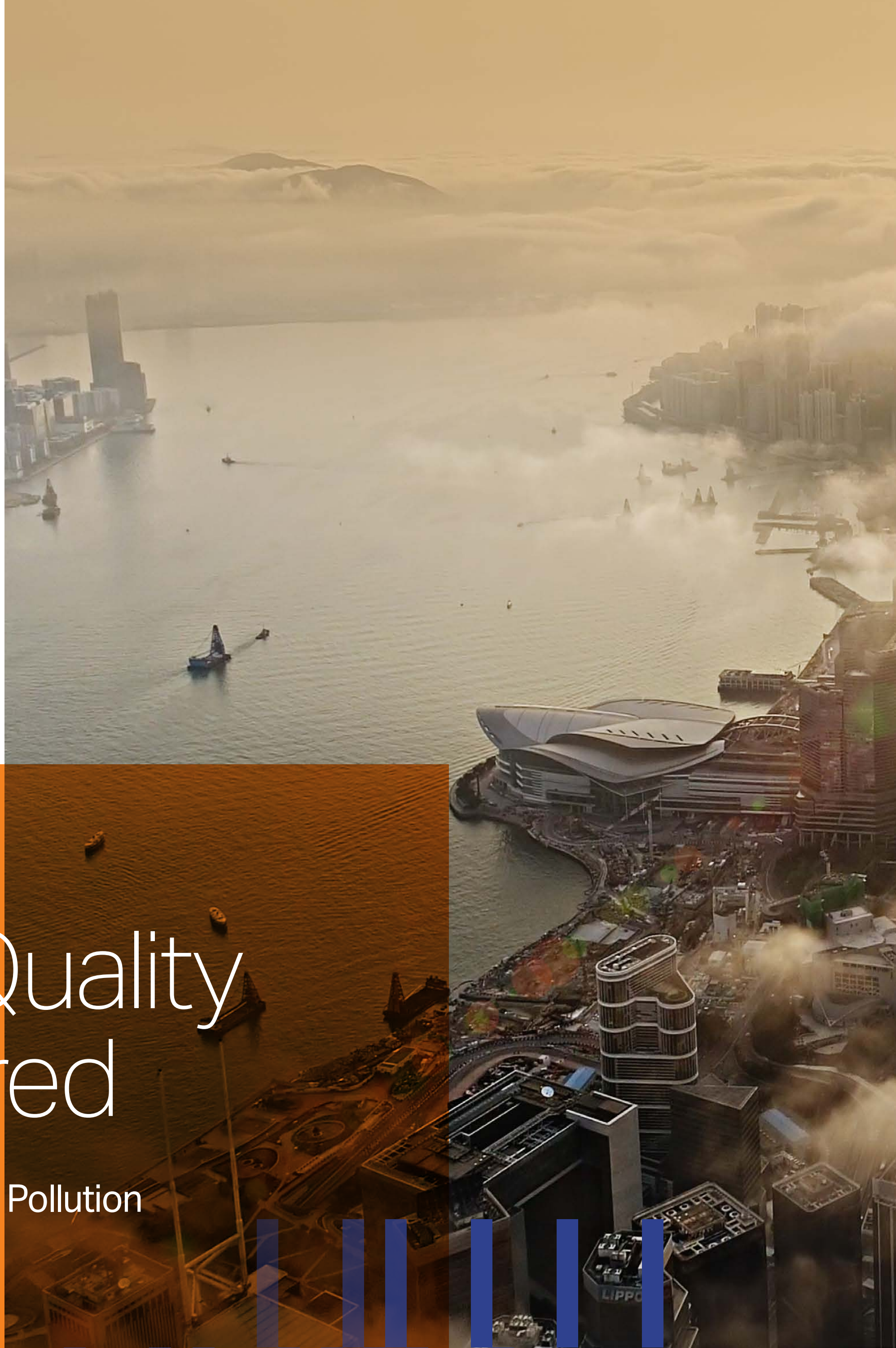
Knowledge Beyond Measure.



