PARTICULATE MATTER
Research and Management in Serbia

by

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Clean air is a basic requirement for human health and well-being. According to [1], air pollution is the largest environmental health risk in Europe, with PM being responsible for majority of the adverse effects. The most commonly used metrics for PM is mass for different PM sizes by aerodynamic diameter: inhalable PM includes PM_{10} for particles equal or smaller than 10 μm, $PM_{2.5}$ for those equal or smaller than 2.5 μm, and ultrafine particles for those smaller than 100 nm. The smaller the particles are, the deeper they penetrate deep into the lungs and even enter the cardiovascular system, increasing the risks to human health [2]. New ways of characterizing PM, and new understanding of mechanisms of adverse health effects, are emerging.

PM have both natural and anthropogenic origin and are emitted directly as well as formed in the atmosphere. Energy production is the largest source of anthropogenic PM in Europe, closely followed by transport [1]. Thus, implementation of measures to improve energy efficiency of residential and public heating, production and consumption in the industrial sector, and technological measures in the transport sector are closely connected with improvements of outdoor and indoor air quality.

Research and management issues of PM cover wide area of topics relevant to scientific community, for policy makers across policy and economic sectors, and to citizens. In order to identify specific knowledge opportunities, needs and gaps for Western Balkan region, the WeBIOPATR conference platform was created in collaboration between Vinča Institute (Serbia) and NILU (Norway), with support of funding from Norway and Serbia. The International Workshop and Conference, Particulate Matter: Research and Management – WeBIOPATR is a biennial event held in Serbia since 2007. By WeBIOPATR, we aim to link the research communities with relevance to PM with the practitioners of air quality management on all administrative levels, to facilitate professional dialogue and uptake of newest research into practice. The workshops usually draw an audience of about 70 and attract media attention

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in Serbia. The events enjoy support of the responsible authorities: Ministry of Education, Science and Technological Development, Ministry of Health, Ministry of Environment, and the Serbian Environmental Protection Agency whose sponsorship is indispensable and gratefully acknowledged. We enjoy also support of international bodies such as the World Health Organization (WHO).

The WeBIOPATR2021, the 8th conference, was held at the Vinca Institute of Nuclear Sciences, Serbia, November 29-December 1, 2021, as a hybrid event. It has been an activity of the VIDIS project - *Virtual centre for distributed atmospheric sensing technologies for reduction of pollution pressures*, https://vidis-project.org/, co-funded by the EC H2020 Framework Programme for Research and Innovation, area *Spreading excellence and widening participation*, ID 952433. VIDIS (2020-2024) is coordinated by Vinca Institute of Nuclear Sciences. Book of Abstracts from WeBIOPATR2021 is available at https://www.vin.bg.ac.rs/webiopatr/#Publications. Thermal Science publishes now 13 full papers related to VIDIS and WeBIOPATR2021. The following are the highlights.

Information on AQ and related hazards, including PM, is seldom perceived as personally relevant. By using affordable personal monitors or by establishing a dense network of monitoring units, in which low-cost sensors (LCS) for various air pollutants, including PM fractions (LCS-PM) are embedded, AQ monitoring can be made personally relevant, but many challenges yet must be addressed. Five papers are related to *Calibration and implementation of Low-cost PM sensors*.

Stojanović *et al* [3] evaluated low-processing data enrichment and calibration of AQ MESH $PM_{2.5}$ low-cost sensors co-located with a SEPA reference station. They show convincing results achieved by combination of data enrichment with multi-linear or a random forest-based regression calibration. Dmitrašinović *et al* [4] carried out a campaign with reference and LCS sensors in the city of Novi Sad under COVID-19 lockdown measures. Fine and coarse PM concentrations increased during the COVID-19 week likely due to increased local heating during a low temperature spell, even if total traffic decreased by 31% on working days and 42% on weekends due to lockdown measures on traffic regime and intensity. Šunjević *et al* [5] used a low-cost device OPC-N2 for PM detection. Combined with modelling, they confirmed that construction sites may be significant PM_{10} and $PM_{2.5}$ pollution sources. Božilov *et al* [6] presented the level of agreement of the PM readings from selected low-cost Klimerko devices to the PM readings of the reference equivalent PM monitors from the National Air Quality Monitoring Network of the Republic of Serbia in the cities of Bor and Belgrade. After application of correction factor to PM_{10} and $PM_{2.5}$ readings of Klimerko device, equipped with PM7003 sensor, accuracy, root mean square error and precision were significantly improved. The paper of Tasić *et al* [7] describes the basic components and characteristics of a portable air quality monitor PAQMAN 2020 based on NOVA SDS 011 PM LCS. The lowest values of R^2 between the PM sensor and reference instruments were obtained outdoors while the highest values were obtained in indoor air with R^2 values higher than 0.93 (30% < RH < 70%). High relative humidity (RH) values (over 70%) negatively affected the PM monitor's response, especially in the case of PM_{10} concentrations (high overestimation). Tests of sensors for temperature, RH, and atmospheric pressure in laboratory indicates a very good agreement between the LCS and laboratory instruments. After applying a correction factor to the PM results, PAQMAN 2020 satisfies data quality objectives for indicative ambient air quality assessment regarding the uncertainties for PM measurements as specified by the Ambient Air Quality Directive 2008/50/EC.

