MASS SPECTROMETRY OF NANOPARTICLES

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Abstract

Nanoparticles with diameters from 10 nm to 1000 nm were analyzed using the scanning mobility particle sizer (SMPS) continuously from October 2020 till May 2021. Mass spectrometry was performed in 129 channels. Measurements of some other air pollution parameters were used for comparison and analysis. A large number of nanoparticles was detected in the period of strong air pollution, as expected. However, a surprisingly large number of nanoparticles was detected in spring and summer, where other parameters of air pollution were good.

Keywords: SMPS; nanoparticles; air pollution; mass spectrometry.

1. Introduction

Although there are several definitions of nanoparticles, we can accept the definition of the European Commission: “A natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm - 100 nm.” [1]. Similarly, ultrafine particles (UFP) are defined as aerosols with an aerodynamic diameter of 100 nm or less. In the context of air pollution by particulate matter, nanoparticles represent smallest of all particles. Detection of nanoparticles is difficult due to their physical properties.

But it is very important to analyze nanoparticles because they may have a serious effect on health [2], may even be used as drugs [3], or may have a role in COVID-19 transmission [4]-[6]. The importance of research of nanoparticles is recognized in the latest World Health Organization’s Global Air Quality Guidelines [7]. Some of the previous studies include a comparison of nanoparticle monitoring instruments [8], [9], characterization of nanoparticles in aerosolized photocatalytic and regular cement [10], systems of monitoring airborne nanoparticles [11], and development of a new nanoparticle sizer [12]. Novelty in this research is long-term continuous monitoring of nanoparticles in an urban environment with periods of strong and mild air pollution.

2. Scanning Mobility Particle Sizer

A mass spectrometer of nanoparticles called SMPS (Scanning Mobility Particle Sizer) was used at the Laboratory for physical measurements of the Faculty of Mechanical Engineering in Sarajevo, which is focused on tropospheric and air quality research [13]-[21]. Figure 1 shows three major components of SMPS:

- X-ray charge conditioner,
- differential mobility analyzer (DMA),
- condensation particle counter (CPC).

The system is configured with long DMA (10 nm – 1000 nm) and counts the nanoparticles in 129 channels using alternating upscans and downscans. Each scan takes about 6 minutes [20]. Before entering the charge conditioner, ambient air is dried using an in-house developed diffusion dryer.

Fig. 1. The Grimm SMPS.

3. Results

Daily average concentrations of nanoparticles in the period 26.10.2020. - 28.5.2021. are shown in Figure 2.

Fig. 2. Concentration of nanoparticles.

A high concentration of nanoparticles during the domestic heating season is expected. Measurement for three months period from December 2020 until February 2021 gave the average value of 15.62 billion nanoparticles per m^3 of air. However, a relatively high concentration was recorded even in May 2021: 8.91 billion nanoparticles per m^3 of air. We should note that the air in May 2021 was 'clean' in Sarajevo, based on $\text{PM}_{2.5}$ measurements, with the monthly average concentration of $\text{PM}_{2.5}$ $8.0 \mu\text{g}/\text{m}^3$. This may be explained using different sources of nanoparticles, some of which are frictional brakes on vehicles, but it must be investigated further before conclusions.

Figure 3 shows mass spectrometry of nanoparticles, where we can see a peak around 100 nm, but a large number of particles is present in the entire 10 nm – 100 nm range. The time evolution of nanoparticles is given in Figure 4. Hourly average values of particle concentrations were calculated and plotted against time and diameter (on a logarithmic scale). Local peaks are usually around 100 nm, but sometimes they appear for even smaller nanoparticles.

Fig. 3. Mass spectrometry of nanoparticles for entire period.

Fig. 4. Distribution of nanoparticles from 11.2.2021 until 21.02.2021.

4. Conclusion

The long-term campaign of mass spectrometry of nanoparticles from 10 nm to 1000 nm was performed. The largest number concentration belongs to particles around 100 nm in diameter, although a significant number of smaller particles (10 nm – 100 nm) exist most of the time. During the period of strong air pollution (December 2020 - February 2021) the number of nanoparticles was high, on average 15.62 billion nanoparticles per m³ of air. However, a surprisingly large number of nanoparticles was measured in May 2021, 8.91 billion nanoparticles per m³ of air, even though the air was considered clean, based on PM_{2.5} concentrations (only 8 mg/m³). This discovery, that a large number of nanoparticles may be present even at low pollution levels, is very important and should be clarified in the future.

5. References

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