BLACK CARBON IN THE ENVIRONMENT

Borut Jereb,
Faculty for logistics, University in Maribor, Mariborska cesta 2, 3000 Celje,
borut.jereb@um.si

Ana Vovk Korže, Mednarodni center za ekoremediacije, Filozofska fakulteta Maribor,
Koroška c. 160, 2000 Maribor,
ana.vovk@um.si

In world measurements is black carbon defined as the second most harmful pollutant of the air. On the local level have studies shown that there is connection between the exposure to the black carbon and diseases like asthma, respiratory infections and congenital defects.

Black carbon and Ångström´s exponent were measured by the instrument called aethalometer® Model AE33 (Magee Scientific / Aerosol d.o.o).
Measurements of black carbon were performed on various locations in different periods of time in Mariborska cesta Celje between 19.1. and 13.2. 2017 and between 13.3. and 8.5. 2017.

The highest concentrations of black carbon were noticed in winter period. In spring time from March till May were measured concentrations of black carbon mostly lower. Reason for such result lies in the end of burning season, which is shown by the lower contributions of biomass burning to the black carbon contributions and bigger dynamics of mixing air layer, that influence the mixing of aerosols in urban environment. Contribution of the biomass burning to the black carbon concentrations is tightly connected to the air temperature, since the intensity of heating is higher in cold weather. At contribution of black carbon from traffic temperature does not influence, since the intensity of traffic does not change and stays relatively constant during the year. Wind direction influences concentrations as well, since it can bring aerosols from other remote sources.

Key words: Air pollution, Black carbon, aethalometer, traffic, biomass,weather, Celje

INTRODUCTION

Black carbon is short term climate pollutant that appears by the uncompleted combustion of fuels and therefore influence negatively on the air quality and health in towns. In world measurements is black carbon defined as the second most harmful pollutant of the air. On the local level have studies shown that there is connection between the exposure to the black carbon and diseases like asthma, respiratory infections and congenital defects.

According to the World Health Organization (WHO) there were 3,7 million of premature deaths in year 2012 a consequence of the polluted outside air, from which there are 88% of those in the countries with low and middle incomes (Jereb, 2017). It is typical for black coal, that from all air particles in the air the most effectively absorbs light. With the incomplete combustion of the carbon fuels we get, next to the black carbon, also other organic components, that add to the light absorption only in the specific light spectre that is why we call them the brown carbon. The device by which we can measure the concentration

of black carbon directly with high time resolution in the air is named aethalomether (Jereb et al, 2017). With its support we performed measurements of the black carbon in Celje.

METHODOLOGY

Black carbon and Ångström´s exponent were measured by the instrument called aethalometer® Model AE33 (Magee Scientific / Aerosol d.o.o). Light source in this model are shining diodes with spectres with maximums at 370nm, 470 nm, 520 nm, 590 nm, 660 nm, 880 nm and 950 nm. Measurements in such wide light spectrum give us the possibility of characterization of aerosol absorption in the area from ultraviolet in infrared light (Jereb et al., 2017).

Absorption coefficient (*b*) is by the various wave lengths dependant from the characteristics of the aerosols, mostly from size and shape of the aerosols and its chemical composition. Ångström´s exponent describe how the absorption coefficient of aerosols changes with the light wave length (Fig. 1).