Papers related to Aerosol characterization are submitted by Karadeniz *et al* [8] and Živković *et al* [9]. Karadeniz *et al* [8] present analyses of content of metals in fine PM samples collected in a one-year campaign during 2011 and 2012 in Bolu Abant İzzet Baysal University Campus (BAIBU), Turkiye. The Al, Ca, Na, Fe, K, and Mg were the elements with largest concentrations. The concentrations of elements in the summer seasons were higher than in the winter season except for As and Bi. The main contributors to the concentrations were sea salt, coal combustion, wood and coal combustion, soil, and industrial activities (iron-steelworks). Higher contributions of the coal combustion were observed in winter. Long-range transport is an important pollutant source in the sampling area for the investigated elements. Živković *et al* [9] present levels of polycyclic aromatic hydrocarbons (PAH), metals and ions of indoor and outdoor $PM_{2.5}$ from 80 samples collected in the microenvironment of a kindergarten located in Belgrade city. The sampling campaign covered end of a heating and beginning of a non-heating season. Daily concentrations of $PM_{2.5}$ were much higher than WHO guidance daily values. Similar sources contribute to both the indoor and the outdoor environment.

Papers regarding the Health and Exposure topics were prepared by Ćujić *et al* [10] and Ćirović *et al*. [11]. Ćujić *et al* [10] applied WHO-developed AirQ$^+$ modeling software, for health impact assessment for Belgrade urban area. The spatial distribution of concentrations was mapped using geostatistical interpolation, revealing hotspots within the city centre and industrial area of the Belgrade urban area. The input data were open data from 13 automatic stations in a two-months period of June and July 2021. The AirQ$^+$ is based on the attributable proportion defined as the section of the health effect related to exposure to air pollution in an at-risk population. The estimated attributable proportion was 19.4% for stroke, 27.2% for IHD, 15.3% for COPD and 9.0% for LC. The estimated number of attributable cases per 100000 population of Belgrade urban area during non-heating season, at risk due to $PM_{2.5}$ air pollution, for stroke, IHD, COPD, and LC, was 28, 34, 15, and 8, respectively. Ćirović *et al* [11] evaluate the impact on air quality of two heating boilers at the Valjevo city (Serbia) heating plant. The AERMOD air dispersion model was used to estimate the dispersion of various pollutants, where air emissions of two heating boilers in the facility were measured using standard reference methodology and used as input data for air quality modelling, combined with topographical and meteorological data. A receptor grid for exposure assessment was defined for a 10 km radius around the heating plant The health risk from the fuel oil boiler was shown to be significantly higher than that caused by the natural gas-fuelled boiler.

Stevanović *et al* [12] is an overview paper related to source apportionment (SA) of oxidative potential. This paper provides an insight into health-relevant characterization of PM that was previously not available and can be the first step in holistic understanding of PM toxicity. Measuring oxidative potential of PM and its relation with specific sources can provide important insights. Further methods development, detailed analyses, and a well-designed and uniform strategy of sampling, measurement, and application of a certain SA technique, could significantly increase the understanding PM toxicity.

Four papers were related to *Monitoring and modelling*, indoors and outdoors. The Radović *et al* [13] study determined that average indoor PM levels in the laboratory were higher than outdoors. A strong correlation was found between PM_{10} and $PM_{2.5}$ levels inside the laboratory and in the outdoor air. Also, a very strong correlation was found between the levels of Pb, Ni, As, and Cd determined in PM_{10} and $PM_{2.5}$ samples inside the laboratory and in the outdoor air. This indicates that these elements originate from the same sources, likely located in the copper smelter complex. The subject of study of Marković *et al.* [14] relates to

emission control of PM, and is a numerical investigation of flow through the rectangular channel with a perforated plate in various positions in the cross-section of the channel. The perforated plates, commonly used for gas flow control in the wide-angle diffusers of electrostatic precipitators of large power plants, were modelled as thin, porous media of finite thickness by using the directional loss model. Numerical experiments are carried out by using CFD software Ansys CFX. Results of pressure drop and velocity distribution behind the plate are compared to the results of CFD simulation of the full 3-D plate model. Some oily wastes, such as waste from olive oil production, might be used for production of second-generation biodiesel. Marstijepovic *et al.* [15] investigate the effect of biodiesel on the characteristics of gaseous pollutant emissions of NO_x and CO from slow-speed two-stroke marine Diesel engines that do not have any after-treatment devices or engine control technology installed to reduce gaseous pollutant emissions. According to the findings, there are tendencies of reduced gaseous emissions when utilizing blended fuel with olive oil waste product.

