks to highlight some common issues encountered in interdisciplinary research, and the increasing push to expand interdisciplinarity to transdisciplinarity, i.e. a push to include societal actors outside research in the research process, in order to better serve the client and societal needs.

A recent study conducted on behalf of the Norwegian Ministry of Climate and Environment aimed to describe the nature, extent, barriers, and challenges of "interdisciplinary research" carried out in Norway within the fields of interest to the Ministry, with special emphasis on interplay between natural sciences, social sciences, humaniora and law. The team has decided to approach the task on several fronts, including using a literature review of one year of published scientific literature. This brought about the need to define terms such as "interdisciplinary", "transdisciplinarity", "environmental research", Norwegian research", and to identify suitably broad keywords that would fit the scope of the study.

Perhaps not surprisingly, and in line with the Ministry's areas of responsibility, we found that most interdisciplinary "environmental" research is done in collaboration between natural and social sciences, but other disciplinary combinations were also found. Interestingly, perception of who engages most in interdisciplinary research, the social scientists "win" over the natural scientists - 54% to 39%.

As a method, interdisciplinary research is recognized for over 100 years already, but in the latter years the disciplinary scope broadens, and a relatively higher proportion of published research can be considered "interdisciplinary". Problem framing is key to a solution: what needs to be included in addressing a problem, and who is best to address it? A number of research frameworks are available for problem conceptualization, most commonly used is perhaps the DPSIR – the Drivers-Pressures-State-Impact-Response based on an OECD work from the 1970's, and its variations.

In the last decade, also the "transdisciplinary" approach is gaining traction, as perhaps a natural extension of interdisciplinarity. The inclusion of user perspective and users/non-scientists in research addressing real-world issues is receiving more attention. It is important to stress that for successful uptake of research results in real life, some best practices are being established. They are based on an analysis of impact of user involvement in different stages of research:

- when defining the research questions, considering societal context allows to shape the expected outcome to serve the needs of the concrete users
- when implementing the research project, societal context leads to a reflection of the research process and shapes also the methods by which the results are obtained
- user involvement in final phases of a project is essential for its sustainability and uptake.

Key questions are, do the users have time to engage with scientists, and is such engagement supported by institutions? The findings of our study, and a number of recent papers, also provide insight needed by funders and institutions on how to enable researchers to carry out interdisciplinary research, and to be recognized for it.

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3.2 THE HYBRID COMPUTATIONAL APPROACH IN REVEALING PARTICULATE MATTER RELATED PROCESSES

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The modern world is facing many environmental issues, with all environmental compartments being affected. Air pollution accounts for an estimated 4.2 million deaths and 103.1 million disability-adjusted life years per year, while around 91% of the world's population lives in places where air pollution levels exceed the World Health Organization limits (WHO, 2021).

The understanding of environmental pollution-related processes is yet to be enhanced based on data-driven research. The enormous potential for the enhancement lies in the effective interrogation of environmental big data by using artificial intelligence, advanced statistical analysis, and numerical modelling, as well as modelling hybridization.

The talk will elaborate on the concept required for an in-depth understanding of environmental pollution from the perspective of contextual data analysis and the ATLAS Project supported by the Science Fund of the Republic of Serbia. ATLAS aims to shift the methodology and current approaches to modelling spatio-temporal data and processes related to the global fate of air pollutants. The shift will enhance the understanding of the global environmental fate of air pollutants and lead to more thoughtful environmental protection practices, policies, and strategies. Also, ATLAS aims to harmonize environmental research via facilitating access to environmental data, data analysis, exploration, and exploitation of the results. This will increase efficiency, creativity, and productivity of research, and at the same time scale up data analysis, support transdisciplinary, and lead to more thoughtful environmental protection practices, policies, and strategies.

The examples of the talk will cover the results produced within the Project Air Quality Plan for the Agglomeration of the City of Belgrade for the period 2021 – 2031, supported by the City Administration of Belgrade (AQP, 2021). The main focus will be on time-resolved, contextual, in-depth, and synergetic modelling of particulate matter pollution, primarily based on machine learning, explainable artificial intelligence, and numerical modelling within the ATLAS software platform.

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4. HEALTH AND EXPOSURE I

4.1 LONG-TERM EXPOSURE TO AIR POLLUTION AND MORTALITY: OVERVIEW WITH FOCUS ON THE LOW-EXPOSURE AREAS

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Air pollution is a major risk factor to health globally, contributing to morbidity and mortality from chronic and infectious respiratory disease, cardiovascular disease, cerebrovascular disease, diabetes, and lung cancer (HEI, 2020). Every year, air pollution leads to 509,000 premature deaths in Europe and serious aggravations of lung and heart diseases that affect millions of children and adults (EEA, 2020). Because of the links with multiple diseases and the ubiquitous nature of the exposure, air pollution is the 4th leading risk factor for morbidity and mortality in the 2019 Global Burden of Disease study, surpassed only by high blood pressure, tobacco use, and poor diet (Abbafati et al, 2019). Moreover, as the newest evidence shows that association between air pollution and health (mortality) is even stronger than previously known (Chen & Hoek, 2020), and as studies are emerging on impact of air pollution on on new health outcomes such as neurodegenerative diseases, neonatal deaths, cancers other than lung, etc., disease burden related to air pollution will rise in the future (HEI, 2020). This talk will give an overview of epidemiological evidence on long-term exposure to PM2.5 and mortality, with special focus on low-exposure areas that comply with current EU limit value of 25 µg/m^3. This talk will also introduce key points from the new 2021 WHO Air Quality Guidelines (WHO, 2021) as well some of the newest studies on $PM_{2.5}$ and mortality that were published after 2021 WHO Gudelines, and address the growing gap between current EU legislation and WHO Guidelines.

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4.2 AIR POLLUTION AND THE GROWTH OF CHILDREN – IS THERE A CONNECTION?

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Urban air pollution is one of the main environmental health challenges in paediatrics (Ortega-García et al., 2018). Several epidemiological studies indicate that exposure to outdoor air pollution is associated with health effects in children. On the other hand, child growth is an important indicator of children's health and includes many social, economic and health-related issues (World Bank Group, 2020). However, air pollution has been ignored as a potentially important cause of growth retardation (Sinharoy et al., 2020). The aim of this study was to examine evidence related to the potential impact of ambient air pollution exposure on stunting. The paper presents and analyzes the available data regarding the impact of air pollution on the growth of children.

Most of the evidence for a link between air pollution and linear growth were obtained from retrospective and observational studies focused mainly on pre-natal exposure to ambient air pollution and adverse birth outcomes such as low birth-weight and pre-term birth. In 2017, a systematic review and meta-analysis (Li et al, 2017.) showed that increased pre-natal exposure to ambient air pollution, measured as fine particulate matter (PM2.5), slightly increased the risk of pre-term birth (odds ratio [OR] 1·03 [95% CI 1·01–1·05]) and low birth-weight at term (1·03 [1·02–1·03]). Low birth-weight at term is a proxy for intrauterine growth restriction that is also independently associated with stunting. The evidence was judged to be of good quality, though the data were all from observational studies and therefore had inherent limitations. Few studies have addressed links between air pollution and post-natal growth. A systematic review and meta-analysis of household air pollution and child survival identified four studies that reported stunting as an outcome. The meta-analysis identified associations (based on adjusted estimates) between exposure to household air pollution (defined as use of solid fuel for cooking) and both moderate stunting (OR 1·27 [95% CI 1·12 to 1·43]) and severe stunting (1·55 [1·04 to 2·30]), but found the quality of the evidence to be low to very low. Another meta-analysis (Bruce et al, 2013) of studies conducted in children aged 0 to 59 months showed the association of growth retardation, and child mortality with exposure to household air pollution. Most of the studies analysed were observational, except for one randomized trial with solid evidence. According to data from Serbia (Nikolić et al, 2014.), air pollution is associated with children's height and weight, specially before the age of 9 years. There was a significant difference in the prevalence of malnutrition in children exposed to higher concentrations of air pollutants ($p = 0.038$). It might be possible that air pollution negatively contributed to the growth rate in urban children.

Child linear growth is a complex, multifactorial process, with the highest risk of growth impairment occurring between conception and 2 years of age and which is influenced by environmental factors. More research is needed to explore the relationship between air pollution and stunting. A better understanding of the interdependence between air pollution and children's development is necessary for the development of new intervention strategies to prevent growth retardation as a global health challenge.

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4.3 HEALTH RISK ASSESSMENT OF PARTICULATE MATTER EMISSIONS FROM NATURAL GAS AND FUEL OIL HEATING PLANTS USING DISPERSION MODELLING

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A significant proportion of homes and apartments in Serbia are still reliant on central heating systems during winter months, with about fifty heating plants in operation. Common fuels used in these plants primarily include fossil fuels such as coal, fuel oil, and natural gas. Some of these fuels have a high sulfur content, leading to an increased concentration of sulfur dioxide and particulate matter in the atmosphere (Todorović et al, 2020; Todorović et al, 2021). This study compares and evaluates the environmental impact of the two heating boilers at the Valjevo city (Serbia) heating plant. The AERMOD air dispersion model was used for estimating the concentrations of the various pollutants (Kakosimos et al, 2011; Mokhtar et al, 2014; Shaikh et al, 2020). Onsite emission data were gathered separately for the two heating boilers at the facility fuelled by natural gas and fuel oil, respectively. A combination of topographical and historical meteorological data were used to set up a receptor grid that was exposed to the gas emission in a radius of 10 km. The environmental impact from the fuel oil boiler was shown to be significantly higher than that caused by the natural gas-fuelled boiler. The resulting distribution of pollutant gases and particles showed that the concentration gradient is less inclined towards the city centre and instead spreads eastwards into the surrounding villages. The data were used to evaluate carcinogenic and non-carcinogenic health risks. It was found that the health risk was acceptable for different averaging periods. However, further study is still required in order to properly assess the cumulative health risk generated by other surrounding industries.

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4.4 ASSESSMENT OF INCREASED INDIVIDUAL-LEVEL EXPOSURE TO AIRBORNE PARTICULATE MATTER DURING PERIODS OF ATMOSPHERIC THERMAL INVERSION

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Airborne particulate matter (PM) negatively impacts human health, reduces life expectancy and increases mortality, and is particularly of interest in urban environments as traffic and other factors contribute additionally to higher concentrations of PM and other pollutants (Anenberg et al., 2019). These factors are compounded when atmospheric thermal inversions (ATI) occur in urban environments, as a consequence of atypical temperature gradients, and produce a "cap" which reduces the diffusion of dust, smoke and other air pollutants. A unique set of conditions present in a subalpine basin (Ljubljana, Slovenia), e.g., concave shape, extended periods of anticyclonic conditions, drag associated with the complex topography, result in frequent foggy days and ATIs, which in turn cause a buildup of PM (Kikaj et al., 2019). Measuring PM concentrations on an individual level, in contrast to city-wide monitoring, provides higher spatio-temporal granularity to observe individual-level exposure, daily fluctuations in diverse urban settings, and the impact of ATIs (Menon & Nagendra, 2018).

This study used next-generation sensing and monitoring technology to determine ATI influence on personal exposure to PM_{10} in an urban environment. Individual-level exposure assessments were based on data obtained from personal PM monitors used as part of the ICARUS H2020 project, where participants carried the devices for one week and additionally provided hourly data on their activities, transport mode and microlocations (Robinson et al., 2021). City-wide data on PM_{10} concentrations and meteorological conditions were provided by the Slovenian Environment Agency. After data cleaning and harmonization, three participants were selected that fit a specific set of criteria: (a) they were involved in the winter campaign, (b) data were available for the period when ATIs occurred, (c) their PM monitors worked well and (d) their Time Activity Diaries (TAD) were full. The indoor/outdoor variable was determined by the TADs and temperature measured by the portable PM monitor. ATIs were determined by calculating the difference in temperature between stations "Ljubljana - Bežigrad" and "Topol" at 299 m and 692 m elevation, respectively. An ATI was defined by temperatures being persistently lower at Bežigrad station that at Topol station. ATIs were observed for a period between February 16th to 18th when temperatures were consistently lower in the basin than at the surrounding elevations. Morning and evening inversions continued until February 23rd when wind speeds increased from 0.2 to 5.0 m/s, average temperatures fell from 9.1°C to 1.1°C and normal conditions returned. PM_{10} concentrations, as measured by monitoring stations followed this trend with average daily concentrations falling from a high of 75 µg/m^3 on February 20th (mean for entire first period from Feb 16th to 22nd of 45 µg/m^3), to 11 µg/m^3 on February 23rd (mean for second period from Feb 23rd to Mar 1st of 26 µg/m^3).

Results showed that exposure during the first period, when ATIs were present most of the day, was higher in all microlocations than the second period, though there were evident differences between activities and specific microlocations. During the first period, participants were exposed to a mean PM_{10} concentration of 42 µg/m^3 (σ±19 µg/m^3) indoors, and 74 µg/m^3 (σ±16 µg/m^3) outdoors, which is in stark contrast with the second period where indoor and outdoor exposures were 27 µg/m^3 (σ±26 µg/m^3) and 27 µg/m^3 (σ±18 µg/m^3), respectively. A similar trend was observed for specific activities such as sleeping, resting, cooking, running, walking and biking, where outdoor activities had a much larger difference in mean concentrations during the first period than the second. These results evidently show that the difference in indoor and outdoor exposure was much higher during the period of ATIs (32 µg/m^3) than after (~0 µg/m^3), which indicates that exposure to PM can be influenced by specific activities and micro-locations during ATIs.

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4.5 HOW WILL THE NEW WHO AIR QUALITY GUIDELINES FOR PM2.5 AFFECT THE HEALTH RISK ASSESSMENT BY THE EUROPEAN ENVIRONMENT AGENCY

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Ambient particulate matter pollution is responsible for one of the largest increases in risk exposure globally in the past two decades (Murray, et al., 2020). In Europe, fine particulate matter ($PM_{2.5}$) levels are causing around 373 000 premature deaths per year (EEA, 2021). The World Health Organisation (WHO) recently published new Air Quality Guidelines (AQG) to provide up-to-date health-based guideline levels for major health-damaging air pollutants. This paper assesses the impact of the new AQG on the health risk assessment by the European Environment Agency (EEA) related to $PM_{2.5}$ exposure and the potential health benefits for the European citizens if AQG levels are achieved. The number of premature deaths (PD) and years of life lost (YLL) were estimated to illustrate the health impact of $PM_{2.5}$ air pollution based on the WHO's 2005 and 2021 recommendations.

