DOI: 10.2507/35th.daaam.proceedings.013

NEW INSIGHT INTO BLACK CARBON ANALYSIS OF STRONG AIR POLLUTION EPISODES

Adnan Masic, Emina Dzaferovic-Masic, Mirnes Durakovic & Halim Prcanovic

This Publication has to be referred as: Masic, A[dnan]; Dzaferovic-Masic, E[mina]; Durakovic, M[irnes] & Prcanovic, H[alim] (2024). New Insight into Black Carbon Analysis of Strong Air Pollution Episodes, Proceedings of the 35th DAAAM International Symposium, pp.0096-0101, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-44-0, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/35th.daaam.proceedings.013

Abstract

Continuous measurement and analysis of black carbon concentrations in ambient air during a two-year period in Sarajevo and Zenica valleys was performed. The central apparatus for this analysis consists of two AE33 aethalometers, which work on optical principles of the attenuation of light by black carbon deposits on filter tape at seven different wavelengths. Measuring solely black carbon concentration would be performed at one wavelength, but expanding the measurements at seven different wavelengths provides an extensive analysis of dependence of attenuation on the wavelength of light. This enables the derivation of the Angstrom exponent, whose values differentiate the origin of black carbon from biomass burning (wood and coal) from liquid fossil fuel (such as diesel oil). This is the first analysis of this type performed simultaneously in Sarajevo and Zenica valley under strong air pollution episodes.

Keywords: Black carbon; Air pollution; Angstrom exponent; Temperature inversion; Source apportionment.

1. Introduction

Black carbon (BC) is a component of air pollution that originates from incomplete combustion of fossil fuels (FF) and biomass burning (BB). It is argued that BC is the second largest anthropogenic climate change factor [1], [2] (carbon dioxide being first). The negative health effects of black carbon are well documented [3], [4]. Previous research articles include Evaluation with a photoacoustic instrument [5], method comparisons [6], vertical profiles over Milan [7], diesel exhaust [8], wood combustion particles [9], emissions from fresh biomass burning [10], and source apportionment [11]. Western Balkans countries are highly affected by air pollution and BC pollution. Those countries that are not members of the European Union may have missing regulations on BC and air pollution and sparse and incomplete monitoring. Bosnia and Herzegovina is a good example: it has strong air pollution due to several factors, some of which are natural, while others are anthropogenic. Sarajevo, the capital of Bosnia and Herzegovina, is well known for air pollution caused by the burning of FF and BM and unfavourable microclimate (temperature inversions in winter time), while the city of Zenica has a steel foundry in the city centre and has been a synonym for air pollution for decades.

This research is advanced measurement and analysis of long-term campaigns in Sarajevo and Zenica simultaneously, which is a very valuable asset in an attempt to understand and solve the air pollution problem in Bosnia and Herzegovina.

2. Experimental setup

Black carbon has the ability to absorb solar radiation (almost the entire spectrum). This property enables the construction of optical-based devices, called aethalometers, for the measurement of BC concentrations. We have used AE33 aethalometers from Aerosol Magee Scientific (Berkeley, California, United States of America). At the beginning of the air sampling line, the inlet cyclone separates particles greater than 2.5 μm in diameter. BC particles are collected on filter tape, and the light absorption method is used to calculate BC concentration at 880 nm wavelength, as described in our previous work [12]. The black carbon facility is one component of a larger project of our research group, where different aspects of air pollution are observed and compared, including toxic gases [13], [14], and particulate matter [15]-[21]. We have used this technique previously [22], but this time, a new location is included: the city of Zenica. Figure 1 shows two measurement locations: one in Sarajevo (Faculty of Mechanical Engineering, N 43° 51' 15'', E 18° 23' 46'') and one in Zenica (Radakovo, N 44° 11' 43'', E 17° 55' 55'').

Although the BC is measured at the wavelength 880 nm, our measurements were performed at 7 different wavelengths: 370, 470, 520, 590, 660, 880, and 950 nm. The reason for this is the following: if we have measurements at multiple wavelengths, we can deduce the Angstrom exponent, which is the coefficient of (logarithmic) dependence of optical attenuation on the wavelength of light. It is possible then to deduce biomass burning (BB) as a percentage of total BC. This technique can be used for source apportionment since it distinguishes solid from liquid fuels as the source of BC.