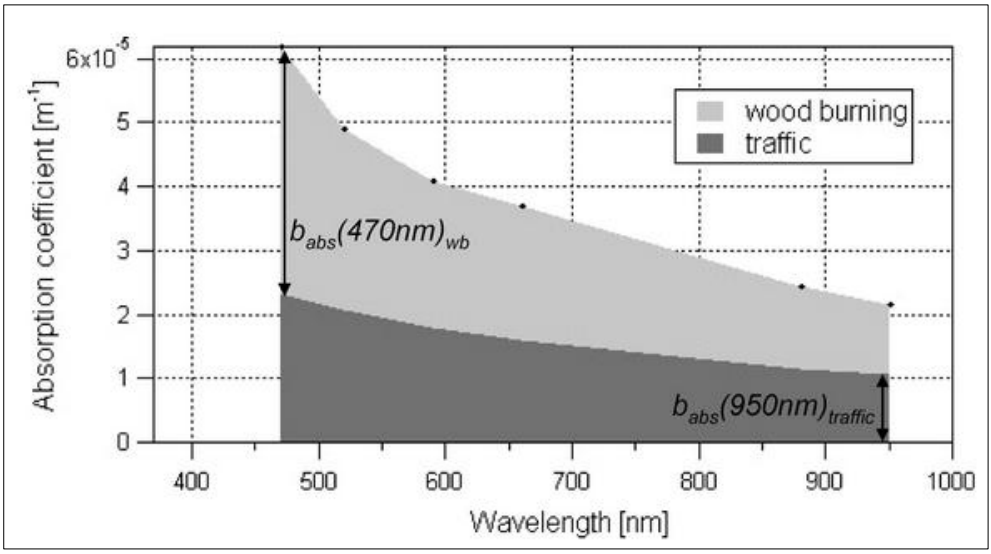

Fig. 1: Absorption coefficient dependency from the light wave length for traffic and wood biomass combustion (Sandradewi et al, 2008).

Ångström´s exponent for completely black aerosols is 1. Aerosols that the most absorbs light by low wave lengths have higher Ångström´s exponent. According to the Ångström´s exponent we can distinguish black carbon that is produced by the diesel fuels combustion for which mayor source are traffic emissions and so called brown carbon that has higher Ångström´s exponent and is mainly produced by wood biomass combustion (Sandradewi et al, 2008). On the upper picture we can see dependency of the light absorption from wave length for traffic and biomass combustion (Fig. 1).

Aethalomether samples particles on filter tape from glass fibres over which air flows in amount a few litres a minute. Above the filter we find the source of light and under it is a detector that measures the permeability of tape and sampled particles for light. We determine the concentration of black carbon by the changes of optical permeability of filter at the 880nm wave length (Ogrin et al, 2014; Drinovec et. al, 2015; Jereb et al, 2017).

Results of black carbon measurements in town Celje

Measurements of black carbon were performed on various locations in different periods of time in Mariborska cesta Celje between 19.1. and 13.2. 2017 and between 13.3. and 8.5. 2017.
Locations of measurements are shown on Fig. 2.

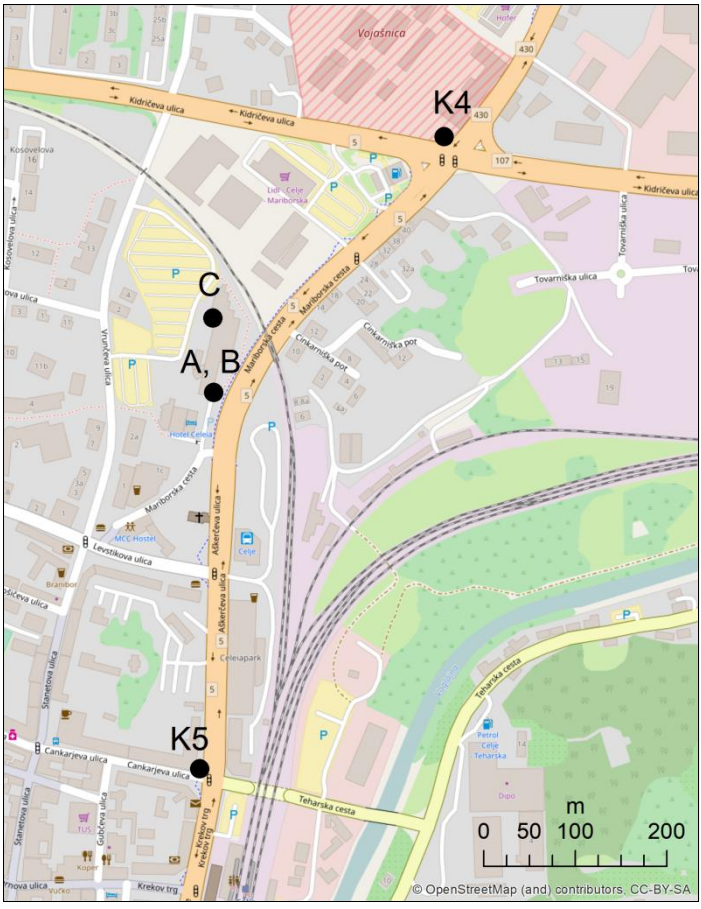

Fig. 2: Locations of measurements marked by: A, B, C – Faculty of logistics (FL UM); K4 in K5

