

Dekati Ltd Application Note

ELPI IN AIR QUALITY MEASUREMENTS

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Introduction

ELPI™ (Electrical Low Pressure Impactor) measures particle size distribution and concentration in real-time. The operation principle is based on particle charging, size classification in an inertial low-pressure impactor, and current measurement with a sensitive multi-channel electrometer.

One of ELPIs main applications is ambient air studies. In fact, a modified version of the standard ELPI™ has been developed specially for outdoor air measurements. This version of the ELPI™ is called Outdoor Air ELPI™, and it has been used in numerous air quality studies for determining particle concentrations in different environments. This paper describes the use of ELPI™ and Outdoor Air ELPI™ in measuring ambient air particle size distributions and concentrations.

- 30nm - 10µm (7nm-10µm with filter stage).
- 30lpm (improved sensitivity)
- automatic recovery from power failures
- independent operation. Stored data can be retrieved from the unit using a USB port.
- integrated humidity and temperature sensor



Figure 1. Outdoor Air ELPI™.

ELPI™ configuration

ELPI™ instruments are provided with two different sample flow rates; 10 lpm or 30 lpm. The 10 lpm ELPI™ is designed for high concentration measurements whereas the 30 lpm is mostly used in low concentration measurements. For ambient air measurements, the 30 lpm version is recommended. The Outdoor Air ELPI™ version has additional features that are useful especially in air quality measurements. These features include temperature and humidity measurements, automatic recovery from power failures and user set data save and zeroing intervals.

Outdoor Air ELPI™ can be operated with or without an external computer running the ELPIVI measurement software. The data is in both cases saved in the ELPI™ internal computer and can be downloaded with the USB drive located in the ELPI™ front panel. If the external computer is used to run ELPIVI, the data is also saved in that computer.

Optional accessories for ambient air studies

Sintered collection plates

Standard ELPI™ collection plates are made of stainless steel, and aluminium or polycarbonate foils should be used on them. The recommended maximum load of particles per one impactor stage is 1 mg. This value can vary depending on the particle type.

Sintered collection plates (IA-211) are used to make longer measurements without the need to clean the impactor. With sintered collection plates about 10 times more particles can be collected on one impactor stage making the cleaning interval of the collection plates longer, and enabling longer measurement periods. Chemical analysis cannot be performed on the sintered collection plates, nor can gravimetric analysis be done. More information on the sintered collection plates can be found in the Dekati Ltd. technical note: Sintered collection plates.

Filter stage

The standard ELPI™ measurement range is 30 nm – 10 µm. With the filter stage this measurement range can be extended down to 7 nm making the complete measurement range 7 nm – 10 µm. The filter stage is recommended for outdoor air measurements to enable detection of nuclei mode particles, and also to get more accurate mass readings. More information on the filter stage can be found in the Dekati Ltd. technical note: ELPI Filter Stage.

External Heating Assembly

ELPI™ temperature range is 0-40 °C. With the External heating assembly the ELPI™ impactor and charger can be heated up to 200 °C. In ambient air measurements heating is sometimes required if the ELPI™ results are compared e.g. to results from other methods that heat the sample up to about 50 °C. Heating the sample may transform the sample and if comparisons are made both instruments should be in the same temperature.

Polycarbonate and aluminium foils

Collection foils are recommended to be used on the impactor stages to make the impactor cleaning intervals longer and optimize the operation. Especially in ambient air measurements where long measurement periods are often preferred, greasing of the collection foils is also recommended. The greasing prevents bouncing of the particles. In normal ELPI™ measurements greased aluminium foils should be used - if chemical analyses are made, polycarbonate collection foils can be used instead. More information on the different foil options can be found in the Dekati Ltd. technical note: Substrates and filters for Dekati® impactors.

Pump

To operate the ELPI™, a vacuum pump is needed to pull the flow through the instrument. As a standard, Dekati provides oil lubricated vacuum pumps for this purpose. These pumps have proven to be efficient enough and reliable in operation. However, due to the operating principle of the pump, oil mist comes out of the pump exhaust. These oil mist particles can interfere with the ELPI™ results if these particles are lead close to the ELPI™ inlet. Oil mist filters can be used to remove these oil particles, but these filters often reduce the pumping efficiency of the pump. In this situation, the pump might not be efficient enough to run the ELPI™ any more. Another option is to direct the pump exhaust far enough from the sampling point to prevent it from having an effect on the results.

