MADISON®

IAQ

Market Opportunity: Sensor Technologies

Executive Summary

Indoor air quality is measured and improved by using sensors which can detect pollutants in the air and provide a signal to occupants or equipment. Sensors are characterized by their sensitivity, selectivity, and response time all of which are important in proper use and application. Currently the widely available sensors are consumer grade and show promise but still are far off from where we need sensors to be. The goal is to be able to utilize sensors to automate IAQ responses within buildings like that of how heating and cooling is controlled; to provide the greatest amount of control with the least amount of human input. IAQ sensors also provide visible data to something that was previously invisible to most building occupants which often leads to more focus on the subject. Lastly, sensors may be able to help determine disease causing bioaerosols which could lead to improved pandemic containment and forecasting.

Explanation of the Science

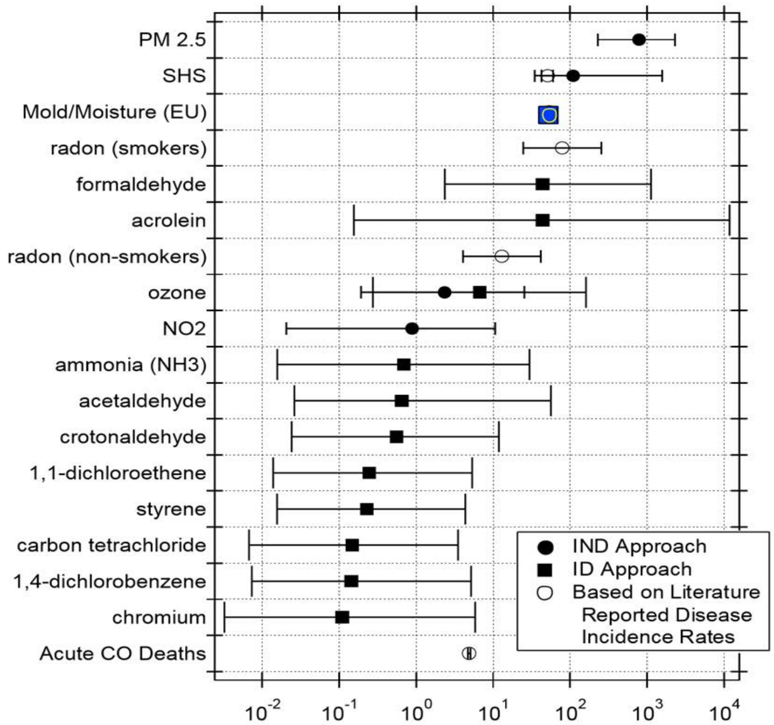
When we look at improving IAQ for a building the first thing we should ask is what are the pollutants, what are the action levels specific to that building's occupants, and how to we address those pollutants. In order to do this, we need to be able to sample the air and measure what is in the air using sensors A working sensor is typically characterized by three parameters: sensitivity, selectivity and response time. Sensitivity is the ability of the sensor to quantitatively measure the test gas or particle under given conditions. It is governed by the inherent physical and chemical properties of the materials used. Selectivity of a sensor is its ability to sense a particular gas or particle free from interference. Response time is a measure of how quickly the maximum signal change is achieved with gas or particle concentration changes. In addition, reversibility, long term stability, size, and power consumption also influence the overall performance of the sensor.

IAQ sensor technologies should be used to accomplish the following in buildings:

1. Determine what pollutants are in the indoor air
2. Activate the proper technology or system to improve IAQ

3. Verify air cleaning, filtration and ventilation systems are working – very important with bioaerosols
4. Pressurize/depressurize zones and/or buildings

The below graph presents the pollutants that are found to be most harmful to humans in US homes.