Location A – groundfloor (2 m above ground) Faculty of logistics University of Maribor (FL UM), lies 20 m from Mariborska cesta that climbs from underpass.
Location B – conference room FLUM (4. floor); 8 m above location A.
Location C – Communication room FLUM (back side of building), near parking, 2 m high.
Location K4 – crossroads between Mariborska and Kidričeva cesta; nearby are 8 driving lanes.
Location K5 – crossroads between Mariborska cesta in Cankarjeva ulica; there are 4 driving lanes.

On location A were measurements performed all the time, while were the measurements on other places performed in shorter periods of time with the purpose to find out the characteristics of spatial distribution of black carbon (Table 1).

Table 1: Location of measurements and standard value of black carbon concentration (BC)

Location	Mark	Period of measurements	*BC* (μg m^{-3}) average ± standard deviation
FLUM – ground floor	A	19.1. - 13.2.2017	6,32 ± 4,86
		13.3. - 8.5.2017	2,69 ± 2,85
FLUM – 4.th floor	B	23.3. - 3.4.2017	2,83 ± 2,31
FLUM – ground floor, back side	C	4.4. - 14.4.2017	1,67 ± 1,43
Crossroads Mariborska and Kidričeva cesto	K4	13.3. - 23.3.2017	7,25 ± 6,06
Crossroads Mariborsko cesta and Cankarjeva street	K5	20.4. - 8.5.2017	2,57 ± 4,04

The highest concentrations of black carbon were noticed in winter period on location A on average 6,32 ± 4,86 μg/m^3 and by busy crossroads K4 on average 7,25 ± 6,06 μg/m^3. In winter 2010/2011 was in measuring spot near hospital, that represents urban background measured average concentration 4,93 μg/m^3 (Drinovec et al, 2012), which is lower than the measured concentrations, measured on point A. In spring time from March till May were measured concentrations of black carbon mostly (except by the crossroads K4) lower (on location A: 2,69 ± 2,85 μg/m^3). Reason for such result lies in the end of burning season, which is shown by the lower contributions of biomass burning to the black carbon contributions and bigger dynamics of mixing air layer, that influence the mixing of aerosols in urban environment. In Summer 2010 was average concentration in urban background behind the hospital 1,63 μg/m^3. Addition of biomass burning to the black carbon concentrations was expectedly the highest in winter time, while in spring decreased (Fig 3).

On contrary we find traffic black carbon concentrations (Fig. 3) unchanged during all period of measurements and are more dependant from the location of measurements, that is how close is the road. In order to find out what is the typical day swinging of the black carbon concentrations separated to different sources for each hour during the day throughout the whole period of measurements and therefore got the average day profile. From the

picture we can see that the traffic (BC_{TR}) strongly contributes to higher concentration of the black carbon during the day in comparison to the biomass burning (BC_{BB}) – (**full line represents average concentration, shadowed area represents 95% level of trust, scales on axis for BC are different).*