Dry pumps are also available in the market. However, these are often even 5-times more expensive than the oil pumps and therefore not normally provided with ELPIs. In ambient air measurements, however, dry pumps can in certain cases be recommended. When the concentrations are low, as in ambient air, the oil mist that comes out of the oil pump can have effect on the particle concentration detected by ELPI™. Of course the oil mist can be directed far away from the sampling point, but if this is not possible, then dry pumps are recommended.

Sampling

Wet and dry particle concentrations

Particles in ambient air consist of different types of compounds, of course depending on the source of the particles. Often these compounds are hygroscopic, which means that as the relative humidity of ambient air increases, the size of the particles increases. And thus the mass of the particles increases. This mass concentration of particles is called the wet concentration of particles.

Many of the reference methods' operating principles are based on measuring the dry concentration of particles. If ambient air mass concentration is measured with gravimetric methods (filter, impactor) or methods where particle sample is heated before it is measured (e.g. TEOM™), the humidity of particles is lost and dry concentration detected. If the relative humidity of air gets close to 100%, the difference between dry and wet particle mass concentrations can get as high as 100%, depending on the hygroscopic properties of the particles. In these cases, the measured dry and wet mass concentrations of particles can be very different.

Dekati® Dryer DD-600

Without a sample-conditioning unit, ELPI™ measures wet concentration of particles. ELPI™ operates in real-time so the water does not have time to evaporate, even in low-pressure impactor, before it is detected. This way the sample is measured as it is in ambient air. Traditionally this water has been removed from the particle sample after gravimetric collection by equilibration or heating of the sample. Both of these methods may also result in loss of other volatile components from the sample.

Dekati® Dryer DD-600 is a particle dryer designed to remove water in real-time from the aerosol sample in air quality measurements. The Dekati® Dryer only removes water from the sample, no volatile components are lost with this method. The operation of the Dekati® Dryer is based on a co-polymer Nafion® tube for removing humidity from the sample. The Dekati® Dryer has been specially designed to minimize particle losses and maximize drying efficiency. The sample flow rate through the dryer is 30 lpm, so it is suitable for use with the ELPI™. The needed amount of drying air is 6 lpm, alternatively vacuum can also be used for drying. In this setup the same vacuum pump that is used to operate the ELPI can also be used to produce the vacuum for the dryer operation.

When the sample dryer is used together with the ELPI™, the Dekati® Dryer Setup DD-601 can be used. The DD-601 setup includes all the needed connections from the dryer into a vacuum line, PM10 sampling inlet and the dryer unit.



Figure 2. Dekati® Dryer DD-600.

In case the DD-600 is not used, ELPI™ measures the wet concentration of particles. Also in this case a sample inlet should be used to prevent rain and e.g. insects getting inside the instrument. The whole ELPI™ must be placed in a rain-proof place, the operation temperature range of the ELPI™ is 0-40 °C. The operating conditions of the pump need also be taken into account.

Example data

ELPI™ has been used for ambient air studies in several institutes around the world. Below are given some examples of the data.

Figure 3 presents an example of data that has been measured with two Outdoor Air ELPI™ units. The figure also shows the reproducibility of two ELPI™ instruments. The data was measured in Pittsburgh during the EPA ETV –verification program and it shows the PM2.5 wet mass concentration measured by the ELPI™.