Kalva [16] in his study that belong to topic related to *Ventilation of indoor environment* proved that measuring indoor and outdoor microenvironment of gas stations is big challenge for several reasons: gas station areas are potentially hazardous with a high environmental risk and explosion hazard. Higher aerosol pollution was observed when the fast-food preparation equipment was operated indoors, as the ventilation systems are not able to remove solid particles from the room immediately. Infiltration from the outdoor environment through the station door is a significant source of PM_{10} pollution. Assessing the effect of the microclimate on particulate matter, it is visible that $PM_{2.5}$ values are more uniform and their concentration in the room is less dependent on the effects of the influence of outdoor environment. At the other side active flow of people has a significant effect on PM_{10} values and their concentration in the air can increase by 50% due to the flow of people.

We look forward to the continued growth of research contributing to knowledge on particulate matter and other air pollutant emissions, distribution, and impacts, enabled also by publishing in journal *Thermal Science*. As the integrated study of air quality connects not only to energy but also to economics, agriculture, meteorology, climate change, and public health, among other subjects, the advancement is well-suited to an interdisciplinary, open-access journal like *Thermal Science*. Thanks to our authors for contributing to journal *Thermal Science* in PM and even air pollution research with such excellent work.

References

[1] ***, EEA, Air quality in Europe - 2019 report. Copenhagen, EEA Report No 10/2019
[2] ***, World Health Organization, 2016. WHO releases country estimates on air pollution exposure and health impact, News release, https://www.who.int/news-room/detail/27-09-2016-who-releases-country-estimates-on-air-pollution-exposure-and-health-impact
[3] Stojanović, B. D. *et al*., Low-Processing Data Enrichment and Calibration for $PM_{2.5}$ Low-Cost Sensors. *Thermal Science*, *27* (2023), 3B, pp. 2229-2240
[4] Dmitrašinović, S., *et al*., Traffic Intensity and Air Pollution Before and During Lockdown in Novi Sad, Serbia, *Thermal Science*, *27* (2023), 3B, pp. 2333-2345
[5] Šunjević, M. *et al*.,, Assessment of Detected in Situ and Modeled $PM_{10/2.5}$ Concentration Levels During the Urban Transformation Process in Novi Sad, Serbia, *Thermal Science*, *27* (2023), 3B, pp. 2275-2286
[6] Božilov, A., *et al*., Civil Air Quality Monitoring as an Alternative and Supplement to the National Air Quality Monitoring Network, *Thermal Science*, *27* (2023), 3B, pp. 2255-2263
[7] Tasić, V., *et al*., A Portable Air Quality Monitor Based on Low-Cost Sensors, *Thermal Science*, *27* (2023), 3B, pp. 2309-2319
[8] Karadeniz, H., *et al*., Chemical Composition and Source Apportionment of $PM_{2.5}$ at a Suburban Site in the Northwestern Part of Turkey, *Thermal Science*, *27* (2023), 3B, pp. 2205-2214

[9] Živković, M., *et al*., Characterisation of Fine Particulate Matter Level, Content and Sources of a Kindergarten Microenvironment in Belgrade City Center, *Thermal Science*, *27* (2023), 3B, pp. 2215-2228
[10] Ćujić, M., *et al*., Assessment of the Burden of Disease Due to $PM_{2.5}$ Air Pollution for the Belgrade District, *Thermal Science*, *27* (2023), 3B, pp. 2265-2273
[11] Ćirović, Ž, *et al*., Aermod Air Dispersion Modeling and Health Risks of Gas and Oil Fueled Heating Plant Emissions, *Thermal Science*, *27* (2023), 3B, pp. 2321-2331
[12] Stevanović, S., *et al*., Source Apportionment of Oxidative Potential – What We Know So Far, *Thermal Science*, *27* (2023), 3B, pp. 2347-2357
[13] Radović, B., *et al*., Chemical Composition, Levels, and I/O Ratios of PM_{10} and $PM_{2.5}$ in the Laboratory Near the Copper Smelter in Bor, Serbia, *Thermal Science*, *27* (2023), 3B, pp. 2287-2295
[14] Marković, Z., *et al*., Numerical Simulation of the Gas Flow Through the Rectangular Channel with Perforated Plate, *Thermal Science*, *27* (2023), 3B, pp. 2241-2253
[15] Marstijepovic, N., *et al*., Application of Biodiesel Derived from Olive Oil Production Wastes at Marine Diesel Engine and Evaluation of Gaseous Emission Trends, *Thermal Science*, *27* (2023), 3B, pp. 2195-2203
[16] Kalva, O., The Role of Microclimate in the Formation of Indoor Air Pollution, *Thermal Science*, *27* (2023), 3B, pp. 2297-2307

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