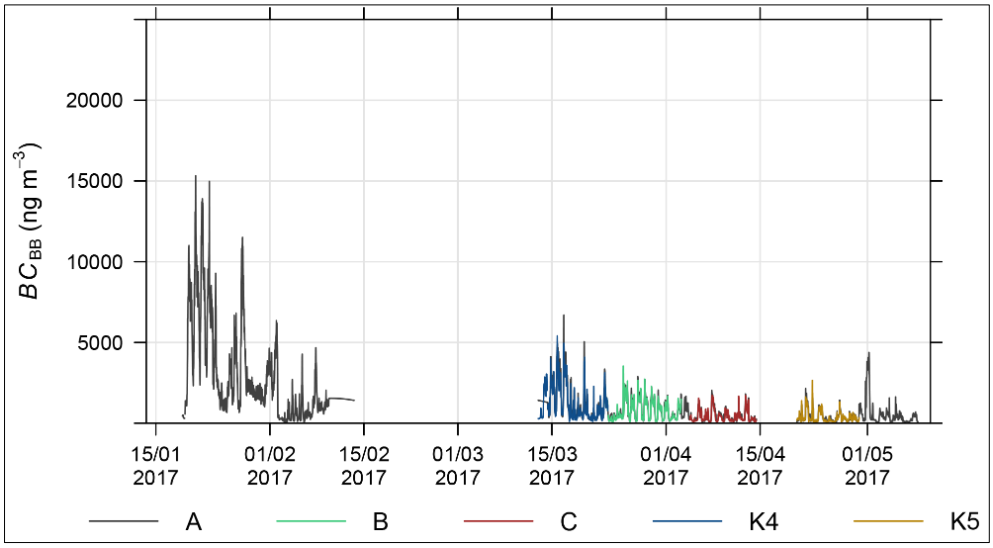

Fig 3: Black carbon concentrations during different seasons

On contrary we find traffic black carbon concentrations unchanged during all period of measurements and are more dependant from the location of measurements, that is how close is the road. In order to find out what is the typical day swinging of the black carbon concentrations separated to different sources for each hour during the day throughout the whole period of measurements and therefore got the average day profile (Fig. 4). From the

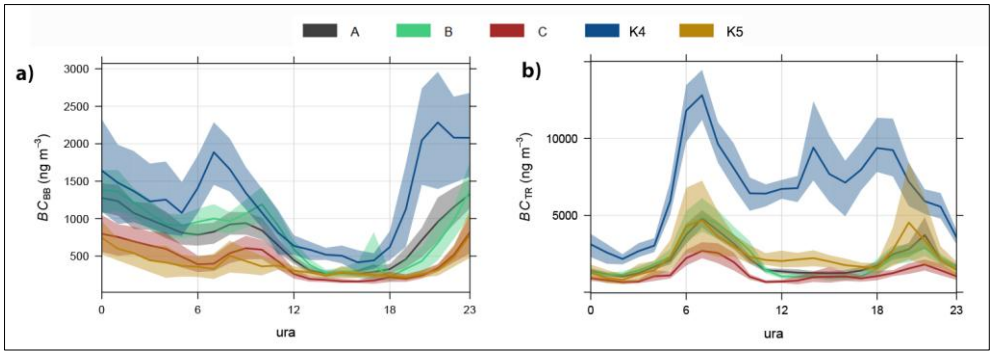

Fig. 4: Time span of the black carbon concentrations from the biomass burning BC_{BB} and from the transport BC_{TR} on various locations.

picture we can see that the traffic (BC_{TR}) strongly contributes to higher concentration of the black carbon during the day in comparison to the biomass burning (BC_{BB}) – (**full line*

represents average concentration, shadowed area represents 95% level of trust, scales on axis for BC are different).

BC_{BB} has two higher peaks, first one in early morning hours and the second one in evening hours, that are the consequence of enlarged night biomass burning for the purpose of heating. During the day and in the other half of night the concentrations of BC_{BB} get low because of the smaller emissions and air dilution. Differennces in the concentrations BC_{BB} on various locations are consequence of different periods of measurements performances. The highest concentrations of BC_{BB} were noticed on the location K4, where the meassurements took place at the beginning of March, when the air temperatures were still low and therfore higher intensity of the emissions. The most representative is location A where the measurements took place during the longer period of time.

For the average day profile of BC_{TR} we have two peaks, first one between six and seven o´clock in the morning and the second one, less obvious in the evening hours. First peak can be connected to the morning rush hour, while the second one is more or less the consequence of slow air dynamics in the mixing layer close to the ground, which increases the concentrations of pollutants in the mentioned air layer close to the ground.

Influence of the traffic is the highest on the crossroads between the Mariborska and Kidričeva cesta and is decreasing with the distance from the road; the smallest concentrations were measured on the other side of the FLUM building (Jereb et al, 2017).

According to the daily course of the concentrations BC_{TR} both measurements by the crossroads stand out (K4 in K5). Concentrations BC_{TR} measured in location K4 are especially higher than the ones on location K5.

