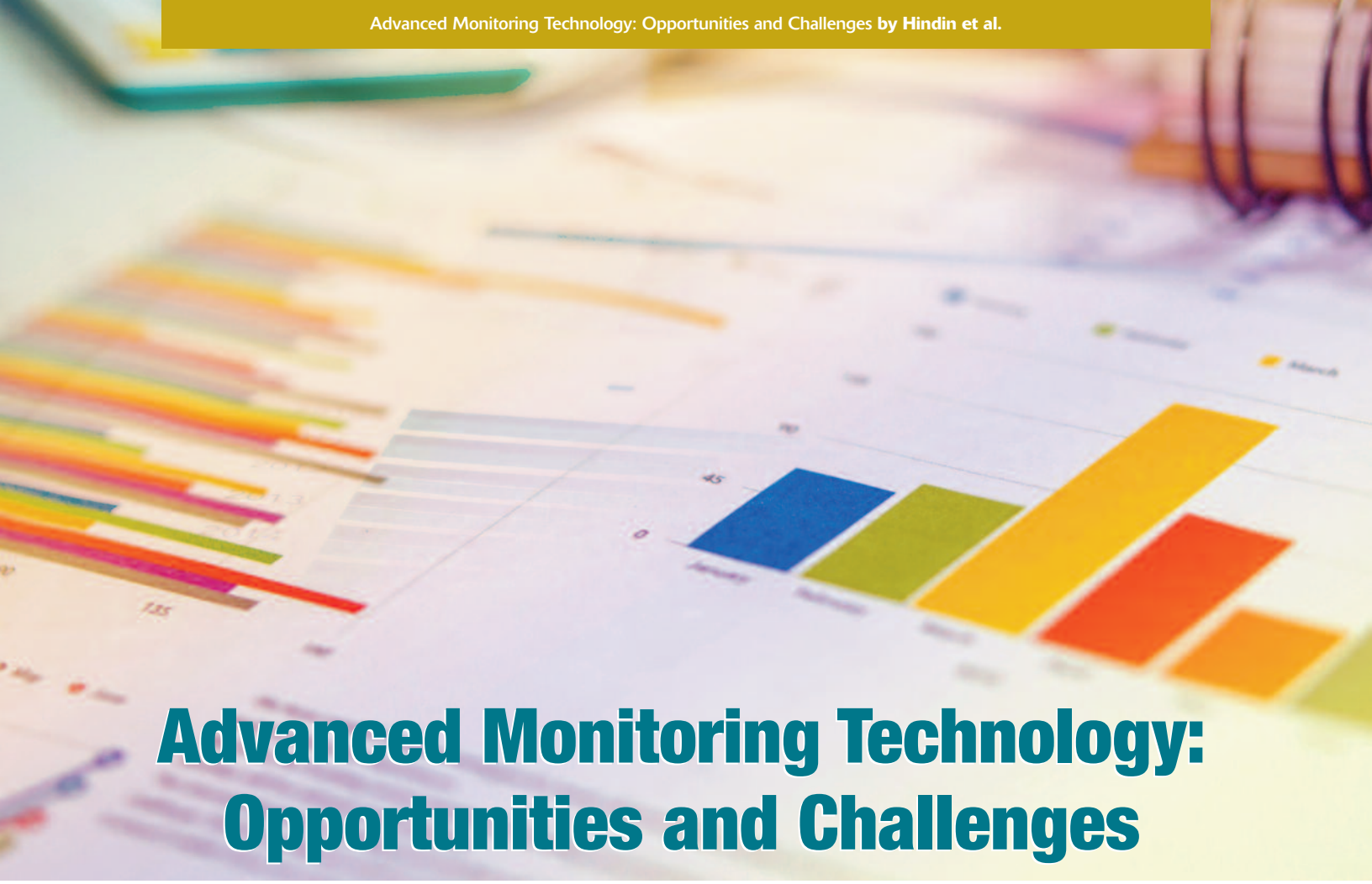


Advanced Monitoring Technology: Opportunities and Challenges

A Path Forward for EPA, States, and Tribes

by David Hindin, Ben Grumbles, George Wyeth, Kristen Benedict, Tim Watkins, George (Tad) Aburn, Jr., Megan Ulrich, Steve Lang, Kelly Poole, and Alexandra Dapolito Dunn

