THE NANOPARTICLES CONCENTRATION IN THE TRAFFIC LOADED URBAN AREA

ADAMEC Vladimír[1], SCHÜLLEROVÁ Barbora[1], HRABOVÁ Kristýna[1], SKEŘIL Robert[2], KADLEC Radek[3], BULEJKO Pavel[1], ADAM Vojtěch[4]

[1] *University of Technology Brno, Brno, Czech Republic, EU*

[2] *Czech Hydrometeorological Institute, Brno, Czech Republic, EU*

[3] *Testo s.r.o., Brno, Czech Republic, EU*

[4] *Mendel University in Brno, Czech Republic, EU*

Abstract

Currently, the issue of nanoparticles is a very dynamic and developing scientific research area. Their positives are indisputable, as proven by a number of scientific papers and studies. On the other hand only a very small part of the overall research on nanoparticles pays attention to their possible negative consequences, especially from the point of view health risks. In many sectors of human activity (industry, energy, etc.), nanoparticles are released into the environment. The same is true in transport, especially in case of combustion of fossil fuels with all their negative consequences on the human organism. This paper presents the results of nanoparticle concentration measurement in traffic-loaded urban area. It includes continuously evaluated data measurements from different periods and different times in relation to traffic intensity at the monitored area. The results of the nanoparticle content readings confirmed the increased concentration of nanoparticles in relation to traffic intensity.

Keywords: Urban area, traffic, monitoring, concentration, nanoparticles

1. INTRODUCTION

The traffic is a significant source of aerosol particles in urban areas. It is necessary to work towards reducing exposure to these particles to assure the protection of public health and environment. Aerosol particles exist in different sizes which can have a multitude of different effects on human health. Particles are usually monitored in different fractions (**Figure 1**). During this monitoring, two different measuring techniques were used with the aim to cover the spectrum of aerosol particles (ultra fine particles <100 nm to particulate matters <1000 nm). Monitoring of these particles has been chosen due to the fact that the traffic is currently the biggest source of these particles in big cities [1, 2]. Most often measurements are taken at traffic intersections, especially signalized ones, as they are the pollution hot-spots of urban areas. But, as mentioned in the study of [3], it is necessary to take into account knowledge about fundamental drivers governing emission, dispersion and exposure to vehicle-emitted nanoparticles at traffic intersections. The combustion engines are most often used in motor vehicles and mobile work machines. These engines are source of emitted particles from one to hundreds of nanometers in size, and their activity is considerably close to the population. It is necessary to mention that the origin of these traffic-related particles is not only the combustion processes, but also the non-combustion processes. During the braking process, particles from 20 nm size are produced [4]. The emitted particles have significant influence on human health as a fraction of them is respirable, inhalable and good at passing through the membranes. Expert research has proven that exposure to nanoparticles is associated with multiple adverse cardiovascular effects and is also connected to affecting pre-existing cardiovascular disease [5]. Experimental measurements [6] lead to conclusion that respiratory diseases may be also be related to traffic emissions containing nanoparticles. Also, even a short exposure of healthy people to traffic-emitted nanoparticles can cause reduction in brain plasticity [7]. The influence of traffic at the signal traffic intersections on the content of aerosol particles is monitoring, as is mentioned in expert studies [8, 9] especially on the fixed monitoring sites around traffic intersections.

