

MILENA
JOVAŠEVIĆ-STOJANOVIĆ¹
ALENA BARTONOVA²

¹University of Belgrade, Institute
Vinča, P.O. Box 522, 11001
Belgrade, Serbia

²NILU Norwegian Institute for Air
Research, P.O. Box 100, 2027
Kjeller, Norway

INTRODUCTORY PAPER

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CURRENT STATE OF PARTICULATE MATTER RESEARCH AND MANAGEMENT IN SERBIA

Particulate matter is the air pollutant that currently receives most attention from the atmospheric research community, the legislative authorities and the general public. Limiting particulate matter in the atmosphere which will result in significant benefits for human health, with associated positive economic consequences. Successful management of particulate matter requires scientific knowledge about particulate matter “from cradle to grave”, covering sources of particles, processes that govern their formation, composition, dispersion and fate in the atmosphere, as well as knowledge about human exposure and associated health and well being. Such knowledge allows to design and perform effective and efficient abatement measures and monitoring. This paper provides an introduction to the research and monitoring regarding particulate matter in Serbia. The contributions were first partly presented at the 2nd international workshop of the WeBIOPATR “Outdoor concentration, size distribution and composition of respirable particles in WB urban area” project in September 2009. This information provides context to the contributions in this number, and was part of the rationale of the project WeBIOPATR.

Key words: air pollution; particulate matter less than 10 μm (PM_{10}); particulate matter less than 2.5 μm ($\text{PM}_{2.5}$); monitoring; research; Serbia.

INTRODUCTION Particulate matter (PM) is the air pollutant that currently receives most attention from the atmospheric research community, the legislative authorities and the general public. European and Serbian legislation [1-3] regulates particulate matter in two size fractions - less than 10 μm aerodynamic diameter (PM_{10}) and aerodynamic diameter less than 2.5 μm ($\text{PM}_{2.5}$). The legislation is based on human health evaluations [4,5]. PM_{10} and smaller particles can be inhaled by humans, and have been shown to have important health effects. More harmful are likely to be fractions with smaller aerodynamic diameters, $\text{PM}_{2.5}$, and less than 0.1 μm , $\text{PM}_{0.1}$, the so-called fine and ultrafine particles. A recent study conducted in three European countries [6] estimated that in the population of 75 million living in Austria, Switzerland and Germany, some 40,000 deaths per year can be attributed to particular matter pollution. Half of all of this mortality can be attributed to traffic, which equals the number of people killed in road accidents per year in the European Union. An assessment done in

relation to the European legislation [7] has estimated that in the EU-25 countries, 3.6 million life-years were lost in 2000 due to particulate pollution. This indicates that limiting particulate matter in the atmosphere will result in significant benefits for human health, with associated positive economic consequences.

Successful management of particulate matter requires knowledge about particulate matter “from cradle to grave”, covering sources of particles, processes that govern their formation, composition, dispersion and fate in the atmosphere, as well as knowledge about human exposure and associated health and well being. National studies are a necessary source of such knowledge, and information.

The main sources of particles are well known. In addition to significant natural sources, the most important man made sources are the industry including thermal power plants, space heating and vehicular traffic. The fine fraction of particulate matter and its precursor gases originate typically from combustion processes - motor vehicles, industrial processes and biomass burning. Source contributions to primary PM emissions and precursor gases vary by area and by region. Industrial processes provide a major contribution in most areas, followed by non-industrial fuel combustion (*e.g.*, residential and local domestic heat-

Corresponding author: M. Jovašević-Stojanović, University of Belgrade, Institute Vinča, P.O. Box 522, 11001 Belgrade, Serbia.
E-mail: mjovst@vinca.rs
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ing) and the transportation sector. In urban environments, road traffic is noted to be one of the major sources of particulate air pollution. Long-range transport from neighboring regions and other countries also significantly influence the levels of particulate matter.

Particles in the atmosphere are not chemically or physically homogeneous entities. Of importance are their amounts, physical properties and chemical composition. To determine the origin of particles, information is needed, *e.g.*, about elemental carbon and organic carbon compounds, oxides of silicon, aluminum and iron, trace metals, sulphates, nitrates and ammonia and the amount of toxicants, *e.g.*, lead (originating from leaded gasoline that still is in use in Serbia) or other carcinogenic substances.

The need for a modern updated air quality monitoring programme stems both from the advances of scientific knowledge, and from requirements of the air pollution related legislation. As the observed levels often exceed the regulatory values, there is urgent need for better planning processes leading to improvement of local air quality. Air quality monitoring data, eventually linked to statistical and numerical models, will enable the authorities to identify management needs and monitor the improvement of air quality. Most importantly, the authorities have to ensure professional implementation and running of the systems and adherence to stringent quality assurance and control protocols. For such program to exist in a country, it needs to be underpinned by research activities to ensure up-to-date quality.