The health risk estimation is based on Soares et al. (2020) methodology with some adjustments to reflect the year in question. PD and YLL are estimated per grid cell, then aggregated to country-level by combining population and demographic data (per country, age, and sex) with gridded concentrations. The reference estimation is set for 2019, the latest monitoring air quality data reported to the EEA. The assessment is based on the concentration-response function (CRF) and counterfactual concentration (C_0) recommended by the HRAPIE project WHO (2013) for $PM_{2.5}$. An additional estimation based on the recommendations by the review supporting WHO's update of the global air quality guidelines (Chen and Hoek., 2020) was done to check how sensitive the results are to the choice of CRF and C_0 for $PM_{2.5}$. Finally, a benefit analysis was done based on a hypothetical situation, where PD deaths and YLL are estimated based on the assumption that the 2005 and 2021 WHO-AQG are attained everywhere in Europe. For example, based on 2005 WHO-AQG, $PM_{2.5}$ concentrations over 10 $\mu g/m^3$ are set as 10 $\mu g/m^3$, while 10 µg/m3 and below concentrations remain unchanged. The benefit is estimated by benchmarking the health outcome values based on the hypothetical scenario with the reference estimation.

The analysis indicates that changes in CRF and C_0 have considerable impacts on the health risk assessment outcome. The results suggest an overall reduction in the $PM_{2.5}$ health endpoints when changing the CRF (26 %) and C_0 (25 %). Though changes across the 41 countries are the same when CFR is changed, the same is not valid for C_0. In WHO (2013) recommendations, all concentration levels should be considered for estimations, with the latest recommendation, only values over 5 $\mu g/m^3$. This implicates that the number of PD and YLL for countries with annual concentrations below this level will reduce significantly.

The benefit analysis indicates that the PD and YLL across the 41 countries will reduce by 22 % and 58 % when compared to the reference estimations if 2005 and 2021 WHO AQG level for $PM_{2.5}$ would be attained, respectively. Benchmarking shows that the countries benefiting the most if complying with the latest AQG are Bosnia and Herzegovina, Kosovo and Serbia, with a quarter of the premature deaths in the reference estimation, and North Macedonia, Albania, Montenegro and San Marino with reductions above 60 %.

Health impacts due to $PM_{2.5}$ air pollution across Europe remain high, especially over central and eastern European countries. However, if countries would attain the 2021 WHO AQG levels, the European population will benefit significantly.

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5. HEALTH AND EXPOSURE II

5.1 BIOMARKERS OF EXPOSURE TO PARTICULATE MATTER AIR POLLUTANTS: A PRECIOUS TOOL FOR STUDYING HEALTH-RELATED EFFECTS

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Particulate matter (PM) and polycyclic aromatic hydrocarbons (PAHs) are among the most health-relevant air pollutants. PAHs are a large group of ubiquitous organic pollutants formed during the incomplete combustion of organic matter that are released from natural but mainly from anthropogenic sources, e.g., the burning of fossil fuels, petroleum, coal, wood, and biomass, among others (Oliveira et al., 2020a, 2020b). Nowadays, PAHs are one of the most relevant pollutants associated with the health risks caused by air pollution, principally in the most urbanized areas (Oliveira et al., 2019). They are known for their toxicity, mutagenicity, and carcinogenicity (IARC, 2010) and they are portioned between the airborne gaseous and particulate phases. Some PAHs are referred in the European Union (EU) and US Environmental Protection Agency (USEPA) priority pollutant list (Directive 2004/107/CE; USEPA, 2005). Several factors affect the mechanisms through which PM and PAHs are absorbed/adsorbed by humans, namely age and metabolism of the subject, routes of exposure and environmental conditions (temperature, moisture, solar radiation, wind speed, and precipitation rates). Inhalation of polluted air is the main exposure route to PM and PAHs; however, ingestion and dermal contact may be also relevant. Assessment of total exposure to PAHs is very difficult, and therefore human biomonitoring through the determination of biomarkers of exposure (exogenous substances, their metabolites, or the products of an interaction between the xenobiotic and some target molecule/cell) in biological fluids, has been progressively assumed as an adequate tool to assess total body burden. Pregnant women, nursing mothers, and their developing offspring are among the most susceptible groups of the population. Early exposure to PAHs may cause negative effects later in life such as lower intelligence quotient, problems with behavior, the development of allergies and respiratory diseases including asthma (Drwal et al., 2019).

Data from several previous studies, namely the characterization of the exposure of nursing mothers to PAHs (by determination of levels of un-metabolized and metabolized compounds in breast milk) and in some occupational groups will be discussed. Overall, positive and moderate to strong associations were found between and within the levels of total and individual PAHs and respective metabolites, thus revealing direct correlations between most of the compounds. Impact of both petrogenic and pyrogenic emissions of PAHs were detected in the studied populations and a principal components analysis allowed the differentiation between samples collected in subjects living in rural districts from those collected in urban areas.

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5.2 EXPERIMENTAL APPROACHES FOR STUDYING VIRAL INFECTIVITY, RNA PRESENCE AND STABILITY IN ENVIRONMENTAL PM: DEDICATED SAMPLING, BIOSENSORS, AND ADAPTATION OF STANDARD TECHNIQUES

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Background and Aims The issue of detecting and monitoring SARS-CoV-2 residual infectivity and presence in air samples still lacks standardization, and relatively few experimental data are available, despite the extent of societal impact of COVID-19. Old and new technological approaches have been proposed for sampling and detecting viruses in the environment; they require field testing to highlight appropriate application scenarios, strengths and limitations for the assessment of environmental viral exposure related to the COVID-19 spread.

Methods An experimental setup on transmissibility of SARS-CoV-2 residual infectivity in aerosols has been designed and realized in a BSL3 laboratory (Zupin et. al 2021), for an assessment of the plausibility of relevance of aerosols smaller than 5 micrometers in the disease transmission. In further studies carried out in the Infectious Diseases' ward at the Maggiore hospital of Trieste (Italy), aerosol sampling with water vapour laminar flow condensation growth tube (CGT) technology (Pan et al., 2016), has been applied by means of Biospot ViVAS sampler. Samples collected by this approach appear to be ideal for infectivity assessment by CytoPathic Effect (CPE) on selected cell lines, since no impact on solid surfaces, and negligible shear forces act on sampled microorganisms; more, the sampling efficiency has been demonstrated to be high also for particle smaller than 300 micrometers. Application of Point of Care (PoC) airborne virus detection by the Cellular Analysis and Notification of Antigen Risks and Yields (CANARY) technology (Rider et al., 2003) has been also tested. Another aspect that has been considered is a study on factors affecting RNA recovery from air filtering membranes by using both Single stranded RNA (ssRNA) fragments and inactivated SARS-CoV-2; quartz fibre filters that have been used for sampling the virus in both outdoor and indoor air with positive and negative results (Setti et al., 2020, Barbieri et al., 2021) were considered in a first study.

Key results of the study We report experimental evidence from laboratory study that aerosol with size distribution smaller than 2.5 micrometres can carry virus capable to replicate, when starting from suspension of at least 10^4 PFU/mL. Our survey in healthcare units has shown presence of RNA in sampled air, but not residual infectivity in samples. The study on QF membranes has shown low RNA recovery, with an effect of storage time at -80°C.

Conclusions The setup of SARS-CoV-2 sampling and analysis from aerosols appears to have still room for optimization and an international effort for standardization of infectivity assessment and RNA detection is required, also in view of an improved identification of exposure scenarios and better qualification of sanification technologies.

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5.3 EXPOSURE TO PARTICULATE MATTER IN FIRE STATIONS: PRELIMINARY RESULTS

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Firefighters are at increased risk for many types of health diseases (IARC, 2010). While most of the studies on this topic focus on exposures and their impacts due to fire combats (Oliveira et al., 2017), firefighters spend large portions of their day-by-day shift within the fire stations, where they can be exposed to a variety of air pollutants, including particulate matter (PM), a known carcinogen. This work aimed to assess the levels of particulate matter (PM) at fire stations and to investigate the possible parameters that may influence the respective levels.

This study was conducted consecutively during 2 weeks in summer 2021 in the north of Portugal. Seven fire houses were included in this study, all of them located in rural areas of Bragança district. Sampling of different indoor (living rooms, rest areas, and etc.) and outdoor spaces was conducted concurrently in each station. Four different fractions, namely PM_1, $PM_{2.5}$, PM_4 and PM_{10} were continuously monitored by a Dustrak™ Aerosol Monitor (model 8532, TSI Inc., Shoreview, USA) and by a Lighthouse Handheld particle counter (model 3016 IAQ; Lighthouse Worldwide Solutions, Fremont, USA) using logging interval of 1 min. Across all fire stations, indoor $PM_{2.5}$ and PM_{10} means ranged between 6.3 and 14.1 $\mu g/m^3$ (mean 8.7$\mu g/m^3$) and from 7.5–16.1 $\mu g/m^3$ (10.5 $\mu g/m^3$), respectively. These results showed that indoor PM was well below the limits set by Portuguese legislation for public spaces (25 and 50 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10}, respectively; Decreto-Lei 118/2013). Indoor $PM_{2.5}$ was mainly constituted of PM_1 (97%) but respirable ($PM_{2.5}$ and PM_4) fractions accounted for the majority of indoor particles (82–88 %, respectively). Outdoor concentrations exhibited similar mean values (4.3 $\mu g/m^3$ for $PM_{2.5}$, 20.6 $\mu g/m^3$ for PM_{10}) but the individual means across all fire stations demonstrated different ranges: for $PM_{2.5}$ 2.3–7.7 $\mu g/m^3$ and 15.8–26.9 $\mu g/m^3$ for PM_{10}. Once again, the obtained levels fulfilled the existing guidelines for ambient air (Directive 2008/50/EC). Similarly to indoors, PM_1 constituted the large portion of $PM_{2.5}$ (up to 76%), but the contribution of coarse particles (*i.e.*, larger than 2.5 µm) in outdoor air was much larger than indoors (79% outdoors *vs.* 18–12% indoors), most likely resulting from re-suspend dust.

The results of the study showed that human occupancy and the activities conducted indoors were the main indoor emission sources; ventilation was also associated with indoor PM. Whereas PM concentrations were relatively low, the chronic exposures, even in small quantities, require further assessment to determine the respective health risks. In addition, assessment of and co-exposure to other pollutants in these settings would be precious.

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5.4 A NUMERICAL MODEL FOR POLLEN PREDICTION: THUNDERSTORM ASTHMA CASE STUDY

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More than 300 million people worldwide have asthma - resulting, at the global scale, in approximately 180,000 deaths annually (To et al., 2012). Approximately 50% of adults and 90% of children with asthma had an allergic form of the disease (Palomares et al., 2017). The allergy occurrence is often caused by pollen, representing one of the major healthcare problems. The strongest risk factors for developing asthma are inhaled particles; pollen grains emitted by trees, grasses, and ragweed are among the most commonly present particles. The pollen dispersion process starts with the pollen emission which depends on plant phenology and on near-surface atmospheric conditions. Emitted pollen is dispersed by vertical air mixing and by free-atmospheric horizontal transport. In the final phase of the pollen atmospheric process, pollen grains settle down to the Earth's surface by wet and by dry deposition (due to gravity and near-surface turbulence). In order to predict the atmospheric pollen process, several pollen models have been developed over the last decade (e.g., Siljamo et al., 2013; Luvall et al., 2013). The prediction of extreme pollen episodes generated by thunderstorm processes is of particular interest. Thunderstorm-caused asthma, usually called "thunderstorm asthma" (TA) is a striking event in which patients could experience life-threatening asthma attacks caused by extreme numbers of pollen grains. If a thunderstorm occurs during a pollen season, favourable conditions for intense pollen uptake and transport are fulfilled. In the TA Melbourne case occurred on November 21st 2016, high near-surface concentrations of grass pollen caused instant allergic reactions in predisposed persons. As a result, within 30 hours there was a 672% increase in visits to emergency services due to respiratory difficulties, and a 992% increase of asthma-related hospital admissions compared with the occurrences in previous 3 years (Thien et al., 2018). In this study, the capacity of the PREAM (Pollen Regional Atmospheric Model) model to predict excessive TA events is examined. PREAM is a version of the DREAM regional dust aerosol atmospheric model (Ničković et al., 2001) modified in our study to predict pollen dispersion. In our study we implemented a regional Euler-type pollen prediction model over the Australian state of Victoria in order to explore its capability to predict the Melbourne pollen event. We set up the model with a horizontal resolution below 10km, sufficiently fine to confidently resolve pollen sources and to adequately represent atmospheric features essential for pollen storm generation (such as non-hydrostatic and convection processes). Furthermore, we introduced an advanced pollen emission scheme which takes into account different near-surface turbulence conditions. The model simulation covering the period 16-22 November 2016 was verified against available pollen counts observed at a Melbourne site. The model correctly identified the increased pollen concentrations from the weaker observed peak on 16th November. The extreme pollen concentrations on the 21st November, which triggered the epidemic asthma, was quite well represented by the model, in terms of both timing and location, thus demonstrating its high potential to successfully simulate extreme pollen events.

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6. PM MONITORING AND MODELLING I

6.1 INTRODUCTION TO TRANSBOUNDARY PARTICULATE MATTER IN EUROPE

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The European Monitoring and Evaluation Programme (EMEP) was initiated in 1977 and the Convention on Long Range Transboundary Fluxes of Air Pollutants (CLRTAP) was established in 1979. Driven by the fish dieback from acid rain in Scandinavia, and later concerns about large scale effects on European forests from air pollution, a comprehensive activity devoted to atmospheric measurements, emission inventories and chemical transport modeling have been established. With time, the focus areas of the CLRTAP have been extended to include effects on crops, materials, climate and health, and the scope of the observations have been extended from acidifying compounds to include photooxidants, heavy metals, Persistent Organic Pollutants and chemical and physical characterization of particulate matter (PM).

This presentation will focus on the history of how particulate matter became one of the key focus areas of CLRTAP, and specifically how the observational capacities and monitoring strategies have evolved to allow the required understanding of particulate matter in Europe. Finally, we will present some key finding from the EMEP work during recent years in relation to PM as presented in the EMEP Status report 1/2021 (EMEP, 2021).

Due to growing concerns about PM being a major contributor to adverse health impacts, EMEP initiated its formal work on PM in the late 1990ies. At the same time, it was also clear that climate forcing from aerosols was significant, and thus a harmonized approach to study chemical and physical properties at remote sites was initiated in close collaboration with WMO-Global Atmosphere Watch, and the research community at large (including the Eurotrac 1&2 programmes). While aerosol inorganic composition was already included due to focus on acidifying and europhying components, it was recognized that the efforts should be extended to include elemental and organic carbonaceous matter, as well as physical and optical properties (size distribution, absorption, scattering etc). Also organic tracers and vertical profiles were seen as important additions to the observational efforts. Gradually, the scope has been extended to include a broad scope of activities, some long-term while others organized in campaigns. During the latter 10 years, the ACTRIS (Aerosols, Clouds and Trace Gas Research Infrastructure) have emerged to improve the quality of observations. Data combined with emission inventories and modeling results are presented in annual reports to policy makers both within CLRTAP and beyond. Data show that while there have been significant reductions in some metrics, concentrations are still high compared to WHO limit values, and further it is evident that log trange transport is important at regional scales with respect to ambient PM-levels.

Obsevation data on particulate matter can be found in the EBAS database infrastructure: www.ebas.nilu.no, while EMEP reports are available at www.emep.int.

