



Air Quality Monitoring Sensor Technologies for a Data Driven Future

Presented by Zach Conway



Agenda

- 01 Introduction to Indoor Air Quality
- 02 Pollutants and their Sensor Technologies
- 03 Controlling Viral Transmission with IAQ
- 04 Benefits of continuous monitoring
- 05 Recap & Key Takeaways
- 06 Q&A and Discussion

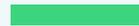


Why measure
indoor air quality
(IAQ)?





Poor IAQ can cause numerous health symptoms.



Headache

Fatigue

Shortness of breath

Stuffy nose

Cough

Sneezing

Allergy flare-ups

Skin reactions

Dizziness

Nausea

The original indoor air quality monitoring solution...

Canaries were used in coal mines starting in the early 1900's to warn workers of unsafe levels of air pollutants.

Air quality management is often driven by workplace safety.

It's 2021 and we have better solutions to ensure healthy air for the occupants of an enclosed space.



Why Continuous Monitoring ?

- ✓ Know the true air quality
- ✓ Resolve issues faster and address concerns
- ✓ Improve ventilation and filtration efficiency
- ✓ Save energy without sacrificing health and comfort

Before we dive in...

Key Considerations

The best way to ensure clean air is to remove pollutants at the source, not purify.

How will the device be calibrated? A correction is not a calibration.

Consider the lifetime cost of the device (include subscriptions, calibration, replacements, installation and operator costs).

How will the device be deployed? (automation, placement)

Pollutants Discussed in this Talk



- Particulate Matter (PM_{2.5}, PM₁₀)
- Carbon Dioxide (CO₂)
- Volatile Organic Compounds (VOC's, TVOC's, formaldehyde)
- Radon (Rn)
- Ozone (O₃)

Particulate Matter

Q: What is particulate matter?

A: Particulate matter are solid particulates that are able to stay airborne. We classify particulate matter based on its *aerodynamic diameter*.

Q: How is it formed?

A: Dust, allergens, smoke, chemical reactions

Q: Why should I care?

A: Particulate matter is the most harmful and common air pollutant.



A 1 $\mu\text{g}/\text{m}^3$ increase in PM2.5 concentration resulted in a 0.6% drop in productivity.

T. Chang, "Particulate Pollution and the Productivity of Pear Packers," *American Economic Journal: Economic Policy* Vol. 8, No. 3 (Aug 2016)

Particulate Matter Sensors



Infrared Sensors	Light Scattering	Beta Attenuation Mass Monitor
<ul style="list-style-type: none">• Cheap \$• Continuous monitoring• Low accuracy• No differentiation on particle size	<ul style="list-style-type: none">• Cheap \$• Continuous monitoring• Can use the diffraction of light to bin particle sizes• Can't measure under 0.3 microns	<ul style="list-style-type: none">• Expensive \$\$\$• Single point analysis• Requires a trained operator• Provides accurate readings no matter the geography

Carbon Dioxide



Q: What is carbon dioxide?

A: Carbon dioxide is an inert molecule containing one carbon and two oxygen atoms.

Q: How is it formed?

A: Occupants breathing and chemical reactions

Q: Why should I care?

A: Lowered productivity, stuffy air, brain fog



For every 400 ppm increase in CO₂, cognitive function scores drop by 21%.



Joseph G. Allen, "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers," *Environmental Health Perspectives* (Jun 2016)

Cognitive scores were 61% higher on days when spaces are better ventilated.



Joseph G. Allen, "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers," *Environmental Health Perspectives* (Jun 2016)



What “higher cognitive performance” is actually worth?



\$6,500 per person per year

on average, using data from the Department of Labor.

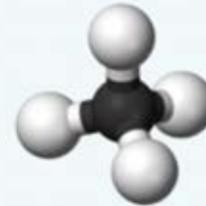
Meanwhile, the increase in energy costs is \$40 per person per year and only \$1 per person per year for energy efficient systems.

Carbon Dioxide Sensors



Electrochemical	Non-Dispersive Infrared
<ul style="list-style-type: none">• Cheap \$• Low accuracy• Hard to calibrate• Will need replacement	<ul style="list-style-type: none">• Cheap \$\$• High accuracy• Easy to calibrate• Long lifespan

Volatile Organic Compounds



What is a VOC?

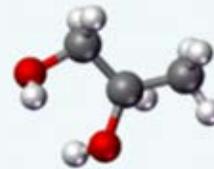
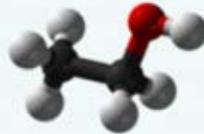
Volatil organic compounds are organic (carbon containing) chemicals with a boiling point less than 482°F

How is it formed?

