IotaComm

# Why Healthy Air Engenders Student Health and Improves Test Scores

## *The Educator's Guide to Healthier Air Quality*

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Why use IoT sensors to improve health and safety, aptitude, and productivity in schools? Numerous tests have been conducted to study the impact of air quality on student cognitive performance. Several recent studies in the US demonstrate that unhealthy air degrades student test scores in Mathematics and English Language Arts.

The following article reveals how secure, reliable and cost effective LoRaWAN wireless internet of things (IoT) sensors can continuously monitor and measure indoor air quality (IAQ) and environmental conditions. Coupled with analytics, IoT sensors provide continuous monitoring of environmental conditions and data where algorithms generate insight with recommendation for improvement. Through continuous data monitoring threshold boundaries can produce alerts with prompt notification to where the issues exist.

Numerous research studies indicate that unhealthy IAQ negatively impacts student test scores as well as their health and safety.

### Why is IAQ Important

- Nearly 90% of student time is spent indoors (1)
- Air containments can often be higher indoors (1)
- Tests show elevated particulate matter or micro dust can lower test scores (2)
- Volatile chemicals are proven to lower test scores (2)
- Green schools on average performed over 60% higher on cognitive test scores (2)
- Excessive CO2 levels can cause fatigue and drowsiness (3)
- Low CO2 levels negatively impact facility energy efficiency
- High humidity levels can generate mold
- Drift in temperature set points can impact energy efficiency
- Air quality can impact student health, attendance, heighten risks and liabilities as well as community trust

Subsequent innovations such as generative Artificial Intelligence (AI) offer new approaches to gaining insight. IoT sensors are capable of capturing real time monitoring of conditions and performance of systems and facilities.

*IoT data and AI enable an innovative approach to a healthy and productive environment.*

### Indoor Air Quality Monitoring

**What metrics are important to measure IAQ?** There are several environmental metrics that we should discuss. The following represent meaningful and accessible air quality metrics where IoT sensors can be deployed to continuously monitor environmental conditions inside and outside of schools.

There are many more VOCs including

**Table 1 IAQ Sensor Metrics** [4]

| Sensor | Description | Measurement | Symbol |
|---|---|---|---|
| CO2 | Carbon Dioxide | Parts per million | PPM |
| VOC | Volatile Organic Compoounds | Microgram per Cubic Meter | ug/m3 |
| PM2.5 | Particulate Matter 2.5 Micrograms | Microgram per Cubic Meter | ug/m3 |
| Temperature | Ambient Temperature | Degrees Fahrenheit | °F |
| Humidity | Ambient Relative Humidity | Percent to Temperature | % |

carbon monoxide, nitrous oxide, ozone as well as chemicals arising from cleaning, flooring, painting and other manufactured substances. The challenge for VOC sensors is the cost of deriving specific chemical compounds from an array of possible substances, when it is easier and less costly just to determine the presence of any harmful volatile chemical compound.

*Nearly 90% of student time is spent indoors* [1]

## CO2 Monitoring and Measurement

CO2 monitoring is important because elevated CO2 levels can cause drowsiness while CO2 levels too low waste energy. [5] So, there is a careful balance to be met to manage adequate air quality while conserving energy. To obtain adequate CO2 levels, ventilation and CO2 monitoring are imperative.

One method is to employ indoor air quality monitoring to modulate the amount of outside air entering the building for cooling or heating. Cooling often costs significantly more because cooling is mainly driven by electric power. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHARE) offers guidelines that refer to CO2 monitoring as a means of assuring acceptable air quality and optimal HVAC efficiency. [5]