Crossroads K4 is bigger than K5, since it has two more lanes. This adds to higher concentration of BC_{TR}. Measurements on crossroads K4 have shown higher concentrations of BC_{TR} also during the day, while they fell on other locations. To add, we can here also see additional peak in early afternoon, what we can assign to traffic jam at the end of the work day.

Day course of the black carbon concentrations is the consequence of two influences, source dynamics – morning and afternoon traffic peaks, burning of the biomass fuel and meteorological conditions. At clear days, when planetary border air thickness rise according to the sun insolation it comes to bigger mixing of the air masses, that is why we expect lowering of the black carbon concentrations. At night the planetary border stabilizes and because of the smaller mixing the concentrations of pollutants increase. At the same time intensity of the emissions of black carbon during the night falls, that is why the concentrations become lower in the second part of the night.

Influences on the black carbon concentrations

Contribution of the biomass burning to the black carbon concentrations is tightly connected to the air temperature, since the intensity of heating is higher in cold weather. At contribution of black carbon from traffic temperature does not influence, since the intensity of traffic does not change and stays relatively constant during the year. On Fig. 5 we see dependency of BC_{BB} in BC_{TR} from temperature, by which is with colourful scale marked wind speed. We can see that the wind speed help to reduce the black carbon concentrations.

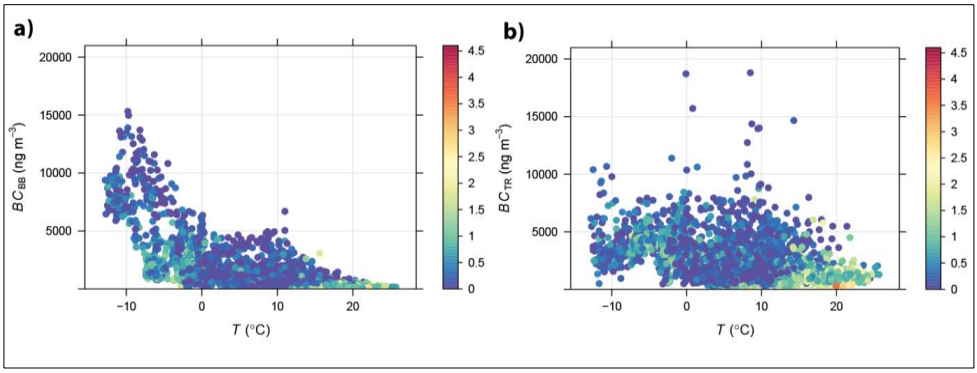

Fig. 5: Dependency of black carbon from biomass burning (BCBB) and carbon from traffic (BCTR) from temperature and wind speed.

Wind influences dilution and transport of black carbon and other aerosols in the air. Wind direction influences concentrations as well, since it can bring aerosols from other remote sources.

