Evaluation of Particulate Sensors - 101

You have a particulate sensor in your hands and you're mapping out an evaluation and testing plan. How do you know if a particulate sensor is good for you? The answer to that question very much depends on your application. There are a variety of attributes and characteristics of particulate sensors that are important to test and ascertain whether it's a good fit for a given application.

- Range of PM values that need to be measured
- Accuracy of data with respect to reference devices
- Precision of sensors (unit-to-unit variance)
- Capacity to withstand high amounts of pollution
- Sensitivity / responsiveness of sensor
- Classification of pollutants (identifying sources of pollution)

Let's consider a fairly common use-case – outdoor air monitoring. Say you are a resident of a suburb in the US interested in measuring air quality outside your home. Measuring PM2.5, and maybe PM10, with reasonable accuracy are likely good enough. If you were a European city manager deploying a network of air quality sensors to monitor a neighborhood, or the entire city, you'd also want the sensors to be precise to obtain consistent data and for those sensors to withstand high levels of pollution. And finally, if you wanted to measure air quality in a hospital, school, or office in that city, you'd also want to measure across the entire range of PM down to PM0.1 with a high level of accuracy to enable classification of pollutants which would then inform your mitigation plan.

Depending on your application, some of the tests detailed below should warrant more of your attention than others. A couple of programming details before we dive into it:

- The rest of this document presumes that you followed the instructions in your device's Quick Start Guide, got your sensor(s) up and running, and have read both the SenseiAQ documentation and 'Interpreting Air Quality Data' on our support site.
- If you intend to work with an independent testing facility/laboratory, contact us at support@pierasystems.com for the 'pro' version of the testing guide

With that out of the way, let's get to some testing! We'll outline a few ways below to test for the above-mentioned attributes; feel free to get creative about modifying below guidelines to suit your needs as your situation warrants.

All of the below noted tests can be conducted in a ‘normal’ room – a dedicated air quality test lab at your office is great but your living room or basement will work just fine as well. Before you dive into these tests, look for a PM2.5 measurement of around 10 ug/m3 – that indicates you have a good air quality baseline that’s typical of a standard room environment.

PM range:

Many low-cost sensors report air quality measurements in a limited number of bins. Piera sensors are the only ones that report 7 bins of PM data (PM0.1, 0.3, 0.5, 1.0, 2.5, 5.0, and PM10).

To test this range, you’ll need to produce particles that span the gamut. One possible source is Smoke Centurion M8, a smoke detector test spray [available through Amazon](#)or your favorite retailer, In a pinch, a room freshener or a body spray will work too.

PM0.1 – PM1.0 particles can be produced fairly simply – lighting a candle, match, or an incense stick; cooking bacon or deep-frying potatoes (we like vegetarians too); or cigarette/vape smoke (which obviously isn’t good for anyone but it does produce quite the range of particles).