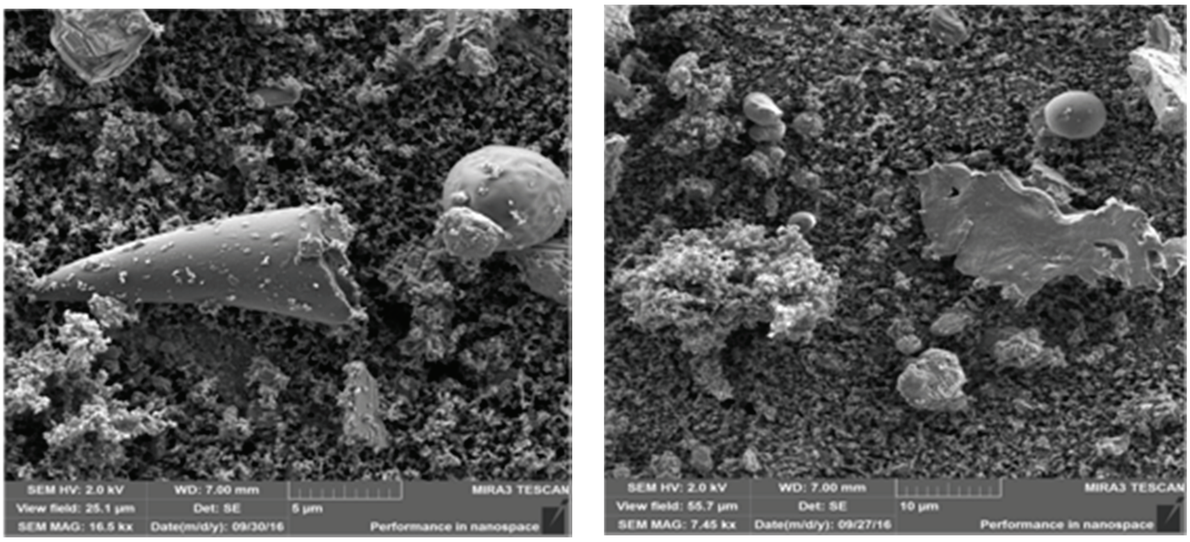

Figure 1 Nanoparticles detected at the traffic intersection in Brno (CHMI)

The continuous monitoring in the Czech Republic is carried out by the Czech Hydrometeorological Institute (CHMI) in selected locations. The paper presents results from the nanoparticle concentration monitoring in urban areas with high traffic density. The location was selected as it has been identified as a CHMI hot spot. With the aim to monitor the air concentration of nanoparticles, the monitoring was supported by the DiSCmini (Testo, Ltd.) device, which is able to measure fractions lower than 100 nm. Based on the use of both devices it was possible to monitor concentration of ultra fine particles approximately in the range of 7 to 1000 nm.

2. METHODOLOGY AND MATERIALS

a) b) c)

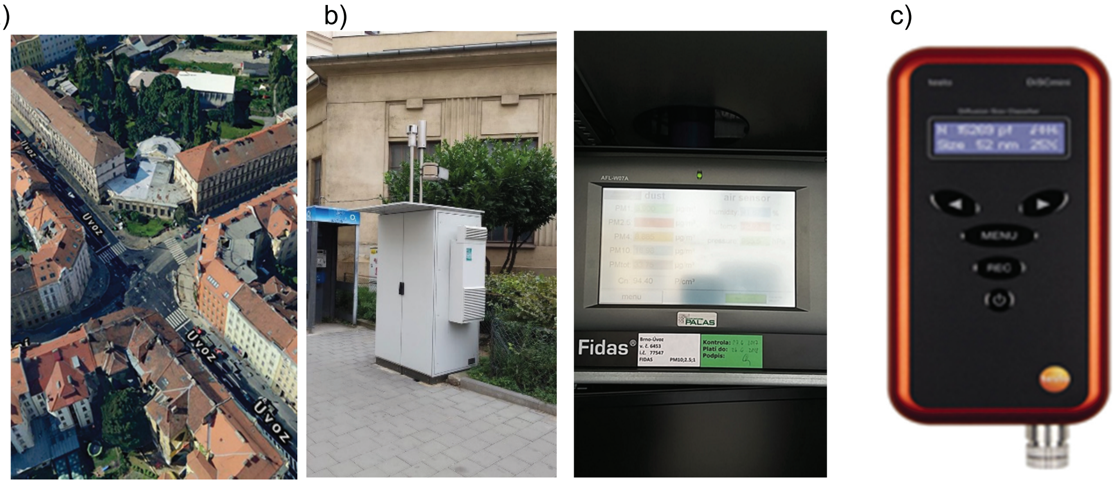

Figure 2 Monitoring *a)* locality and instruments *b)* FIDAS®200/200S, *c)* DiSCmini

