Regulatory Considerations of Lower Cost Air Pollution Sensor Data Performance

by Robert Judge and Richard A. (Chet) Wayland

Robert Judge and **Richard A. (Chet) Wayland** are both with the U.S. Environmental Protection Agency. E-mail: Judge.Robert@epa.gov; Wayland.Richard@epa.gov

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Low-cost, portable air quality sensors could be the next generation of air monitoring, however, this nascent technology is not without risk. This article looks at how the U.S. Environmental Protection Agency (EPA) uses air monitoring data, the procedures we follow to ensure and assess its quality, and the ways we help ensure consistent measurements nationally. It also touches on future uses of air sensor data.

What if everyone had the ability to monitor air quality at all places, all the time? In this age of cellular connections, smartphones, and electronic gadgets of all sorts, measuring air quality right here, right now is within reach for everyone. Now that air sensors that can measure air quality are inexpensive and widely available, the amount of air quality data generated will grow exponentially. These inexpensive air sensors could be the next generation of air monitoring. In this article, we explore the tremendous opportunity we have to collect air quality data from these sensors, and the tremendous risk we have if we don't know the quality of the data that are generated and reported by these sensors.

Using Air Monitoring Data

EPA uses air monitoring data for a variety of purposes. At EPA, and for each of the state, local, and tribal organizations that EPA works with, the importance of collecting high-quality air monitoring data cannot be overstated. EPA's 10 regional offices are at the front lines in ensuring the quality of air monitoring data, so they can be used in a variety of ways to protect and inform the public.

EPA has many uses for air monitoring data. For example, EPA uses near real-time air monitoring data to generate graphical depictions (maps) of air quality throughout the country. These maps are available online, in newspapers, and on television. This information informs the public about local air quality conditions, and alerts them when air pollutant levels are high, so that they may take appropriate precautions regarding their outdoor activities.

Another way that EPA uses air monitoring data is to help determine whether health-based air quality standards, also known as National Ambient Air Quality Standards (NAAQS), are being achieved or exceeded. Areas that are determined to have air quality that is "above" (or dirtier than) the NAAQS are obligated to develop and implement plans known as State Implementation Plans (SIPs) to reduce pollution concentrations. Developing SIPs may involve adopting regulations designed to curb, or minimize, air pollution from a variety of sources that are contributing to the problem. Often, these regulations result in a cost to those sources.

Finally, EPA and states collect air monitoring data that may be used in health studies that help the agency determine whether the current NAAQS are sufficiently protective of public health. If these studies were to show that an existing NAAQS needed to be strengthened, it could result in further SIP development, additional pollution controls, and additional costs to mitigate pollution from the air pollution sources.

Setting the Standards for Monitoring

EPA establishes minimum criteria to help characterize ambient air quality by defining how many of different types of air pollution monitors need to be deployed to establish an air monitoring network in a given geographic area. This network, known as the State and Local Air Monitoring Network (SLAMS), must meet minimum federal requirements relative to the number and placement of monitors. Typically, these monitors are placed throughout metropolitan and more rural areas to characterize pollution across broad geographic areas. The scale that these monitors represent may range from a few hundred meters to more than 100 kilometers, depending on the pollutant being measured and the characteristics of that geographic area. In many cases, states and local air pollution control agencies deploy even more monitors than required by federal regulations to

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better characterize the local pollution problem and protect their citizens. Still, funding is not unlimited, and all areas need to balance the desire to know the air pollution concentrations throughout each part of the area with fiscal and logistical realities.

In advancing the idea of less-expensive air sensors, some believe that using simpler, less-expensive air monitoring devices to measure pollutants will improve state and local abilities to make air quality decisions. In some cases, a lower cost air sensor may play a role by providing air monitoring data in areas without existing state and local monitors, in essence supplementing the air monitoring network. If nothing else, the tremendous interest in air sensors demonstrates that the public cares about air quality and is interested in the work currently being performed by the state and local air agencies in this regard. The public cares about air pollution and has invested in trying to measure it to assess potential problems, and we hope, work collaboratively toward finding solutions to improve air quality.

Quality Assurance and Quality Control

Before advancing the use of air sensors too far, we should understand why EPA required the development of more complicated and expensive measurement devices in the first place. It is vitally important to understand the quality of the data collected, because the consequences of collecting poor quality data can be significant. If data from a monitor were biased high, EPA and the states could erroneously judge that area to be out of compliance with the NAAQS, resulting in potentially costly air pollution regulations being imposed. Alternatively, inaccurate air monitoring data used in health studies could overstate, or understate, the risks of a given pollutant to the general public or at-risk individuals.

Because this data will be used to make decisions that may have far-reaching health and cost implications for the public or affected sources, EPA established data quality objectives for quality assurance and quality control (QA/ QC) of air monitoring data to ensure that the quality of the data supports using it to make agency decisions. EPA established data completeness objectives and requirements for precision, bias, and overall accuracy of the measurements. The agency also required that all monitors used in NAAQS decision-making conform to stringent EPA criteria, as defined in the Code of Federal Regulations (CFR), and that they meet Federal Reference Method (FRM) or Federal Equivalent Method (FEM) criteria.

EPA required that monitoring organizations develop Quality Assurance Project Plans (QAPPs) that contain the instructions for how individual projects, such as measuring air quality, are to be implemented. QAPPs document exactly what needs to be done, how to do it, and when it will be done. Standard operating procedures provide a clear description how to operate and properly maintain monitors. By establishing uniform national criteria for measurements, EPA is assured that high-quality data are collected, reported, and effectively used for decision-making.