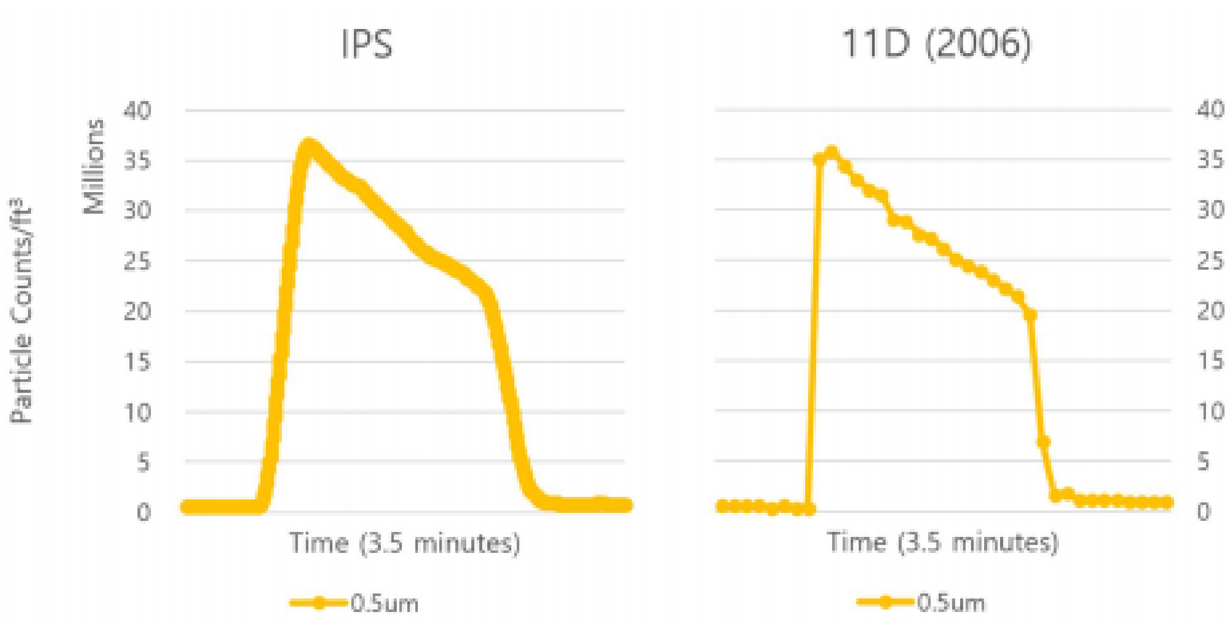
PM2.5 – PM10 (Corn starch, cement dust, or even oil burning, etc.)

Locate your sensor(s) in close proximity (<1 meter to start, you can increase the distance over time) to the pollution source and measure away.

You are looking for: data in all 7 bins (for Piera) and compare it corresponding bins of other sensors in your experiment

Accuracy:

This is straightforward especially if you have access to a high-quality measurement instrument (Grimm, Brechtel, for example). You create pollution (lighting a candle or an incense stick will suffice), measure with the Piera sensors and correlate it to the measurements from the instrument. It’s important to keep the test conditions (location, temperature, relative humidity, pollution source, etc.) as similar as possible, so the best way is to do this test simultaneously with the Piera sensor and the instrument co-located in close proximity. A competing sensor can be used in place of an instrument for a head-to-head evaluation for a direct comparison.



You are looking for: correlation of data from Piera sensors to the instrument; how well, and how quickly, the sensors measure the smallest changes in the environment; and how they perform in low concentrations of pollutants.

Precision:

Sensors can be accurate but not precise and vice-versa. In this context, we define accuracy as an attribute of a single device as measured against a known good quantity (high-quality instrument, for instance) whereas precision is a measure of correlation between several sensors that are expected to produce similar and consistent data.

It follows then that to measure precision of the Piera sensors, you'll need several of our sensors. Co-locate the Piera sensors (and any other sensors under test) in a similar environment, induce pollution (using any pollutant source mentioned above), and take measurements. Swapping out locations of sensors can also be a useful test as that can sometimes have an impact on measurements.