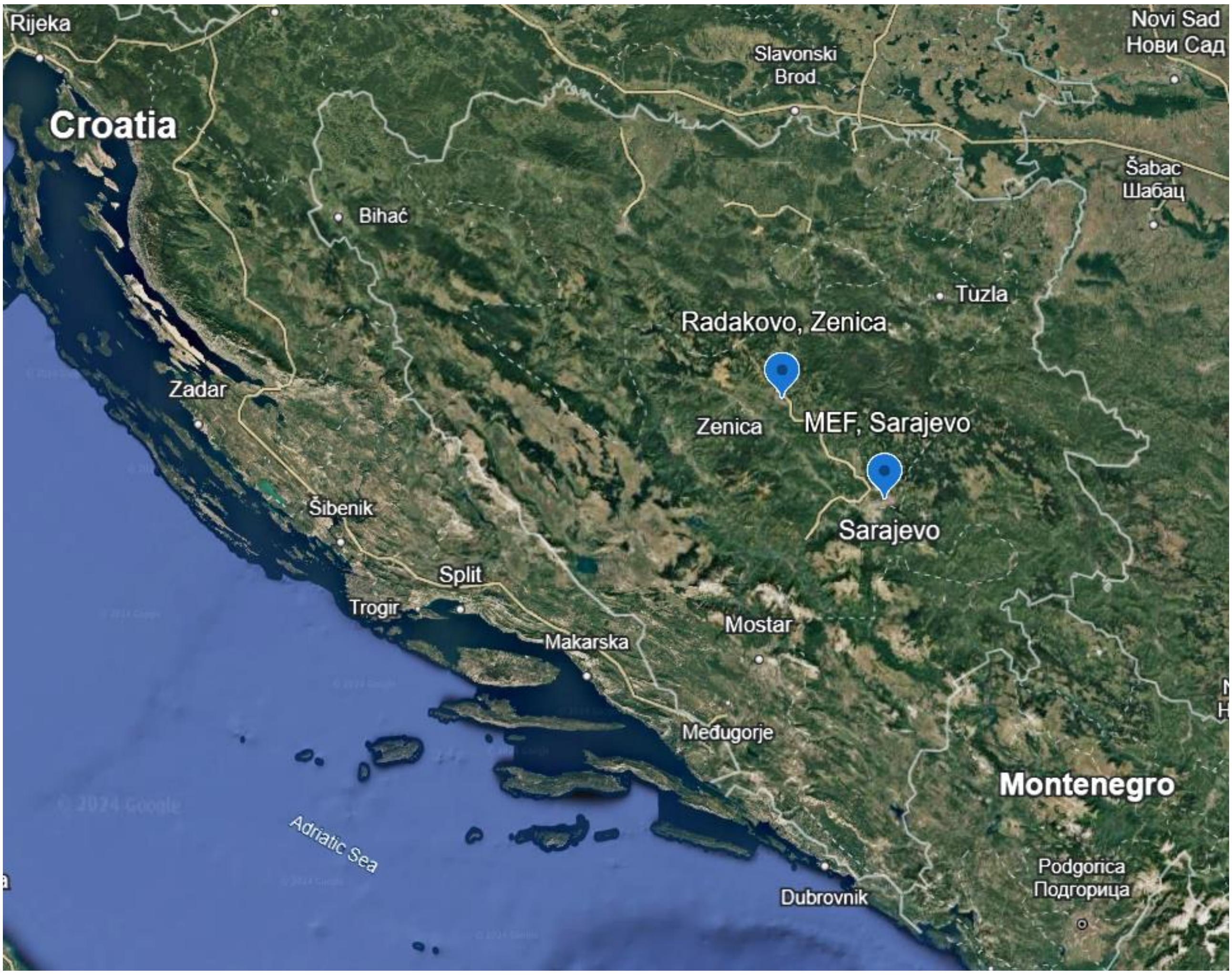

Fig. 1. Locations of measurements

3. Results

The measurements were performed in Sarajevo and Zenica simultaneously in 2023 and 2024 (up to 07/OCT/2024). A rigorous quality assurance (QA) procedure was implemented: all measurements are checked against multiple criteria (flow rate ratio, optical performance, etc.), and only those with near-perfect status are kept.