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6.2 SAMIRA-SATELLITE BASED MONITORING INITIATIVE FOR REGIONAL AIR QUALITY – LESSONS LEARNED AND PLANS

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The satellite-based monitoring initiative for regional air quality (SAMIRA) was set up to demonstrate the exploitation of existing satellite data for monitoring regional and urban scale air quality. Through collaborative efforts in four countries (Poland, Romania, The Czech Republic, and Norway) with different, but pressing, air quality problems, SAMIRA aimed to support the selected institutions and associated users in their national monitoring obligations as well as to generate novel research in this area. The project focused on aerosol optical depth (AOD), particulate matter (PM), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2).

SAMIRA was built around several research tasks:

i. an AOD retrieval from the the geostationary spinning enhanced visible and infrared imager (SEVIRI);
ii. a retrieval for ground-level concentrations of $PM_{2.5}$ using the SEVIRI AOD in combination with WRF-Chem output;
iii. an operational algorithm for data fusion that was extended to make use of various satellite-based air quality products (NO_2, SO_2, AOD, $PM_{2.5}$ and PM_{10}). And
iv. a geostatistical downscaling algorithm for satellite-based air quality products was developed to bridge the gap towards urban scale applications.

Here, we give a short overview of the SAMIRA projects, its outcomes, lessons learned, and plans for future work.

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6.3 CHEMICAL COMPOSITION OF PM PARTICLES INSIDE THE LABORATORY AND IN THE AMBIENT AIR NEAR THE COPPER SMELTER IN BOR, SERBIA

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Background and Aims: Numerous studies have reported that PM and its specific chemical constituents were linked to the incidence of respiratory diseases and mortality as well as lung function. Transition metals present in PM are able to damage DNA, induce mutations, and initiate carcinogenesis (Perrone et al, 2013). However, the quantity of every single metal in PM does not depend only on the magnitude of the source, but also on weather conditions; meteorological factors, such as wind direction and intensity, spread, dilute or even accumulate metals in breathable air (Garza-Galindo et al, 2019). The relationship between pollutant concentrations in the atmospheric environment and meteorological factors has been reported by numerous papers (Ledoux, et al, 2017). The main aim of this study is to determine metallic content in PM_{10} samples taken near the copper smelter. Outdoor PM_{10} samples were taken simultaneously at several locations in the close vicinity of the copper smelter, while the indoor PM_{10} samples were taken in the laboratory located inside the fenceline of the copper smelter complex in Bor, Serbia.

Methods: The measurement campaign was conducted during June and July in 2020. At all sampling sites, PM_{10} samples were collected with the low volume samplers (Sven/Leckel LVS3) on quartz fiber filters (Whatman QMA, 47mm) as the collection medium. The loaded filters, after gravimetric measurements, were further prepared for chemical analyses in accordance with the procedure of SRPS EN14902: 2013. The samples were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP MS). Urban particulate matter Certified Reference Material 1648a was analyzed for quality control and verification of the applied procedures for microwave digestion and trace element analysis. Recoveries were in the range from 80 to 120% for all measured chemical elements. In this way, the mass concentrations of 18 trace metals (As, Cd, Pb, Ni, Zn, Cu, Co, V, Mn among others) in PM_{10} samples were identified and quantified.

Key results: The results of the examination of the content of suspended particles of the PM_{10} fraction inside and outside the laboratory show that a significant part of the air pollution from the external environment reaches the laboratory except for As, Ni, and possibly Bi and In.

Conclusions: Of particular concern is that levels of most of the metals detected in PM_{10} samples are several times higher near point sources in the smelter than at a distance of a few hundred meters far from the copper smelter fenceline.

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6.4 PLANNING AND CONDUCTING MOBILE AEROSOL MONITORING CAMPAIGN: EXPERIENCES FROM BELGRADE AND NOVI SAD

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Aim and background: In metropolitan areas, compliance monitoring networks can give high-quality data on the concentrations of main air pollutants. However, because the data is spatially very sparse, it is difficult to determine short and long-term exposure on a fine spatial scale, which is needed for personal level exposure assessment. Furthermore, such sparse data requires additional modelling steps (Davidovic 2015), or data fusion with additional GIS databases to achieve needed downscaling (Beloconi, 2020). Mounting high grade equipment on vehicles can help both in terms of increasing spatial resolution and reducing modelling efforts in data fusion. This paper aims to highlight key points/issues that are encountered when conducting mobile monitoring campaign and illustrate example outputs.

Method: To do this, we will use two most recent examples of mobile monitoring campaigns which were already conducted (BeoAirDATA project, Belgrade) or are planned to be performed (Novi Sad), and target cities of Novi Sad and Belgrade. High grade instruments that were/will be used for PM data acquisition include TSI NanoScan SMPS Model 3910 (13 channels from 10nm to 420nm with 1-minute resolution) and TSI Optical particle sizer 3330 (17 channels from 0.3um to 10um with 1-second resolution). Each measurement point must be properly geolocated and timestamped. Each day of the measurement campaign, vehicle with mounted instrumentation, conducted/will conduct two sampling runs - one in the morning and one in the afternoon/night. In between the runs maintenance such as inlet cleaning, battery recharging, zero testing, data acquisition is a necessary step. Vehicle also uses aerosol inlet, which is cone shaped, mounted to the right-hand side of the vehicle, and two sampling tubes which conduct sampled air to TSI instruments inside the passenger cabin.

Results: Figure below shows one example output of mobile monitoring campaign – interactive PM pollution map for Belgrade, which is zoomable and color-coded. This stands in stark contrast to the more precise, but very sparse data offered by compliance monitoring networks (for example, city of Novi Sad has only one monitoring station which measures both PM_{10} and $PM_{2.5}$ with hourly samples made public). Interactive map allows for easy inspection of various air pollution phenomena, such as time of day pollution variation on a specified location, and similar.

Figure 1. Example of finding timestamped geolocated hotspots and coldspots a) weekday night in city center (Vukov spomenik), PM_{10}~14µg/m3, b) workday early afternoon in city center (Brankov most), PM_{10}~400µg/m3

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6.5 ASSESSMENT OF DETECTED IN SITU AND MODELLED PM CONCENTRATION LEVELS DURING URBAN TRANSFORMATION PROCESSES IN NOVI SAD, SERBIA

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Background and Aims: Ambient air pollution is a very considerable and complex physicochemical and environmental issue. Particulate matter (PM) is one of the key pollutants found in ambient air. PM diffusion dynamics and transport through the air allows particulates to affect not only their place of origin but a larger area. A rapidly expanding construction industry and constant urban transformations in the city of Novi Sad, Serbia produces high concentrations of PM. The large and expanding number of construction sites as pollution emission hotspots create constant nuisance for people, buildings and the environment overall. Serbian legislation has set PM pollution borderline values for daily emissions, but the Air Pollutant Registry still does not recognise construction sites as sources of PM emergence. Understanding the importance and the effects of PM emission from construction sites is crucial to environmental protection. Proper environmental pollution modelling is needed to be able to prepare and apply methods and techniques for prevention and mitigation. The aim of the paper is to assess and determine applicability of the Tier 1 prediction model designed by EPA to observed construction sites in Novi Sad, Serbia.

Methods The chosen location for monitoring was road reconstruction in Novi Sad. On the construction site, the concentration of PM emissions was monitored by specially designed sensor based on OPC-N2 (Optical Particle Counter developed by Alphasense). During the monitoring period, meteorological data were also tracked. The EPA Tier 1 model was used for determining the emission coefficient. Environmental Software ADMS-Urban was used as comprehensive system for modelling air quality.

Key results of the study Obtained results of construction site monitoring have shown high PM10 and PM 2.5 concentration levels and a potential environmental hazard. Modelled results indicate also high concentration levels of particulate matter. Results exhibited divergence between monitored and modelled results, exposing a need for correction measures in that process. The key result of this study was determining the correction coefficient.

Conclusions Assessment of concentration levels of PM emission monitored and modelled data generated by urban transformation on a construction site in city of Novi Sad, Serbia, exposed gaps in the Tier 1 prediction model. Obtained results open a requirement for additional monitoring and modelling with the goal to adopt and improve the defined correction coefficient. It can be concluded that with use of a correction coefficient, proper modelling can be achieved using the Tier 1 prediction model. Application of a prediction model is significant in environmental protection and prevention of ambient air pollution.

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7. PM MONITORING AND MODELLING II

7.1 ACCOUNTING FOR SPATIOTEMPORAL INFORMATION IMPROVES THE IMPUTATION OF MISSING PM2.5 MONITORING RECORDS

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With the irrefutable evidence of causal associations between exposure to air pollution, especially fine particulate matter ($PM_{2.5}$), and adverse health outcomes (Bräuner et al., 2007; Grahame et al., 2014; Janssen et al., 2011), air quality monitoring (AQM) networks have been established in the past decades around the world to track ambient pollutant levels. The better the spatiotemporal coverage of the measurements, the greater the ability of regulatory agencies to enforce environmental standards, and of environmental epidemiologists to use the data to estimate exposure and obtain reliable risk metrics. However, oftentimes the monitoring data suffer from missing observations over both long and short time periods, which result from device failure, calibration procedures, maintenance practices, or other technical difficulties. Imputing these missing observations is a prerequisite step to many statistical analyses that require complete datasets, like factorization methods, which are used for source-apportionment. This work examines the application of an improved multivariate *k*NN imputation algorithm (w*k*NN*r*) on a large $PM_{2.5}$ dataset, comprised of thousands of observations from dozens of AQM stations that have reported between the years 2012-2019. The method accounts for the correlation between all AQM stations when examining similarities between $PM_{2.5}$ observations. It further accounts for preceding and subsequent values of each missing observation as additional model inputs, leveraging the advantage of univariate interpolation models in imputation of short time-windows. We compared our results against those obtained by iiET - an iterative imputation model with an ensemble of extremely randomized decision trees (an algorithm known as Extra Trees, ET). Hyperparameter tuning with cross-validation (CV) assured best performance of both models, with the model evaluation carried out on a set-aside validation-set that contained missing time-windows of different lengths. We found that the w*k*NN*r* model performed better for short missing time-windows (0.5h-1h) while the iiET model performed better for longer missing time-windows. Adding the preceding and subsequent observations around the missing records further improved the w*k*NN*r* model performance. We therefore concluded that the best imputation product for our dataset (and possibly for a general case as well) could be obtained by combining w*k*NN*r* imputation for short gaps of missing data with iiET imputation for long gaps of missing data. In this work, we offer an imputation workflow that is applicable to other environmental datasets. The w*k*NN*r* model extends beyond previous *k*NN algorithms as it accounts for adjacency among datapoints in both space and time, thus truly absorbing the spatiotemporal nature of the phenomena. As opposed to previously published air-pollution imputation studies that used external data, such as time, meteorological parameters, concentrations of other co-measured pollutants, etc., to enhance their predictions (Junninen et al., 2004; Shahbazi et al., 2018), we demonstrated an alternative approach – accounting only for monitored $PM_{2.5}$ from a network of AQM stations, and achieved very good imputation performance. Such an approach has a huge advantage if the imputed dataset is then used for further analysis, as it frees all external data to be used as covariates in an advanced analysis.

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7.2 A METHOD FOR TRACING THE SOURCES OF AIRBORNE DUST USING SOURCE-SIMULATION AND MULTIVARIATE PLS MODELLING OF CHEMICAL ANALYTICAL DATA

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This paper describes a method for tracing the sources of airborne dust (source apportionment) developed by the present author and utilized in several studies on urban dust pollution in Reykjavík, Iceland. This method is a form of receptor modelling, but fundamentally different from those most widely used for this purpose, i.e. Chemical Mass Balance (CMB) and Positive Matrix Factorization (PMF). CMB and PMF have been reviewed and compared by Lee et al. 2008. The present methodology involves source-simulation, i.e. collecting dust samples form suspected source materials, using the same dust sampler as used for unknown samples. The results presented here to demonstrate the technique are from the most recent study, collecting the $PM_{2.5}$ fraction close to a high-traffic road junction in Reykjavík in spring and autumn, respectively, 2019. This model work was carried out for the Icelandic Road authorities and mainly aimed at estimating the contribution from road traffic to the PM pollution. In particular the effect of the use of studded tires, which requires estimating rather similar sources like dust from asphalt, soil erosion and ash from volcanic eruptions, respectively - sources that are likely to be estimated in frequently used receptor models like the two mentioned above.

Source-simulation is here carried out by flushing samples from actual dust sources into the inlet of a dust sampler using compressed air. For this, the same sampler and dust separator is used as for collection of ambient dust samples and the PM-fraction is collected onto 47mm teflon filter discs. Variables for multivariate modelling, 51 in all, were concentration values for 35 chemical elements, determined by ICP-MS from dissolved filters as well as non-destructive reflectance measurements at 19 wavelengths in the near-infrared spectral region (NIR) measured from the surface of the filters before dissolution. NIR-spectra were collected as 909 spectral points in the wavelength range 909nm to 2604nm. The spectra were pre-treated through smoothing and derivation (1^{st} derivative) and the 19 variables (reflectance measurements) were chosen at wavelengths where responses for individual source materials were proportional to the collected mass (two or three samples of different weight for each source material). Contributions from individual dust sources to ambient dust samples were estimated through Partial Least Squares (PLS) regression, modelling one source at a time. PLS is a widely-used multivariate technique (Miller and Miller, 2010) utilizing principal components. It can be tuned by giving different variables different weights and this tuning has been used here to improve correlation for calibration samples (sources) as well as to avoid insignificant results, such as negative source contributions or contributions that are less than the estimated modelling error.

The quality of the modelled results may be evaluated by adding mass contributions from each dust source to individual ambient dust samples and comparing the sum with the actual collected amount of dust. The correlations in the present study were very acceptable, considering the relatively simple approach.

The main strength of the present methodology is flexibility, allowing the modelling of similar sources through source-simulation. NIR-reflectance spectrometry is an established analytical method within agricultural, food and pharmaceutical analysis. Although it has been applied to environmental analysis (Brackx et al, 2017; Druckenmüller et al., 2018) it has not been previously utilized as in the present work.

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7.3 SEASONAL VARIATION IN AMBIENT PM10 CONCENTRATIONS OVER THE NOVI SAD AGLOMERATION

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Cities in Serbia often have high average annual values of the concentration of suspended PM10 particles, the source of which at the national level is predominantly from local combustion plants and heating plants with a capacity of less than 50 MW. Novi Sad is a city that, except in 2019, in other years for which monitoring data are available, was not excessively polluted, taking into account the average annual value of concentrations. Novi Sad is an agglomeration in AP Vojvodina, where natural gas heating is very widespread, so it is interesting to take an agglomeration of such characteristics for analysis in order to examine the impact of local combustion plants and heating plants. The results obtained by measurements during 2020 were used for the analysis, and the measurements were conducted in the state and local air quality monitoring networks. The periods of cold and warm half of the year, i.e. the periods January-March and October-December and April-September, were observed separately. Statistical values: mean value, 25th, 50th and 75th percentile were used for analysis as well as the number of days with exceeding the allowed daily values. The analysis shows that the most common exceedances of daily limit values were recorded at stations for monitoring pollution originating from traffic. Further analysis showed a significant seasonal difference of the 75th percentile at all stations. A comparative presentation of statistical quantities in different seasons at stations of different types shows that it is a more complex cause of pollution and that local furnaces cannot be cited as the dominant cause.