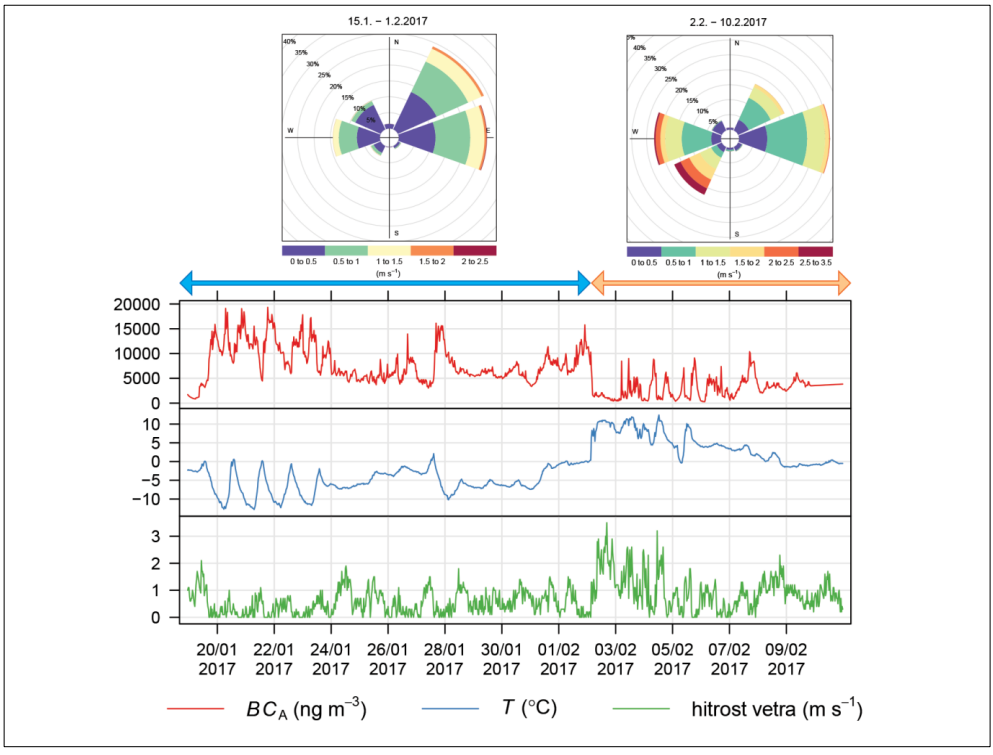

Fig. 6: Time span of the temperature (T), wind speed (ws) and black carbon concentration (BCA, half-hourly averages) on measuring point A.

Influence of the direction and wind speed is clearly noticeable on location A in the winter time Figure 6 – wind rose show direction of wind in the period from the beginning of the measurements to 2.2.2017 (1.period marked with blue line) and from 2.2.2017 – 10.2.2017 (2.period, marked with orange line). In the first period(15.1.-1.2.2017) we can see the overrule of the East and North-East wind with speed up to 2m/s. In the second period (2.2.2017 – 10.2.2017) wind direction changes and stronger South –West and West wind start to blow and still some weak East wind was present. In the second period when the wind direction changes the black carbon concentration distinctively lowers. Additional lowering of the concentrations is also a consequence of higher temperatures that rapidly jumped from 0 to 10°C. By higher temperatures we see decrease of the heating and therefore lowering of the black carbon emissions (Fig. 6)..

Wind has a bit bigger influence on the biomass burning additions to the black carbon concentrations than to the traffic concentrations. Smaller influence of wind on black carbon from traffic is attributed mostly to the proximity of sources (Jereb et al, 2017).

For determination of changes of black carbon concentrations with the height (from floor) we used two measuring points – A and B location A is measuring point on height 2m, location B is 8 m from floor on the same location. We can see that the concentration with height on average does not change. We can see some individual peaks on location A, timely limited on a few minutes and derive from traffic. It is most likely that the location is part of the road canyon and that polluted air from road rise by the buildings.

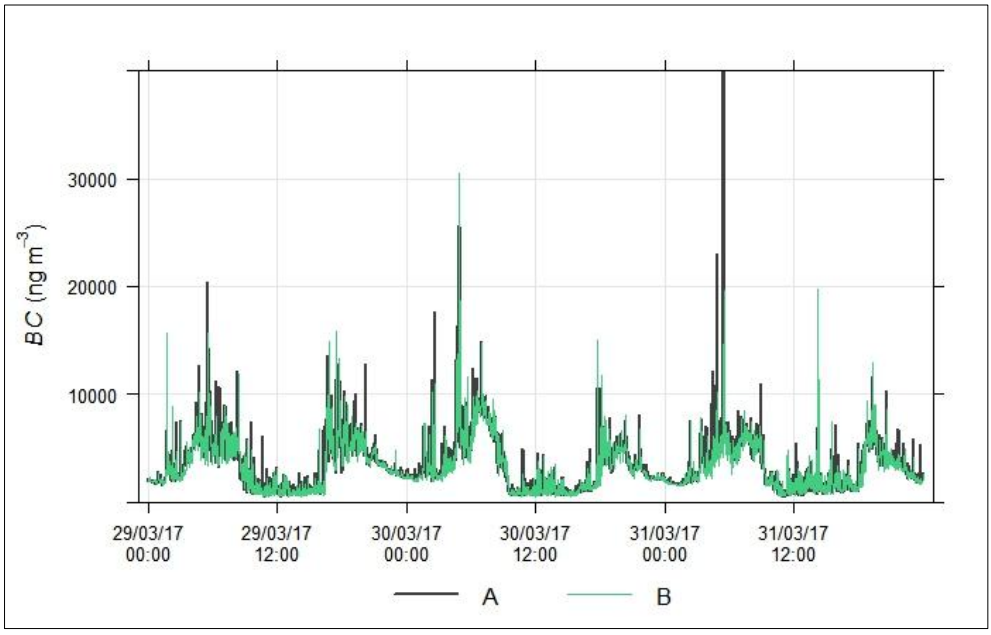

Fig. 7: Comparison of the time course of black carbon on different heights (measuring point A – 2 m from floor; measuring point B – 8 m from floor)