There are several key performance criteria that help define data quality. Precision is often reported as the ability to repeatedly get the same answer when measuring the same thing. Bias is the persistent tendency of a monitor to measure either high or low in its overall measurements. The goal of data quality is to achieve high precision and low bias. Another way of looking at this is to consider a bulls-eye on a target: you'd like to hit the center of the target over and over again. If you succeed in doing so, you'd be both precise and unbiased. However, if your shots were over and over again at the same location, consistently to the top right-hand side of the target's center, you'd be precise, but biased. If your shots were evenly scattered around the center point, sometimes high and sometimes low, you'd be unbiased, but imprecise. EPA established FRMs and FEMs to ensure consistent high-quality data that is both precise and unbiased, or accurate. By establishing these specific criteria, one can be confident measurements are repeatable and accurate within a certain pre-established error range.

Beyond setting forth stringent QA/QC standards for monitors and procedures used for collecting state and local air monitoring data, EPA also established a program of independent audits (the National Performance Audit Program, or NPAP) to further verify measurements meet all quality criteria. This is done by independently challenging the ability of the monitor to compare favorably against an EPA reference monitor, one that is independently verified. By taking all these steps, EPA can be confident that the measurements made for EPA and state programs, as described earlier, are of the highest quality and can easily be compared to reference measurements.

Low-Cost Air Quality Sensors

As these lower cost air quality sensors become more widely used, it is important to consider the purpose for which they are being used or deployed, and to know the quality of the data they collect. As one searches various sources, such as online stores, it is easy to find a plethora of inexpensive air pollution monitoring devices, or air sensors. Many are handheld units that provide immediate results. They often list operating ranges and sometimes report accuracy ranges. But how does one know how good a given sensor's measurement was? How would one know if another sensor, of the same type, located at the same location, would give the same result? Would that same device also provide repeatable measurements if exposed to the same pollutant concentrations?

In other words, how "precise" were these measurements? Even if all of these measurements are precise/repeatable, how well do they compare to a known concentration? Is the measurement biased (does the sensor report values that are higher, or lower than the "correct" concentration)?

At any given location and time, there is only one correct air concentration for a given pollutant. EPA's FRM/FEM monitors are designed to measure and report that correct value by having well-established QA/QC protocols and well-quantified instrument performance. Air sensors of unknown quality give no assurance that the correct value will be measured or reported, though efforts are being put forward to better assess data quality from these sensors. Measurement bias and precision concerns can never be eliminated, but by establishing a quality system for air monitors, such uncertainties can be minimized.

With that said, air sensors of lesser quality than those used for the regulatory purposes, as described above, are not without merit. They may be a very effective screening tool to identify a problem area, such as a "hot spot" along roads or even to help identify the best location for a regulatory-type monitor. They could be useful to individuals interested in determining their own personal exposure to a pollutant, and guide them, in a *qualitative* sense, how to reduce their exposure. This could be an individual with particular air pollution sensitivities, or it could be for a jogger or bike rider exercising.

Sensors could even be used by deploying them along the fence line of a pollution-emitting facility, informing the facility about its potential effects on its neighbors, and/or by that local neighborhood to learn about the impacts of the facility on the neighborhood. In addition, from a general environmental awareness or educational perspective, being more aware of air pollution in the environment is helpful. While regulatory use of these air sensors will likely be limited at best, that is not to say that collecting air monitoring data from air sensors is not useful.

It is also important that the public not be confused if there are differences in data collected between these lower-cost sensors and official SLAMs monitors. In the process of developing air sensors, developers should become familiar with the principles used for the high-quality monitoring devices used for regulatory purposes. The developers should establish clear operating procedures, and schedules for maintenance and calibrations. It would be beneficial for these developers to benchmark, or locate, their sensors near a SLAMs site, or another monitor known to be of high quality to establish how well the sensor compares to these "gold standard" sites. Sensor developers should work up front to establish performance criteria such as detection limits, operating ranges, and any other operating limitations such as temperature.

Also, consideration should be given to who will be using the devices, what their skill levels are and how prone an instrument would be to operator error. Air sensor developers need to be aware of the instrument's calibration needs for a given purpose (or data quality objective), and provide clear instructions to ensure proper calibration is maintained. Ideally, a well-designed and developed air sensor would include all of this information in each air sensor package that is sold or distributed. Collectively, there are a variety of QA/QC issues and questions that need to be considered. One must decide which quality procedures need to be in place to meet the objectives of the measurement.

Moving Forward

There is no question that the wide availability of air sensors will have an impact on the measurement and reporting of air quality throughout the country. As the air sensor community continues to develop and sensor users report their data, questions will need to be addressed about these measured concentrations, how the sensor data compares to EPA and state data, and how it will be used.

EPA and states have been in the "business" of monitoring the air and reporting that data to the public for years. The procedures to ensure the quality of this air monitoring data are well established, and defined in the CFR. The ultimate use of that data, to establish whether health based standards are met, and the steps taken to achieve those standards when they are not in compliance, has been the foundation of air pollution monitoring and air quality planning under the U.S. Clean Air Act.

As air monitoring data become available from lower-cost air pollution sensors, EPA and the states will become more comfortable understanding this alternative source of information. Low-cost air sensors are here. EPA and the states, as well as the public, should seize the opportunity to better understand the quality control and quality assurance issues associated with these new devices and embrace their strengths, as well as recognize their weaknesses. **em**

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