Basamatikum - Combined Wide Size Range Aerosol Spectromeeter

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BASAMATIKUM - COMBINED WIDE SIZE RANGE AEROSOL SPECTROMETER

Jakub ONDRÁČEK, Ludmila MAŠKOVÁ, Jiří SMOLÍK

Laboratory of Aerosol Chemistry and Physics, ICPF AS CR, v.v.i., Prague, ondracek@icpf.cas.cz

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SUMMARY

Combined wide size range aerosol spectrometer Basamatikum allows to measure particle number size distribution in a range between 20 nm – 20 μm. The instrument separates the measured aerosol particles into 58 size bins. The instrument can automatically switch the scanning between two sampling points (e.g. indoors and outdoors). It consists basically from two aerosol spectrometers (UFPM and APS), electrically actuated ball valve, sampling tubing with isokinetic subsampling to both of the two spectrometers and two sampling lines. The overall control, data logging and saving to file, the switching between sampling lines and the user interface is provided by the means of the LACP-made (Laboratory of Aerosol Chemistry and Physics) software in LabVIEW programming environment.

INTRODUCTION

Big part of the research studies in the field of aerosol science is focused on the measurements of indoor environment, because people spend most of their daily time indoors (e.g. Kousa et al., 2002). The indoor aerosol particles are of major importance not only because of the inverse health effects (e.g. Pope and Dockery, 1999), but also because of the negative effects on indoor environment itself and eventually also on cultural heritage (e.g. Hatchfield 2002). Indoor air is generally affected by both indoor and outdoor sources (e.g. Raunemaa et al., 1989). The outdoor aerosol concentration depends on numerous factors like source emissions, ambient weather conditions, various removal processes, etc. (Hussein et al., 2006; Narumi et al., 2009). On the other hand, the indoor aerosol concentration is affected by outdoor concentration, factors influencing the indoor-to-outdoor relationship (such as ventilation rate, penetration factor, etc.), indoor emissions and removal processes (deposition of particles on inner surfaces) (e.g. Nazaroff, 2004).

Therefore, there is an increasing need to measure the aerosol concentration both indoors and outdoors at once (or at least with reasonable time gap between indoor and outdoor measurement). The other demand, especially when such an instrument is placed indoors, where the inhabitants or employees reside, is often a limitation for the instrument to not bring any additional discomfort to indoor air (alcohol odors, radioactive source, etc.). At the same time we usually need to obtain information in quite a wide range of particle sizes. All these circumstances brought us to idea to combine the two commercially available aerosol spectrometers and a switching valve to form one measurement instrument allowing easy measurements of indoor/outdoor environments.

INSTRUMENT SET-UP

As mentioned earlier, the Basamatikum spectrometer (see Fig. 1) consists of two commercially available aerosol spectrometers UFPM 3031 and APS 3321 (both TSI). More detailed description of the operating principle of both instruments is given in following paragraphs.

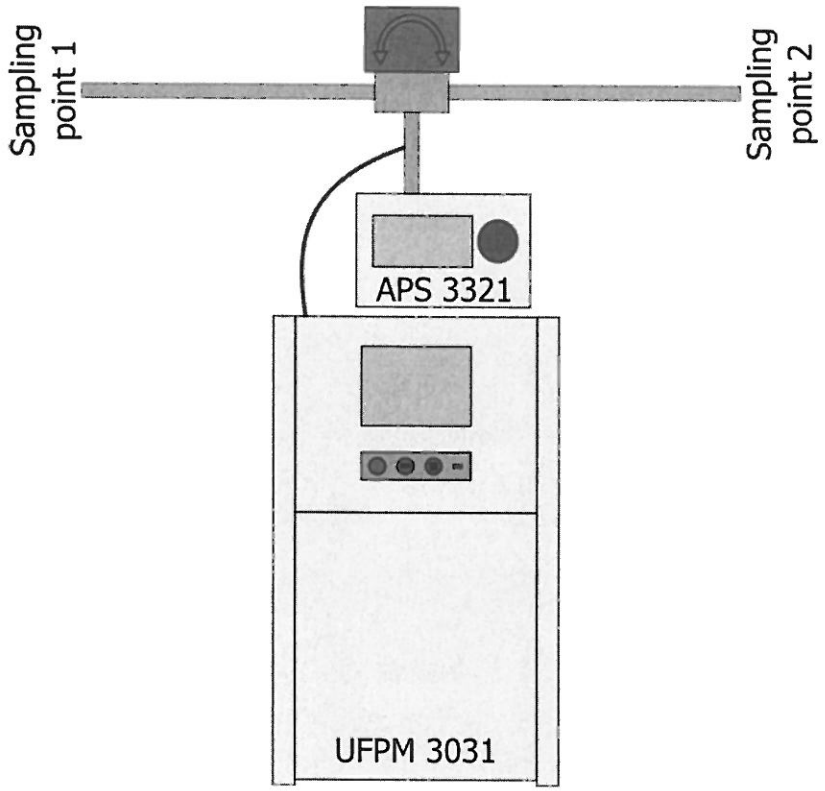

Fig. 1: Schematics of Basamatikum spectrometer.

