8.10.2018

White Paper Pegasor AQ Urban™

What needs to be measured from outdoor air?

Today legislative measurements from outdoor air are based on mass. TSP (mass of Total Suspended Particles, PM10 (mass of particles below 10 microns in size), PM2.5 (mass of particles below 2.5 microns in size). Devices to measure these quantities include among others filter PM mass measurement, Optical scattering devices, TEOM (Tapered Element Oscillating Micro Balance) and beta attenuation monitor (Beta Gauge). None of these techniques are sensitive to ultrafine particles that correlate with the harmful health effects. The measurement instrument must be sensitive to ultrafine particles in order to measure Lung Deposited Surface Area of Particles (LDSA), quantity used quite often today to describe adverse health effects of ultrafine particles.
It is quite well understood that mass of particles does not correlate well with the adverse health effects of particles but since measurement legislation is slow to change, mass measurement will continue during the years to come. Some countries like Canada, Hong Kong, Mainland China, India, Mexico, United States, United Kingdom and even Europe have established Air Quality Indexes or similar to better correlate air quality with health effects.
It is known that PM1 (mass of particles below one micron in size), PN (total particle number concentration), Particle Surface Area (PA) or LDSA better correlate with the harmful effects of particle pollution than TSP, PM10 or PM2.5. Most of the particles that contribute to the PN PA and LDSA come from combustion sources such as vehicle engine, wood combustion, cooking and remote combustion sources. Ultrafine particles produced in combustion remain airborne for very long time and can travel hundreds of kilometers away from the initial source.
Advanced organizations and universities have started to measure PN and LDSA in outdoor air. Devices used to measure PN and LDSA are typically expensive, complex to use, require separate air-conditioned container, need consumables and fair amount of user attention. Devices that can be used to measure PN and LDSA must be sensitive to ultrafine particles. Such devices are Condensation Particle Counters (CPC). CPC in combination with a Diffusion Mobility Particle Sizer (DMPS) enables the user to measure LDSA. Pegasor AQ Urban™ can be used to measure PN and LDSA with one single unit. This paper describes the benefits of Pegasor AQ Urban™ in outdoor air measurement.

Pegasor AQ Urban™

Operation principle

The operation of Pegasor AQ Urban™ sensor with PPS-M inside is based on electrical detection of aerosol following the “escaping current” technique, which was first described by Lehtimäki [1]. A sample of the outdoor air gas is charged by a corona-ionized flow as it is being pumped by an ejector diluter built in the sensor's construction. While the majority of the corona ions return to the grounded sensor's body due to their high electrical mobility, a small quantity is lost with the charged particles exiting the sensor. This “escaping current” is a measurement of the particle concentration in the outdoor air. The sensor responds to particle size and concentration with a function that lies between the response to PN, PA, LDSA and PM [2, 3]. Pegasor AQ Urban operation principle is shown in fig. 1, PPS-M sensor is shown in fig. 2, which forms the core of Pegasor AQ Urban™ (fig.3.).

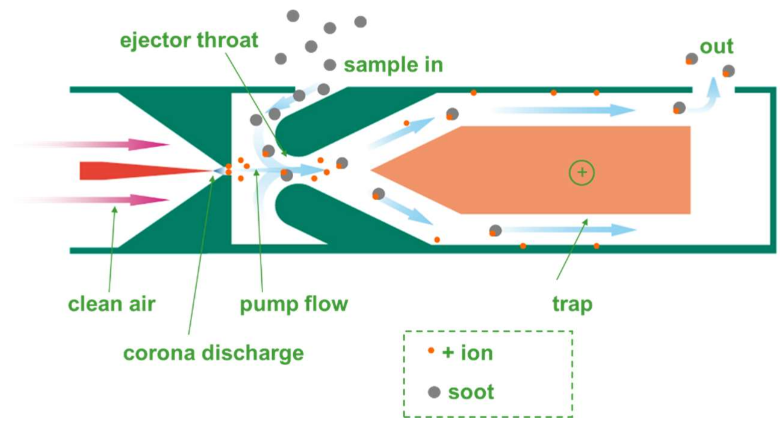

Fig. 1. *Schematics of Pegasor Particle Sensor PPS-M, which is inside Pegasor AQ Urban™ sensor.*

Fig. 2. *PPS-M sensor which forms the core of Pegasor AQ Urban™*

Fig. 3. *Pegasor AQ Urban™ in operation.*

Pegasor AQ Urban™ features the world's fastest ultrafine particle measurement measurement technique. Pegasor AQ Urban™ provides the user simultaneously total ultrafine PM and ultrafine PN and LDSA concentrations in real time from 10 nm and up. Pegasor AQ Urban™ is a non-collective, flow through device which enables it to work continuously without maintenance for extended periods of time. Additionally Pegasor AQ Urban™ has so called modulating trap electrode, which provides the sensor data analysis size information making data calculation for all three measured quantities very exact.

