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# Air Quality Measurement Using Portable Sensors

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There is an increasing awareness of the health and economic costs of air pollution. In the past several years, the field of portable air quality sensing technology has evolved at a rapid pace, with products now commercially available for ozone, nitrogen dioxide, particulate matter, volatile organic compounds, as well as for other pollutants. While the potential for these technologies is great, significant challenges in their application remain. This fact sheet aims to focus on how ambient air quality is assessed traditionally, what portable sensor technology may be able to deliver and the challenges of interpreting the data generated by these sensors in the context of the health-based National Ambient Air Quality Standard (NAAQS).

## How Is Air Quality Data Collected and Managed?

Ambient air monitoring is the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding outdoor air. The locations for monitoring stations depend on the purpose of the monitoring. Most air quality monitoring networks are designed to support human health objectives, and monitoring stations are established in population centers. Monitoring stations may also be established to determine background pollution levels away from urban areas and emissions sources. Most of regulatory ambient air monitoring networks are operated by tribal, state or local governments. EPA develops requirements and provides guidance for the design and operation of these networks, including regulatory monitor designation, quality assurance/quality control, data accuracy and completeness requirements. The real-time air quality information of the regulatory air monitor networks is available on AirNow data website (https://www.airnow.gov/), which is used to determine attainment or nonattainment areas.

## Why Low-Cost Air Quality Sensors?

On a global scale, the geographic coverage of monitoring networks has been limited due to the cost, infrastructure and personnel requirements for air monitoring stations. Even in developed countries with well-established air quality measurement networks supporting regulations, spatial variability resulting from localized activities (such as near-road vehicle pollution) motivates monitoring on a finer geographic scale. Lower-cost sensor technologies are developed to meet these needs. Lower-cost sensor

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| Areas for Comparison | Current Technology | New Sensor Technology |
|---|---|---|
| Cost | Expensive | Lower cost |
| Monitoring duration | Often snapshot | Often continuous |
| Resource requirement | Big footprint with dedicated power source | Small footprint or mobile, battery or solar power |
| Operation | May require expertise to use | Relatively easy to use |
| Data process | Often delays for lab analysis | Real-time without lab analysis |
| Quality assurance (QA) | Established QA protocols | QA protocol lacking |
| Collectors/users | Government, industry, researchers | Communities and individuals |
| Data sharing | Stored and explained on government websites | Shared and accessed on non-government sites |

technology applications were also found for activities that do not require the highest quality data – community engagement, education and condition indicator. These efforts are further promoted by information technology companies who provide data storage, sharing and public access (1,2). The table above compares new sensor technology with the traditional technology.

## Air Quality Measurement and Management Considerations

Measuring atmospheric pollutants is challenging. Most gaseous pollutants, such as nitrogen dioxide or ozone, occur at parts-per-billion (ppb) levels in air and are blended with thousands of other compounds. Unburnt fuel, for example, contributes many different hydrocarbons to the urban atmospheric mix. Particulate matters are sensitive to water vapor, which is abundant in the air in fluctuating amounts.

A wide range of portable air quality sensors is available. The cheapest, costing a few dollars each, use technologies that have been repurposed from hazard detectors, such as metal-oxide sensors that measure oxidizable gases. For tens to hundreds of dollars, electrochemical or photoionization detection can observe particular compounds or classes. In the $150 to $1,500 range are miniaturized instruments, such as optical particle counters, that can fit in your palm. In general, reducing sensor cost inevitably reduces specificity or sensitivity or both.

The lower-cost air sensors may not have established quality control and quality assurance measures, completed rigorous Federal Reference or Federal Equivalent Method testing and analysis (with exceptions in **Useful Resources**) and are likely not being operated according to respective requirements. Some sensors may have diminished accuracy from humidity or temperature when transitioning from indoors to outdoors. For example, particle counters using light scattering techniques can be influenced by particle sizes, shape and humidity of air. Varying air pollution mixtures, significant change from calibration condition and near-road measurements can introduce uncertainty. Lack of collection of supporting data such as simultaneous wind or humidity makes data interpretation difficult.

Data interpretation can also be challenging. Health research has been primarily focused on long-term exposures to air pollution and the resulting health impacts. While low-cost air sensors are capable of producing data in a matter of minutes, their readings are not directly comparable to the National Ambient Air Quality Standards (NAAQS) or the related Air Quality Index (AQI) categories. The averaging intervals of the criteria air pollutants of NAAQS, e.g., 1 hour (carbon monoxide, nitrogen dioxide and sulphur dioxide), 8 hours (ozone) or 24 hours ($PM_{2.5}$), are established on a scientific basis.

In response to the rapid explosion of AQ sensor applications, federal, tribal and state agencies have been working on various fronts, including addressing data quality (such as a voluntary certification program) and data exchanges. Research involving the collocation of sensors with reference-grade equipment near sources has been conducted in ambient stationary environments (3,4). Long-term (more than 12 months) performances are characterized to quantify drift with time.

## Summary

While low-cost, portable air sensors can be useful in citizen science applications, users should be aware that collecting and managing data is only a part of characterizing air quality. Used properly, these tools can allow citizens to explore their local environment as well as learn about air quality and the U.S. Clean Air Act. As technology continues to improve, low-cost air sensors may be able to augment regulatory networks or detect pollution hotspots.

## Glossary

**Nitrous oxides** – Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air.

**Particulate matter** – General term for a mixture of solids and liquid droplets suspended in the air.

**Volatile organic compounds (VOCs)** – Compounds that contain carbon, oxygen, hydrogen, chlorine and other atoms. They vaporize (become a gas) into the atmosphere at room temperature and help form ozone near the ground. They are found in nature as well as in a wide array of products – paints and lacquers, paint strippers, cleaning supplies, pesticides, building furnishings, office equipment, correction fluids, graphics and craft materials including glues and adhesives. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors.

**Ozone** – Ground level ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOCs). This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants and other sources chemically react in the presence of sunlight. Ozone at ground level is a harmful air pollutant because of its effects on people and the environment, and it is the main ingredient in "smog."

**National Ambient Air Quality Standard (NAAQS)** – Nationally established maximum allowable concentrations of pollutants in the ambient air often referred to in federal health standards. NAAQS regulate six common air pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide and particulate matter. The standards are reviewed periodically and may be revised.

## Useful Resources

As of May 2017, two personal air sensors have been designated as a Federal Equivalent Method (FEM) – the Personal Ozone Monitor (POM) (2B Technologies) and the Model 405 nm $NO_2$/NO/NOx Monitor (2B Technologies). A user would need to ensure that the instrument is used according to FEM protocol, including appropriate ambient conditions and calibration.

- EPA's National Advisory Council for Environmental Policy and Technology's report: *Environmental Protection Belongs to the Public – A Vision for Citizen Science at EPA*. https://www.epa.gov/sites/production/files/2016-12/documents/nacept_cs_report_final_508_0.pdf
- EPA's index for reporting daily air quality https://airnow.gov/index.cfm?action=aqibasics.aqi

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2. Array of Things. See https://arrayofthings.github.io
3. Air Quality Sensor Performance Evaluation Center (AQ-SPEC). See http://www.aqmd.gov/aq-spec
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