Next the weather also the proximity of the sources influences the black carbon concentrations. The highest concentrations are expected right at the exhausts and would get lower with distance mainly because of the dilution. With measurements on different points we wanted to guess what was the space heterogeneity of the black carbon concentrations from various sources.

On Fig. 7 we see measurements of black carbon from biomass burning (BC_{BB}) and traffic (BC_{TR}), on location A that lies in the ground floor of FLUM and location C that is on the back side/other side of the building and looks away from Mariborska cesta. Despite being away from road, we cannot forget about big parking on the other side that as well represents smaller source of the black carbon (Jereb et al, 2017).

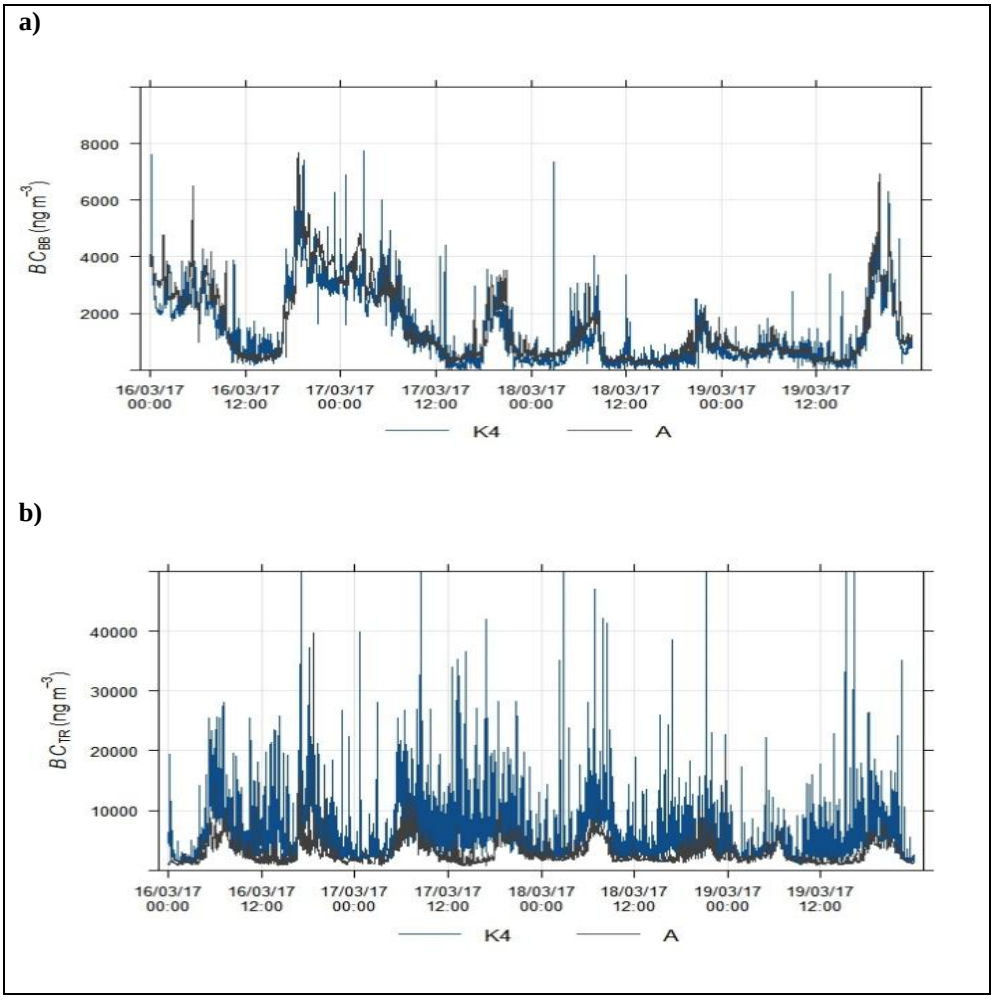

Fig. 8: Comparison of the time course of black carbon (a – biomass burning contribution, b – traffic contribution on measuring point A (ground floor of the FLUM building) and K4 crossroads.