This paper provides an introduction to the research and monitoring regarding particulate matter in Serbia. This information provides context to the contributions in this number, and is part of the rationale of the project WeBIOPATR, "Outdoor concentration, size distribution and composition of respirable particles in WB urban area". The contributions were first partly presented at the 2nd international workshop of the project in September 2009.

PM MONITORING ACTIVITIES IN SERBIA

The recently adopted Law of Air Protection [2] and the Regulation for condition for monitoring and requirement for air quality [3] enable harmonization with EU legislation in air pollution monitoring and management. Instead of collecting total suspended particulate matter, the historically monitored air pollutant, the new Law and Regulation introduce mandatory monitoring of PM₁₀ and PM_{2.5}, and require determination of heavy metals and benzo-*a*-pyrene BaP.

Data about air pollution in Serbia have been reported into the European Environment Agency operated AirBASE [8] since 2003, but data about particulate matter fractions are still scarce. Monitoring of PM₁₀ began in Belgrade city in 2003. In other towns, particulate matter monitoring has been established during the last few years. In addition to urban areas, particulate matter needs to be monitored also at background sites; this is not yet fully developed.

In Belgrade, at first, PM₁₀ was measured at one urban-traffic site. In 2007, the Public Health Institute of Belgrade started to measure PM₁₀ at 3 stations. Today there are 6 automatic stations that belong to the local monitoring network of Belgrade Metropolitan, 4 of them in the city and 2 in the vicinity of thermal power plants Obrenovac and Kolubara. Monitoring data are presented at <http://www.beoeko.com> with 1 and 24 h average of PM₁₀ registered at all sites of the local monitoring network in Belgrade.

Pančevo town, well known as a highly polluted area due to the presence of the petrochemical complex, is located 13 km NE from city center of Belgrade. Municipality of Pančevo conducts monitoring of air pollution with automatic monitoring at three sites, including one site for PM₁₀. Data are presented at <http://ekologija.pancevo.rs/ekografatest/EkoGrafDisplay.aspx>. An additional automatic monitoring station in Pančevo area has been donated by the Municipality of Ravenna and Venice, Italy. Monitoring results for this site are available only as monthly average values (http://www.pancevo.rs/Mesečni_izvestaj_monitoring_sistema_imisije-171-1).

The Serbian Environmental Agency (SEPA) has started measuring air pollution including PM₁₀ with automatic monitors in 2006. In all, SEPA operates air pollution monitoring at 37 automatic monitoring stations. 28 stations have been equipped in the framework of EuropeAid/124394/D/SUP/YU "Supply of Equipment for Air Monitoring" project, and started operating in 2009 and 2010. The other nine stations were established before 2009. Of these stations, SEPA monitors particulate matter (PM₁₀, PM_{2.5} and PM₁) at 13 automatic monitoring stations which are located in Belgrade (5) and in towns of Smederevo (3), Bor (2), Niš (1), Novi Sad (1) and Beočin (1). Data about air pollution monitoring are presented at <http://www.sepa.gov.rs>.

Further monitoring is done under the auspices of Province of Vojvodina Secretary of Environmental Protection. Six automatic stations, including 4 sampling sites in towns in Vojvodina (Zrenjanin, Subotica, Sombor, Kikinda) are monitoring PM₁₀. Data

for 2008 and 2009 are available at <http://www.eko.vojvodina.gov.rs>.

In summary, there are currently running 25 automatic stations that perform monitoring of PM₁₀ and/or its smaller fractions. Spatial coverage of Serbia by PM₁₀ monitors is uneven as more than 60% of PM₁₀ monitors are concentrated in Belgrade Metropolitan and towns in its surrounding (Smedervo and Pančevo). In the eastern part of Serbia, monitoring is done at Bor and Niš. Representativeness of PM₁₀ monitoring in southern and western part of the Republic of Serbia needs to be improved, as there are only about 12% of stations that collected PM₁₀ located in areas south from the Belgrade region.

PM RESEARCH IN SERBIA

Several research projects (current and past) were dealing with particulate matter. The research activities are spread over several institutions, with no national coordination of the efforts.

Since 2002, Institute of Physics, Belgrade, Serbia, has led a "Fundamental Project" funded by the Ministry of Science, with particulate matter mass, chemical composition and sources as one of the main topics: "Air Quality Studies in Urban Areas: Heavy Metals, Radionuclides and Their Interaction in the Atmosphere" (2002-2005) was followed by an ongoing project "Emission and transmission of pollutants in an urban area" (2006-2010). The results of the two projects are more than 40 papers published as one book chapter [9], papers in peer-review journals [10-16] and a number of presentations at international and national conferences. PM₁₀ and PM_{2.5} data collected in the framework of these projects are collected at sampling sites in Belgrade city center, and mass of particulate matter and trace metals are determined using several analytical techniques.