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7.4 AN OVERVIEW OF MONITORING AND RESEARCH OF ATMOSPHERIC PARTICULATE MATTER IN SERBIA IN THE PAST HALF DECADE

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Air quality standards in the EU are set for protection of health, for levels of particulate matter (PM) and its constituents measured daily in PM_{10}: $PM_{2.5}$, PM_{10} and BaP, As, Ni, Cd. In 2021, WHO revised guidance levels for daily $PM_{2.5}$ and PM_{10} (15 resp. 45 $\mu g/m^3$) and annual average and (5 resp. 15 $\mu g/m^3$).

Serbia and other Balkan countries have some of the highest $PM_{2.5}$ levels in Europe (EEA, 2020). In 2018, SEPA reports PM_{10} from 18 stations and presents also results for 16 sites with indicative measurements, and the number of automatic monitoring stations (AMS) is increasing (Table 1).

Table 1. Airborne PM at State and Local monitoring stations in Serbia: exceedance of limit and target values

PM	Type	Sum of exceedance of limit and target values	2017	2018	2019	2020
PM_{10}	AMS and gravimetric (reference)	Number of sites with annual mean value over 40 $\mu g/m^3$ / total number of sites and its percent	11/13 ***84,6***	12/18 ***61,1***	15/32 ***46,8***	19/36 ***52,7***
		Number of days over 50 $\mu g/m^3$/: range at sites and average number of days over 50 mg/m^3 for all sites	71-157 ***28,9***	34-170 ***24,3***	6-169 ***21,2***	6-148 ***21,4***
	Indicative measurements	Number of sites with annual mean value over 40 $\mu g/m^3$/total number of sites and its percent	7/11 ***63,6***	9/16 ***56,3***	9/18 ***50,00***	7/14 ***50,0***
		Percent of days over 50 $\mu g/m^3$/: range at sampling sites and average percent of days over 50 mg/m^3 for all sampling sites	0-44 ***29,4***	0-49 ***30,1***	0-49 ***21,6***	0-42 ***20,1***
$PM_{2.5}$	AMS and gravimetric (reference)	Number of sites with main value over 25 $\mu g/m^3$/total number of sites and its percent	4/4 ***100***	5/5 ***100***	12/16 ***75***	15/28 ***53,6***
	Indicative measurements	Number of sites with main value over 25 $\mu g/m^3$/total number of sites and its percent	2/3 ***66,7***	4/5 ***80,00***	2/4 ***50,0***	2/4 ***50,0***

In the majority of urban areas, PM pollution is related to traffic and domestic heating, and levels of PM are much higher during heating season. The industrial site station Bor had no exceedance of annual limit and target for PM_{10} and $PM_{2.5}$, but shows the highest levels of metals in PMs, and of SO_2. (SEPA, 2020). The regional background EMEP station at Kamenicki Vis, registered PM_{10} annual mean value between 14-18 $\mu g/m^3$ in 2017-2020.

Serbian researchers participate or have participated in a number of ongoing and completed national and international projects and actions, and regularly publish papers in high-ranking journals. Only a closer collaboration between these researchers, SEPA and institutions and companies that monitor air quality will deliver the necessary in-depth analyses and identify the best way to reduce PM pollution and improve air quality in the Republic of Serbia.

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8. OXIDATIVE STRESS

8.1 REAL-TIME REACTIVE OXYGEN SPECIES MEASUREMENTS IN CHINESE CITIES

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Air pollution exposure is associated with a range of adverse health effects, including cardiovascular and respiratory diseases. Particle-bound ROS has been recognized as one of the prevailing parameters to indicate the toxic potential of airborne particulate matter (PM). The temporal variability of particle-bound ROS is a very important metric crucial for the improvement of public health and risk assessment policies. Various methods of assessing PM-bound ROS changes were developed in recent years using specialized ROS detection probes, but only few of these methods have been developed into a fully functioning real time ROS detector capable of operation over a longer time period of days to weeks. Several systems that have been developed to address this, using both commercially available and in-house designed instrumentation coupled with either the DCFH-DA or DTT probes (Fuller et al. 2014, Zhou et al. 2019). These systems are limited in effectiveness by probe reaction times, time resolution, sensitivity, and ease of use. For this reason, a new ROS probe, BPEAnit profluorescent nitroxide (Stevanovic et al. 2012), was combined with a purpose-built particle collector and miniature flow-through fluorimeter to create the particle into nitroxide quencher (PINQ) (Brown et al. 2018). This instrument has a faster response time and lower limit of detection than any other instrument presented in the literature.

The PINQ collects PM for oxidative load measurements with > 97% efficiency and a cut-off size of >20 nm, regardless of chemical composition. This is achieved through a custom made steam collection device known as the insoluble aerosol collector (IAC). Aerosol is continuously sampled, grown into water droplets, and collected into a solution of DMSO and the BPEAnit probe inside a vortex collector. The liquid sample is then debubbled and passed through the fluorimeter for quantification of ROS.

This system was coupled with a flow switching assembly to alternate between total and gas phase samples, with the difference in fluorescence response being proportional to particle phase ROS. The system is fully automated, with a time resolution as low as one minute and software providing real time data analysis. In this configuration the instrument has been involved in a number of campaigns over several years where it operated for a total of over 5 months over 5 separate campaigns in the Chinese cities of Hong Kong, Guangzhou, Heshan, and Beijing.

The presentation will give an overview of all of the previous measurements and correlation with main pollutants will be discussed to develop a better understanding of the main parameters that influence outdoor particle bound ROS concentrations, its diurnal trends and transport.

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8.2 SOURCE APPORTIONMENT OF OXIDATIVE POTENTIAL – WHAT WE KNOW SO FAR

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The impact of exposure to particulate matter (PM) is assessed using the particle mass, size, concentration, and chemical composition. In recent works, it has been recognised that PM2.5 is not the best-suited metric to estimate and measure the effect of PM on human health. Particle mass may not be very informative of the number of ultrafine particles that have the highest potential to penetrate the deepest regions of the respiratory system and potentially cross the blood-brain barrier. Also, not all the components and sources are equally potent in driving the acute health effects of PM. The chemical composition of PM, surface reactivity and the oxidative potential (OP) of PM are proposed to be driving the adverse health effects. However, the findings presented in a limited sample of literary works in this field are conflicting.

Scientists are unified to nominate and validate potential techniques that can be better proxies for public health warnings and monitoring. Reactive oxygen species (ROS) measurements are one of the leading contenders to be applied for this purpose. The existing gap in knowledge is how well ROS measurements that present the reactivity of PM predict air toxicity. To better understand the relationship between the reactivity of particles and their OP and toxicity, particles from different sources and of the different chemical compositions should be tested.

Over the last couple of years, source apportionment methods were employed worldwide to understand better the processes contributing to and influencing concentrations and the residence time of PM in the atmosphere. To do this, direct modelling approaches such as chemistry transport models (CTMs) using tagged species (Kranenburg et al., 2013) or field studies coupled with receptor models (RMs) (Pernigotti et al., 2016), specifically positive matrix factorization (PMF) (Jain eta al., 2020) were used.

It has been established that PM originates from various sources. Particle formation processes are accompanied by a series of photochemical reactions in which ROS can be involved. Therefore, chemistry, reactivity, size and particle OP will vary within the urban environment from season to season, which induces significant changes in the health impacts. Field observations and modelling studies showed that primary and secondary sources of PM do not contribute equally to the OP (Daellenbackh et al., 2020). OP is mainly contained in small SOA particles, and is very well correlated with the transition metals, oxygenated organics (Stevanović et al., 2013) and the presence of persistent free radicals.

Not all the PM components were shown to have a contribution towards the OP. Therefore, it has become increasingly important to link the chemical species and sources of ambient PM with OP, which provides us with critical information to effectively reduce emissions from sources that release PM with more significant toxicity. Nevertheless, there is still much to be learned. A better understanding of source apportionment of ROS may help develop mitigation strategies to reduce mass concentrations, as it may be more effective to reduce specific sources and not the overall PM mass.

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8.3 A STUDY ON TROPOSPHERIC AEROSOLS CHANGE DURING THE COVID-19 LOCK-DOWN PERIOD: EXPERIENCE FROM EARLINET MEASUREMENT CAMPAIGN

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To slow down the rate of spread of corona virus, most of the countries in Europe have followed partial-to-complete lockdown measures in 2020. The lockdown period provided a unique opportunity to examine the effects of reduced anthropogenic activities on changes in the atmospheric environment. Aerosol lidars with their high temporal and vertical resolution, provide reliable information on the atmospheric structure, its dynamics, and its optical properties. The European Aerosol Research Lidar Network, EARLINET, was established in 2000 as a research project with the goal of creating a quantitative, comprehensive, and statistically significant database for the horizontal, vertical, and temporal distribution of aerosols on a continental scale (Pappalardo et al., 2014). EARLINET is part of ACTRIS (Aerosols, Clouds and Trace gases Research Infrastructure) a pan-European initiative consolidating actions among European partners producing high-quality observations of aerosols, clouds and trace gases.

As a part of the ACTRIS initiative for studying the changes in the atmosphere during the COVID-19 lockdown period in May 2020 a dedicated EARLINET measurement campaign was organized in order to: monitor the atmosphere's structure during the lockdown and early relaxation period in Europe, and to identify possible changes due to decreased emissions by comparison to the aerosol climatology in Europe. During the campaign the near-real-time (NRT) operation of the EARLINET was demonstrated following previous experience from the EUNADICS-AV exercise (Papagiannopoulos et al., 2020). The Belgrade lidar station (Ilić et al., 2018) participated in the campaign together with 21 EARLINET stations providing vertical aerosol profiles twice per day (minimum two hours measurements at noon, and minimum two hours after sunset). The measurements were submitted and processed by the Single Calculus Chain (SCC) in the near-real-time. The SCC is a tool for the automatic analysis of aerosol lidar measurements developed within EARLINET network (D'Amico et al., 2015, D'Amico et al., 2016). The main aim of SCC is to provide a data processing chain that allows all EARLINET stations to retrieve, in a fully automatic way, the aerosol backscatter and extinction profiles (measures of the aerosol load) together with other aerosol products. This first analysis was based on the data processed by the SCC and directly published on the THREDDS server in NRT. The preliminary analysis made on aerosol lidar data shows that by simply comparing the observed backscatter values with the climatological values from 2000-2015 is not sufficient to extract a clear conclusion on how much the COVID-19 lock-down has impacted the aerosols in the atmosphere, but a certain effect for low troposphere can be seen. Beyond the scientific goals of this campaign, the actions organized by EARLINET/ACTRIS (NRT delivery of the data and fast analysis of the data products) proved that aerosol lidars are useful for providing information not only for climatological purposes, but also in emergency situations. A more quantitative analysis based on re-analyzing additional data products will be made to consolidate the conclusions.

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8.4 COMPARATIVE STATISTICAL ANALYSIS OF PARTICULATE MATTER POLLUTION AND TRAFFIC INTENSITY ON A SELECTED LOCATION IN THE CITY OF NOVI SAD

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Urban air pollution by fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter is one of the major and complex issues in the modern world. Special emphasis has been gained on traffic-related pollution near roadways, where PM concentrations (conc.) tend to be most severe (Hilker et al., 2019). PM air pollution in Novi Sad is often influenced by individual boilers and furnaces, intensive traffic in urban areas, and thermal power plants. Some of the factors that impact traffic contribution to $PM_{2.5}$ and PM_{10} are traffic mix and volume, age of vehicles, meteorological conditions, local topography, etc (Wang et al., 2010). The aim of the study was to analyze the relationship between $PM_{2.5}$ / PM_{10} conc. and traffic density and meteorological factors (temperature, T, pressure, P, relative humidity, RH), on working days (WD) and weekends (WED), and traffic emission contributions (EC) to PM, during the week with regular traffic regime (SW1) and the first week of COVID-19 lockdown (SW2). Sampling period lasted from 09.03. - 22.03.2020 on selected traffic location in Novi Sad (TRFsite) with heterogeneous traffic flow.

$PM_{2.5}$, PM_{10}, T, P, RH, background (BCG) $PM_{2.5}$, PM_{10} conc., and traffic count data are collected from the public services. Vehicle categorization was passenger cars (A1), vans (A2), lightweight trucks (B1), trucks (B2), and buses (C1). Collected data were analyzed using the JASP software and Excel. EC was calculated by $PM_{2.5}$ / PM_{10} conc differences between TRFsite and $PM_{2.5}$ / PM_{10} conc. from the BCG.

Results have shown higher PM, P, EC values, lower T, RH values, and lower traffic counts for all vehicle categories in SW2. On WD, PM conc. and the number of A1-C1 vehicles were higher during both SWs. A positive correlation (corr.) was present in SW1, between $PM_{2.5}$/A1 and B1, PM_{10}/A1-C1 compared to non-corr. in SW2. During SW1 and SW2 (WD and WED), ECs for $PM_{2.5}$ were in the range from 4.3-17.7 $\mu g/m^3$, 2.1-2.6 $\mu g/m^3$ and from 5.5-48.2 $\mu g/m^3$, 2.9-31.9 $\mu g/m^3$. ECs for PM_{10} during SW1 and SW2 (WD and WED) were in the range from 15.6-45.1 $\mu g/m^3$, 2.8-9.9 $\mu g/m^3$ and from 21.3-88.3 $\mu g/m^3$, 5.1-56.4 $\mu g/m^3$. BCG $PM_{2.5}$ / PM_{10} conc. were moderately corr. to total traffic (TT) count during SW1 (r=0.84), for both PM and non-corr. to TT in SW2. Corr. of $PM_{2.5}$ / PM_{10} conc. with T, P, and RH showed very strong and moderate positive corr. for $PM_{2.5}$/T and for PM_{10}/T during SW2 (r=0.92, r=0.91).

PM conc. increased during SW2, but TT decreased by 68.7% on WD and 22.09% on WED, what is evidence of the impact of lockdown measures on traffic regime and intensity. The relationship between $PM_{2.5}$ / PM_{10} from TRFsite, and different vehicle categories were confirmed by moderate or strong corr. only during SW1. The corr. of PM and traffic during SW1 was also only confirmed by the positive corr. of BCG $PM_{2.5}$ / PM_{10} with TT. Besides this fact, in SW2, PM and EC conc. were higher, which strongly indicated on secondary emission source of PM. Very strong and strong positive corr. of $PM_{2.5}$ / PM_{10} with T during SW2 confirmed lower T impact on PM conc. and, consequently, increased impact of heating, as an emission source, due to lockdown measures and people staying at their homes.