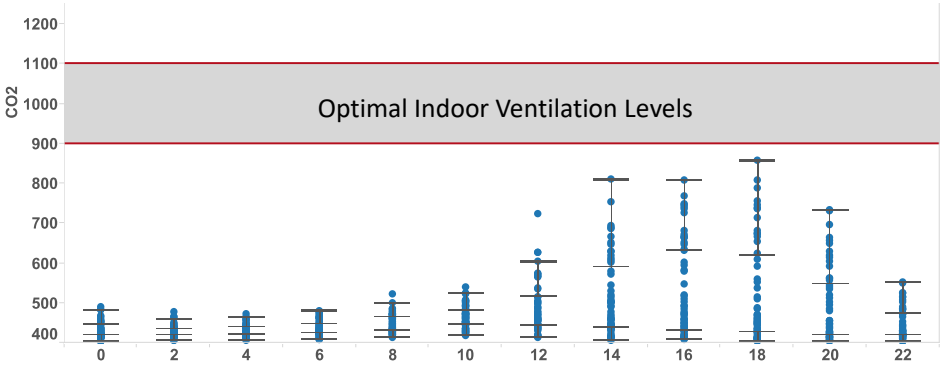
The IAQ Index has levels set by the EPA for particulate matter - PM2.5 particulate matter (micro-grams per cubic meter), - VOC volatile organic compounds (micro-grams per cubic meter) and - CO2 (parts per million). [4] As seen in figure 1, the CO2 readings consistently fall below the optimal HVAC efficiency zone of acceptable air quality. In this example, CO2 levels remain close to actual outside air levels indicating an inordinate level of outside intake with respect to ventilation. The key point is that knowing the CO2 levels allows adjustments to maintain a healthy environment while conserving energy.

*Green schools on average performed over 60% higher on cognitive test scores* [2]

The following figures 1-3 for CO2, VOC and PM2.5 represent tabulations of IAQ metrics aggregated by hour of the day to identify potential concerns regarding health, safety and cognition. Essentially, each figure arranges one month of reporting IAQ parameters into a 24-hour snapshot to identify trends, outliers and anomalies.

This environmental monitoring approach is data-driven using cost effective wireless LoRaWAN IoT sensors. Our analytics framework

**Figure 1. CO2 Levels by Hour of the Day**



includes a dashboard with threshold alerts for notification of abhorrent conditions. Our analytics and IoT data AI platform blends data from various sources such as weather, building envelope, and occupancy to evaluate and analyze conditions and performance of resources such as air, water and energy as well as human health and safety.

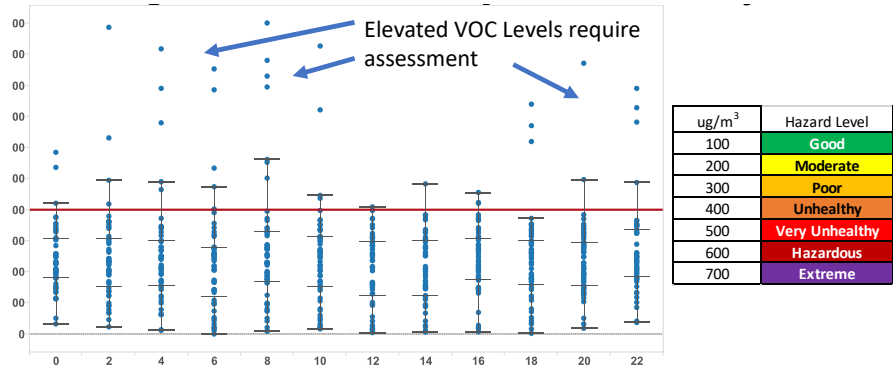
## VOC Monitoring & Measurement

**IoT and analytics enable an innovative approach by using IoT devices to remotely monitor, measure and curate quantifiable metrics on environmental conditions and apply analytics to optimize desired outcomes.**

VOCs can negatively impact test scores and human health. While Figure 2 VOC Levels by Hour of the Day remain acceptable most of the time, elevated VOC levels should be examined for root cause. VOCs could originate from cleaning products, paint, or flooring material. What is crucial is that highly elevated VOC and PM2.5 levels are a real concern. Persistent and reoccurring elevated VOC levels require mitigation and corrective action.

