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Air Quality Sensors

Air quality sensors have hit the market and offer a wide range of designs and capabilities. Policymakers are starting to ask whether these devices, which collect highly localized, real-time data on air pollution, have promise as a tool that complements the existing air quality monitoring network. This factsheet draws on research into sensors by clean air agencies. It highlights issues for agencies wanting to learn more about sensors to consider, and provides ideas on where to turn to for more information.

Why Sensors?

Air quality varies greatly based on when and where it is being measured. As part of "Smart Cities" and other data-driven programs, many local and state governments are exploring the use of dense networks of low-cost sensors to provide data on transportation, energy and air quality that can be leveraged to solve problems like traffic congestion, reliable energy and air pollution.

Until recently, air quality monitoring was conducted almost exclusively by governments using large, expensive, carefully calibrated monitoring stations. Today, inexpensive sensor instruments and software can be used by anyone to measure air pollution over broad areas and over many increments of time. For example, some communities use sensors to take measurements of air quality along routes used by bike commuters, or to detect leaks from tank farms that are imperceptible to the naked eye. These low-cost, portable sensors are starting to play a supporting role in supplementing ambient air monitoring stations and someday they may be important for providing source compliance information.

What are these sensors?

The South Coast Air Quality Management District (SCAQMD) in California and the US EPA have begun cataloguing and benchmarking the performance of sensors. Although the field is evolving rapidly, today three technology types dominate the sensor market. **Gas sensors** use reactions between semiconductor metal oxides in the instrument and gases in the atmosphere, and use changes in conductivity to measure concentrations of the gas being measured. **Electrochemical sensors** operate by reacting with the gas being measured and producing an electrical signal proportional to the gas concentration. **Optical sensors** use beams of light and receptors that detect how those beams are scattered by particles. All three technologies collect large quantities of data that must be analyzed and turned into useful information, so computer hardware and software are another component of these systems.

The marketplace for sensors is currently dominated by small hardware and software companies, with few standards to help them create uniformity of calibration, use, performance and durability. Although there has been a great deal of interest in monitoring local air quality, demonstration and proof-of-concept projects are still underway, with some promising – but early – results.

How are 'sensors' different than 'monitors'?

Regulatory and enforcement actions must be based on data collected under consistent and rigorous standards. Experts think that sensors may supplement – rather than replace – the current system of monitoring equipment required by the Clean Air Act. The law requires every state to establish networks of air monitoring stations for criteria pollutants, using criteria set by EPA for their location and operation. The monitoring stations in these networks are large, carefully calibrated, permanent systems called the State and Local Air Monitoring Stations (SLAMS). In addition, Special Purpose Monitors (SPMs) can be deployed for limited periods of time to address specific, local objectives. The vast majority of the ambient air monitoring stations in the United States are operated by state, local or tribal monitoring agencies.

The key objectives supported by the major U.S. ambient monitoring networks include implementation of the National Ambient Air Quality Standards (NAAQS), assessment of long-term trends, sustaining public awareness by reporting to the Air Quality Index, and supporting health and ecological research studies. In addition to the criteria pollutant monitoring networks (such as the National Core (NCore) network), state and local monitoring stations are also used to assess air toxics; the National Air Toxics Trends Stations (NATTS) monitor a subset of key hazardous air pollutants that drive risk. The Photochemical Assessment Monitoring Stations (PAMS) are specifically designed to measure ozone precursors.

High-quality information does not just depend on hardware: how we gather and use the data matters as well. EPA scientists develop, evaluate and designate Federal Reference Methods (FRMs) and Federal Equivalent Methods (FEMs) to accurately and reliably measure the six NAAQS; they are codified at 40 CFR Part 53, *Ambient Air Monitoring Reference and Equivalent Methods*. In a November 2017 article, EEI's John Kinsman reported on progress to designate sensor systems' capabilities in this area.

What opportunities could sensors unlock?

Field research undertaken by sensor expert Tim Dye during the California wildfires of 2017 showed that, done thoughtfully, larger networks of inexpensive sensors offered opportunities to create hybrid networks that filled in the data gaps and offered a broader situational picture than just SLAMS and other more rigorous tools. In these situations, sensors relied on the reference network of the air quality monitoring system and supplied additional data points from times and places that the monitors were unable to reach.

In the United States, Baltimore MD, Lafayette LA, the state of Minnesota, and several cities in California have tested this technology. Research in cities in from Mumbai, India to Barcelona, Spain, are running pilots to show how wearable or mobile monitors can measure and map air pollution in ways that were previously impossible.

However, sensors do face challenges related to their operation, calibration and quality assurance. Also, because they can be more inexpensively deployed in great numbers and take a large number of readings, the volume of data they collect can be dramatically larger than that collected by nearby reference or equivalent monitors – a data management challenge that would need to be addressed.

EPA has examined sensor technologies as part of its "Next Generation Air Monitoring" (NGAM) effort, which explored how sensors can lead to better protection of public health and the environment, provide communities with better data on pollution in their neighborhoods, help regulated entities better-manage their facilities, create business opportunities, and reduce the costs of air pollution monitoring for public agencies, companies and researchers. The NGAM effort characterized a number of uses, including for education, research, and personal exposure monitoring. For state and local agencies, three use-cases stand out as being especially promising:

- Supplementing Existing Monitoring: placing sensors within an existing state/local regulatory monitoring area to fill in coverage.
- Source Identification and Characterization: establishing possible emission sources by monitoring near the suspected source.
- Monitor site screening: siting a monitor properly for SLAMS use can be expensive, and construction, equipment purchases and land use agreements can take time, all before the site is even known to be the best location. Sensors may be useful to deploy based on modeling to screen sites for appropriateness.

Some applications are suited to community-scale deployments, while others (generally, the lowest-cost, least rigorously calibrated and tested) are appropriate for personal interest uses.

Where can I learn more?

In addition to the information hyperlinked in this factsheet, EPA offers sensor evaluation reports based on independent sensor testing by EPA and SCAQMD. Good references are also available thanks to a September 2017 conference held by local clean air agencies in California called the "Making Sense of Sensors" Conference that convened experts from government, academia, environmental organizations, community groups, and industry. Its online materials offer a wealth of information on air quality sensors.

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