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9. AEROSOL CHARACTERIZATION I

9.1 MEASURING AEROSOL ABSORPTION – THE ADVANTAGE OF DIRECT OVER OTHER METHODS, AND MULTI-WAVELENGTH CALIBRATION

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Among the many methods of aerosol light absorption measurement, the most commonly employed are indirect opnes, especially measurements with filter absorption photometers. These determine the particle optical properties by drawin air through a filter on which the sample is deposited, and then measure the light transmission through this particle-laden filter. Some additionally measure light reflection from the filter in offline (Bernardoni et al., 2017; Massabo et al., 2013) and implementations (Drinovec et a., 2015; Hansen et al., 1984; Ogren et al., 2017; Petzold and Schönlinner, 2004). They convert these measurements to mass concentration of equivalent black carbon (eBC) using a mass calibration. Some report the aerosol absorption coefficient. These conversions assume filter properties and use external or measured parameters to determine the measurement non-linearities (Drinovec et a., 2015, and references therein) and the mass-absorption-cross section. Their cross-sensitivity to scattering needs to be taken into account at high sample single-scattering albedo (SSA) (Yus-Díez et al., 2021).

The direct methods make use of the change in the sample due to the absorption of light and are in-situ and measure aerosol suspended in the air. Using a high-power laser to heat the sample they probe the effects of the transfer of heat from the particles into the surrounding air. Photothermal interferometers (PTI) measure the change of the refractive index in the heated the sample with the lower density. PTI detection is linear and can be traced to first principles (Moosmüller and Arnott, 1996; Sedlacek, 2006).

We present a new PTI instrument for the measurement of aerosol absorption at two wavelengths (532 nm, 1064 nm) and the calibration of the measurements at both wavelengths (Drinovec et a., 2021). We show the advantages of direct methods over indirect ones in a laboratory measurement of the enhancement of absorption due to secondary organic coatings (Kalbermatter et al., 2021).

We use the direct in-situ methods to calibrate the filter photometers. This is a pedantic and time consuming taks, but it needs to be performed only periodically. Using calibrated filter photometers, we show many interesting measurements in the laboratory and ambient air.

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9.2 APPORTIONMENT OF PRIMARY AND SECONDARY CARBONACEOUS AEROSOLS USING AN ADVANCED TOTAL CARBON – BLACK CARBON ($TC-BC_{7-\Lambda}$) METHOD

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High time-resolution apportionment of carbonaceous aerosol is essential to identify the main pollution sources and separate species that have the highest impact on public health and the planetary radiation balance. Carbonaceous aerosols were measured by the CASS system (Carbonaceous Aerosol Speciation System, Rigler et al., 2020), which combines the Total Carbon Analyzer TCA08 and the Aethalometer AE33, providing high time-resolved data on the carbonaceous aerosol composition and optical properties in real-time.

Apportionment of the carbonaceous matter is based on the simplified TCA08 method, where the organic carbon (OC) content is calculated as $OC = TC - BC$, the difference between total carbon (TC) and black carbon (BC). The multiple-wavelength analysis of the Aethalometer AE33 data allows apportionment of the optical absorption into two components: black carbon (BC) and brown carbon (BrC) (Wang et al., 2019). Furthermore, the BC tracer method is used to separate organic carbon into the primary and secondary OC (Wu and Yu, 2016). The advanced TC-BC method was validated on a 2-year measurement campaign in LA Basin (LA Central and LA Riverside measurement sites, CA, USA). This study presents results from two intensive campaigns: Berkeley measurement station, CA, USA – "Camp Fire event (November 2018)", and Highway 401 measurement station, Toronto, Canada.

For measurements at the Berkeley measurement station, the TC concentration varied between 3 and 16 µg/m3 before the wildfire impact and reached concentrations up to 101 µg/m3 with an average of 37 µg/m3 during the Camp Fire event. Additionally, the event influenced the OC/BC ratio, which indicates the aerosol composition. Before and after the plume event, the BC-to-TC ratio varied strongly between 4% and 77%: the typical daily cycle shows high morning BC due to rush hour traffic and high afternoon OC caused by the secondary OC aerosol formation. The eBC-to-TC ratio stayed almost constant and below 24% during a wildfire event. The light absorption at the lower wavelength (370 nm) increased by a factor of 7 relative to the non-impact periods. During the event, the share of the light absorption at 370 nm due to BrC increased to 42% on average: significantly higher than the average 6% contribution observed before and after the event.

The intensive measurement campaign at Highway 401 measurement station in Toronto, Canada, was conducted between 30 April and 14 May 2019. Measurement results were evaluated with complementary measurements of OC/EC, PM2.5, organics with aerosol chemical speciation monitor (ACSM), and various trace gases. During the workdays, the diurnal variation of BC, BrC, primary and secondary OC is strongly influenced by the temporal patterns of emissions from traffic. On the weekend evenings also a small contribution of biomass burning is present. Primary carbonaceous emissions (BC+primary OC) contribute 60% to TC during workdays, while the secondary OC prevails during weekends with a share of almost 70%. Correlation of TC-BC and ACSM measurements shows OM/OC ratio of 1.85 for the duration of the measurement campaign.

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9.3 VARIATION OF BLACK CARBON CONCENTRATION IN COLD AND WARM SEASONS IN SKOPJE URBAN AREA

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South-East Europe and particularly continental parts of the Balkan peninsula are among the areas with highest ambient air pollution levels in Europe. Most of the regional capitals exceed the EU annual limit value, and when considering the stricter WHO guidelines, all cities exceed the $PM_{2.5}$ annual mean guideline (Almeida et al, 2020). The objective of our study was to assess Black Carbon concentrations in $PM_{2.5}$ size-segregated aerosols and to estimate the contribution of fossil fuel combustion (BC ff) and biomass burning (BC bb) to equivalent black carbon (eBC) concentrations in the urban area of Skopje, North Macedonia.

Measurements were conducted intermittently at one urban background and one urban traffic-exposed sites, from January to August 2021. The aerosol light absorption coefficients were retrieved using a 7-wavelength aethalometer (Rack Mount Aethalometer Model AE33, Magee Scientific Corp., Barkley, CA, USA). Aethalometer readings were corrected in real-time for multiple scattering in the filter matrix and loading effects, using the DualSpot Technology® (Drinovec et al., 2015). Using the Aethalometer model (Sandradewi et al. 2008), the absorption coefficients produced from the aethalometer were utilized to estimate the contribution of biomass burning and fossil fuel to total BC concentrations. $PM_{2.5}$ samples were collected on PTFE filters using a low volume sampler (Sequential sampling system with automatic filter changer and Peltier cooler, PNS 18, DM-6.1, Comde-Derenda GmbH, Germany) and analysed for potassium (K) and other major ad trace elements using an X-Ray fluorescence (NEX CG II EDXRF Spectrometer, Applied Rigaku Technologies, Inc., Tokyo, Japan). One-hour averaged data for fine particulate concentrations ($PM_{2.5}$), carbon monoxide (CO) and nitrogen dioxide (NO2) were obtained respectively from a co-located monitoring station, part of the State Monitoring Network, operated by the Ministry of Environment and Physical Planning (MOEPP).

Measured equivalent black carbon concentrations were similar to other pollutants connected with low efficiency combustion processes like $PM_{2.5}$ and CO - exhibiting strong seasonal variation at both sites, ranging from high 6.96 ± 6.82 (urban background) and 6.24 ± 6.54 (traffic exposed site) during the cold season, to significantly lower 1.41 ± 1.16 (urban background) and 2.78 ± 2.03 (traffic exposed site) during the warm season. During the cold season, the mean relative contribution (%) of biomass burning reached 52.18 ± 15.22 % of the total black carbon concentration at the urban background site and 32.35 ± 19.22 % at the traffic-exposed site, and exhibited a strong diurnal pattern with maximum values during the evening and late-night hours. The mean relative contribution of biomass burning significantly lower during the warm season, reaching 16.27 ± 8.28 at the urban background site and 7.65 ± 6.03 % at the traffic-exposed site, with no clear diurnal pattern.

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10. AEROSOL CHARACTERIZATION II

10.1 SECONDARY ORGANIC AEROSOL FORMATION FROM DIRECT PHOTOLYSIS AND OH RADICAL REACTION OF NITROAROMATICS

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Aromatic compounds are widely spread in the urban atmosphere with important contributions to atmospheric pollution, climate change and human health. Aromatics are found precursors for photooxidants and secondary organic aerosol (SOA) formation (Calvert et al., 2002). Nitroaromatics are mainly released from biomass burning and exhibit toxic effects on the human body and on vegetation, with contributions to the SOA budget, radiative balance and oxidation capacity of the atmosphere. Nitroaromatics are formed also as degradation products of aromatic precursors in the reaction with main atmospheric oxidants. Nitrophenols and nitrocresols could form HONO during direct photolysis as a result of hydrogen transfer from OH groups to NO_2 entities followed by C-N bond scission (Bejan et al., 2006).

This study aims to investigate the potential formation of the aerosols from the direct photolysis of nitrocresols and from the OH radical-initiated degradation of nitrocresols. 2-nitrophenol has been already reported as precursor for SOA during photolysis at 365 nm (Bejan et al., 2020). All the investigations were carried out in a 1080 L quartz-glass photoreactor in synthetic air (296 ± 3 K and 1013 mbar). A FTIR technique has been employed to monitor nitroaromatics during the experiments. IR spectra were recorded at a spectral resolution of 1 cm^{-1} using a Nexus FT-IR spectrometer equipped with liquid nitrogen cooled MCT detector.

The study reports SOA-dependent yields on the NOx concentrations and OH radical scavenger concentration. Quick aerosol formation has been observed from photolysis experiments. Significant OH radical scavenger effect is reported. All the SOA formation experiments have been fitted using the Odum model considering one major component for the partition between gas and particle phase.

The impact of nitroaromatics photolysis on the atmosphere will be discussed and the importance of these processes for modeling studies will be assessed.

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10.2 EMERGING POLLUTANTS IN ATMOSPHERIC AEROSOLS IN LATVIA: PRESENT SITUATION OVERVIEW

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The negative effects of airborne aerosols on human health and the environment is well documented: currently 83% of EU citizens living in urban areas experience PM_{10} concentrations that exceed WHO Air Quality Guidelines. While some pollutants are regulated and have set thresholds and monitoring requirements, the growing intensity of human activity is producing hazardous pollutants, that don't have such requirements yet – these pollutants are described as "emerging", however, it is important to note, that their presence in the environment is not an entirely new development (Chen et al, 2019; WHO, 2013; Robichaud, 2020).

The overall goal of the overview is to highlight the need for in-depth monitoring and modelling of emerging pollutants to facilitate and better the creation of up-to-date EU and local regulations.

The paper contains an overview of the history of airborne emerging pollutants monitoring in Latvia, existing measurement results and an overview of methodology used in obtaining said results. An attempt to qualitatively describe the main sources and define potential sources has been made in the process of writing this paper. Additionally, an analysis of reasons for discontinuing some of the monitoring is included, which sheds light on national and regional constraints that EU states face in regards to emerging (i.e. unregulated) contaminants.

Preliminary results show that current monitoring and subsequent gathered data is lacking in the capability to accurately describe the main sources of emerging pollutants and sufficiently address the problem. Further research is required in this regard across Latvia and EU as a whole.

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10.3 CHEMICAL COMPOSITION AND SOURCE APPORTIONMENT OF PM2.5 AT A SUBURBAN SITE IN THE NORTHWESTERN PART OF TURKEY

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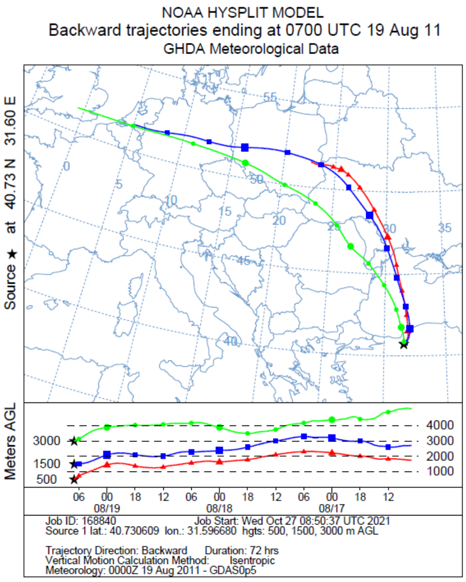
In this study, daily fine particulate matter ($PM_{2.5}$) were sampled between 22 February 2011 and 22 February 2012 in Bolu Abant İzzet Baysal University Campus (BAIBU). 277 $PM_{2.5}$ samples were collected by using a "GENT" stacked filter unit (SFU). Fifty-one elements (Li, Be, Na, K, Mg, Al, P, S, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ge, As, Se, Rb, Sr, Y, Mo, Cd, Sn, Sb, Cs, La, Ce, Pr, Nd, Eu, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, W, Pt, Au, Pb, Bi, Tl, Th, U) were determined by using ICP-MS technique. The concentrations of elements were investigated by using seasonal variations and transport patterns. The most frequently observed elements were Ti, V, Cr, Mn, Fe, Ce, and Cd in $PM_{2.5}$. Aluminum, Ca, Na, Fe, K, and Mg were the elements having the highest arithmetic means. In the Bolu station, the most frequent annual winds were from the WSW sector carrying the long-range pollutants to the sampling station. The concentrations of elements in the summer seasons were higher than the concentrations of elements in the winter season except for As and Bi.

Source apportionment of elements was performed by using positive matrix factorization (PMF). Five sources were determined for the samples namely sea salt (Na, K, Mg, Ca), coal combustion (As, Pb, Bi, Tl, Cd, Sb, Se, Mo), wood and coal combustion (K, Rb, Se, Cs, Sb, Pb, Bi, Tl, Fe, Mn, Cd), soil (Ca, Mg, Ti, Fe, Y, La, Ce, Pr, Nd, Sm, Gd, Th) and industrial activity (iron-steel works) (Cr, Mo, Fe, Ni, Cu, Mn, Cd, Sb, Ca). The daily variations of G-scores were evaluated and associated with back trajectories of the days having the highest G-scores. The wood and coal combustion factor showed the same trend in the region in the whole year. However, higher G-scores for coal combustion factor were observed in winter. The trajectories for 01.08.2011, 08.08.2011, 19.08.2011, and 31.01.2012 were investigated and the higher G-score values for these days in the industrial factor were found to be associated with the industrial activities coming from iron-steel works in Karabük and from European countries. The trajectory for August 19, 2011 is shown in Figure 1.



10.4 KEY FACTORS GOVERNING PARTICULATE MATTER ENVIRONMENTAL FATE IN AN URBAN ENVIRONMENT

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According to recent estimates, the mortality rate due to exposure to high levels of air pollution accounts for 8.9 million deaths annually (Burnett et al, 2018). Containing several hundred types of chemical species, some of which are toxic, mutagenic, and carcinogenic, particulate matter (PM) pollution rises as a significant problem in urban areas. The fate of PM is governed by a diversity of emission sources, meteorological factors, or topographic features, as well as their mutual interrelations.