How Air Quality is Measured

Understanding Particulate Pollution

Mass, Number, and Size
Three Perspectives on Particles

Air pollution affects everyone. It's a multi-faceted problem, and there are many ways to measure it. Our white paper "Understanding Particulate Pollution: Why Air Quality Matters" describes the fundamentals of how and why air quality is monitored.

As a Brief Summary

- Mass-based measurements are usually expressed as micrograms of particulate matter per cubic meter of air. Mass concentrations are usually expressed as PM10, PM2.5, or similar, which means that the measurement includes particles of 10 microns (or 2.5 microns) and smaller.
- Number-based measurements count all of the particles, regardless of how big or small they are. These measurements give us valuable insight to the quality of ambient air, since they can suggest the relative impact of certain pollution sources on a given location.
- Particle size distributions tell us how large or small the particles are in a given area. This data gives us insight into the health hazards posed by pollution, and the potential sources of the pollution in a certain area (i.e., local and/or upwind).

This document describes some of the techniques used to measure particulate air pollution.

Measurement Techniques and Practices

Since particle mass, number, and size are three different characteristics, different techniques need to be used to measure these characteristics. Accordingly, these techniques are used in standard particle measurement practices, and may even be specified in national standards.

PM

Particulate Matter (Mass)

The simplest way to measure the mass concentration of particles in the air is to pull ambient air through a filter using a pump. The measured pump flow multiplied with the total sampling time provides the sampled volume of air. The weight difference of the filter before and after the sampling period provides the mass of particles sampled from the air. Dividing the sampled particle mass by the sampled air volume results in the particle mass concentration. This general technique is used in the official 'reference method' established by the US EPA [1], and is very widely used in the US and elsewhere.

This filter method typically results in one measurement per day, or per multiple-day period. This is convenient in that it produces a relatively small amount of data to handle, but it also requires a working laboratory to determine the filter weights.

As technology has progressed, other technologies capable of measuring mass concentration have become available. While the filter method described above has its advantages, it does not give any insight into fluctuations in the mass concentration during the sampling period. Newer technologies are able to increase the time resolution of the collected data, and in some cases increase the automation of the data collection process. These faster PM measurement methods can provide up to several data points per hour and some of the technologies have been observed to produce results equivalent to the reference method described above. When this happens, the alternative method or technology is referred to as "an equivalent method" [2]. Time-resolved data can provide deeper insights like correlating fluctuations in concentration to wind direction, or to local short-term sources such as rush hour traffic.

Some reference methods (and their equivalents) provide only mass concentration data, and do not provide any information on particle size. Cascade impactors are a measurement tool that allow the measurement of both mass concentration and particle size simultaneously. In cascade impactors, particles are not sampled on only one substrate (filter), but are distributed within the cascade impactor according to their size. A variety of impactors are available. Low-resolution impactors may have only three stages, e.g. PM1, PM2.5 and PM10. High-resolution impactors can size-segregate particles from 10 nm to 10 µm into over 12 samples.

A specialty amongst mass measurement methods is to quantify black carbon (BC) material mass concentrations. Black carbon results can be correlated to emission sources and therefore be of interest in urban environments.

PN

Particle Number

Determining the particle number concentration of atmospheric aerosols in the size range of ~1 nm to ~1 µm is mainly done using a single particle counting technique. This technique utilizes a condensation process to make those tiny, invisible particles visible to an optical counter. The so-called Condensation Particle Counters (CPCs) work from very low to very high concentrations and can therefore be used in heavy polluted areas as well as at background stations with low particle concentrations.

A European technical standard [3] describes the use of CPCs to determine the particle number concentration of atmospheric aerosol. The calibration of these particle counters is described in ISO 27891:2015.