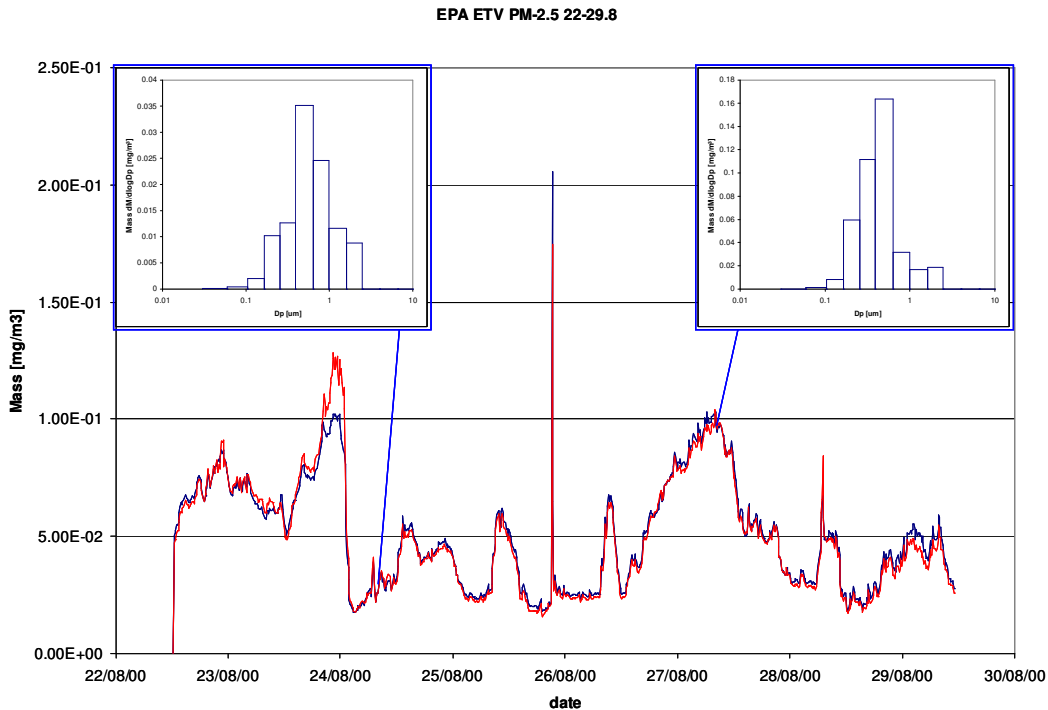


Figure 3. Example data measured with ELPI™.

Figure 4 shows more results from Pittsburgh. The graph shows PM2.5 mass result from an ELPI™ unit, and also the corresponding humidity measured with the humidity sensor inside the instrument. As can be seen, the mass concentration increases as the ambient air humidity increases; the need for a particle dryer is evident if dry concentration of particles needs to be measured.

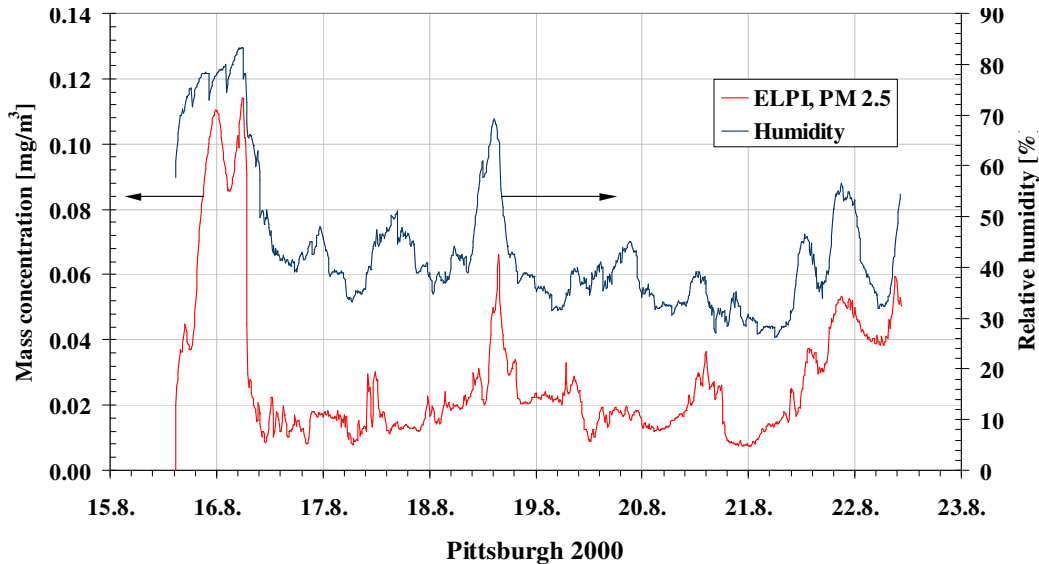


Figure 4. Example data on ELPI™; mass concentration and ambient air humidity.

Figure 5 shows particle mass size distributions measured with two Outdoor Air ELPI™ units in different ambient relative humidities (RH80, 65 and 50%), the other one equipped with the Dekati® Dryer DD-600, the other one sampling wet ambient aerosol. A clear difference between the two data sets is seen, and it is caused by water absorbed in the particles. A slight decrease in mass median diameter is also observed. The measurements were conducted in Cincinnati, Ohio USA.