Monitoring has been performed by FIDAS®200/200S (PALAS, Ltd.), which is capable of real-time monitoring particles from 172 nm, as well as $PM_{2,5}$ and PM_{10} particles. Sizes in the range of 172 - 1000 nm were selected for the monitoring and evaluation. This measuring device was equipped with sensors for monitoring of meteorological conditions (temperature, and humidity) as shown on **Figure 2**. The FIDAS®200/200S is a stationary device and has been used by CHMI since 2015 for continual aerosol particle monitoring at locations with high traffic density in selected urban areas including Brno (**Figure 2**). Monitoring was supported with the measuring device DiSCmini (Testo, Ltd.) which is able to real-time monitor of number of particles and also average size of particles in range from 10 to 700 nm (**Figure 2**). The DiSCmini is a mobile, personal device. This instrument was chosen to allow a range extension of particle sizes and a more detailed monitoring. With regard to the purpose of this device (mobile device for short time monitoring), it was used for monitoring in the time interval from 15:00 to 18:00 h. In addition of those instruments, the traffic intensity on the intersection Údolní and Úvoz street in Brno city (**Figure 3**) during the rush hour from 15:30 to 16:30 h. has also been taken into account. The experimental interval was from 15:00 to 18:00 to allow the possibility of monitoring the particle range before and after rush hour.

3. RESULTS

a) *b)*

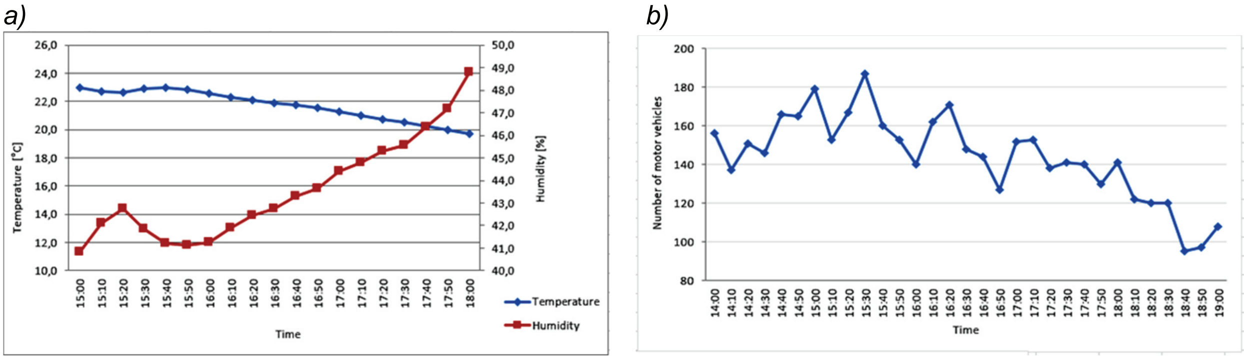

Figure 3 Traffic intersection *a)* meteorological conditions, *b)* traffic intensity

