Rise of the IAQ Monitor

These devices may lack accuracy, but they can teach us how we play a role in maintaining indoor-air quality

BY SCOTT GIBSON

The World Health Organization attributes a long list of chronic illnesses and millions of premature deaths annually to polluted air inside and outside the home. Instead of offering a refuge from dirty air, our homes can harbor a variety of problem compounds we don't even realize are there.

Air pollution comes in many forms. One concern is PM2.5—particulate matter measuring less than 2.5 microns in diameter. These microscopic bits of debris can travel deep into the lungs and cause serious health problems, even death, says the U.S. Environmental Protection Agency. Volatile organic compounds (VOCs)—chemicals used in and released by many materials used to build and furnish homes—are another concern.

Measuring these airborne contaminants once required tools costing tens of thousands of dollars. These are lab-grade devices, big and impractical to install in individual houses. But as technology advanced, manufacturers found ways to approximate these functions in much smaller devices that cost a few hundred dollars. Although not as accurate, indoor-air-quality (IAQ) monitors are now widely available, and because they are relatively inexpensive, they give homeowners an opportunity to track air quality at home in a way that wasn't possible a decade ago. What was a trickle of products five years ago now includes dozens of gizmos costing $300 or less.

Monitoring air quality at home

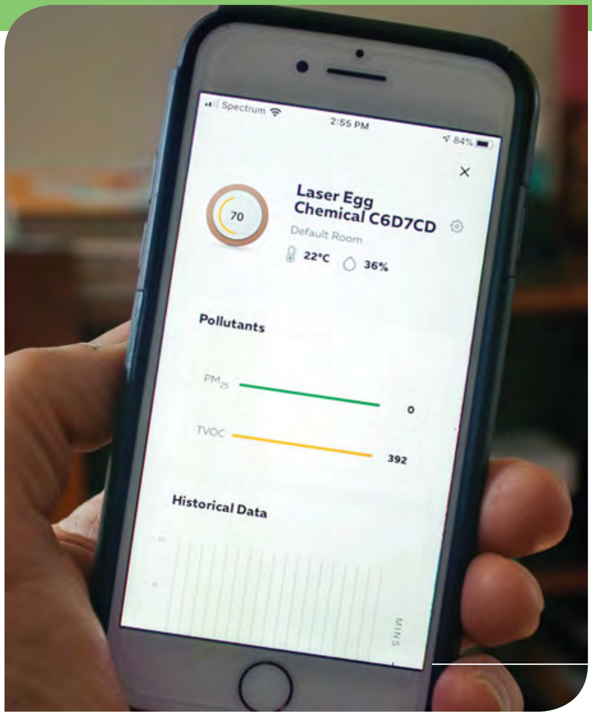
Some of these consumer-grade devices measure PM2.5 concentrations, some measure both PM2.5 and total volatile organic compounds (tVOCs), and others also track CO_2, temperature, and humidity. Some units can be connected to a database that provides a network of real-time air-quality observations for a whole community. Others can be integrated with a home automation system so that they turn on a fan or other device when pollutants cross a certain threshold.

How well do they work? How long do they last? What compounds can be detected, and which ones go under the radar? At the moment, there are no standardized accuracy or performance tests that would allow buyers to answer all of those questions. Manufacturers make their own claims, but there are also several independent sources of information (to be mentioned later), including several university studies, research from the Lawrence Berkeley National Laboratory, and an evaluation

Photo: Rodney Diaz

Put to the test

Curious to try out these monitors myself, I asked two manufacturers—Awair and Kaiterra—for loaners and set them up on my desk. With the devices operating side by side and results available via smartphone app, I took readings of the air quality in my office, and also exposed them to pollutants—including an open jar of varnish. Both were generally able to detect contaminants, though they didn't always agree on their concentrations.



of monitors from an air-quality agency in Southern California.