That is the reason why we have some gaps in data, but the quality of such data is the highest possible. Figure 2 shows measurements in Sarajevo. Hourly and daily average values are plotted. The average value of BC concentration was 2.943 $\mu g/m^3$. It is observable from Figure 2 that the highest peaks are in winter months, namely in December, where we have measured the highest value of daily average BC concentration of 35.212 $\mu g/m^3$.

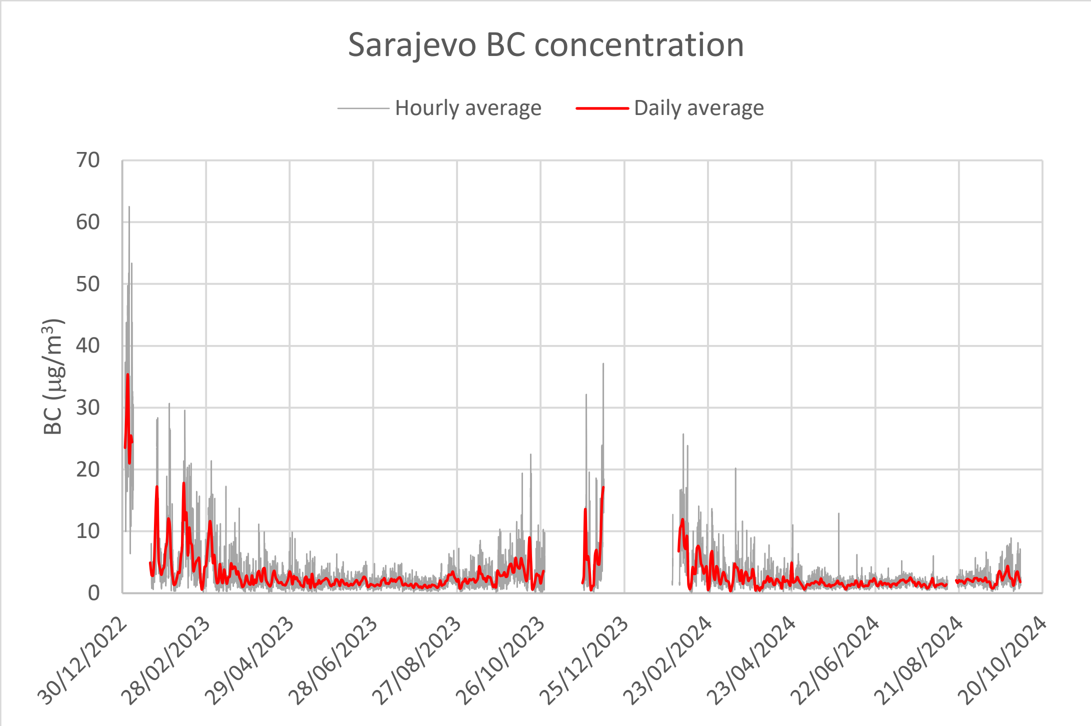

Fig. 2. BC concentration in Sarajevo

Figure 3 shows the BB percentage during the same period. While BB is above 50% during the winter, it drops to less than 20% during the summertime. This clearly indicates the primary source of air pollution in Sarajevo: burning solid fuels such as wood and coal for domestic heating! The average BB during the entire period was 27.48%.