a) *b)*

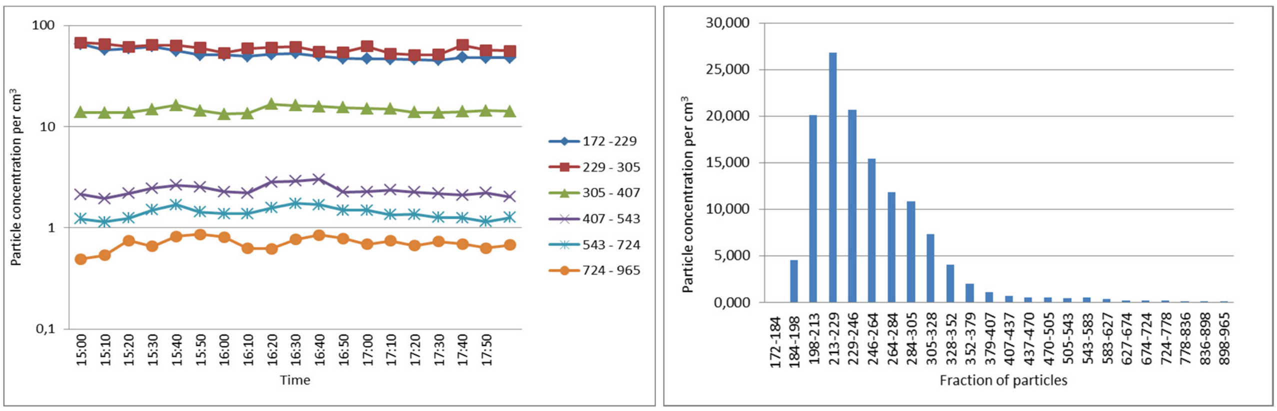

Figure 4 Average number of particles of individual *a)* concentration and fraction *b)* (per 3 hours)

The results of nanoparticle concentration development on the location with a high traffic intensity show that there is an increase in volume and a certain correlation to the traffic density. It's necessary to take into account that the concentration of these air particles is also dependent on different types of vehicles, especially for vehicles with specific technical issues, e.g. dismantled filters. The results of the monitoring on the intersection of Údolní and Úvoz street in Brno show the increase of nanoparticles, especially during the beginning of the rush hour from 15:30 pm, when there were on average 140 to 160 motor vehicles present every 10 minutes (**Figure 3**). With the increase of traffic intensity particle size has also increased, which is probably caused by resuspension. It could be also affected by the season or dispersion conditions. This is closely connected with typical characterization with these ultra fine particles. During the beginning of rush hour at 15:30, particles in the range of 213 to 229 nm have been monitored by the FIDAS®200/200S instrument (**Figure 4**). For demonstration of the increase and decrease of nanoparticles concentration, all day interval was also monitored (**Figure 5**) and **Figure 6** depicts the average number of particles of individual fractions from the continual monitoring. There is an obvious increase not only during rush hours but also in dependence on the heating season. The results show that during day interval and especially during rush hours, ultra-fine particles concentrations are higher but the increase continues after the rush hour.

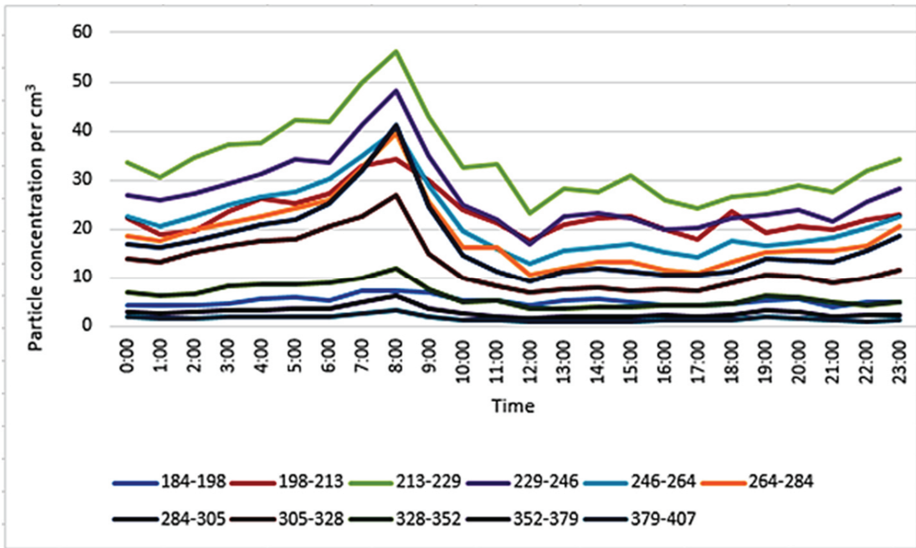

Figure 5 Avarage number of particles of individual fraction (per 24 hours)