An ongoing national research project of "Technological Development", titled "Development of pilot system for the automatic prevention of ash lifting from ash depots" (2008-2010), is led also by the Institute of Physics. The topics include transportation of dust and ash by wind from depots of thermal power plants near Belgrade. Ash depots are usually sprinkled by water, through processes of moisturizing and forming a „water mirror“, in order to minimize and/or disable ash release, as described by Gršić *et al.* [17] in the current issue.

Another ongoing project of "Technological Development", led by Institute Vinča, is titled "Characterization of respirable particulate in outdoor and indoor environment in Serbia" (2008-2010). The project is a collaboration between Vinča, the Institute of Mining

and Metallurgy at Bor and the Faculty for Occupational Safety at the University of Niš. In the framework of this project seasonal sampling campaigns are performed with simultaneous collection of PM₁₀ and PM_{2.5} in outdoor and indoor environment. In Serbia this is the first investigation of relationship between the ratio of PM₁₀ to PM_{2.5} in an area where the primary air pollution source is a copper smelting process, town of Bor, and in an area where the main air pollution sources are vehicular traffic and local heating, town of Niš. Results of this ongoing project have been presented in international and national journals and conferences as well as in the current issue [18-20].

Institute of Chemistry, Technology and Metallurgy - ICTM (Belgrade, Serbia), Scienze Ambientali Università Ca' Foscari (Venice, Italy), Istituto di Scienze dell' Atmosfere e dell Clima (Lecce, Italy) and Chemical Faculty from Sarajevo (Bosnia and Hercegovina) collaborated in a project „Scientific cooperation between research institutions for the study of airborne fine particles in Important Cities of the Adriatic area" - SICMA, funded through the Adriatic New Neighborhood Programme INTERREG/CARDS-PHARE (INTERREG IIIA), (2006-2008), <http://www.ihtm.bg.ac.rs/sicma/>, They planned to collect particulate fraction less than 20 µm and to analyze it for a number of organic and inorganic compounds. The results of this project are expected in the upcoming period.

Institute of Occupational and Radiological Health "Dr. Dragomir Karajović", Ministry of Science and Technological Development of the Republic of Serbia and Vinča Institute of Nuclear Sciences, Belgrade, Serbia, collaborate with partners from 20 countries (mainly nuclear regulatory bodies and nuclear research institutions) in an ongoing IAEA Technical cooperation project "Characterizing Seasonal Variations in Elemental Particulate Matter Concentrations in European Urban and Rural Areas under Different Climatic Conditions" (2009-2011), http://www.tc.iaea.org/tcweb/projectinfo/projectinfo_body.asp,

The objective of this project is to characterize atmospheric particulate matter pollution using nuclear and related analytical techniques in order to identify pollution sources, and to prepare guidelines/recommendations to reduce PM levels; and to assess the impact of PM on human health and the environment.

THE WEBIOPATR PROJECT

In order to take stock of current research and management of particulate matter in Serbia, and to contribute to knowledge and monitoring skills, the

WeBIOPATR project "Outdoor concentration, size distribution and composition of respirable particles in WB urban area" was funded by the Research Council of Norway. It was performed in collaboration between the Vinča Institute of Nuclear Sciences, the Public Health Institute Belgrade (PHI), and NILU - Norwegian Institute for Air Research. A monitoring site was established and equipped with European standard monitoring for particulate matter, and a meteorological tower. It was co-located with an existing monitoring facility of the PHI. Standard operating procedures were elaborated covering the chain from sample collection and monitoring to providing results of gravimetric and chemical analyses. A clean weighing room was established at the PHI. PM sampling in three fractions followed by chemical analyses was done in two preliminary one week campaigns [21] and eight 20-30 day campaigns, in all seasons in selected periods of 2008 and 2009. For sampling PM, it was chosen one of sampling sites that belong to municipal network of Belgrade, in New Belgrade, but located at roof instead at street level. PM₁₀, PM_{2.5} and PM₁ mass concentration was determined. Chemical analyses included cations, anions, polyaromatic hydrocarbons (PAH) including benzo-*a*-pyrene (BaP), elements, organic (OC) and elemental (EC) carbon and wood burning tracers (levoglucosan, mannosan and galactosan). So far, the results were presented at WeBIOPATR Workshops [22-23], in two PhD theses [24-25] and partly reported in this issue [20,26]. Results show significant seasonal variation of PM fraction concentration between heating and non-heating period. Mass concentrations of PM₁₀ do not differ from previously obtained results on the air quality in Belgrade, or from mass concentration in regions with significant exceedances of 24 h-limit value. Results also show that the measured PM₁₀ levels are systematically higher at rooftop than levels reported by the PHI monitoring collected at same site at street level [26].