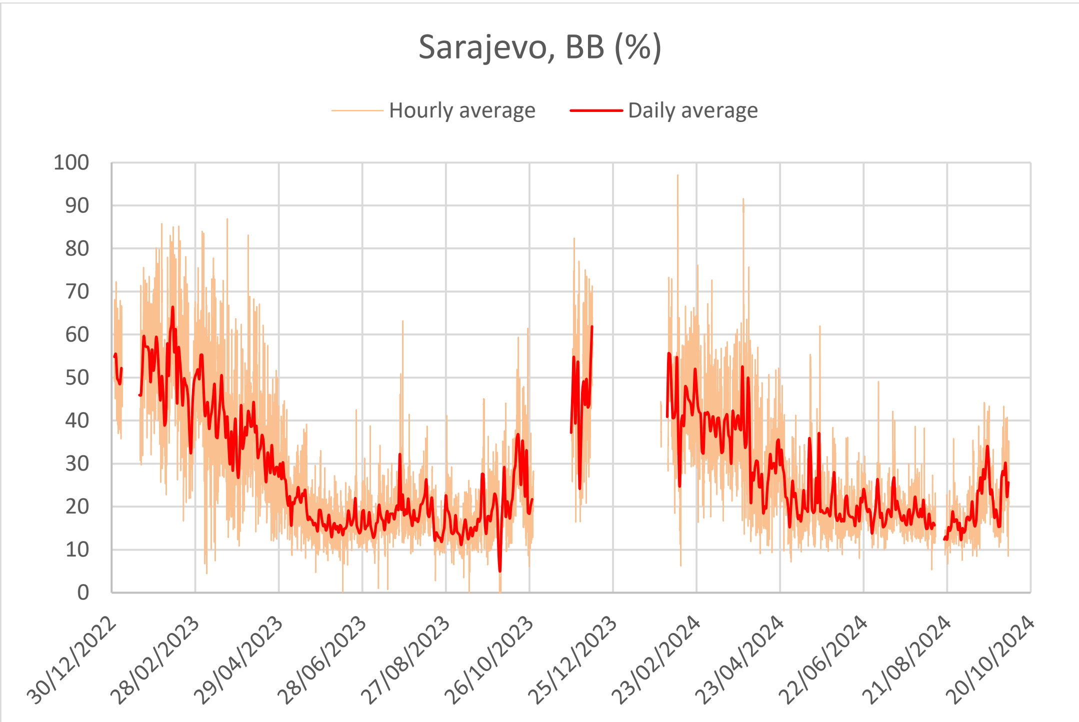

Fig. 3. BB percentage in Sarajevo

Measurements in Zenica are shown in Figure 4. The average value of BC concentration was 2.064 µg/m³, while the highest measured daily average value was 11.971 µg/m³. BB percentage was around 20% during the summer and around 60% during the winter. A similar conclusion about sources remains: the primary source of BC during the winter is the burning of solid fuels. The average BB during the entire period was 36.15%. Interesting comparisons could be drawn. While there was a greater BC concentration in Sarajevo than in Zenica, the BB percentage was lower in Sarajevo than in Zenica. Since BB is one of the main sources of BC [23], it follows that BC concentration captured in Sarajevo comes from other sources, not just BB. Zenica valley is known for its industrial sites, which would explain the difference in BB percentage in Sarajevo and Zenica. This needs further analysis and clarification.