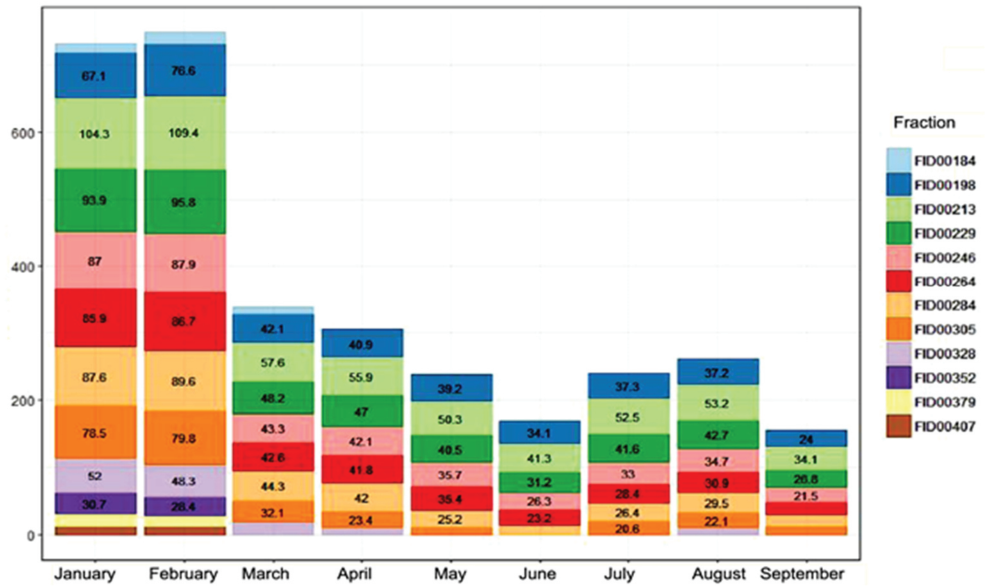

Figure 6 Average number of particles of individual fractions (January - Septembre, 2017)

The particles monitored by DiSCmini showed the increase of particle concentration during the monitoring interval with the average size of 42 - 43 nm. For comparison of these locations with high traffic density a background location inside the courtyard was chosen. The results show the dependence on the distance from the source of nanoparticles from traffic. At the background locality the average volume and number of particles was obviously lower, which confirms the dependence of the volume of particles on the distance from the source (**Figure 7**). The particles of this size are able to get into the pulmonary alveoli and could have a negative impact on human health (**Figure 8**), as has been declared by experts and their research [3].

a) b)

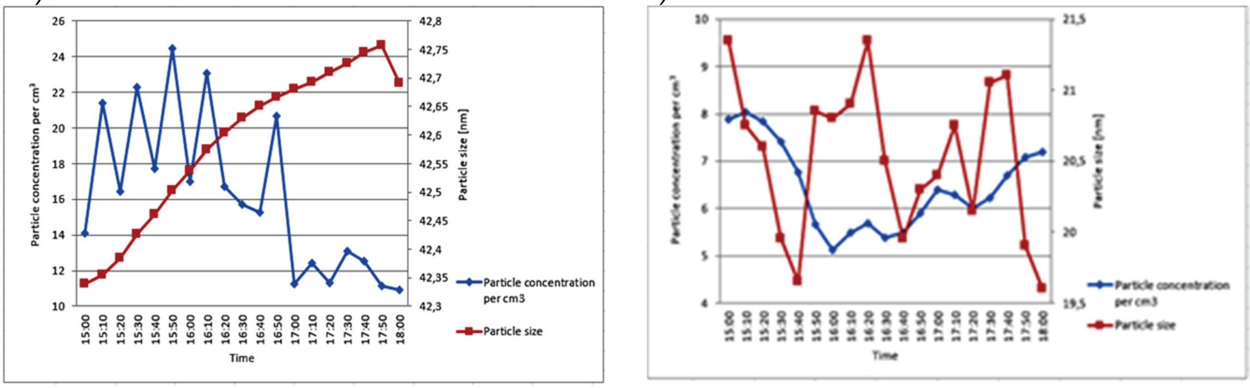

Figure 7 Size and quantity of particles in time a) traffic intersection, b) background locality