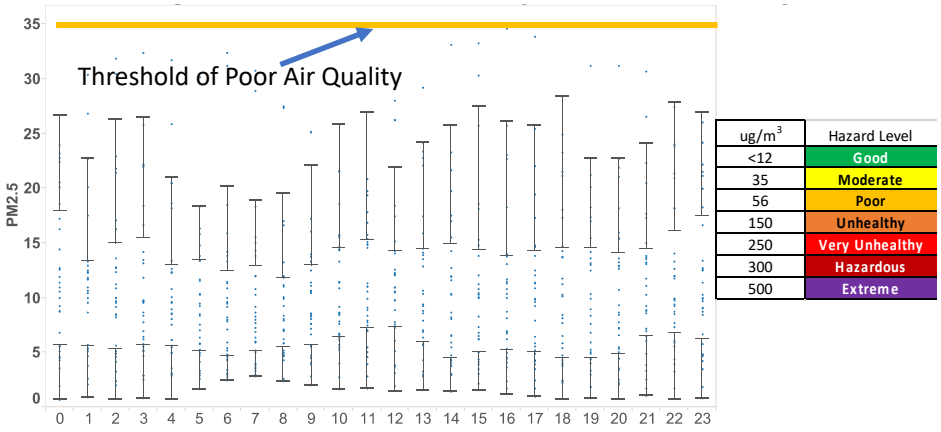
*In June of 2023, Canadian wildfires created smoke plumes to blanket much of the US East Coast which in turn, drove particulate matter levels reaching 484 micrograms per cubic meter in NYC. (6)*

**Figure 2. VOC Levels by Hour of the Day**




| ug/m³ | Hazard Level |
|---|---|
| 100 | Good |
| 200 | Moderate |
| 300 | Poor |
| 400 | Unhealthy |
| 500 | Very Unhealthy |
| 600 | Hazardous |
| 700 | Extreme |

**Figure 3. PM2.5 Levels by Hour of the Day**




| ug/m³ | Hazard Level |
|---|---|
| <12 | Good |
| 35 | Moderate |
| 56 | Poor |
| 150 | Unhealthy |
| 250 | Very Unhealthy |
| 300 | Hazardous |
| 500 | Extreme |

## PM2.5 Monitoring & Measurement

The nature of PM2.5 is that the particles are too small to see. This is a primary reason why IoT sensors play an important role in identifying air quality concerns. IoT sensors are engineered to identify microscopic particles and provide readings to assess potential impact on child safety and cognitive productivity. PM2.5 is attributable to cognitive impairment and yet they are too small to know they are present in the air you're breathing.

Research in Brazil showed an 11% decline in test scores with a ten particle increase in PM10 in micrograms per cubic meter (5). In June of 2023, Canadian wildfires created smoke plumes to blanket much of the US East Coast which in turn, drove particulate matter levels reaching 484 micrograms per cubic meter in NYC. (6) PM2.5 is a particularly pernicious because micro dust particles can accumulate in the lungs causing health and perhaps chronic breathing issues.