The UFPM spectrometer (UltraFine Particle Monitor, TSI, model 3031) measures the size distribution of aerosol particles in the size range 20 – 1000 nm, where the upper limit depends on the type of the inlet (using cyclone it is 450 nm, using the special environmental sampling system it is 850 nm and without any inlet it reaches about 1000 nm). The size distribution is measured in 6 size bins (20-30 nm, 30-50 nm, 50-70 nm, 70-100 nm, 100-200 nm and > 200 nm). The resulting quantity is then the number of particles measured in these individual size bins. The spectrometer itself consists of three basic parts: diffusion charger, DMA (Differential Mobility Analyzer) and very sensitive electrometer. The aerosol sample travels first through the cyclone or other inlet, where the large particles are deposited to prevent the contamination of the instrument and make the data evaluation easier. The aerosol particles, which passed through the inlet, continue to the equalization tank, where the short term fluctuations in the aerosol concentration can be smoothed out. From the equalization tank the particles flow across the diffusion charger (unipolar corona charger), where they are positively charged. The charged particles are then selected in the electrostatic field of the DMA (the inner rod has negative charge) based on their mobility in the electrostatic field. The particles selected in the DMA are at the end collected by a conductive filter. The current imparted by the particles is then measured and is proportional to the particle concentration (based on calibration). Scanning among individual size bins is performed by changing the voltage applied on the inner rod of the DMA.

After going through all the size bins, the resulting data are displayed as a number concentration in individual size bins. (Detailed description is available in the manual of UltraFine Particle Monitor 3031, TSI).

The APS spectrometer (Aerodynamic Particle Sizer, TSI, model 3321) is able to measure the size distribution of the aerosol particles in the range 0.5 – 20 microns. The resolution of the APS spectrometer is 32 size bins per decade, in other words it means 52 size bins in total. This spectrometer measures the size of the particles based on their inertia. The stream of the air containing aerosol particles is first accelerated in a nozzle (acceleration higher than 10^6 m/s^2). The aerosol particles are separated in such a way based on their aerodynamic properties (the smaller is the aerodynamic diameter of the particle the higher is the final speed). Two parallel laser beams are positioned (about 100 ?m apart) just below the accelerating nozzle and consequently the time of flight of the particle between these two laser beams is measured. The measured time is then directly proportional to the particle aerodynamic diameter. The particles are continuously sized in this way and also the number of particles in individual size bins is counted. The results are again being evaluated as a number of particles in individual size bins. (Detailed description is available in the manual of Aerodynamic Particle Sizer 3321, TSI).

The electrically actuated ball valve switches between two sampling points in defined time intervals (usually correlating with sampling time of the two spectrometers). The control system of the valve takes care of the timing and is able to monitor the current position of the valve.

The sampling tubing is made out of stainless steel, having inner diameter of 1" and appropriate length (depending on the sampling conditions). Both sampling lines have the same length in order to have the same losses of particles. This assumption makes the final evaluation easier – resulting in neglecting the losses in sampling tubing, when evaluating the indoor/outdoor ratio. The subsampling to both aerosol spectrometers was designed to fulfill isokinetic conditions.

The LabVIEW code controls the whole measurement system, logs the measured data into files and controls the valve switching and the overall timing of the measurement. Regarding the control of the two spectrometers, only the APS spectrometer is fully controlled. The internal software of the UFPM spectrometer does not allow the control of the instrument in the current version. So the controlling software monitors only the measured values from the UFPM and logs them into the file. The controlling code recalculates automatically (based on user settings) between various available concentration units (raw counts, concentration and dN/dlog(dp)) and also between the APS diameter units (aerodynamic to mobility).

All the parts of the Basamatikum spectrometer are mounted into the wheel rack to allow easier manipulation with the whole instrument.

RESULTS

The combined spectrometer Basamatikum was utilized during indoor/outdoor measurement campaigns focused on the monitoring of the air quality in four archives in the Czech Republic, which are representing four different outdoor environments: Zlatá Koruna (rural), Třeboň (small city with seasonal tourism), Teplice (industrial area), and Prague (large city with traffic). This project was aimed mainly to investigate the concentration and sources of PM and gaseous pollutants in the indoor environment of the archives. The presented instrument was used in part of the measurement campaigns to monitor the indoor/outdoor particle number concentration and to evaluate the indoor-to-outdoor relationship. Because this contribution is

not aimed to evaluate the measured data, but to present a new instrument, there are no data results shown here. More detailed presentation of the measured data can be seen for example in Mašková and Smolík, 2013.

CONCLUSIONS

A new combined wide size range aerosol spectrometer was developed. The instrument was thoroughly tested during several intensive campaigns (almost one year of continuous measurement in Zlatá koruna, 4 two-week campaigns in Teplice and 4 two-week campaigns in Prague). Small issue connected with the charging in the UFPM spectrometers can be easily neglected, when we take into account that the primary purpose of the combined instrument is to evaluate the ratio between the two measurement places. Generally, the overall performance of the instrument was satisfactory and the whole instrument is suitable for deployment for a long term unattended operation. In the near future, some small improvements will be made in regards to control software as well as to solve the overall control of the UFPM.

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