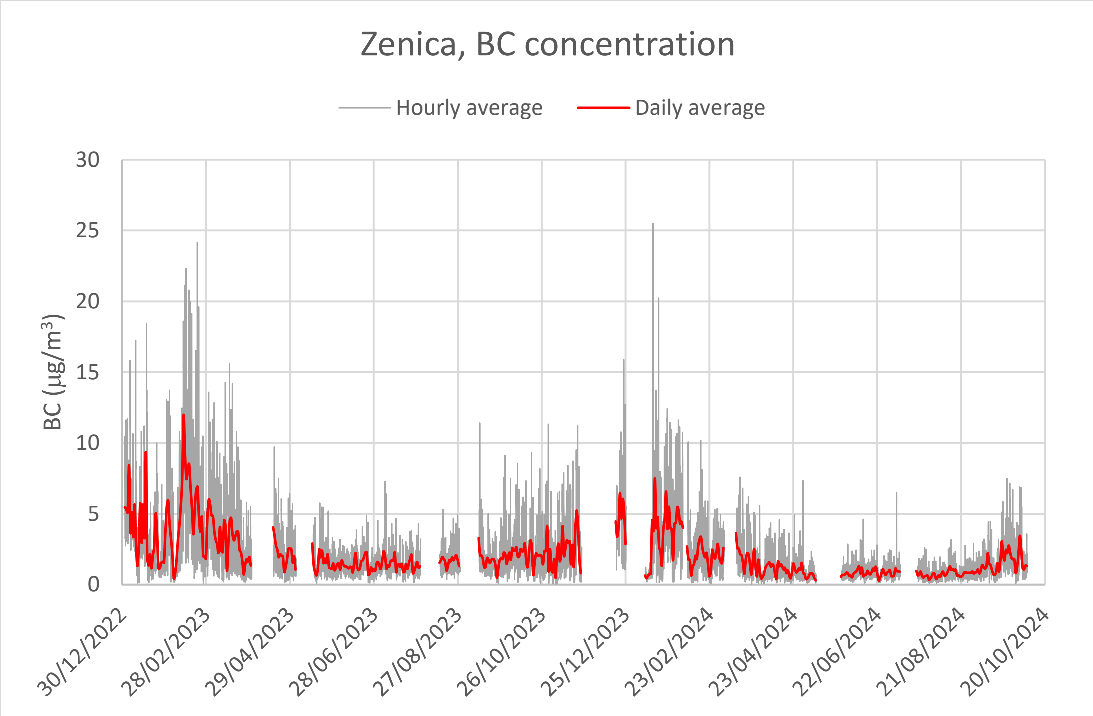

Fig. 4. BB percentage in Sarajevo

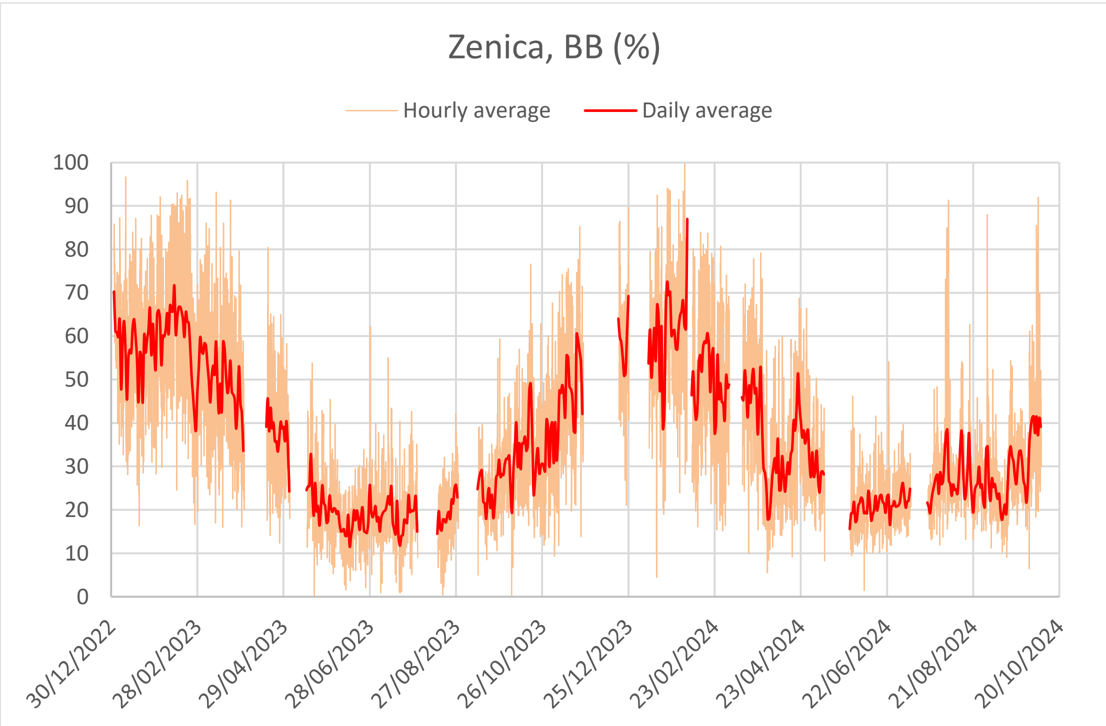

Fig. 5. BB percentage in Sarajevo

4. Conclusions

The long-term BC measurement and analysis campaign in Sarajevo and Zenica was performed using two AE33 aethalometers. The results are auspicious and very promising: it is possible to distinguish now the primary source of black carbon (and consequently the air pollution) using the Angstrom exponent, which is calculated from measurements of 7 different wavelengths of light. A very similar pattern is observed in Sarajevo and Zenica: BB drops to about 20% during the summer and rises above 50% during the winter. Average concentrations of BC were high, particularly during the winter. This research should continue in the future. Every new winter season is of particular interest. Comparison with EU member states would be indicative as well.