If you're in the market for a low-cost monitor, you'll have to do some homework to sort out what features you want and what the most recent published test results have to say. The industry is evolving. "The technology is amazing," says Michael Heimbinder, founder and executive director of HabitatMap, a nonprofit that markets the AirBeam monitor. But, he adds, some manufacturers are over-selling their products. "They are making claims that aren't backed by science," he says in an email. "I'd say negligent misrepresentation is very prevalent in the low-cost air-quality-monitoring market both among small-scale manufacturers and large conglomerates."

Counting fine particulates

Inexpensive consumer-grade monitors approximate PM2.5 concentrations with technology that measures how light scatters when it strikes airborne particles, says Dustin Poppendieck, an environmental engineer at the National Institute of Standards and Technology (NIST). A sensor inside the monitor detects a change in light intensity when some of the light is reflected by passing particulates. Software built into the monitor converts this count into a number representing mass, or concentration of particles up to 2.5 microns (2500 nanometers) in size. Readings are a combination of what the sensor sees and how the manufacturer's software interprets the readings, Poppendieck says. But the technology has its limitations. Sensors based on light reflection can only detect particles down to about 300 or 400 nanometers before the particles no longer interfere with the wavelength of the light and, in effect, become invisible.

Software is key. Two monitor manufacturers could be using the same sensor but different software, so two monitors sitting side by side might show different readings. Monitors measuring the effect of such things as pan-frying bacon or burning candles might show different results even if they were using the same sensors.

There are a lot of assumptions that go into writing the software that interprets the data, Poppendieck says, and sensors are calibrated by the manufacturer to a general, default setting that doesn't take into account local variations where a unit might be installed. "For more accurate measurements, these monitors should be calibrated for specific location and, if possible, the specific air pollutant(s) of interest," a report from researchers at Rutgers University says.

Researchers have learned that different types of particles have different densities, different sizes, and different reflectivity. "When the light hits the particles, it may scatter in a similar manner as the unit was calibrated, or it may not scatter at all compared to the way the unit was calibrated," Poppendieck says. Most devices, however, don't give consumers the option to recalibrate their monitors.

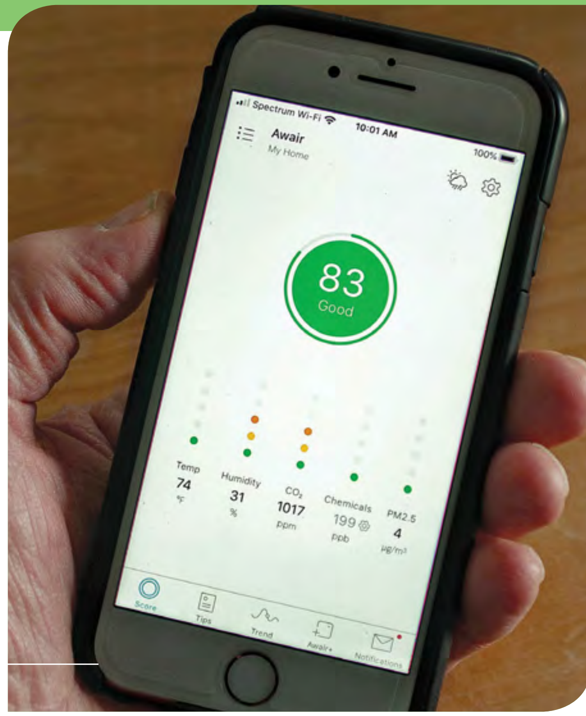
Poppendieck says research conducted at Lawrence Berkeley National Laboratory and Ohio State University has shown that "most of the units will tell you if indoor emissions have happened. They could tell you if the stove turned on because it went right above a baseline a little bit. But the relative amount and how accurate that is was highly variable, even between units of the same brand and manufacturer."

Given all of that, I was curious: How accurate are these things?

"Nobody knows," Poppendieck says.