Depending on season, total carbon content is 25-40 %, ions, 20-35 %, elements, about 5-10 %, and content of 30-40 % of PM₁₀ mass is chemically unidentified. Preliminary analyses suggest differences in source contribution during winter and summer seasons. Contribution of particulate matter from traffic is higher in winter than in summer. Biomass burning including domestic heating was identified as the most dominant man-made source in winter. Other significant sources include soil erosion and secondary aerosol formation that are dominant in summer. The total mass of 16 measured PAHs in PM₁₀ is much higher in winter (29 ng/m³) than in summer (2.4 ng/m³); ratio of PAH in PM₁ to PM₁₀ is about 0.5 for both

seasons. Average values of BaP are higher than 1 ng/m³ in winter and less than 0.1 ng/m³ in summer period in both particulate fractions (PM₁₀ and PM₁). The observed levels of BaP were comparable with levels reported for sampling sites of the local monitoring network in Belgrade, that provides BaP levels in PM₁₀ since May 2008 [20].

FINAL REMARKS

The WeBIOPATR project had as one of its aims to promote networking of the Serbian and Balkan professional PM community. The first workshop "Particulate matter - Research and Management" was held in 2007 in Belgrade [22], and partly reported in this Journal [27-29]. The 2nd WeBIOPATR Workshop with the same title was held at Mečavnik, Serbia, 28th August- 1st September, <http://www.vinca.rs/webiopatr/index.php> [23]. In both workshops, the participants presented research results and discussed air quality issues, research needs and management tools and strategies. Workshop topics included Sources identification and source apportionment, Pollution trends and levels, Air quality management issues and Exposure and Health. As this journal number testifies, it is promising that besides the WeBIOPATR Project there is a number of recently finished and ongoing national projects as well as project with international participation. These projects will provide important contributions to knowledge regarding particulate matters in Serbia, and thus a good starting point to being able to successfully manage this important and pressing problem that has implications in several policy areas - most notably, urban air quality and climate change mitigation.

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MILENA
JOVAŠEVIĆ-STOJANOVIĆ¹
ALENA BARTONOVA²

¹Univerzitet u Beogradu, Institut
Vinča, p. pr. 522, 11001
Beograd, Srbija

²NILU Norwegian Institute for Air
Research, P.O. Box 100, 2027
Kjeller, Norway

UVODNI RAD

TREKUTNO STANJE ISTRAŽIVANJA I UPRAVLJANJA RESPIRABILNIM ČESTICAMA U SRBIJI

Od zagađivača prisutnih u ambijentnom vazduhu, naučna zajednica, regulatorna tela i najšira javnost najviše pažnje danas poklanjaju respirabilnim česticama. Granične vrednosti za PM_{10} i $PM_{2.5}$ (čestice manje od 10 i 2.5 μm) će doprineti da se smanje koncentracije respirabilnih čestica u vazduhu spoljašnje sredine, što će rezultovati značajnijim poboljšanjima zdravlja ljudi, a takođe doprineti pozitivnijim ekonomskim pokazateljima. Za uspešno upravljanje respirabilnim česticama potrebna su naučna znanja o respirabilnim česticama "od koleveke do groba", uključujući izvore čestica, procese koji dovode do njihovog formiranja, hemijski sastav, rasprostiranje i sudbinu čestica u atmosferi, kao i znanja o izloženosti i zdravstvenim efektima. Rezultati naučnih projekata omogućavaju da se projektuje i sprovodi monitoring i uspostave efektivne i efikasne mere za sprečavanje aerzagadenja. Ovaj rad predstavlja uvod u sadašnje stanje u oblasti istraživanja i monitoringa respirabilnih čestica u Srbiji, a u tom kontekstu i uvod specijalnog broja ovog časopisa. Objavljeni rezultati su prvo delom prezentirani na 2. međunarodnoj radionici WeBIOPATR „Spoljašnja koncentracija, raspodela veličina i sastav respirabilnih čestica u urbanim oblastima Zapadnog Balkana” projekta u septembru 2009. koja je bila deo je realizacije WeBIOPATR projekta.

Ključne reči: aerzagadenje; PM_{10} (čestice manje od 10 μm); $PM_{2.5}$ (čestice manje od 2.5 μm); monitoring; istraživanje; Srbija.