CONCLUSION

Influence of the source distance can be described also with the comparison of the measurements on location A (20 m from the road) and K4 crossroads (right next to the road). Concentration BC_{TR} is on the crossroads K4 distinctively bigger than on the location A. Measured average value of BC_{TR} also show bigger concentration; the measured value on point A is A 2,76 µg m^3 and on the crossroads K4 6,01 µg m^3. Characteristic are short time peaks, dependant from the traffic exhaust intensity, while in the short mid periods concentrations lower to the level of the urban background.

Measurements of the black carbon from wood smoke are similar on both locations, from which we can determine that the black carbon from biomass is more homogeneously distributed than the black carbon from traffic.

References:

Drinovec, L., Ježek, I., Močnik, G. (2012): Meritve in viri ogljičnih aerosolov, Celje, 2010/2011. Poročilo. Ljubljana: Aerosol d.o.o.

Drinovec, L., Močnik, G., Zotter, P., Prévôt, A. S. H., Ruckstuhl, C., Coz, E., Rupakheti, M., Sciare, J., Müller, T., Wiedensohler, A., and Hansen, A. D. A. (2015): The "dual-spot" Aethalometer: an improved measurement of aerosol black carbon with real-time loading compensation: Atmospheric Measurement Techniques. v. 8, no. 5, p. 1965-1979.

Jereb, B., Gregorič, A. (avtor, fotograf), Vovk Korže, A., Močnik, G., Strle Mašat, N., Kovše, Š., Herman, L., Čeh, I. (avtor, fotograf), Bezgovšek Teja (avtor, fotograf), Brezovšek, N., Batkovič, T. (avtor, fotograf) (2017): . Black bicycle : kolesarske poti ob vpadnici v Celje : študentski projekt Po kreativni poti do znanja 2017. 1. elektronska izd. Celje: Fakulteta za logistiko, 58 str. ISBN 978-961-6562-83-6. http://lab.fl.um.si/labinf/wp-ontent/uploads/sites/4/2017/08/BLACK-BICYCLE-final.pdf.

Ocvirk, M. (2009): Spremembe v gospodarski strukturi občine Celje po letu 1991. Diplomsko delo. Maribor: Filozofska fakulteta.

Ogrin, M., Vintar Mally, K., Planinšek, A., Močnik, G., Drinovec, L., Gregorič, A., and Iskra, I. (2014): Koncentracije dušikovih oksidov, ozona, benzena in črnega ogljika v letih 2013 in 2014. Oddelek za geografijo Filozofske fakultete Univerze v Ljubljani.

Sandradewi, J., Prévôt, A. S. H., Szidat, S., Perron, N., Alfarra, M. R., Lanz, V. A., Weingartner, E., and Baltensperger, U. (2008):. Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contributions to particulate matter. Environmental Science & Technology, v. 42, no. 9, p. 3316-3323

Authors

Borut Jereb holds a teaching position at the University of Maribor, Faculty of Logistics as an associate professor. He received his Ph.D. degree in Computer Science from the University of Ljubljana in 1991. In 1991–1992 he was Visiting Professor at Oregon State University, USA. Upon his return to Slovenia he gained extensive experience by managing and consulting for companies and government agencies. His current research interests include standardization, risk, investments and environmental management.

Ana Vovk Korže is a full professor, researcher and project leader at the Faculty of Arts University of Maribor. Teaching areas: water, soil, regional geography, field and laboratory work, natural resource protection, regional development. Research areas: self- sufficient supply, ecoremediation, public participation in environmental decision-making, regional development and sustainable regions. Innovative research achievements: learning polygons for self-sufficient supply and ecoremediation experiential research, testing green technologies for the economy. Establishment of Learning Regions Dravinja valley. Setting up Development Centre of nature in the municipality Poljčane - Centre for Sustainable Development.