Rapid changes in monitoring technology have the potential to dramatically improve environmental protection by providing industry, government, and the public with more complete and real-time information on pollution releases and environmental conditions. With more real-time monitoring, we will have a much richer understanding of environmental conditions, and will be able to identify and fix environmental problems sooner. These developments may change not only how environmental programs operate, but also the roles played by citizens, researchers, industry, and others. We recently recognized this possibility in a 2013 article.[1] Now, we need to act to ensure we are able to take full advantage of the opportunities while addressing the challenges.[2]

Some of the challenges from new monitoring technology relate to the use of devices by citizens. The ability of individuals using low-cost sensors to gather information previously requiring highly expensive government equipment could greatly enrich our knowledge of environmental conditions, especially at a local level. At the same time, uncertainties about the quality of these devices and the interpretation of the data they generate are limiting their impact (see "Interpreting and Communicating Short-Term Air Sensor Data" by Keating et al. elsewhere in this issue). For example, we do not currently have uniform data exchange standards that are needed to allow information from multiple sources to be compiled, analyzed, and understood, especially when the data is for short-term readings (e.g., 1 minute) but the federal standards and the Air Quality Index are grounded in studies based on longer pollution exposure (e.g., 1, 8, or 24 hours).

At the same time, new technology could transform the work of agencies, giving them richer and more current information on environmental conditions, and assessing compliance. These tools can also allow industry to be more proactive in anticipating and preventing problems. But agencies are hard pressed to keep up with these developments (e.g., determining whether a new monitoring technology should be considered for a particular use). The question of for what purposes the new technology will be used is a central challenge.

In short, there is a compelling need to come together to address these challenges and take advantage of the opportunities to use advanced monitoring to improve environmental protection. The U.S. Environmental Protection Agency (EPA), states, and tribes have come together to do just that.

Citizen Science: Possibilities and Questions

Members of the public can easily browse the Internet and purchase low-cost monitoring devices. Areas like Chicago, Pittsburgh, Baltimore, and Los Angeles are deeply engaged in or just getting started with a new breed of research driven by the development of low-cost air monitoring or sensor technology (see Figure 1).

Further, several high-profile information technology giants are showing interest in hosting data generated by advanced monitoring technologies, which is likely to speed up, not slow down the process. In addition to air monitoring, similar technologies are becoming critical to the water quality monitoring network and a high priority for water quality agencies across the country.

This revolution in advanced monitoring technology raises many questions:

- "How well do these devices work?"
- "Which ones work best for which purposes and which ones need more work?"
- "With the data often varying by quality, time, space and unit of measurement, what do the data mean, and how can we make sure users understand the data?"
- "How do we analyze reams of new data? Can we make use of lots of imperfect data taking statistical advantage of the wealth of embedded information potential?"
- "What are the potential uses of the data? Better understanding exposure? A tool for industry to avoid compliance problems by tracking early indicators? How to best locate high end, higher cost monitoring equipment? Integrated exposure and risk assessments?"

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Leading the Way: The SCAQMD's AQ-SPEC Program

In an effort to inform the public about the actual performance of commercially available "low-cost" air quality sensors, the South Coast Air Quality Management District (SCAQMD) has established the Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program. The AQ-SPEC program aims to perform a thorough characterization of currently available low-cost sensors under ambient (field) and controlled (laboratory) conditions. For more information, visit the website (http://www.aqmd.gov/aq-spec/home).

The main goals and objectives of the AQ-SPEC program include:

- Evaluating the performance of commercially available low-cost air quality sensors.
- Providing guidance and clarity for ever-evolving sensor technology and data interpretation.
- Catalyzing the successful evolution, development and use of sensor technology.

Figure 1. South Coast Air Quality Management District AQ-SPEC Program.

Responding to the Challenges

EPA has been assessing the changing paradigm of air pollution monitoring for the past few years.[3] As predicted, the revolution has continued to grow and the agency recently partnered with state and tribal environmental agencies—organized under the auspices of E-Enterprise for the Environment—to form a team to address the challenges and opportunities presented by rapidly changing monitoring technology.[4] For more information, visit the website (http://e-enterprisefortheenvironment.net/).

Under the direction of the E-Enterprise Leadership Council, an Advanced Monitoring Team was formed in April of 2015 to lead the joint effort (see Figure 2). The E-Enterprise Advanced Monitoring Team includes state environmental commissioners, state and local technical experts, and representatives from EPA's Office of Enforcement and Compliance Assurance (OECA), Office of Air and Radiation (OAR), Office of Water (OW), Office of Environmental Information (OEI), Office of Research and Development (ORD), and EPA Regional Offices. Recommendations from the team to move forward on five projects have been approved by the E-Enterprise Leadership Council and are described here.