In this study, we used the eXtreme Gradient Boosting (XGBoost) regression machine learning method to investigate the relation between PM and other air pollutants, and meteorological parameter dynamics in the urban area of Belgrade, Serbia. The air pollution data (PM_{10}, benzene, SO2, NO, NO_2, and NOx) was obtained from six air quality stations within the Institute of Public Health Belgrade network, while the meteorological parameters were obtained from ARLs Global Data Assimilation System (GDAS1).

We used the SHapley Additive exPlanations (SHAP) explainable artificial intelligence method to investigate and interpret the governing factors in shaping PM_{10} levels. The method uses Shapley values, calculated as a measure of feature importance based on a game-theory approach, that provide an impact of features on individual predictions (Lundberg et al, 2020). These values are considered as fairly distributed payouts among the cooperating players (features) depending on their contribution to the joint payout (prediction). The main advantage of the approach is that SHAP represents the only possible locally accurate and globally consistent feature attribution method. We used Python XGBoost and SHAP implementations, and the TreeExplainer method which reduces the complexity of exact Shapley value computation from exponential to low-order polynomial time by leveraging the internal structure of tree-based models (Stojić et al, 2019). The stabilities of the obtained SHAP values were evaluated by 50 times replicated bootstrap method.

As shown, the most important variables which describe PM level dynamics in the urban area of Belgrade include meteorological variables – momentum flux intensity, standard lifted index, volumetric soil moisture content and temperature, as well as the concentrations of benzene, NO, NOx, and SO_2.

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10.5 HARMONIZATION OF UFP MEASUREMENTS: A NOVEL SOLUTION FOR MICROPHYSICAL CHARACTERIZATION OF AEROSOLS

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Characterization and continuous monitoring of ambient ultrafine particles (UFP) has been one of the major priorities within ACTRIS for the last three decades. With much experience gained during this time, the next important step is harmonizing these measurements on the European level. In this direction, the CEN/TS 16976:2016 guideline on “Ambient air – Determination of the particle number concentration of atmospheric aerosol” will soon be converted into a European standard. In addition, CEN/TS 17434:2020 on “Ambient air - Determination of the particle size spectra of atmospheric aerosol using a Mobility Particle Size Spectrometer (MPSS)” is now being applied to gain real world experience.

This study shows results of atmospheric aerosol measurements obtained using a newly developed wide-range Scanning Mobility Particle Sizer (model 3938W50, TSI Inc., USA). The development of this system aims to fully close the gap between the current SMPS systems and CEN/TS 17434:2020 requirements. The system is based on the well-known Classifier platform (model 3082, TSI Inc.) as well as the CEN 16976-compliant Condensation Particle Counter (CPC model 3750-CEN, TSI Inc.). In order to provide the required scan range from 10 to 800 nm, a new Wide-Range Differential Mobility Analyser (DMA, model 3083, TSI Inc.) has been introduced. It is based on the TROPOS design of the Vienna type DMA (Winklmayr et al. 1991). For continuous monitoring of relative humidity and temperature in the aerosol stream, a sensor (model RHT3000, TSI Inc.) has been integrated. In addition, the Aerosol Instrument Manager software with monitoring capabilities, provides all the data and parameter output required by CEN/TS 17434:2020 and ACTRIS.

Measurements of atmospheric aerosol are presented; the data were recorded using a fully integrated measurement setup including a novel ambient sampling system for UFP fully compliant to the CEN technical specifications. For the quality assessment of the results, the total integrated number concentration data were compared to a stand-alone CPC used as a concentration reference.

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11. POSTER SESSION

11.1 EFFECTS OF BIOMASS FUEL SMOKE ON MATERNAL HEALTH AND PREGNANCY OUTCOMES

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Biomass fuel smoke exposure can occur in a variety of settings, ranging from residential exposure to woodstoves or cook stoves to community-wide exposure from nearby wildland fires or agricultural burning [Cincinelli and Martellini, 2017]. The influence of harmful smoke that is released by burning fossil fuels is primarily reflected in the appearance acute respiratory infections of lower respiratory tract and asthma [Juntarawijit and Juntarawijit, 2017]. In recent years more and more attention is drawn to the vulnerability of women and reproductive health outcomes, especially birth weight and stillbirth [Wylie et al, 2014; Franklin et al, 2019; Milanzi and Namacha,2010].

The main goal of the present study was to determine the effects of biomass fuel smoke on pregnant women health and pregnancy outcomes**.**

The study was conducted in the city of Niš during 2018.In this study we evaluated data from a sample of 1076 never-smoking pregnant women, ages 20-40 years, who have lived in part of the town with low concentrations of outdoor air pollutants and has not been professionally exposed to air pollution. According to the responses which are collected by a questionnaire regarding exposure to biomass smoke, the interviewers are divided into two groups: the exposed (n = 523) and control group (n = 553). Pregnant women of both groups do not have symptoms of any cardiovascular or pulmonary diseases, anemia, diabetes and pathological condition of pregnancy. All of these pregnant women are enrolled in early pregnancy (gestational age <10 weeks). The questionnaire about respiratory symptoms and illnesses adapted the American Thoracic Society [13] and validated questionnaires for Serbian language. Data on pregnancy were collected on the basis of physical examinations, laboratory analyzes, fetal ultrasounds and hospital registrations. Multiple logistic regression analyses were performed to analyze the relationship between health outcomes (anemia, high blood pressure and respiratory symptoms and disease) and exposure to biomass fuel smoke, as well as relationship between pregnancy outcomes **(first trimester** vaginal bleeding, spontaneous abortion, stillbirth and low birth weight) and exposure to biomass fuel smoke.

Exposed women had a higher prevalence of all pregnancy outcomes than non-exposed women, but no statistically significant. Only prevalence of first trimester vaginal bleeding was statistic significantly higher in group of exposed women. Depending on the value of the relative risk the greatest influence on the incidence of first trimester vaginal bleeding had occupational exposure to gas/dusts/fumes (RR: 2.93; 95% CI: 1.45 to 4.14), and at least exposure to biomass fuel smoke (RR:1.43;95%CI:1.69 to 1.85). Suffered from anemia is 2.1 times increased risk for first trimester vaginal bleeding.

Our results suggest that exposure after and during the pregnancy to biomass fuel smoke may be associated with a upper respiratory symptoms and first trimester vaginal bleeding in pregnancy.

Key words: biomass fuel smoke, pregnancy outcomes, women, air pollution, vaginal bleeding.

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11.2 EFFECT OF SUBSTITUTION OF OLD COAL BOILERS WITH NEW BIOMASS BOILERS ON THE CONCENTRATION OF PARTICULATE MATTER IN AMBIENT AIR: A CASE STUDY MIONICA

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Residential and commercial solid fuel burning in stoves, small and medium combustion plants have been designated as the largest sources of fine particles with serious impacts on air quality, climate and human health. Having in mind the age and condition of the plant, as well as domestic raw lignite of poor quality which is widely used in these plants, this problem becomes even more pronounced in Serbia during the heating season. An additional reason for such high dust emissions certainly lies in the fact that most of these combustion units, in addition to being in very poor condition, work without any flue gas system for dedusting, also the mentioned lignite is low in calorific value with high ash and moisture content. Replacement of such combustion units with modern biomass boiler units is certainly appropriate, and in places where natural gas is not available, this energy source is the best solution.

In this paper and for the case study of Mionica town, the influence on the concentration of PM in ambient air will be presented by replacing two old coal boilers with new biomass boilers. Namely, two old boilers (2x950 kWth) covered the heat demand of the sports centre as well as primary and secondary school, these boilers were replaced with two new biomass boilers of the same installed thermal capacity.

In order to analyse the influence of boilers substitution on PM concentration in ambient air, the regulatory air dispersion model, recommended by the US Environmental Protection Agency (US EPA) AERMOD, is used, which is based on the Gaussian model. Air dispersion modeling within this Study includes only sources which are associated with this Case Study. Other sources of emissions and background pollution are not included. The aim of this Study is not to show the air quality in the domain, but rather to provide a representative assessment of the impact of boilers substitution on PM concentration in the model domain. For the purpose of this Study NASA digital maps SRTM1 - Shuttle Radar Topography Mission (resolution ~ 30m, or 1 arc-sec) are used and processed by the AERMAP, while meteorological, data processed by the AERMET, are site specific MM5 (Grid Cell 12 km x 12 km), giving an hourly-modelled meteorological data set for full five consecutive calendar years. The results presented in this paper were obtained using a model which includes the emissions of TSP, PM10 and PM2.5 from the old and new boilers. An emission inventory has been prepared based on combustion calculations and emission factors (EMEP/EEA, 2019) for old coal fired boilers, while for new biomass boilers, site-specific measurements and PM size distribution factors (US EPA, AP 42, 2003) have been used.

Modelling results consist of graphical (isopleth diagrams) ground level concentrations for TSP, PM10 and PM2.5 and various average periods.

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11.3 CIVIC AIR QUALITY MONITORING AS AN ALTERNATIVE AND SUPPLEMENT TO THE STATE AIR QUALITY MONITORING NETWORK

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Background and Aims: Poor air quality causes an estimated 400 000 premature deaths in Europe every year because of the fact that a significant number of Europe's population lives in areas where air pollution is pure and poses a risk to health (Schaefer et al, 2020). The European initiatives for citizens' inclusion in the air quality monitoring process, impacted the participants' knowledge, self-efficacy, and attitudes towards air pollution; they resulted in changed or adjusted behaviour of the involved citizens towards measures to exposure and contribution to air pollution, led to a higher sense of community, stimulated discussions with policy makers, and influenced political decisions in the involved regions (Schaefer et al, 2020). Such experiments in the Republic of Serbia, with self-made sensor kits "Klimerko - Air to the Citizens" started in 2018 (Klimerko, 2018). Since then, it has been continuously improved in terms of its hardware and software. Klimerko measures: a) air humidity; b) air temperature; c) concentration of PM_1, $PM_{2.5}$, and PM_{10}. It has not been calibrated, since it was established that PMS7003 sensors are precise enough for civil measurement. This has been once confirmed with the installation of 4 PMS7003 sensors on a vehicle of the Institute of Public Health "Dr. Milan Jovanović Batut" and comparing the data with their professional sensors, as well as by comparing official values obtained by the Serbian Environmental Protection Agency (SEPA) with the values obtained by the Klimerko devices that are located in the close vicinity of the SEPA monitoring stations (Klimerko, 2018). As there are no processes yet to guarantee data quality adequate for regulatory actions regarding PM, the main aim of the mentioned project "Klimerko - Air to the Citizens" is to inform, raise awareness, and educate. At the moment, about 140 Klimerko devices are deployed on the entire territory of the Republic of Serbia: a good part of them is located on the territory of the city of Belgrade. Our intention was to compare the PM readings from Klimerko devices to the readings of the calibrated PM device in the town of Bor in order to confirm once again their usability for indicative measurements of suspended particles in the ambient air.

Methods: The results obtained by the Klimerko devices (PM_{10} and $PM_{2.5}$ (PMS7003), temperature and relative air humidity (BMPE80)) were compared to the results obtained by the reference instruments located at the SEPA air quality monitoring stations as well as with the calibrated PAQMON2020 monitors (SDS011 PM sensor, DHT22 temperature, and relative air humidity sensor) that were located next to the Klimerko devices. The comparison of the results was carried out during a one month period, from 27th of July to 6th of September 2021.

Key results: Determination coefficients obtained by the comparison of mean hourly levels of PM ($R^2 = 0.59$ and 0.72 for PM_{10} , and $R^2 = 0.64$ and 0.73 for $PM_{2.5}$) from the Klimerko devices deployed in the Bor town and reference instruments (from SEPA station in Bor) indicate a very strong linear relationship between the measurement results of the reference instruments and the PMS7003 sensors which were placed in Klimerko devices.

Conclusions: The Klimerko devices that we have tested were showed very good stability and reliability during the comparison period with the reference instruments. So, the conclusion is that Klimerko devices could be applied for indicative measurements of PM mass concentrations in ambient air.

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11.4 PM EMISSIONS FROM NEWLY-BUILT WOOD CHIP COMBUSTION PLANTS: CASE STUDY FOR SERBIA

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There is evident increase in air pollution in recent years. The dominant sources of air pollution in urban and rural areas, during the heating season, are small individual appliances. In recent years, new combustion plants have been built in several places in Serbia, which use biomass as fuel - wood chips. These plants were built in order to replace multiple existing low-rank coal combustion plants, combining them in one combustion plant. This paper gives review of PM emissions measurements, that were conducted in 8 newly-built wood chip combustion plants. Combustion plants provided heating power between 0,5 and 1,5 MW. Also, proximate and ultimate analysis of fuel is presented for every boiler under consideration.

11.5 AIR POLLUTION AND TRAFFIC ACCIDENTS – IS THERE A CONNECTION?

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Traffic accidents impose serious medical, economical, and human costs on society and injuries and deaths caused by these accidents are a major public health issue (WHO, 2013). The majority of traffic fatalities in Serbia occur in urban areas (OECD, 2013.). The contribution of weather and air pollution to traffic accidents remains under-studied, even noting that air pollution greatly reduces the visibility of the air, leading to frequent traffic accidents. The aim of the paper was to analyse the main causes of road traffic crashes in Niš, Serbia.

Based on the statistical data on the state of traffic safety in Serbia (Road Traffic Agency of Serbia, 2015), and previous research on traffic crashes in the area of the city of Niš (Radojković, 2016), the methodological approach to the determination of the nine key risk indicators of crashes in road traffic has been established, organized into four groups.

A total of 3593 traffic accidents were recorded by the police force of Niš city between January 2010 to July 2013 and the most accidents occurred in the populated parts of the city of Niš with highest value of air pollution. Also, the highest number of persons killed in traffic crashes in the city of Niš was identified in crashes that occurred in the populated parts of the city. In the winter season with higher level of air pollution in the city of Niš (November-February) against other months (March-October), a significant difference in the number of traffic accidents has been identified ($\chi2 = 12.71$, $p = 0.0053$). According to experts' assessments, the most important risk factor of road traffic crashes is 'Causes of crashes and sanctions' and the second one is 'location of crashes'.

To conclude, air pollution could be connected with traffic accidents. Implemented measures and activities to improve air quality in urban environments can also improve traffic safety in the Republic of Serbia.

