Title: Low-cost Sensors for Exposure & Health Science: How It Started, How It's Going?

Time/Date: December 7, 2022 8:00 AM - 9:30 AM Mountain Daylight Time (MDT) 3:00 PM – 4:30 PM Coordinated Universal Time (UTC)

Questions not answered as part of the live webinar. Note - some questions were modified to aid in clarity.

Question: Why do we use only sensors that identify 1.0 (PM?) vs. 0.1 - 0.3 where viral loads sit?
Response: I'm not sure the intent of this question but low-cost PM sensors are not appropriate for determining risk from exposure to potentially infectious respiratory pathogens because respiratory aerosols are estimated to make up less <1% of typical indoor PM concentrations. And while it's true that the SARS-CoV-2 and influenza virions are around 0.1 microns in diameter, these virions, when emitted from the human respiratory tract, can reside on particles that span sizes from 1-100 microns in diameter.

Question: The SPS30 and the Plantower saturate at around 1000 ug/m3. Yet concentrations in kitchen of solid fuel user can reach 10x or 20x this concentration. Second question: is there a way to modify this cheap OPC to go beyond this limit? Or if it is not possible, how does this limit affects the accuracy of PM2.5 measurement in kitchens?
Response: The SPS30 can actually measure up to 10,000 ug/m3. The spec sheet might say 1000 ug/m3 but our laboratory tests say otherwise.

Question: What is the future scope for the Low Cost Sensors to detect nano particle matter ?
Response: The physics of light scattering suggest that optical sensors are many, many years away from being able to detect particles smaller than 100 nanometers (i.e., laser power and detector sensitivity would need to increase by a factor of ~1,000). There are electrical and condensation-type counters that can estimate total number concentration (but they cost >$10,000 USD). While these sensors could be miniaturized and mass-produced, I don't believe the market demand is large enough for investment to make it happen. That said, there are a lot of smart people thinking about this problem, so let's hope that some innovation takes place in the years to come…but don't hold your breath!

Question: How about VOC sensors? How do they currently compare with low-cost PM sensors in terms of cost, robustness, etc.?
Response: There are many low-cost VOC sensors on the market that aim to detect "total VOC" concentrations, but our experience tells us that they are not reliable (yet). Based on our experience (and published literature), these low-cost VOC sensors are very sensitive to environmental conditions (temperature, RH, pressure) and cannot detect specific VOC species (e.g., benzene) apart from the many other VOCs present in air. As a result, their applications have been very limited in the field of environmental health.

Question: Are there any special considerations when using low-cost sensors in mobile applications?
Response: A few specific considerations come to mind. The first is the need for a reliable power source. Although low-cost sensors are often require reasonably small amounts of power, they do need some. Another important consideration is the particles being measured. The accuracy of optical particle counters, the technique used in nearly all low-cost PM monitors, requires the sensor to be calibrated for a specific aerosol or aerosol mix. In mobile applications, it is common for the size and composition of the particles being measured to vary with location. Therefore, it is important for special care to be taken when calibrating the sensors and to consider the potential impacts on the accuracy of the reported values if the monitor measures particles different from those used for calibration.

Question: When people wear sensors, does it affect their behavior enough to affect results?
Response: This is an interesting question, and one that I am unsure if anyone has specifically looked out with regards to low-cost sensors. There is the concept of the "Hawthorne effect," the fact that an individual may change their behavior when being observed. It is reasonable to think that this could apply for low-cost sensors. The goal is to minimize these effects through good study design and by making the equipment as unobtrusive as possible but it recognizing this risk and potential bias is important when considering the results of a study.

Question:Is there any value for researchers to work closely with sensor developers prior to starting the monitoring campaign in large cohort or population studies?
Response: I think there is always value in collaboration, especially collaborations between developers and researchers. I think there are opportunities for new and innovative technologies to be tested as part of large cohort studies; however, the technologies used in these studies often must be extremely well vetted and tested prior to them being used as the primary measurement technique. What I do this is critical is to have open communications between these groups in order to identify where technological gaps exist. There are numerous opportunities for improving how we conduct large cohort studies, where the gap often exists is connecting those who know where measurements could be improved with those with the technological expertise needed to make the required changes.

Question: The majority of the low-cost particle sensors on the market appear to focus on mass-concentration. Why don't more sensors report particle counts or surface area information?
Response: Many sensors on the marketplace provide particle counting information, this data is just typically not the main metric reported. Data is typically reported on a mass concentration basis as these are the units often used for health and environmental regulations.

Question:Why do low cost particle counters using the same sensor technology (i.e. Plantower) show such wide variability across different makes and models?
Response: First, it's important to realize that a particle counter is not a primary standard, meaning that it does not measure particle size/concentration directly; it measures the light scattered by particles as they pass through a laser beam. For this reason, all of these devices

must be factory calibrated and such calibrations depend on the sensor type, internal geometry, flow rate, laser/detector sampling rate, and so on. How a sensor is calibrated is entirely up to the manufacturer and they can change their approach from year-to-year or sensor-to-sensor. Indeed, no primary standard (instrument or method) exists for counting and sizing particles in air. We have expensive reference instruments (mobility and aerodynamic particle sizers) that we “think” are accurate, but even they can be off by 25%. Additionally, most counters only “see” a small fraction of the particles that enter the instrument, so their output is really a guess at the total particle concentration. A good analogy here is looking outside during a rain or snowstorm and trying to count how many drops / snowflakes are falling per unit area…your eyes can take in the totality of the falling drops, but to count them you need to focus on a small area, so making a quantitative measurement is challenging.