An Opportunity and Challenge of Great Interest to States, Tribes, and EPA

Advanced monitoring technology refers to a broad range of sampling and analytical equipment, systems, techniques, practices, and technologies for enhancing detection and measurement of environmental conditions. This new technology is generally defined by one or more of the following factors:

- It is not yet in widespread use in a particular sector or particular regulatory program.
- It provides data by monitoring pollutants on a real-time or near-real-time basis, often without lengthylag times for laboratory analysis.
- It is less expensive, easier to use, and/or more portable compared to technologies currently in widespread use.
- It provides acceptable data quality that is more complete or easier to interpret and can meet a specific need.
- It is a new technology or an existing technology that is being used in a new way to provide better information on pollutants, pollution sources, or environmental conditions.

Figure 2. E-Enterprise Leadership Council (EELC). The EELC is composed of 10 State Environmental Commissioners and 10 EPA Senior Executives. The EELC has had tribal participation for its most recent meetings. E-Enterprise is managed through joint governance, in which the states, territories, tribes and EPA jointly identify and define problems and opportunities, and jointly develop and implement solutions and approaches thereto. This joint governance model is driving transformative reforms across the national enterprise of environmental protection.

Environmental agencies have a longstanding role as leaders in developing monitoring methods and procedures and in collecting, storing, and communicating the meaning of environmental data to the public. EPA is uniquely qualified to convene organizations to leverage evaluation and pilot programs to address market shortcomings. The E-Enterprise initiative on advanced monitoring is designed to begin the process of addressing the most common hurdles associated with new technologies.

A common thread in our preparation for the future of advanced monitoring is recognition that the technology can be used in a variety of applications, including (but not limited to) environmental research; personal exposure monitoring; science, technology, engineering, and math (STEM) education; site screening; compliance monitoring; and hotspot identification (see Table 1). These different applications may have different performance and quality requirements for the equipment. For example, some applications may require a top-of-the-line, lab-quality instrument, while other applications may be able to meet needs with data from simple, low-cost sensors. As data are increasingly generated by the public and other non-governmental parties, we need to define the level of data quality required if the data are to be used for regulatory purposes, for less rigorous screening purposes, or for personal use. Our work across all the projects will recognize these differences.

The Priority Projects

The E-Enterprise initiative on advanced monitoring has identified and begun to work on five specific projects to prepare for the changes in environmental programs resulting from advances in new monitoring technology.

Project 1: Options and Feasibility Analysis for an Independent Third-Party Evaluation/ Certification Program

Without trustworthy information on new technology performance used in combination with well-developed

evaluation methods, there is significant risk that poor-quality data will proliferate and be indistinguishable from reliable data. This effort is designed to determine the feasibility of creating an independent third-party program to evaluate the performance of new sensors. This kind of a certification process will ensure that new technology is marketed and used in ways that are consistent with the capabilities of the new technologies and will generate data that will be useful to the public and governments.

Such evaluation and potential certification of a particular device should be done by a competent and independent entity: that is, not the manufacturer nor anyone associated with the development, production, distribution, sales, financing, or marketing of the device. Government agencies will play an important role in setting data standards and/or initiating a third-party evaluation/certification program.

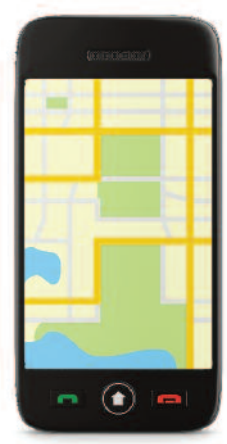
Project 2: Technology Scan, Screen, and User Support Network

EPA, state, tribal, and local agencies currently lack an established, coordinated way to determine whether a new technology has potential for use in environmental programs (on an informal basis that does not replace the "gold standard" procedures used to approve regulatory monitors). This effort will develop a process that can rapidly assess new technologies that are available now or that may be coming to market soon to determine the utility of each technology for various purposes, and recommend specific sensors for further and more rigorous evaluation. The network of EPA, state, tribal, and local experts can screen whether a new technology appears to be scientifically sound and relevant for further consideration based on all readily available data, including information provided by the manufacturer.