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11.6 ASSESSMENT OF THE BURDEN OF DISEASE DUE TO PM2.5 AIR POLLUTION FOR THE BELGRADE DISTRICT

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The health effects attributed to the long-term exposure to ambient $PM_{2.5}$ concentrations above 10 μg/m^3 by using the AirQ$^+$ modelling software were assessed. The hourly concentrations of $PM_{2.5}$ were collected from 13 air pollution monitoring stations in Belgrade during June and July 2021, and then have been used as input data for the AirQ$^+$ software. The average concentration of $PM_{2.5}$ for two-month monitoring from 13 sampling sites in the city was 14.8 μg/m^3, the maximum daily concentration was 55.7 μg/m^3, while the maximum concentration per hour was 364.8 μg/m^3. The burden of diseases, such as stroke, ischemic heart disease (IHD), chronic obstructive pulmonary disease (COPD) and lung cancer (LC), due to the ambient $PM_{2.5}$ pollution was evaluated according to the WHO methodology for health risk assessment of air pollution. The model used for this assessment is based on the attributable proportion defined as the section of the health effect related to the exposure to air pollution in an at-risk population. The estimated attributable proportion was 19.4% for stroke, 12.2% for IHD, 15.4% for COPD and 9.0% for LC. The numbers of estimated deaths due to the $PM_{2.5}$ air pollution manifested by stroke, IHD, COPD, and LC, were 189, 119, 182 and 88, respectively. The spatial distribution of concentrations was mapped using geostatistical interpolation, revealing hotspots within the city center and industrial area of the city.

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11.7 MODELING CONTROLLED AEROSOL ATMOSPHERE BY UTILIZING PHYSICS BASED MODELING: EXPERIENCE FROM USING COMPUTATIONAL FLUID DYNAMICS APPROACH

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Background and Aims: Having access to a controlled aerosol atmosphere is desirable in a number of scenarios, such as testing/calibrating PM monitors, testing mask efficiency, performing exposure experiments and similar. Such atmosphere is typically realized using an aerosol chamber, two most common types being static and dynamic aerosol chamber, with common elements such as air inlet and outlet, optional mixing fans/ventilators. Knowing exact details of aerosol concentration distribution and time evolution is essential for performing experiments which require a high level of repeatability, such as low-cost sensor testing.

Methods: In this paper, we analyse a design approximating our existing laboratory design of an aerosol chamber, situated in the Vinca Institute, using a computational fluid dynamics and multiphysics approach in both static and dynamic setting, with two types of aerosol inlets (point-like inlet and standard circular diffusion mesh with 0.24m diameter). The chamber was a rectangular parallelepiped made from combination of acrylic glass and stainless steel with dimensions 0.45m x 0.45m x (0.10 steel + 0.45) m (width x depth x height), with the aerosol inlet situated at the top centre, and an (optional) exhaust at the bottom corner. For the considered combinations of static/dynamic chamber and point-like/diffusion-mesh aerosol inlet, detailed examination of distribution and time evolution of aerosol concentration was performed for several relevant sizes of monodisperse test particles.

Key results of the study: Multiphysics-based modelling enabled several insights without the need to perform costly modifications to the existing chamber design. Since the main aim is the use of chamber for low-cost PM monitor testing, we have derived possible options for optimal placement of the sensors within the chamber, by analysing air flow fields and particle trajectories. Variations in the aerosol concentration for distinct positions of low-cost sensors (position(s) within a chamber which should exhibit a similar concentration suitable for calibration), were quantified compared to a reference position (position within a chamber at which the inlet of a reference PM monitor was situated).

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11.8 PORTABLE AIR QUALITY MONITOR BASED ON LOW-COST SENSORS

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Background and Aims: National systems of automatic air quality monitoring are based on automatic measuring instruments that are installed in stationary air quality monitoring stations. Substantial financial resources are required for the procurement, installation, calibration, and maintenance of such measuring devices. For this reason, existing national and local air quality monitoring networks are not able to provide a high temporal and spatial resolution of measurement results. In the last ten years, as a possible alternative to the conventional approach to air quality monitoring, real-time monitoring systems using cheap (low-cost) sensors and sensor platforms have begun to be applied (Jovasevic-Stojanovic et al, 2015). This paper describes the basic characteristics of a portable air quality measuring device PAQMAN 2020 based on low-cost sensors. Part of the results of comparative measurements of this device with the measurement results of the reference instruments is presented in the paper.

Methods: PAQMAN 2020 uses an Arduino Mega microcontroller as a control board. An SDS011 sensor module is used for measurements of PM_{10} and $PM_{2.5}$ mass concentrations from the range of 0-2000 µg /m^3. A DHT22 sensor module is used for temperature (-10 to +40 °C) and relative humidity (20 to 90 % RH) measurements. NDIR S8 CO_2 module is used for the measurement of CO_2 concentrations in the range from 400 to 2000 ppm. The measurement results are stored in text files on the microSD card and displayed on the device's LCD display (LCD2004). Device programming was done in C through the Arduino IDE. Results of measurement could be downloaded from PAQMAN 2020 to PC over a standard USB serial port.

Key results: The PAQMAN 2020 was tested in the laboratory and in the field. Mean 15-minute or mean hourly values were compared, depending on the available time resolution of the results from the reference instruments. Figure 1 show comparison of PM concentrations (SDS011 as DUT vs ref.) measured in the laboratory. Determination coefficients (R^2 = 0.957 for PM_{10} and R^2 = 0.945 $PM_{2.5}$) indicate a very strong linear relationship between the measurement results of the reference instrument and the SDS 011 sensor.

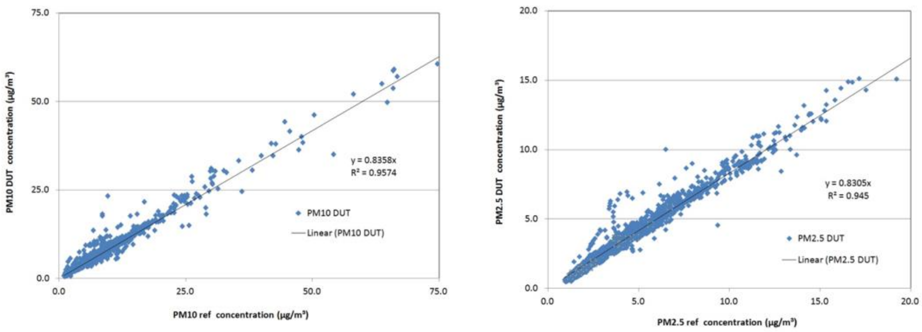

Figure 1. Comparison of results for the PM concentrations measured in the laboratory

Conclusions: The PAQMAN 2020 monitor was showed very good stability and reliability during the test period. So that, it could be applied for temporary or continuous indicative measurements of indoor and outdoor air quality.

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11.9 DETERMINATION OF LEVOGLUCOSANE AND ITS ISOMERS IN AMBIENT AIR PM USING GAS CHROMATOGRAPHY WITH MASS SELECTIVE DETECTOR IN THE BELGRADE URBAN AREA

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The aim of many studies has focused on the chemical characterization of airborne particulate matter (PM), not only because of health effects, but also because it allows source apportionment to be carried out (Padoan et al., 2020). Identification and quantification of the source emissions is important in order to reduce particulate pollution. A significant source of atmospheric aerosols all over the world is biomass burning. Pyrolysis of cellulose at temperatures above 300 °C produces levoglucosan and its isomers mannosan and galactosan. The major constituent is levoglucosan and it is very important to estimate the fraction of aerosols attributed to biomass combustion from the PM/Levoglucosan emission ratio (Bhattarai et al., 2019). Levoglucosan has proved to be a suitable tracer for biomass combustion.

The method in this paper which was used for the determination of levoglucosan, mannosan, galactosan and other anhydrous monosaccharides in samples of suspended particles in ambient air is the GC / MS technique after methanol extraction and derivatization with BSTFA (N,O-bis(trimethylsilyl) trifluoroacetamide). After sampling, 47 mm-diameter filters were extracted with methanol in an ultrasonic bath at room temperature. The extract was transferred to an evaporation vessel through a 0.45 μm filter. The methanol extraction was repeated, and the extracts collected and evaporated down to 0.25 ml. Before GC-MS analysis, it was necessary to perform derivatization. The entire extract was transferred to a vial together with a solution of D-sorbitol (injection standard) and the internal standard of sedoheptulose anhydride monohydrate. The was evaporated extract in a stream of nitrogen to dryness. and derivatized with 100 μL of BSTFA and 900 μL of pyridine. The vial was closed and allowed to stand for two hours at room temperature before analysis by GC. The obtained results have shown that average response for levoglucosane was 10.66%, uncertainty was 14.14% and LOD 0.002 ng/m3.

Key words: PM; source apportionment, biomass burning

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11.10 COMPARISON OF LOW-COST PM SENSORS IN AN INDOOR ENVIRONMENT

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Background and Aims: Based on previous research, people spend more than 90% of their time indoors. Contrary to popular belief, indoor air can be more polluted than outdoor air. The interior of the building is a specific closed environment in which the possibilities for dilution and self-purification of air are reduced, which causes increased concentrations of pollutants. Real-time PM particle concentration monitoring, based on reference measurement methods, is a demanding and expensive process. Advances in miniaturization and reduced production costs have led to the development of small and relatively inexpensive optical PM sensors, which due to low cost and high response speed have obvious potential for application in modern real-time air quality monitoring systems [1, 2]. In this paper, a comparison of two low-budget devices for measuring the concentration of PM particles indoors is performed and the results of comparative measurements are presented.

Methods: Comparative measurement of the concentration of suspended particles $PM_{2.5}$ and PM_{10} was performed in the premises of the Faculty of Occupational Safety in Niš for 10 days using an air quality measuring device based on SDS011 sensor module and Arduino platform - PAQMON2020 and Dylos DC1700 (Dylos Corporation) PM monitor, which is widely used to monitor the concentration of the number of particles in the indoor air. The PM concentrations measured by the Dylos DC1700 monitor were compared to the results obtained by the PAQMON2020 device using linear regression.

Key results: The test was conducted in the premises of the Laboratory for Air Quality Management, Faculty of Occupational Safety in Niš, University of Niš. The devices were placed on the same desk, at a distance of 15 cm from each other, and were exposed to the same conditions of air pollution for 10 days. The average hourly values of PM mass concentrations obtained using the PAQMON2020 and Dylos device were compared. It was found that there is a strong positive linear correlation between mass concentrations for both PM fractions (for $PM_{2.5}$ $r = 0.80$ and for PM_{10} $r = 0.82$).

Conclusions: The test showed that the obtained results of measuring PM concentrations using PAQMON2020 and Dylos DC1700 devices are very compatible and that both devices can be used for indicative measurements of $PM_{2.5}$ and PM_{10} concentrations indoors after appropriate calibration with a reference instrument.

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11.11 EVALUATION OF GASEOUS EMISSION CHARACTERISTICS DURING FOREST FUEL COMBUSTION IN MASS LOSS CALORIMETER COUPLED WITH FTIR APPARATUS

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Background and Aims: The influence of forest fires on the global composition of the atmosphere is well known, and especially its influence is much more pronounced at the beginning of the 21st century, with increasingly frequent occurrences of large-scale fires. In most cases, its dramatic impact on air quality is expressed in forest fires that last for tens of days. Due to the increased frequency, there is a need to monitor the parameters that contribute to ambient air pollution, which means improving the quantification of fire emissions. Emission gases from forest fires consist of a large number of gases, aerosols, and particle matter. The most common are carbon dioxide (CO_2) and carbon monoxide (CO), methane (CH_4), and other volatile organic carbon compounds (VOCs) (Solene Turquety, 2013). This paper investigates the chemical composition of smoke, during the combustion of terminal branches of *Pinus sylvestris*. The paper includes the research of the chemical structure of combustion products in laboratory conditions.

Methods: Controlled combustion of *Pinus sylvestris* was performed in laboratory conditions using a mass loss calorimeter, whose environment was further adapted to sample emission concentrations. Samples were exposed to heat flux of 50 kW/m^2. Sampling was performed with a gas analyzer Gasmet DX4000, which works on the principle of FTIR technology. The gas analyzer has a library of 16 different compounds. In addition to emission concentrations, flammability parameters were also measured and analyzed.

Key results: Results show the presence of H_2O, CO_2, CO, NO, NH_3, CH_4, and C_2H_4 concentrations. Compounds with concentrations below 10 ppm were not taken into further analysis. Measured concentrations were compared with heat release rate (HRR), mass loss rate (MLR), to find the dynamics of generating the emissions concentrations.

Conclusions: During the tests, H_2O, CO_2 were released during the flaming and smoldering stage. Increase concentrations of CO, NO, NH_3, CH_4, and C_2H_4 concentrations were observed during the flaming stage. Dynamic combustion and gaseous emissions primarily depended on the chemical composition, physical structure, and moisture content of samples.

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11.12 LOCK-DOWN INFLUENCE ON AIR QUALITY IN BELGRADE DURING COVID–19 PANDEMIC

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The environmental Protection Agency of the Republic of Serbia continuously monitors and collects air quality parameters at many measuring points in the country. Those collected results indicated that the levels of air pollution recorded during the period of lockdown differed from the same period in the previous years. In this paper, we performed analysis of pollutant concentration trends in 2020 and a few previous years to determine the underlying causes of these trends.

The pollutants were measured at five stations in Belgrade: Beograd_Stari grad, Beograd_Novi Beograd, Beograd_Mostar, Beograd_Vračar, Beograd_Zeleno brdo, in 2017, 2018, 2019 and 2020, for the same period - from the beginning of March to the end of July. Measured values of pollutants were public data of the Environmental Protection Agency of Serbia. Measured values of nitrogen dioxide, sulfur dioxide and suspended particles PM10 and PM2.5 are average daily values, while for carbon monoxide and ozone, daily 8-hour maxima are shown, because no hourly data were available. Concentrations were compared and averaged only in cases where data were available for the same period over the years, i.e. comparison of 2020 with previous years.

The obtained values were compared with the annual and daily limit values (for ozone and carbon monoxide 8h maxima), and the differences in concentrations over the years were compared. The purpose of determining and presenting these values is to specifically indicate a change in air pollution during the isolation period due to the COVID-19 virus pandemic.

Analysis included data from automatic monitoring stations for main pollutants (CO, NO2, O3, PM2.5, PM10, and SO2) and meteorological parameters (t., RH, wind speed, wind direction) that are collected in agglomeration for Belgrade and the following is obtained:

1. Measuring station Beograd_Stari grad:
- 17% lower NO2 concentration compared to 2019, especially in the period of "lock down",
- reduction of PM2.5 concentration by 28% compared to 2018 and 3% compared to 2019,
- increase in PM10 concentration by 15% compared to 2018 and 18% compared to 2019.

2. Measuring station Beograd_Novi Beograd:
- eight-hour maximums of CO concentration are significantly higher by June compared to all three years,
- the average value of NO2 concentration is lower by 38% compared to 2019,
- the average value of SO2 concentration is significantly higher compared to previous years.

3. Measuring station Beograd_Mostar:
- the average NO2 value in 2020 was lower for 41% and 44% compared to 2019 and 2018 respectively,
- reduction of PM2.5 concentration by 3% compared to 2019,
- the average values of PM10 particles were lower by 61% compared to 2019 and 36% higher compared to 2018.

4. Measuring station Beograd_Vračar:
- the average value of SO2 concentration is significantly higher than in previous years; twice compared to 2018 and 46% compared to 2019.