5. References

[1] Ramanathan, V. & Carmichael, Gregory. (2008). Global and Regional Climate Changes Due to Black Carbon. Nat Geosci. 1. DOI: 10.1038/ngeo156.

[2] Bond, T. C. et al. (2013), Bounding the role of black carbon in the climate system: A scientific assessment, J. Geophys. Res. Atmos., 118, 5380– 5552, DOI: 10.1002/jgrd.50171.

[3] Bové, H.; Bongaerts, E.; Slenders, E. et al. (2019). Ambient black carbon particles reach the fetal side of human placenta. Nat Commun 10, 3866 (2019). DOI: 10.1038/s41467-019-11654-3

[4] Janssen, N. A.; Hoek, G.; Simic-Lawson. M.; Fischer, P.; van Bree, L.; ten Brink, H.; Keuken, M.; Atkinson, R. W.; Anderson, H. R.; Brunekreef, B. & Cassee, F. R. (2011). Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM10 and PM2.5. Environ Health Perspect. 119(12):1691-9. DOI: 10.1289/ehp.1003369

[5] Arnott, W. P.; Hamasha, K.; Moosmüller, H.; Sheridan, P. J. & Ogren, J. A. (2005). Towards Aerosol Light-Absorption Measurements with a 7-Wavelength Aethalometer: Evaluation with a Photoacoustic Instrument and 3-Wavelength Nephelometer, Aerosol Science and Technology, 39:1, 17-29, DOI: 10.1080/027868290901972

[6] Babich, P.; Davey, M.; Allen, G. & Koutrakis, P. (2000). Method Comparisons for Particulate Nitrate, Elemental Carbon, and PM2.5 Mass in Seven U.S. Cities, Journal of the Air & Waste Management Association, 50:7, 1095-1105, DOI: 10.1080/10473289.2000.10464152

[7] Ferrero, L.; Mocnik, G.; Ferrini, B.S.; Perrone, M.G.; Sangiorgi, G. & Bolzacchini, E. (2011). Vertical profiles of aerosol absorption coefficient from micro-Aethalometer data and Mie calculation over Milan, Science of The Total Environment, Volume 409, Issue 14, 2011, Pages 2824-2837, ISSN 0048-9697, DOI: 10.1016/j.scitotenv.2011.04.022.

[8] Ning, Z.; Chan, K.L.; Wong, K.C.;.Westerdahl, D.; Močnik, G.; Zhou, J..H. & Cheung, C. S. (2013). Black carbon mass size distributions of diesel exhaust and urban aerosols measured using differential mobility analyzer in tandem with Aethalometer, Atmospheric Environment, Volume 80, 2013, Pages 31-40, ISSN 1352-2310, DOI: 10.1016/j.atmosenv.2013.07.037.

[9] Wang, Y.; Hopke, P. K.; Rattigan, O. V.; Xia, X.; Chalupa, D. C. & Utell, M. J. (2011). Characterization of Residential Wood Combustion Particles Using the Two-Wavelength Aethalometer Environmental Science & Technology 2011 45 (17), 7387-7393, DOI: 10.1021/es2013984

[10] Pan, X.; Kanaya, Y.; Taketani, F.; Miyakawa, T.; Inomata, S.; Komazaki, Y.; Tanimoto, H.; Wang, Z.; Uno, I. & Wang, Z. (2017). Emission characteristics of refractory black carbon aerosols from fresh biomass burning: a perspective from laboratory experiments, Atmos. Chem. Phys., 17, 13001–13016, DOI: 10.5194/acp-17-13001-2017

[11] Zotter, P.; Herich, H.; Gysel, M.; El-Haddad, I.; Zhang, Y.; Močnik, G.; Hüglin, C.; Baltensperger, U.; Szidat, S. & Prévôt, A. S. H. (2017). Evaluation of the absorption Ångström exponents for traffic and wood burning in the Aethalometer-based source apportionment using radiocarbon measurements of ambient aerosol, Atmos. Chem. Phys., 17, 4229–4249, DOI: 10.5194/acp-17-4229-2017