Checking for VOCs

Volatile organic compounds include a wide range of aromatics, some of them harmful and others not. A number of consumer-grade monitors, according to manufacturers, will check for VOCs as well as PM2.5. Here, as is the case with particulate measurements, inexpensive monitors can't replicate the way expensive lab equipment measures chemicals in the air. Instead, manufacturers use a photo ionization process to spot VOCs, Poppendieck says. The problem is that they



can't tell one molecule from another. "You really don't have any idea what you're measuring. You're measuring something that has caused the detector to give you a signal."

A homeowner might understandably be concerned if the monitor gives a high VOC reading, when in fact the VOCs the device is seeing have little or no health effect. Conversely, some VOCs are dangerous in very small amounts.

Further, the monitor could be set up to hunt for certain chemicals and not for others.

Developing a universal standard

One reason that comparing various models on the market is difficult is that consumers have no independent yardstick with which to rate performance and accuracy. Change is on the horizon.

Poppendieck's role at NIST is to support a subcommittee of ASTM, an international standards-writing organization that develops and publishes a variety of consensus-based technical standards. The group is currently working on an ASTM standard for consumer air-quality monitors, a lengthy process that won't be wrapped up for a year or more. When the group's work is done, there will be standard test protocols that can be used to measure how well air monitors work.

Poppendieck admits that it's been difficult to identify reference particulates for the standard that correlate with what's commonly found in indoor air. A draft of the ASTM standard uses salt and Arizona road dust as references—but these inorganic particulates may have little to do with what is found in indoor air.

"We may be calibrating all of these systems to these inorganic particles when what we see indoors are very much more organic particles," he says. "But there's really no good alternative right now.

"Right now there's no playing field. There's nothing to compare these monitors other than the random studies that people do," he continues. "We can't judge any manufacturer's claims. Even though we might not have the perfect measuring stick to compare these to, it's better to have a yardstick than none."

Where they may be most useful

Consumer-grade air-quality monitors are not designed to replace expensive, laboratory-grade testing equipment capable of giving extremely precise results. The idea is to make something that gives reasonably accurate and consistent results while remaining affordable.

The real value in these low-cost monitors may be to help homeowners spot changes in baseline readings so they can either take corrective action—like turning on a range hood or opening a window to bring the concentrations of pollutants down—or stop doing things that clearly kick up indoor PM2.5 or VOC readings. In one sense, it's not an absolute value that's most useful but how values change in relation to what's going on inside.

Poppendieck says most consumers will learn most of what they need to know about the connection between air quality and personal behavior within a couple of months. After that, they might turn the device over to a neighbor or friend and let them use it for a while.

"I think these would be great tools you could check out of a lending library," he says.

Using a monitor at home

I was curious to see how measurements might read when two different units were sitting side by side just inches apart. On one afternoon, readings for humidity and temperature were fairly close at 33% vs. 36% and 74° vs. 70° F. One unit reported PM2.5 at 1 micrograms per cubic meter; the other read 3. On VOCs, one was reading 30 ppb (parts per billion) while the other reported 265 ppb. So, not even close. The following day, VOC readings showed the same variation.

What happened when I lit a candle? Within a couple of minutes, one unit showed a PM2.5 reading of 7, which is still considered "good," while the other read 6, also "good." One read VOCs at 261 ppb while the other detected nothing. When the candle was blown out, PM2.5 readings jumped to 900 ppb on one, and 203 ppb on the other.

Presented with an open jar of solvent-based spar varnish, the two monitors reported very different levels of VOCs: 130 ppb on one, 298 ppb on the other.

This completely unscientific experiment seems to confirm what experts like Dustin Poppendieck are saying—maybe it's not the absolute values that are most important but the changes in air quality as conditions change that can really educate the user.

The eye-opener for me was the CO_2 readings. They were a little elevated, averaging 740 ppm, but sometimes spiking to more than 1500 ppm during the afternoon. Assuming those numbers are fairly close, it means I probably should open a window more often. □

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