CPCs are fully automated systems with very low user interaction during long-term operation. PN concentration data is typically available with one second resolution or faster, and software can be used to average PN concentrations to other time intervals. CPCs do not offer particle size resolution when operated stand-alone, but often can be employed in particle sizers.

PSD

Particle Size Distribution

Airborne particles are present in a wide size range (~1 nm to ~10 µm). Because this size range is so wide — a factor of 10,000 in particle diameter — various technologies have been developed to quantify particle diameters.

Ultrafine particles can be measured with high time and size resolution typically covering a particle size range between 1 nm and 1 µm. These ultrafine particle spectrometers are based on electrical mobility measurement (a standardized method described in ISO15900:2009) and utilize CPCs to count the number of particles in each size channel.

Larger particles in the size range between 0.3 µm and 10 µm are typically measured with optical particle sizers (OPS). In these instruments, particles are illuminated by a laser beam and the amount of light scattered correlates to particle size. Particle material and shape can influence this correlation.

Particles in the size range of 0.5 µm to 20 µm can be separated in an accelerated air flow via their aerodynamic properties. One technique utilizing the correlation between time-of-flight and particle size is an aerodynamic particle sizer (APS), which provides high particle size and time resolution. Unlike cascade impactors, the APS does not collect particle samples for offline analysis. The cascade impactors described previously are based on aerodynamic separation, but with fewer channels of particle size resolution than the APS provides.

Particle Sampling

As with any scientific undertaking, how you treat your sample prior to making a measurement can affect the accuracy of your measurement. This is of particular importance for air quality data, as many of those data are made available to the public. Fortunately, some guidelines and standards on how best to sample particulate matter have already been developed, or are in development.

Since the measurement instruments are typically hosted inside a container or building, "sampling" means successfully transporting the particles from the ambient environment all the way to the measurement instruments' inlets while imposing as little change as possible on the particles. The particle sampling systems, then, are used to transport the ambient aerosol from the outside to the instrument and to condition it to reproducible or even standardized conditions.

The first part exposed to the aerosol is the sampling head. Sampling heads are typically omnidirectional (i.e., air is sampled from 360 degrees around the sampling head) and either allow all particles to enter (TSP, total suspended particulate) or allow only particles below a certain cut-off particle size (PM10, PM2.5, or PM1). The second part is a device to control the aerosol temperature and humidity; an example is described in CEN/TS 16976. A third optional part is a flow splitter, which may be necessary if: a) multiple instruments are connected to one sampling inlet; b) a transport flow higher than the instrument flow is used in order to achieve the sampling head's design cut-off size, or c) a dilution system is used to adjust the concentration levels. It is advisable to use sampling inlets which are characterized for size-dependent particle losses.

Next Step

Instruments That Measure Air Quality

If you are ready to turn your focus from the underlying science to choosing the tool that is right for you, we invite you to continue reading on in our brochure:
The Full TSI® Solution.

Learn more at
tsi.com/ambientair

References

1) US EPA, Ambient Monitoring Technology Information Center (AMTIC), PM 2.5 - Federal Reference Method (FRM), https://www3.epa.gov/ttnamti1/pmfrm.html
2) Christopher A. Noble , Robert W. Vanderpool , Thomas M. Peters, Frank F. McElroy , David B. Gemmill & Russell W. Wiener (2001) Federal Reference and Equivalent Methods for Measuring Fine Particulate Matter, Aerosol Science & Technology, 34:5, 457-464
3) CEN/TS 16976:2016, Ambient air. Determination of the particle number concentration of atmospheric aerosol

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TSI Incorporated - Visit our website **www.tsi.com** for more information.

USA	Tel: +1 800 874 2811	**India**	Tel: +91 80 67877200
UK	Tel: +44 149 4 459200	**China**	Tel: +86 10 8219 7688
France	Tel: +33 1 41 19 21 99	**Singapore**	Tel: +65 6595 6388
Germany	Tel: +49 241 523030		

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