Idaho Department of Environmental Quality

Low-Cost Air Sensors

FAQs

What are low-cost air sensors?

These are low-cost, portable devices used to measure particulate matter (PM). These sensors are commonly from a family of optical particle counters and use a laser to count and size particles based on the frequency and magnitude of a reflected laser beam passing through a stream of air. Because particle shape, density, and reflectivity will vary by source and season, manufacturers apply a proprietary algorithm with an assumed particle composition to calculate a mass concentration in micrograms per cubic meter ($\mu g/m^3$). These sensors are inexpensive, with prices ranging from a few hundred to a few thousand dollars. They are often presented as a turn-key, ready-to-deploy monitoring device—making them appeal to researchers, educators, and the general public alike. There are no U.S. Environmental Protection Agency (EPA) or industry performance standards established for low-cost sensors.

This real-time data may be useful for identifying:

- Spatial variation in an airshed
- Localized air impacts or hotspots
- Emission sources

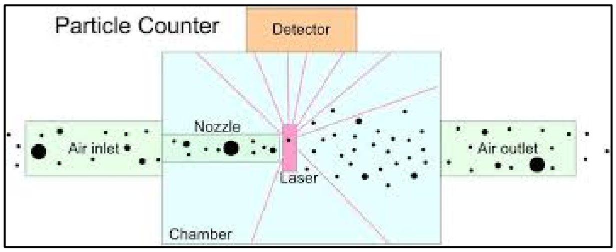

Figure 1. Typical optical particle counting method.
Image downloaded from: https://particlesplus.com/air-quality-instrumentation-part-iii-particle-mass-pm-estimation/

What are regulatory air monitors?

Regulatory air monitors measure mass concentrations of PM and most often report a one-hour or 24-hour average. They are frequently operated by government entities and can cost upwards of $20,000 or more.

These monitors are subject to extensive performance testing by manufacturers and the EPA before field deployment. They must report accurate readings while subject to harsh elements, in any part of the country, during all seasons. They require significant infrastructure and expertise to install and operate, which can be prohibitive for local citizen groups or small research teams.

What is the Air Quality Index?

The EPA developed the Air Quality Index (AQI) to communicate air quality and human health effects, focusing on the impacts experienced hours or days after breathing polluted air. However, in response to the need for more real-time air quality information, the EPA developed the NowCast. The NowCast uses the previous 12 hours of air data and weighs those values based on changing conditions, relying more on recent values during rapidly changing conditions (e.g., wildfires). This ensures the NowCast best reflects the current air quality conditions people are experiencing.

There is no EPA AQI equivalent for real-time readings less than a one-hour interval and it is not recommended to generate an AQI reading from a single or short-term (sub hour) reading. Using a single, short-term measurement will result in a potentially misleading AQI value.

Why don't regulatory monitors and low-cost sensors show the same concentration?

In order for the sensors to report accurate concentration levels, they must be corrected or calibrated to local, regulatory-level monitors. Studies show that low-cost sensors can read up to 1.5 to 2.5 times higher, than regulatory monitors due to the following factors:

QA/QC Checks—Regulatory air monitors are both factory and field-calibrated. They are subject to quality assurance/quality control (QA/QC) checks and standard operating procedures to ensure data can be validated using established scientific methods. These standards have not been developed for low-cost sensors.

Siting Criteria—Placement of regulatory monitors must account for air flow, proximity to nearby obstructions, and local pollution sources, which yields accurate, airshed-level readings. Low-cost sensors often report very localized measurements and could be biased due to inadequate use or siting.

RH and Temperature Controls—Most monitors are impacted by relative humidity (RH) and temperature. For example, air particles absorb moisture when RH rises above 50 percent, causing them to swell and change shape. Regulatory monitors have controls to account for these impacts. Without RH controls, low-cost sensors will overestimate the size of these swollen particles and atmospheric concentrations.

Location and Source Variations—Low-cost sensors rely on estimates of particle shape and composition to convert a count to a concentration. However, particles from a wildfire will have a different composition than dust particles from a gravel pit or from secondary-formed aerosols, and low-cost sensors may interpret these compositions as different concentration levels. To account for these source variations, a site or region-specific correction factor needs to be developed before reporting an AQI.

Drift—Drift refers to a gradual change in an instrument's response characteristics, which can skew readings. Regulatory monitors and some hand-held sensors can be recalibrated using *zero air*, also known as clean air, to correct instrument drift. These adjustments are often not possible for low-cost sensors and require a factory recalibration.

Nonlinear Bias—Studies have shown that low-cost sensors exhibit a nonlinear bias, meaning they may read accurately at low concentrations but show greater variation at higher concentrations. This is a concern during wildfire or inversion events when users are more likely to use a low-cost sensor when they are most at risk of overestimating concentrations.

Response Time—Regulatory monitors can accurately measure concentrations using a 1-hour reporting time. Low-cost sensors provide fast and, in some cases, minute-by-minute readings, but are subject to greater variability and noise between readings. The short, sub-hour readings should not be used to generate an AQI or NowCast value.

Can we use low-cost sensor data to compare to the NAAQS?

No. Low-cost sensors do not meet the necessary performance standards to make regulatory decisions, including comparison to the National Ambient Air Quality Standards (NAAQS). These health-based standards are based on exposure studies not yet performed using single, real-time PM exposures.

What are the key takeaways?

Low-cost sensors cannot replace traditional monitors, but they do create opportunities to expand access to air quality information. Users need to be educated about the advantages and limitations of each instrument.

Advantages of Low-Cost Sensors

- Relatively cheap.
- Easy to operate and deploy.
- Provide fast, real-time data.
- Potentially useful as a general indicator of hotspots or changes in pollutant levels within an airshed.

Limitations of Low-Cost Sensors

- Single, short-term measurements are not recommended for generating an AQI without the proper measurement time-scale and concentration correction factor.
- Long-term performance has not been tested.
- Known to read 1.5 to 2.5 times higher than regulatory monitors.
- No standard operating procedures, calibration requirements, or QA/QC procedures.
- No standards or guidelines for locating low-cost sensors or how to analyze results.

Resources

Scientists, researchers, and public officials are working to establish a framework to help users understand the advantages and limitations of low-cost sensors while also carving out room in the air quality arena for new, more user-friendly, accessible tools. The following links are resources to guide users to understand the accuracy and limitations of their particular sensor:

- **Air Quality Sensor Performance Evaluation Center (AQ-SPEC)—**Characterizes the actual performance of low-cost air quality sensors and educates the public about the advantages and limitations. *http://www.aqmd.gov/aq-spec*

- **Quality Assurance Handbook and Guidance Documents for Citizen Science Projects—**Resource for organizations interested in setting up a citizen science-based project. Includes QA/QC and documentation recommendations. *https://www.epa.gov/citizen-science/quality-assurance-handbook-and-guidance-documents-citizen-science-projects*

- **EPA's Air Sensor Guidebook—**Advice on what to look for in a sensor, selecting pollutants, and calibrating sensors. *https://www.epa.gov/air-sensor-toolbox*.

For additional information, contact your regional office.