Pegasor AQ Urban™ needs no container to protect and condition the sensor. Sensor can be installed for example in a light or traffic light pole at a height that eliminates vandalism to the sensor. Typically installation height of 3-4 meters is enough. Pegasor AQ Urban™ heats the measured sample to 40 °C above ambient thus enabling the sensor to measure in 100% Relative Humidity (RH) conditions. Sampling is also wind, snow and rain protected. Therefore Pegasor AQ Urban™ provides data in all weather conditions. Pegasor AQ Urban™ needs no complex sampling trains designed to separate water from the sample or stabilizing the sample flow. Pegasor AQ Urban™ has no consumables. The most important features and benefits are given below.

Features

- Data averaging from 3 s up to 4,7 h.
- Total ultrafine particle mass, total ultrafine particle number, total particle surface area and LDS measurement simultaneously from 10 nm and up
- modulating trap voltage providing size information to the sensor for data calculation.
- No sample conditioning needed
- Flow through design
- Very low maintenance need

Benefits

Pegasor AQ Urban™ has no consumables. Periodic cleaning of the insulators is enough when sensor is used according to instructions. Annual or biannual sensor calibration at manufacturer's site is provided for Q&A purposes when needed.
Pegasor AQ Urban™ has extensive self-diagnostics to ensure correct measurement results at all times. Sensor informs the user when cleaning of the sensor is necessary (10 x before the contamination has any effect on the result). Additionally, all critical parameters (corona current, corona voltage, impedance and trap voltage) can be recorded on the data file with alarm function attached, if out of set range.

Specifications

- Sensor temperature always 40 °C above ambient eliminating moisture effects
- Extracted sample temperature can be from -40 °C up to 45 °C
- No additional sample conditioning needed besides sample heating
- Time response 3 s – 4,7 h
- Measured ultrafine particle size range adjustable from 10 nm and up
- Trap voltage adjustable using Plotter software. Trap voltage determines the lower cut size of the sensor (10 nm, 23 nm or other up to 90 nm)
- Concentration range for particle number 1000 1/cm^3 up to 100*10^6 1/cm^3
- Concentration range for particle mass 1 µg/m^3 up to 100 mg/m^3
- Dimensions 320 mm x 250 mm x 1000 mm, weight 20 kg
- Clean air/Nitrogen supply 9 LPM @ 0,1 bar overpressure
- Data acquisition GUI (laptop, PPS Plotter software), Modbus over Ethernet, wireless 3G/4G modem
- Operating voltage 85-264 VAC
- Continuously self-diagnosed for trap voltage, corona voltage, corona current, electronics temperature, and sensor impedance (correlates to sensor loading)

Pegasor AQ Urban™ Strengths

Pegasor AQ Urban™ has been designed for affordable aerosol concentration measurement from remote location to densely populated urban area. Competing devices are typically labor consuming and require frequent service and plenty of consumables/user attention. Pegasor AQ Urban™ is measuring well defined aerosol concentration with no interference nor material dependence in the aerosol itself. E.g. filter measurement of urban outdoor air PM concentration can sometimes be problematic because used filter media may react with gaseous compounds contained in the outdoor air.
Pegasor AQ Urban has so called modulating trap function. This function provides particle size information for data calculation thus getting very exact concentration data for all measured quantities.

Measurement Data

LDSA can be measured by Pegasor AQ Urban and for example with DMPS (Differential Mobility Particle Sizer). One study from March 13th until September 3rd, 2017 compared LDSA concentrations measured by Pegasor AQ Urban™ and DMPS. One hour averages from both instruments were plotted in one graph (Fig.5). Correlation between the two instruments was 95%.

Pegasor AQ Urban™ has been extensively used and studied in Helsinki, the capital of Finland. Helsinki has total of ten Pegasor AQ Urban™ sensors around the city. Some in rural area, some on the side of busy roads and some on the side of main highways. Highest LDSA concentrations were measured on the side of busy roads and in rural areas during times when temperature was low and wind conditions were mild. Household wood heating produced a lot of ultrafine particles which remained still in the rural area.