Source: Logue et al 2011

Thus, we should be looking to utilize sensor technologies to determine the levels of these pollutants. There are good IAQ sensors used to detect many of the common pollutants, but they come at the research grade and cost which makes it tough to widely deploy. Many consumer grade IAQ sensors have come on the market in recent years with the rise of the IoT community. In order to avoid the use of high cost sensors, many of these consumer grade sensor packages use algorithms to try and offset their sensor capabilities. Foobot, for instance, does not have a CO2 sensor but utilizes an algorithm to devise CO2 from tVOCs, which is less than accurate (Moreno-Rangel et al 2018). In addition to algorithms, most of the consumer sensors group VOCs into one sensor for tVOCs due to the high cost of individual VOC sensors. Lastly, consumer grade IAQ monitors have been shown to miss major particulate events and provide false positives under certain conditions due to lower cost sensor technologies (Singer and Delp

2018). There has been a lot of research and government focus on these monitors as the price point makes them available to consumers and there is concrete research linking poor IAQ with health issues.

Bioaerosol sensors are uncommon in the building world and utilize expensive advanced technologies in order to discriminate a particular bioaerosol from other particles of the same size (Huffman et al 2020). This could be done through mimicking DNA receptors, mass spectrometry, or potentially through less expensive technology. As we move into the post-COVID-19 pandemic world, sensors like these will be developed in order to monitor public places and get a jump on pandemic causing bioaerosols. The challenge in developing these sensors is that the size, structure, and genetic make-up of the bioaerosol must already be known. However, similar types of bioaerosols, like viruses classified as SARS, could be grouped together. In addition, other technologies that mimic cellular activity could be developed in order to detect unknown bioaerosols of concern.

Current IAQ Sensor Technology

Carbon Dioxide (CO2)

The most common CO2 sensors are infrared gas sensors (NDIR) and chemical gas sensors.

NDIR sensors detect CO2 in a gaseous environment by its characteristic absorption. This requires an infrared source, a light tube, a wavelength filter, and an infrared detector. As the gas passes through the light tube, electronic circuitry measures its absorption of IR light.

Chemical CO2 gas sensors require very low power and can be made quite small. On the other hand, they have a large drift and short lifetime.

Ozone (O3)

The best known method for ozone measurement has been to use an analyzer based on the UV absorption principle. The expense of such equipment has driven many to look for lower cost ways of measuring ozone.

In an electrochemical sensor, ozone diffuses across a porous membrane into a cell containing electrolyte and electrodes. Ozone contacting the electrolyte causes electrons to flow. As the presence of ozone increases, the electrical signal increases proportionally. Sensor life is <2 years and output is cross-sensitive to humidity.

Heated metal oxide sensors heat a special metal substrate which allows it to become very sensitive to ozone gas. An electrical current passes through the metal substrate. Its resistance changes according to the amount of gas present. The sensor converts the resistance to an output reading. These sensors are somewhat cross-sensitive to VOCs. HMOS is considered the most cost effective for air monitoring use.

PM2.5

Commercially available PM sensors measure the light scattered by particles when the particles pass in between a light beam and an ocular sensor. These sensors have various draw backs including their inability to operate accurately across various relative humidity levels and are often calibrated using a particular dust which may not be representative of what they will be measuring. These sensors can be improved by utilizing a gravimetric filter that can cross reference the optical sensor and improve accuracy.

VOC

There are two common types of VOC sensors: Photoionization Detector (PID), and Gas Sensitive Semiconductor (GSS). Both types are non-selective. PID type VOC sensors are more resilient and can detect a wider variety of VOCs.

Note that the non-selective nature may limit usefulness to verify performance of air cleaning and filtration strategies. For example, ammonia (not a VOC) will be picked up by many PID devices as part of the total VOC load though the cleaning/filtration strategy would be very different than for VOCs.

Carbon Monoxide (CO)

Metal oxide semiconductor (MOS) technology is far and away the most common sensing method.

MOS based sensors react with CO gas via reduction and oxidation, which affects electrical properties of the sensing elements. It is this change in electrical properties that helps detect the presence of CO.

Biomimetic sensor: A gel changes color when it absorbs carbon monoxide. This technology is an analog to carbon monoxide’s effects on hemoglobin in the blood.

Optical methods exploit the molecular absorption phenomena of CO gas within a specific range of light spectrum. This technology is still under development.

PLEASE CONTACT ONE OF OUR EXPERTS TO HELP YOU IMPROVE YOUR INDOOR AIR HYGIENE

Email:

sales@madisoniaq.com

Website:

madisoniaq.com