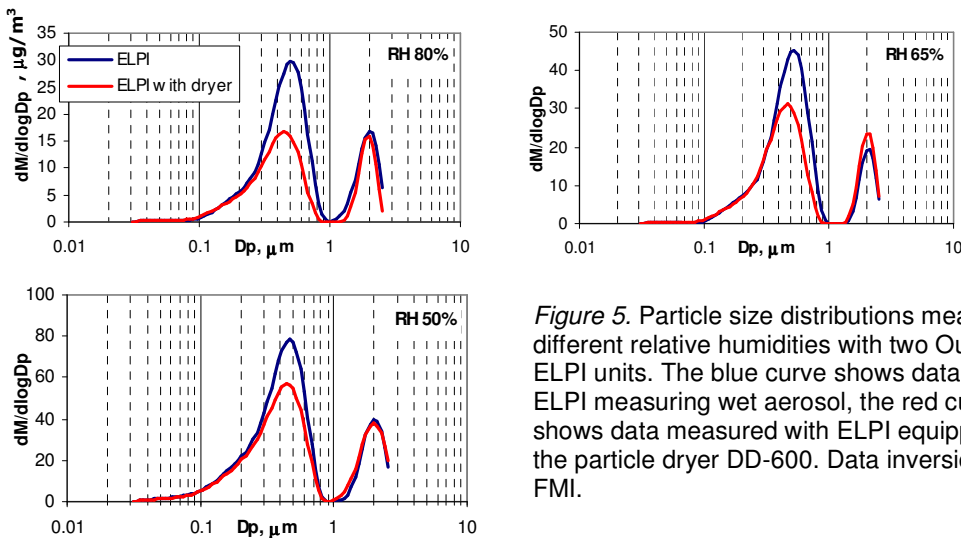


Figure 5. Particle size distributions measured in different relative humidities with two Outdoor Air ELPI units. The blue curve shows data from ELPI measuring wet aerosol, the red curve shows data measured with ELPI equipped with the particle dryer DD-600. Data inversion by FMI.

The Finnish Meteorological Institute has used the ELPI™ to measure ambient air particle concentration in the northern part of Finland, Lapland, where the particle concentrations are very low, about 200#/cc. The graph in Figure 6 shows data measured in Sevettijärvi measurement station in October 2001. ELPI™ shows good

correlation with CNC (Condensation Nucleus counter) for total particle number concentration. The spikes in CNC data were due to instrument malfunctions.

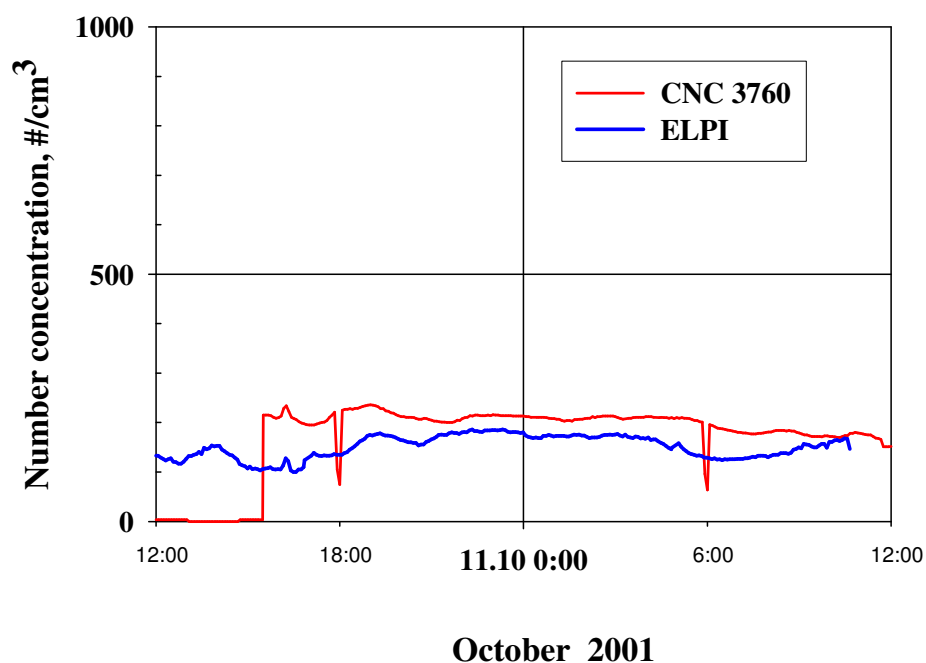


Figure 6. ELPITM vs. CNC data from Lapland

Discussion

Legislations for ambient air quality monitoring requires nowadays only monitoring of PM₁₀ and/or PM_{2.5} mass. Outdoor Air ELPITM measures much more than this; it measures PM₁₀ particle number concentration and PM_{2.5} mass concentration (with a suitable sampling system) in real-time, and also gives information on the size distribution every second. Since ELPITM is a collecting device, further analysis of the size classified particles can also be made.

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