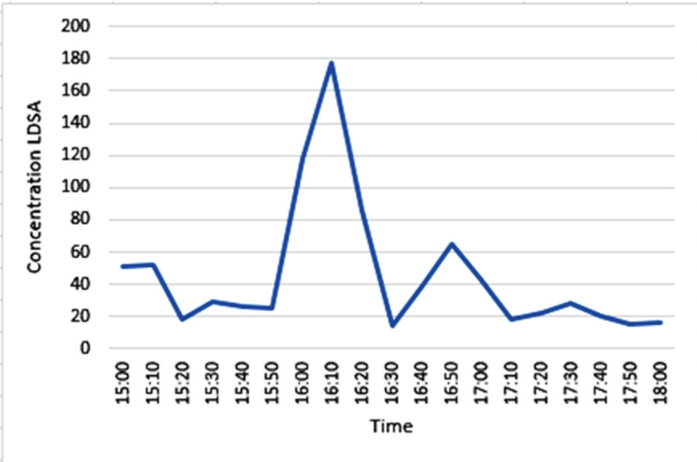

Figure 8 Lung deposited surface area

a) b)

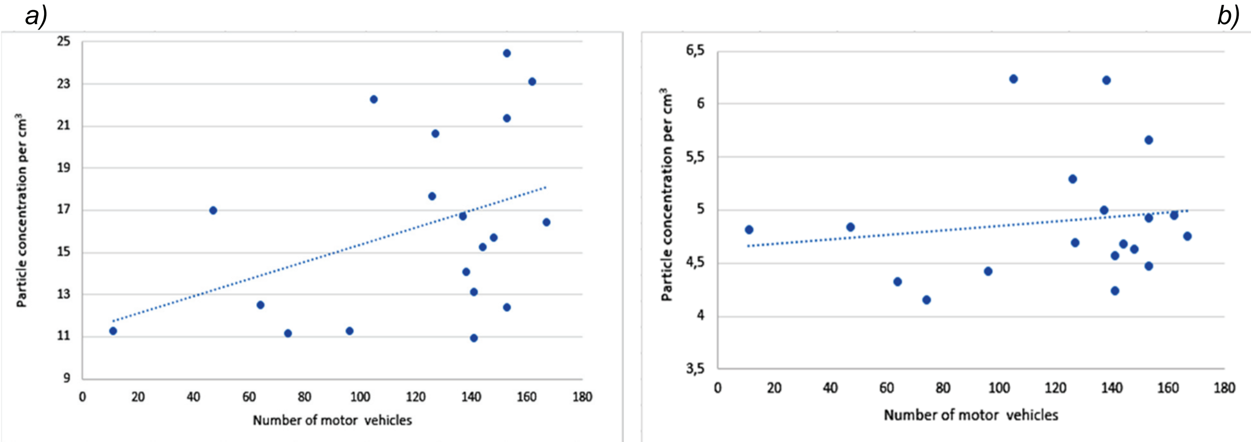

Figure 9 Particles denendence a) DiSCmini, b) FIDAS®200/200S

From dependence of particle concentration on the motor vehicles number (**Figure 9**) is appreciable the positive correlation (r= 0.3982), statistically significant at the level alpha = 0.05. Even when there's an obvious dominant influence of the traffic intensity, another influence like air temperature and humidity, type of engine (diesel/ petrol), motor vehicles speed (in case of traffic congestion deteriorative particle dispersion) or meteorological conditions also have an important role, how is demonstrate on **Figure 10**.