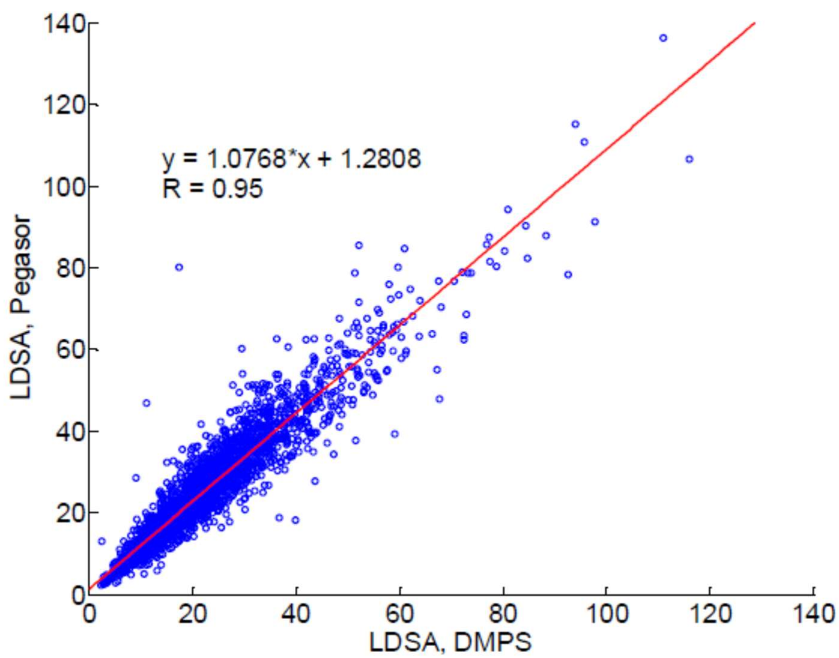

Fig 5. *Comparison between Pegasor AQ Urban™ and DMPS showed 95% correlation between the two instruments. Data courtesy of HSY/ Anssi Julkunen, Harri Portin*

LDSA measured by Pegasor AQ Urban™ on January 20th, 2018 as a function of day time is shown in fig. 6. It is a cold winter day in Finland. High LDSA events do correlate sometimes with for example NOx (Nitrogen Oxides, source traffic) or CO (Carbon Monoxide, source incomplete combustion). Data from these sensors can be used to identify sources of LDSA measured by Pegasor AQ Urban™.

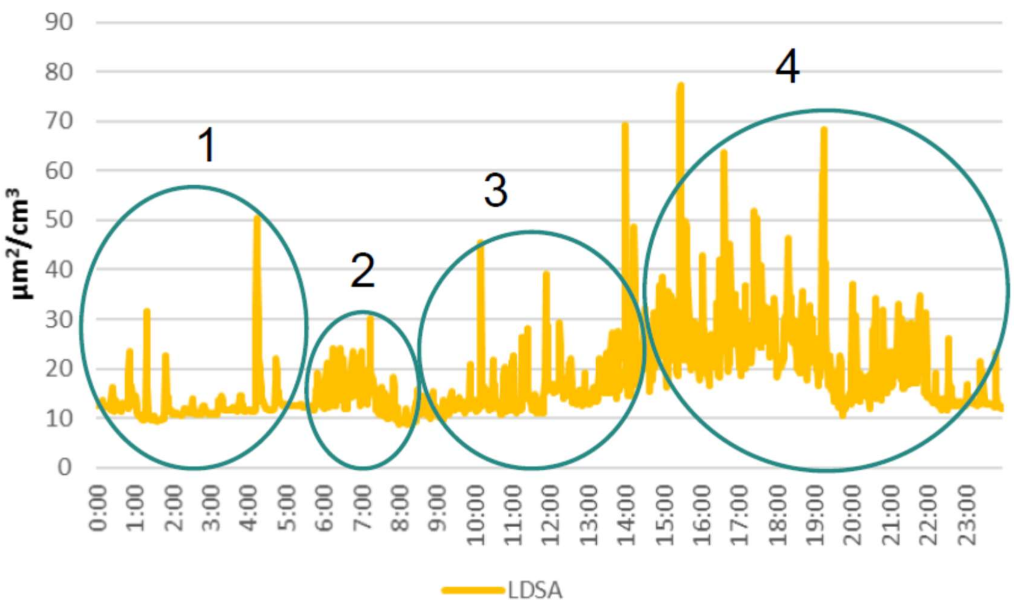

Fig.6. *LDSA as a function of daytime hours. Four high concentration events are identified. Number 1 during the night had also high NOx concentration. Source most likely traffic. Night time busses. Event number 2 had high CO. Source most likely incomplete wood combustion from household heating. Event number 3 had also high NOx. Source most likely daytime traffic activities. Event number 4 had high CO, source incomplete wood combustion. LDSA from all these events is recorded by one single Pegasor AQ Urban™ sensor. Data courtesy of HSY/ Anssi Julkunen, Harri Portin*

In fig. 7 Pegasor AQ Urban™ data is shown together with CO data. Correlation is clear in case of incomplete wood combustion.