This network will not officially endorse technologies but rather will support environmental agencies in understanding the opportunities for how to use the new technology. The network will provide user support to EPA and state, tribal, and local agencies. to help them decide which equipment they should purchase or pilot for a particular use. This network will also help state, local, and tribal environmental agencies and EPA respond to citizen and community groups by providing screening-level information on the quality of select sensors.

Table 1. Potential uses and use tiers of advanced monitoring data. (Performance and quality requirements for these uses may vary.)

Directly Support Regulatory Programs
Permitting: Part of record for issuance of rules or permits
Regulation and Compliance: Identification of nonattainment areas/impaired waters; removal of designations when conditions improve; self-monitoring pursuant to a permit or an applicable rule
Enforcement: Evidence in an enforcement action
Aid or Supplement Regulatory Action
Action Prioritization: Targeting, development, and prioritization of enforcement actions
Problem Identification: Hot-spot identification and characterization, or analysis for program planning purposes or future regulatory action
Additional Data: Supplement current regulatory monitoring for planning
Emergency Response: Pollutant identification, characterization of conditions and risks, response action planning, and status assessment following a response
Temporary Source Monitoring: Temporary monitoring (e.g., construction sites)
Educate/Inform the Public (Non-Regulatory)
Program Evaluation: Evaluation of research, programs, and other policy outside of regulatory actions
Transparency: General information made available to the public about their environment
Other Uses
Facility Self-Monitoring: Use to inform operational control by facilities (e.g., drinking water systems)
Personal Health: Personal exposure monitoring and crowdsourced networks
Education: Use of technology as a teaching tool (e.g., Science, Technology, Engineering, and Math [STEM] education)
Research: Use by universities and others for research purposes
Hazard Alert Systems: Alert building occupants of a problem



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Project 3: Data Interpretation

As advanced technologies producing real-time data (reported by the minute or second) become more widely available, these data are often being misunderstood by users, especially when compared to public health standards based on longer-term exposure. To help address such misunderstandings, environmental agencies and the public would benefit from a better understanding of how to interpret and respond to the data.

This effort is designed to provide context and interpretation of advanced monitoring data as it relates to potential adverse environmental and health effects or regulatory compliance. This context will help mitigate stress on government resources that may otherwise be spent responding to public confusion or concern over erroneous information.

This project will build on current efforts to communicate short-term data (see "Interpreting and Communicating Short-Term Air Sensor Data" by Keating et al. elsewhere in this issue) (see Figure 3).

Project 4: Data Exchange Standards

With the proliferation of new technology, data are being collected in inconsistent formats and at varying levels of quality. Uniform standards for the exchange of data are needed so that information collected by different parties, using different devices, can be shared and analyzed, and so that users will know how and under what circumstances the information was gathered.

Therefore, this project will develop data standards defining the representation, format, definition, structure, transmission, and management of data for each tier. From these efforts, a minimum set of metadata and data quality descriptions will be proposed and then evaluated through several pilot projects. This standardization will provide a foundation for the development of data tools to maximize the value of large yet imperfect databases.

EPA's Air Sensor Toolbox for Citizen Scientists

EPA's Air Sensor Toolbox for Citizen Scientists provides information and guidance on new low-cost compact technologies for measuring air quality. Since citizens are interested in learning more about local air quality where they live, work, and play, EPA scientists created the toolbox to provide citizens resources to effectively collect, analyze, interpret, and communicate air quality data.

Figure 3. EPA's Air Sensor Toolbox for Citizen Scientists.

Project 5: Lean the Current Technology Approval Process

In addition to the four projects described above, another critical element of the E-Enterprise advanced monitoring initiative is to simplify the regulatory approval process for new monitoring methods to be more timely, efficient, and transparent. This will primarily be implemented through each of the EPA program offices involved in methods development and approval using EPA's "Lean" initiative for streamlining agency processes. State, local and tribal agencies will provide input as part of this effort. EPA's Lean initiative is described online (https://www.epa.gov/lean/lean-government).

Next Steps and the Future

On April 13, 2016, the E-Enterprise Leadership Council voted unanimously to move forward with the five projects described above. The Steering Committee for this effort has established a set of initial action items and target completion dates that phase in the initiative over the next two years. Routine updates will be provided on the status of the advanced monitoring initiative through the E-Enterprise website (http://e-enterprisefortheenvironment.net/our-projects/advanced-monitoring-projects/advanced-monitoring/). **em**

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