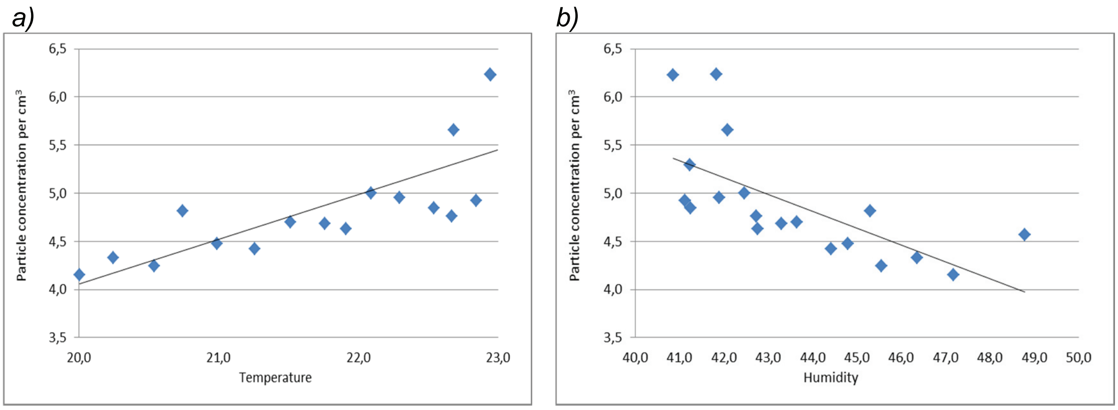

Figure 10 Particles denendence FIDAS®200/200S on temperature (a) and humidity (b)

4. CONCLUSION

Results of this study indicate the importance of nanoparticle monitoring. The increase of ultra-fine particles concentration with the traffic intensity is obvious from the correlation. However, it is important to take into account all other possible influential elements such as meteorological conditions, long-distance particle transport, other combustion devices or technical state of motor vehicles. Although these can have influence on the nanoparticles concentration, it can't be neglected that traffic is a significant source of air pollution. Due to this fact it is important to continue with further research and focus on this area, especially from the point of view of preventing and protecting the population's health and environment.

REFERENCES

[1] Kumar, P.; Morawska, L.; Birmili, W.; Paasonen, P.; Hu, M.; Kulmala, M.; Harrison, R.M.; Norford, L.; Britter, R. Ultrafine particles in cities. *Environ. Int*. 66, 2014. pp. 1-10.

[2] Brines, M.; Dall'Osto, M.; Beddows, D.C.S.; Harrison, R.M.; Gómez-Moreno, F.; Núñez, L.; Artíñano, B.; Costabile, F.; Gobbi, G.P.; Salimi, F.; et al. .Traffic and nucleation events as main sources of ultrafine particles in high-insolation developed world cities. *Atmos. Chem. Phys*. 15, 2015. pp. 5929-5945.

[3] GOEL, A., KUMAR, P. A review of fundamental drivers governing the emissions, dispersion and exposure to vehicle-emitted nanoparticles at signalised traffic intersections. *Atmospheric Environment* 97, 2014. pp. 316 - 331.

[4] Kukutschová J., Moravec P., Tomášek V., Matějka V., Smolík J., Schwarz J., Seidlerová J., Šafářová K., Filip P. On airborne nano/micro-sized wear particles released from low-metallic automotive brakes. Environmental Pollution, 159 (4), 2011. pp. 998-1006.

[5] Newby D.E., Mannucci P.M., Tell G.S., Baccarelli A.A., Brook R.D., Donaldson K., Forastiere F., Franchini M., Franco O.H., Graham I., et al. Expert position paper on air pollution and cardiovascular disease. *Eur. Heart J.* 2015, 36. pp. 83-93.

[6] VAL, S.; MARTINN, L.; CACHIER, H.; YAHYAOUI, A.; MAFRAING, H.; BAEZA-SQUIBAN, A. Role of size and composition of traffic and agricultural aerosols in the molecular responses triggered in airway epithelial cells. *Inhal Toxicol*. 2011, 23 (11). pp. 627-40

[7] Bos, I.; Jacobs, L.; Nawrot, T.S. et al. No exercise-induced increase in serum BDNF after cycling near a major traffic road. *Neurosci. Lett*. 500, 2011. pp. 129 - 132.

[8] Holmes, N.S., Morawska, L., Mengersen, K., Jayaratne, E. Spatial distribution of submicrometre particles and CO in an urban microscale environment. *Atmos. Environ*. 39, 2005. pp. 3977 - 3988.

[9] Wang, Y., Zhu, Y., Salinas, R., Ramirez, D., Karnae, S., John, K. Roadside measurements of ultrafine particles at a busy urban intersection. *J. Air & Waste Manag. Assoc*. 58, 2008. pp. 1449 - 1457.

[10] Mapy.cz. Křižovatka Údolní. [online]. ©seznam.cz, ©OpenStreetMap. [cit. 2017-09-08]. www.mapy.cz.