[12] Masic, A.; Bibic, D.; Kamenica, I.; Bektesevic, J.; Haziabdic, V. & Mehuljic, M. (2020). Mobile Measurements of Black Carbon for Source Apportionment Studies, Proceedings of the 31st DAAAM International Symposium, pp.0227-0231, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-29-7, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/31st.daaam.proceedings.031

[13] Masic, A.; Bibic, D.; Pikula, B. & Razic, F. (2018). New approach of measuring toxic gases concentrations: principle of operation, Proceedings of the 29th DAAAM International Symposium, pp.0882-0887, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-20-4, ISSN 1726-9679, Vienna, Austria, DOI: 10.2507/29th.daaam.proceedings.127

[14] Bibic, D.; Pikula, B.; Masic, A. & Razic, F. (2018). New approach of measuring toxic gases concentrations: application examples, Proceedings of the 29th DAAAM International Symposium, pp.0876-0881, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-20-4, ISSN 1726-9679, Vienna, Austria, DOI: 10.2507/29th.daaam.proceedings.126

[15] Masic, A.; Pikula, B.; Bibic, D.; Musemic, R. & Halac, A. (2018). Calibration and Assessment of Low-cost Dust sensors, Proceedings of the 29th DAAAM International Symposium, pp. 523-528, B. Katalinic (Ed.), Published by

DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria, DOI: 10.2507/29th.daaam.proceedings.075

[16] Masic, A.; Bibic, D. & Pikula, B. (2019). On the applicability of low-cost sensors for measurements of aerosol concentrations, Proceedings of the 30th DAAAM International Symposium, pp.0452-0456, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-22-8, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/30th.daaam.proceedings.060

[17] Masic, A.; Pikula, B. & Bibic, D. (2017). Mobile Measurements of Particulate Matter Concentrations in Urban Area, Proceedings of the 28th DAAAM International Symposium, pp.0452-0456, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-11-2, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/28th.daaam.proceedings.063

[18] Masic, A.; Bibic, D.; Pikula, B.; Dzaferovic-Masic, E. & Razic, F. (2018). Visualization of Data from Network of Sensors: Appropriate Spatial Interpolation Method, Proceedings of the 29th DAAAM International Symposium, pp.0529-0533, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-20-4, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/29th.daaam.proceedings.076

[19] Masic. A.; Bibic, D.; Pikula, B.; Blazevic, A.; Huremovic, J. & Zero, S. (2020). Evaluation of optical particulate matter sensors under realistic conditions of strong and mild urban pollution. Atmospheric Measurement Techniques, 13, 6427–6443, DOI: 10.5194/amt-13-6427-2020

[20] Masic, A.; Pikula, B.; Haziabdic, V.; Mehuljic, M. & Bektesevic, J. (2020). Evaluation of Face Mask Filtering Efficiency Using High-End Scanning Mobility Particle Sizer, Proceedings of the 31st DAAAM International Symposium, pp.0224-0226, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-29-7, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/31st.daaam.proceedings.030

[21] Masic, A.; Kepnik, G.; Bektesevic, J.; Mehuljic, M.; Saric, I. & Haziabdic, V. (2020). The Network of Smart Sensors for Indoor Air Quality Monitoring, Proceedings of the 31st DAAAM International Symposium, pp.0232-0235, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-29-7, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/31st.daaam.proceedings.032

[22] Masic, A.; Kepnik, G.; Bibic, D.; Mesic E. & Pikula, B. (2021). Long-term measurement of black carbon concentration and source apportionment, Proceedings of the 32nd DAAAM International Symposium, pp.0131-0135, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-33-4, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/32nd.daaam.proceedings.020

[23] Katz, S. D.; Kelly, R. P. ; Robinson, R. S. et al. (2024). Biomass burning is a source of modern black carbon to equatorial Atlantic Ocean sediments. Communications Earth Environment 5, 536 DOI: 10.1038/s43247-024-01642-x