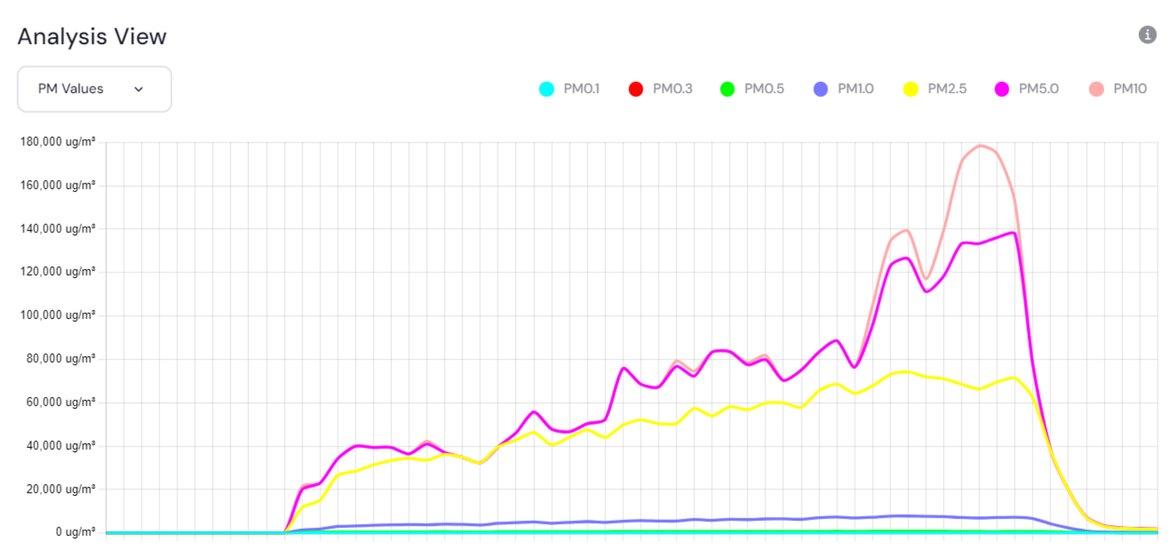
You are looking for: close correlation of data between the various sensors of the same kind, i.e., you should see predictable, consistent results when all the other variables such as testing environment, pollutant source, etc. are kept nearly constant and by comparing minute averages.

High pollution or Concentration:

Self-explanatory, but the goal here is to create large amounts of pollution and measure the sensor's ability to withstand it. There are many pollution hotspots in the real world (wildfires, urban environments, factory floors, etc.) where this becomes an important attribute.

Burning multiple incense sticks all at once or deep-frying until it's quite smoky are but a couple of ways to get there. [In case it needs to be said, while we think the world of our sensors, it's not worth burning your house/lab down, so please be careful with this phase].

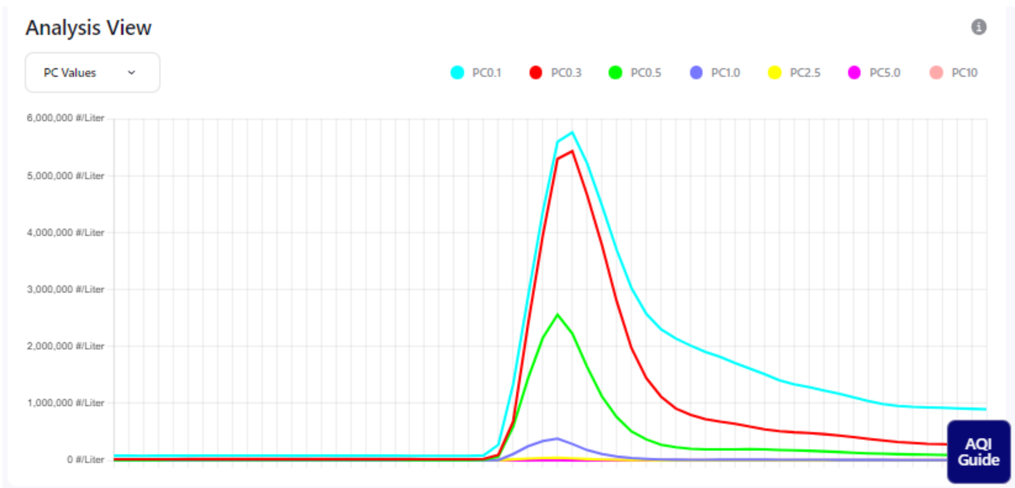
You are looking for: the sensor's ability to measure large amounts of pollution which is typically measured in ug/m3. Look for the various sensors' ability to continue measuring as pollution increases or if they hit a high-ceiling and start clipping off data. Many low-cost sensors peak out at 1000 ug/m3, as an example, while the Piera sensors can go much higher. In the example above, you can see a PM10 value of over 160,000 ug/m3; this pollution event was generated by burning three large incense sticks fully within 1 ft of the sensor and later ventilating the room using fans.