5. Measuring station Beograd_Zeleno brdo:
- the average value of NO2 concentration was lower compared to 2017, 2018 and 2019 by 17%, 20% and 35% respectively.

Generally, for Belgrade in 2020: lower NO2 concentration at 4 stations; reduction of PM2.5 concentration at 2 stations; increase in PM10 concentration at 1 station, and also decrease at 1 station; eight-hour maximums of CO concentration higher at 1 station and SO2 concentration is higher compared to previous years (2017-2019).

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11.13 ENGAGEMENT OF PUBLIC HEALTH INSTITUTIONS IN MONITORING OF HEAVY METALS' PRESENCE IN PM10 IN THE VICINITY OF INDUSTRIALLY CONTAMINATED SITES IN SERBIA

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Background and Aims: Industrial contamination with PM_{10} emission in Republic of Serbia is generated through mining and metal-processing in Bor, Veliki Krivelj, Cerovo, Majdanpek, Sevojno; coal mining and power generation at coal-firing power plants in Obrenovac (2 power plants), Grabovac (plant ash landfill), Kolubara, Kostolac, Veliki Crljeni; cement production in Kosjerić, Popovac, Beočin. Main objectives are to focus on potential public health hazards of heavy metals at industrially contaminated sites (ICSs) in Serbia, and to point out coverage in monitoring of urban ambient air concentration of Cd, Ni, As and Pb in PM_{10} within the Network of Institutes of Public Health (IPHs) (Matić et al., 2017; Todorović et al., 2015).

Materials and methods: This is a cross-sectional study, with data from regular on-going programme activity for the MoH implemented by the National IPH in 2020. Results were obtained from City of Belgrade IPH, IPH Požarevac, Pančevo, Zrenjanin, and Institute of Mining and Metallurgy in Bor.

Results: In 2020, heavy metals (Cd, Pb, Ni, As) in PM_{10} were monitored at 32 sampling sites, of which there were 10 in urban Belgrade; 10 urban sites in other settlements, and 12 in settlements with long-lasting industrial activity (or ones close to it), such as: Bor, Krivelj, Veliki Crljeni, Lazarevac, Veliko Gradište, Vranovo, Elemir, Zrenjanin, Kolubara-B power plant, Pančevo, Ralja, and Smederevo. At no point of measurement, has Pb exceeded the given mean annual value (MAV) of 0.5 $\mu g/m^3$. MAV for Cd was beyond LV (5.0 ng/m^3) in Bor (15.5 ng/m^3), Elemir (5.25ng/m^3), Zrenjanin (5.50 ng/m^3). Arsenic (As) concentration was at its peak in Bor with a MAV of 131.50 ng/m^3, a more than 20-fold value towards an ALV of 6 ng/m^3. Higher than permitted levels of As in PM10 were also noted in Elemir (17.0 ng/m^3), Zrenjanin (15.25 ng/m^3), Krivelj (7,60 ng/m^3) (Regulation, 2010). The only two sites at which nickel ALV is beyond the given value are Zrenjanin (40.0 ng/m^3) and its neighbouring settlement Elemir (25.0 ng/m^3), both involved in petrochemical industry activities (Peltier et al., 2009).

Conclusions: Presence of As and Cd in PM_{10} close to ICSs, due to abundance of naturally occurring heavy metals and metalloids is a public health issue (Entwistle et al. 2019). Serbia lacks the legal framework for continuous institutionalized human biomonitoring of the population vulnerable to environmental exposure, although measured values indicate urgent need for such activities.

Keywords: *PM_{10}, heavy metals, monitoring, public health*

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11.14 CHARACTERISATION OF FINE PARTICULATE MATTER LEVEL, CONTENT AND SOURCES OF A KINDERGARDEN MICROENVIRONMENT IN BELGRADE CITY CENTER

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In the present work, we investigated a data set of indoor and outdoor $PM_{2.5}$ from 80 samples collected in the microenvironment of a kindergarten located in Belgrade city centre during weekdays in a period crossing over from the heating to non-heating season, from March to May 2010.

Taking into account results from European cohorts and other studies (Strak et all, 2021), WHO recently published new 24-hour AQ guidelines (AQG) levels for main pollutants including fine particulate matter. 24-hour AQG for $PM_{2.5}$ in ambient air are now lower, these are changed from 25 µg/m^3 to 15 µg/m3 (WHO, 2021). The results indicated that the outdoor and indoor $PM_{2.5}$ daily mean values were much higher than 25 µg/m3, 82.5% and 75%, respectively, and even much more when taking in account newly-established WHO AQG. The I/O ratio ranged between 0.47 and 1.88 for $PM_{2.5}$ (mean 0.91).

The most abundant detected elements were Al, Fe, Ba, Cr, Cu, Zn and Pb, and the most abundant detected macro-components were Ca, Na, NO_{3-} and SO_4^{2-}. In this study, Se was the most enriched metal (EF values > 1000), followed by Sb, Cd, As and Pb (EF values > 100). In addition, Cd and Pb, classified in Group 1A by the IARC (carcinogenic to humans), never exceeded standard annual outdoor levels of 5 ng/m3 and 0.5 µg/m^3, respectively, settled by actual EU legislation (Directive 2008/50/EC, 2008). On the other hand, As and Ni, also classified as carcinogenic to humans, exceeded standard annual outdoor levels of 6 and 20 ng/m$^{3:}$ 3 days for As and 1 day for Ni in outdoor air, out of total 40 analysed samples collected during weekdays.

Indoor/outdoor ratios of individual PAHs and ΣPAH were less than 1 which indicated that indoor PAHs originated mainly from the outdoor environment. BgP, Ind, BaP, BbF, BkF and Chy were most abundant, especially in outdoor particles.

Principal component analyses (PCA) with Varimax rotation were applied to the data sets consisting of elemental and total PAH concentrations of indoor and outdoor PM2.5 fractions. The PCA analysis suggested six potential sources of both indoor and outdoor $PM_{2.5}$ fractions. The factor profiles are very similar between indoor and outdoor datasets. PCA identified separate factors relating to pyrogenic and petrogenic sources of PAHs, traffic emission, coal combustion, building materials, industrial activities, and secondary aerosols.

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11.15 NUMERICAL SIMULATION OF GAS FLOW THROUGH PERFORATED PLATES INCLINED TO THE MAIN FLOW

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Background and Aims: The new, restrictive best available technology requirements posed by EU Decision 2017/1442 clearly define the need to take measures to improve existing flue gas treatment installations. The process of removing particulate matter from the flue gas generated in coal-fired boilers of thermal power plants, by electrostatic precipitators (ESP), or by using filter bags, is significantly affected by uniformity of flue gas flow through the dedusting zone (Bäck, 2017). In order to improve the flue gas flow distribution through the ESP, perforated plates are used to establish as uniform as possible flow over the cross-section of the wide-angle diffuser exit. A computational Fluid Dynamics (CFD) method with source terms in the momentum equation defined according to the porous medium model is widely used for numerical simulation of flow through the perforated plate. Permeability and internal resistance per unit thickness of the perforated plate, considered as homogenous porous material, are usually calculated based on results of experiments. With these parameters defined for the streamwise direction, the porous medium model is useful in cases where the incoming velocity is almost perpendicular to the perforated plate. But this model loses prediction accuracy for the velocity distribution behind the perforated plate, as well as for the pressure drop through the plate, when the direction of the incoming fluid velocity deviates from the perpendicular (Guo et al, 2013), which is always the case for the wide-angle diffuser of one ESP. The aim of the present work is to add to the existing porous medium model when used in modelling a perforated plate by introducing a new approach for determination of the momentum losses regarding both streamwise and transverse directions for wide range of yaw and pitch angles of incoming flow.

Methods: The permeabilities and loss coefficients are calculated based on the results of CFD numerical simulations for different angles of incoming flow. The numerical calculations were performed by using ANSYS CFX finite-volume-based software to resolve the RANS equation for the solution domain. The key simulation properties are defined to be parameters representing one design point. The output parameters for all design points are solved by using Design of Experiments (DOE) technique. The permeability and loss coefficient algebraic dependencies on the angle are defined and implemented in the porous medium model. The proposed procedure is applied on the case of a plate of thickness 5mm, with face porosity 0.3 formed of circular openings in quadrilateral pitch.

Key results of the study: The results obtained for several pitch and yaw angles by applying the proposed approach are compared to the results of the full-scale CFD numerical simulations as well as to the CFD simulations relying on the standard porous medium model with permeability and loss coefficient defined in the direction orthogonal to the perforated plate An acceptable correlation was obtained and directions for future work highlighted (influence of the wall and other structural elements).

Conclusions: The study shows that the proposed approach is suited to predict pressure drop and velocity distribution behind the perforated plate for a wide range of yaw and pitch angles of incoming flow. More reliable prediction of the flow distribution in the exit of the wide-angle diffuser allows optimization of the flow through the ESP, and therefore a decrease in particulate matter emission.

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Keywords: perforated plate, porous medium model, CFD, DOE.

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11.16 PM LOW-COST SENSORS IN-FIELD CALIBRATION: THE INFLUENCE OF SAMPLING COVERAGE AND INTERVALS

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Background and Aims: In recent years, low-cost multi-sensor devices have proven to be an effective way of supplementing existing air pollution data. While their accuracy, and means of improving it, are still a matter of intensive research efforts they can be effectively used for a wide variety of different purposes such as: teaching the young population in schools, raising awareness of air pollution, identifying and characterizing hotspots, complementing monitoring networks at the state and municipal levels, and assisting with personal exposure monitoring as well as regulatory monitoring. However, effective methods for calibrating low-cost sensors that take into account specific device implementation details such as sampling coverage and sampling intervals are clearly needed, in order to increase our ability to form evidence based optimal device implementation.

Methods: Two types of commercially available devices for air pollution monitoring equipped with several low-cost sensors were used in this research: the AQMESH v. 3.5 units and DunavNET devices. Both are modular devices which can be applied for measurements of the concentration of air pollutants as well as meteorological parameters and they were employed within the CITI-SENSE project 2012–2016 (2017). Both types of devices that were used in this study are equipped with sensors for NO2, NO, CO, O3, PM2.5, PM10, pressure, temperature and relative humidity. However specific implementation details were different, here we focus on PM sensors. DunavNET devices used Dylos monitors while not known type of PM sensor was embedded in AQMESH. The sampling coverage was also different, as AQMESH devices' PM sensors and internal pumps were idle the majority of the time, measuring continuously for a minute every 15 minutes, whereas DunavNET devices had finer temporal resolution, measuring continuously and outputting approximately one sample every minute. Data for the study was obtained via collocation campaign, in which devices were located within 50m of the sampling inlet of the automatic monitoring station. The first campaign was performed entirely during summer, from 26/07/2015 to 27/08/2015 (denoted as SG1). The second one was conducted in late summer and early autumn, in the period from 30/08/2015 to 01/10/2015 (denoted as SG2).

Key results of the study: In this paper we have compared the performance of the simple linear calibration models, when they operate on differently sampled data, originating from two different low-cost multi-sensor devices. While more complex calibration models, such as artificial neural networks based on machine learning, can also improve the accuracy, in this work we focus on univariate linear calibration model. However, error analysis was done in a way that is well-established in machine learning practice, by having a dedicated part of the data for the test(error) analysis that is never used for training. Linear calibration model has a single input and a single output, in our case input is PM low-cost sensor reading, and target is reference PM measurement.

Conclusions: AQMESH platforms which sample PM measurements every 15 minutes, had slightly lower accuracy, using simple linear regression, compared to DunavNET devices which measure every minute. Approximately, first one third of the measurement samples was used to train the model, and the remaining samples for test.

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11.17 PRELIMINARY RESULTS FROM PM MOBILE MONITORING PILOT CAMPAIGN IN BOKA KOTORSKA BAY: PM LEVELS AND OBSERVED MODES IN ONSHORE AND OFFSHORE AREA

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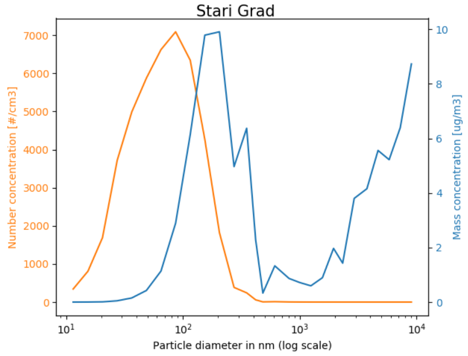
Background and Aims: In the last decade s, the touristic income in Montenegro was largely focused on the cruising and nautical tourism sectors. This led to rapid modernization and development of the Boka Kotorska Bay, and its ports, notably Port of Kotor, protected by the UNESCO as natural and cultural heritage- However, increase in activities is also coupled with increase in environmental burdens, since cruises activities in urban coastal areas generate large amounts of pollution of different categories, including air pollutants, both in gas and particulate phase. Such activities can significantly contribute the amount of total suspended particles in ambient air, sometimes up to the 15%. Elevated levels of air pollution can influence human health and wellbeing, degrade ecosystem, damage natural and cultural heritage. Thus, characterizing air pollution in coastal urban areas is a paramount first step in mitigating its detrimental influence.

Methods: Measurement instrumentation setup included the following: PM concentrations for diameter of particles going from 10 nm to 420 nm in 13 size channels were detected using TSI NanoScan SMPS Model 3910; PM concentrations for diameter of particles going from 0.3 µm to 10 µm in 16 channels were recorded using TSI Optical particle sizer 3330; all measurements were georeferenced. The measurement campaign consisted of two parts realized in the summer (high) season. The onshore part was conducted using a vehicle, which covered coastal area of Boka Kotorska Bay, and offshore part of measurements was conducted using a small boat in the vicinity of berthing area in the Port of Kotor.

Key results of the study: Short preliminary mobile monitoring campaign enabled insights into levels and size distribution of particulate matters in the ambient air of the Boka Kotorska Bay and Port of Kotor. In addition to identifying local hotspots, this type of analysis provided additional insights into dominant modes (in terms of both number and mass concentration). Figure below shows examples of emission profiles recorded during the vehicle campaign (Fig. 1a), and small boat campaign (Fig. 1b). More specifically, figure represents peaks in number concentration in previously mentioned campaigns.



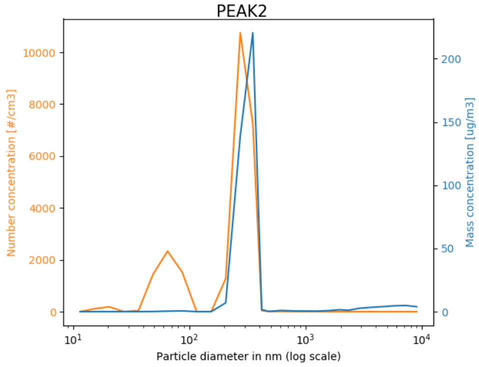


Figure 1. Examples of emission profiles for PM number concentration peaks a) recorded in vehicle campaign b) recorded in small boat campaign

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