VOC's commonly enter a building through off gassing of building materials (carpets, paints, adhesives)

Why should I care?

Some VOC's have high toxicity. There is evidence that VOC's impact productivity.





A 500 $\mu\text{g}/\text{m}^3$ increase in VOC concentration decreases cognitive function scores by 13%.

Joseph G. Allen, "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers," *Environmental Health Perspectives* (Jun 2016)

Volatile Organic Chemical Sensors



Metal Oxide Semiconductor	Photo Ionization Detector	(GC, FID) Mass Spectrometry
<ul style="list-style-type: none">• Commercial Grade• Cheap \$• Poor selectivity• Less accurate• Low power• No training required• Needs eventual replacement	<ul style="list-style-type: none">• IAQ Consultant Grade• Moderate Price \$\$• Good selectivity• Good accuracy• High power required• Training required	<ul style="list-style-type: none">• Lab Grade• Expensive \$\$\$• High selectivity• High accuracy• Training required

Radon

Q: What is radon

A: Radon is a naturally occurring, colorless, odorless radioactive noble gas.

Q: How is it formed?

A: The radioactive decay of naturally occurring uranium in the ground.

Q: Why should I care?

A: Alpha decay of radon causes lung cancer among other health implications.

•²³⁴U, 2.45*10⁵ years, alpha decaying to...
•²³⁰Th, 7.54*10⁴ years, alpha decaying to...
•²²²Rn, 3.82 days, alpha decaying to...
•²¹⁸Po, 3.10 minutes, alpha decaying to...
•²¹⁴Pb, 26.8 minutes, beta decaying to...
•²¹⁴Bi, 19.9 minutes, beta decaying to...
•²¹⁴Po, 0.1643 ms, alpha decaying to...
•²¹⁰Pb, 22.3 years, beta decaying to...
•²¹⁰Bi, 5.013 days, beta decaying to...
•²¹⁰Po, 138.376 days, alpha decaying to...
•²⁰⁶Pb, stable.

Radon Sensors



Test Strips	Alpha Spectrometry
<ul style="list-style-type: none">• Three month analysis• Cheap \$• Easy to invalidate the results• Can identify if radon is a concern in the space	<ul style="list-style-type: none">• Continuous monitoring• Cheap \$• Can identify anomalies

Ozone



Q: What is ozone?

A: Ozone is three bonded oxygen atoms, also known as tri-oxygen.

Q: How is it formed?

A: High voltage, reactions of NO_x or VOC's with UV light and oxygen

Q: Why should I care?

A: Ozone is a harmful pollutant that can decrease lung function, aggravate asthma, cause i

Tropospheric ozone \neq stratospheric ozone.

Ozone Sensors



Electrochemical	Metal Oxide Semiconductor	Ultraviolet
<ul style="list-style-type: none">• Cheap \$• Low accuracy at low levels• Cross sensitive with NO₂ and Cl₂• Can correct for NO₂ if it is measured• Long warm up period• Will need eventual replacement	<ul style="list-style-type: none">• Cheap \$• Low accuracy at low levels• Cross sensitive with VOC• Long warm up period• Will need eventual replacement	<ul style="list-style-type: none">• Moderate Price \$\$• Long Lifespan• High accuracy



Influenza virus transmission is most efficient under cold, dry conditions. The infectivity decreases significantly at higher RH levels.

Anice C. Lowen, "Roles of Humidity and Temperature in Shaping Influenza Seasonality," *Journal of Virology* (Jul 2014)
John D. Noti, "High humidity leads to loss of infectious influenza virus from simulated coughs," *PLoS ONE* (Feb 2013)

Gain Insight with IAQ data



- Assess the efficacy of your **HVAC's air filtration system** with **PM2.5 readings**
- Know how **disinfectants and cleaners** impact your air quality through **TVOC monitoring**
- Keep track of **occupant density and ventilation** through **carbon dioxide** measurements
- Slow down viral spread by tracking indoor **relative humidity**
- Ensure **radon** is not present or that it is being managed appropriately
- **Showcase key air quality indicators** to boost trust and confidence

Key benchmarks



Particulate Matter:

PM2.5 levels should be kept below **10 ug/m³**



Volatile Organic Compounds:

VOCs should be controlled in occupied spaces



Ozone:

Ozone should be controlled and kept below **25 ppb**



Carbon Dioxide:

CO₂ levels should be kept below **800 ppm**



Radon:

Radon should be measured for and kept below **100 Bq/m³**



Relative Humidity:

RH should be maintained between **40-60 percent**

Key Takeaways

- How to evaluate air quality monitoring companies:
- What are the goals of the project?
- How to decide what gases to measure?
- How to calibrate the device?
- How will the device be deployed?



Q & A

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