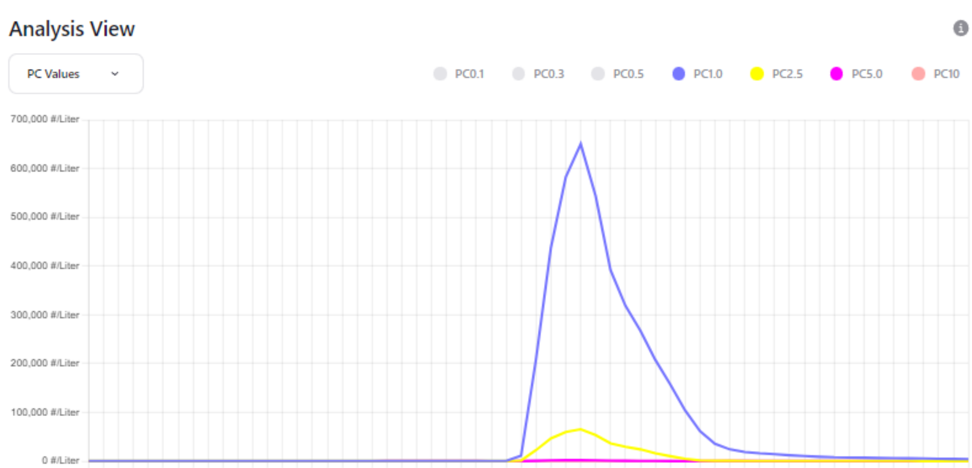
Low Concentration:

The goal here is to see the sensor's ability to measure 'events' (rapid changes) in pollution when pollution is low (below the EPA's recommended guidelines for PM2.5 and 10) and particle counts below PM1.0 are low (PC0.1 <100k, PC0.3 < 25k, PC 0.5 < 10k, PC1.0 <2k). Ideally this will establish your baseline or 'ground truth' for your testing environment.

Now introduce a small amount of pollution, using any of the above-noted pollution sources, for a limited period of time to see how quickly the sensor can detect rapid changes and the amount. Candle burnt and quickly extinguished; within 1 ft of sensor



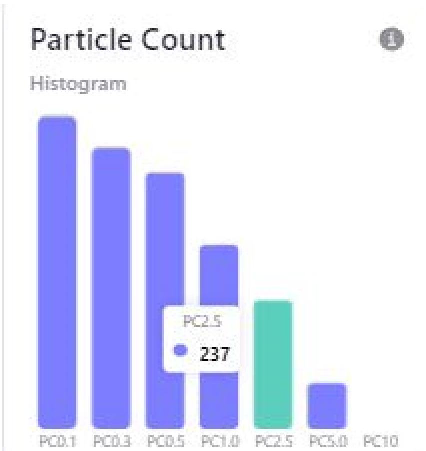
You are looking for: the sensor's ability to measure small amounts of pollution in a good environment typically measured in ug/m3. Look for the various sensors' ability to detect rapid changes as pollution increases. Many low-cost sensors do not accurately measure low concentrations and can require increases over a period of time. Piera sensors have faster response and measure low concentrations.



The figure above shows a candle burnt and quickly extinguished; within 1 ft of sensor; PC1.0 and above turned on in Analysis View

Classification:

Last but definitely not least, is the ability of your sensor to provide you with the right data so that you can classify the sources of pollution. If a sensor can provide you with the right granularity of data (typically translates to a lot of different ‘bins’ of data) with enough accuracy and consistency, then you’ll be able to establish specific patterns that correspond to different pollutants.



For this experiment, you should use various sources of pollution, measure the data, clean out your test environment, and then rinse and repeat. The more data you have, the easier it is to distinguish and establish patterns correlated to the source of pollution.

You are looking for: histograms of the various bins of data (as shown in this screenshot from our SenseiAQ software). Under the right test conditions, you should be able to reproduce the same histogram for a given pollutant which then gives you the ‘pollutant signature’ that you are targeting.

And now you are done! Any combination of these experiments coupled with published data such as test reports from accredited testing bodies like KETI should give you the assurance that you can now deploy your chosen sensor into your application.

Please visit pierasystems.com/support/ for more information about our products or all things air quality in general, If you have questions about this document or during any of your experiments, please contact support@pierasystems.com and we’ll help you get to a successful evaluation.