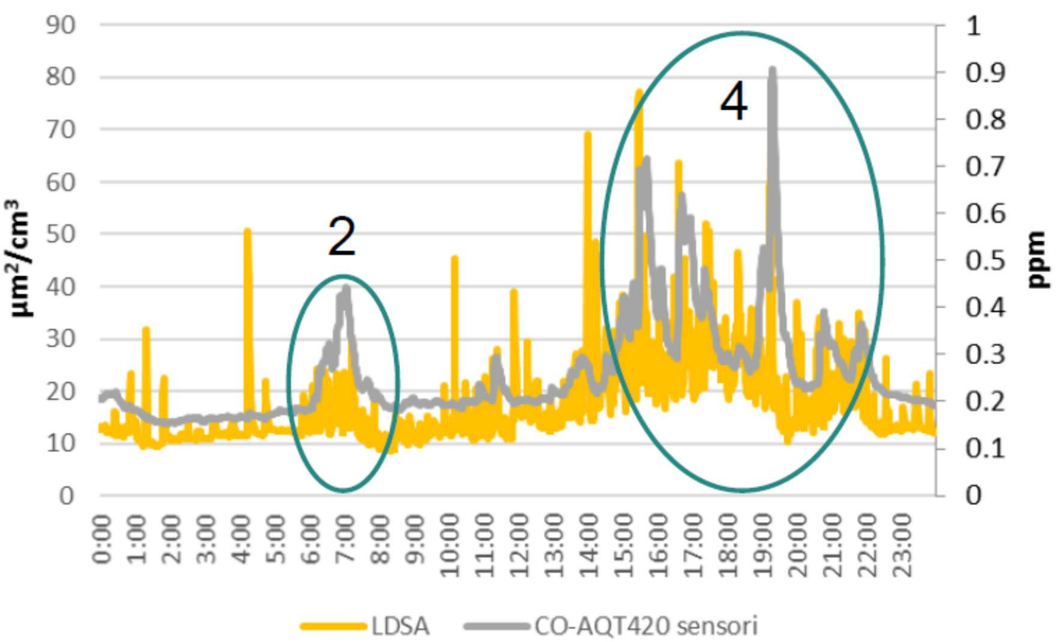

Fig.7. *LDSA and CO concentration as a function of daytime. High CO concentration is an indication of incomplete combustion. This happens in circles 2 and 4. LDSA and CO have relatively good correlation in case of incomplete wood combustion. Data courtesy of HSY/ Anssi Julkunen, Harri Portin*

Summary

Pegasor AQ Urban™ offers world’s fastest ultrafine particle concentration measurement as well as LDSA measurement. Pegasor AQ Urban measures ultrafine particle number concentration, ultrafine particle surface area, LDSA and ultrafine particle mass concentration and LDSA simultaneously from 10 nanometers and up.

Pegasor AQ Urban™ does not require any external sample conditioning. Sample taken to the Pegasor AQ Urban™ sensor is heated 40 °C above ambient thus eliminating effects of water and allowing measurements to be done up to 100% relative humidity.

Pegasor AQ Urban™ initialization is done by PPS Plotter graphical user interface. Sensor parameters are set with the software and transferred to sensor firmware when ready. PPS Plotter can also be used to monitor and record data, if needed. Data is available via Modbus over Ethernet protocol and can be transferred via LAN or wireless networks (3G/4G modem, radio modem etc.). Pegasor AQ Urban™ has extensive self-diagnosis and it informs the user on service any action needed to keep the sensor data reliable and accurate.

Scientific Publications

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- M. Besch et al., (2011), 'Assessment of novel in-line particulate matter sensor with respect to OBD and emissions control applications', Proceedings of the ASME 2011 Internal Combustion Engine Division Fall Technical Conference, ICEF2011 October 2-5, 2011, Morgantown, West Virginia, USA, ICEF2011-60142.
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- F. Gensdarmes et al., (2011), ‘Evaluation of Pegasor PPS Response Time for Real Time Aerosol Concentration Measurements’, EAC 2011, September 4-9, 2011, Manchester, UK.
- L. Ntziachristos et al. (2012), ‘Mass Calibration of a Novel PM Sensor’, 22nd CRC Real World Emissions Workshop, March 25-28, 2012, San Diego, USA.
- M. Besch et al., (2012), ‘On-Road Particle Matter Emissions Assessment from a Compliant HD Diesel Truck While Driving Across the US’, 22nd CRC Real World Emissions Workshop, March 25-28, 2012, San Diego, USA.
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[3]. Rostedt, Antti et al. "Characterization and response model of the PPS-M aerosol sensor". In: Aerosol Science and Technology 48.10 (2014), pp. 1022–1030.

Notes