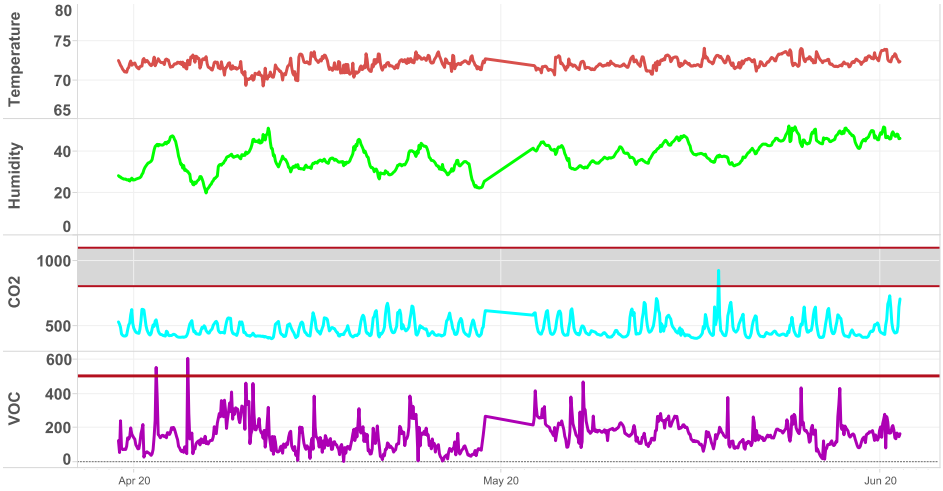
## Temperature and Humidity

As mentioned above, continuous monitoring of temperature and humidity are important not only to maintain constructive and productive environments but also plays a role in energy efficiency and equipment protection. Contort level is necessary to maintain student productivity. Drift in temperature set points can cause unnecessary calls for heating or cooling which in turn wastes energy.

Humidity levels also require continuous monitoring. High humidity levels often lead to precipitated moisture where any accumulation can be destructive to equipment and result in mold. The recommended humidity level for a healthy indoor environment is between 30-60%. Low humidity levels are not good either. Besides dry skin and eyes, low humidity can create static electricity and lead to allergic reactions including drying mucus membrane thereby making it harder for the body to remove germs.

Not only can monitoring indoor air quality provide crucial fabric to the health and safety of students and building occupants, but can reduce cost by optimizing energy efficiency according to air quality conditions. Various studies have shown that cognitive function is directly correlated to air quality. One study from Harvard University demonstrated that cognitive skills and productivity declined with excessive amounts of CO2. [7]

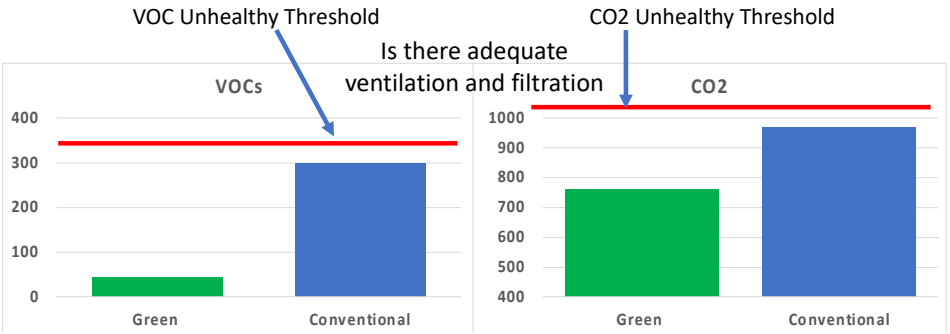
**Figure 4 Multiple Sensor Metrics**




## Comparing Green Facilities to Conventional

Green buildings adhere to a sustainability plan often adopting guidelines from Well Building Standard ASHRAE or EPA standards. As air quality monitoring and measurement pertain to school student test scores it's helpful to offer perspective in comparing Green versus Conventional buildings as it pertains to unhealthy VOC and CO2 air threshold levels. Green buildings offer significantly better air quality as measured by substantially lower concentration of VOCs and CO2.

**Figure 5 Comparing Green to Conventional Buildings**




## How can we improve school IAQ?

The bottom line is that through continuous monitoring and measuring of indoor air conditions, when a reading breaches an established threshold, an alert for unacceptable conditions can be sent to a designated recipient. Notifications can be sent via text and email. Online monitoring is available through PC or smart phone using our Delphi 360 platform. The takeaway is that IoT data digitizes the physical world and AI algorithms enable insight to optimize desired outcomes.

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**ADDITIONAL RESOURCES**


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For a summary of the impact of indoor environmental quality on work and school performance, as well as other IAQ research findings, see the IAQ Scientific Findings Resource Bank (SFRB) established as a cooperative venture between EPA and the Lawrence Berkeley National Laboratory: Accessible at http://www. iaqscience.lbl.gov/performance-summary.html

Juan Palacios, Massachusetts Institute of Technology (MIT) - Center for Real Estate; IZA Institute of Labor Economics; Piet Eichholtz, Maastricht University; Nils Kok, School of Business and Economics, Maastricht University; Nicolas Duran, University College London - Bartlett Real Estate Institute, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4296077#:~:text=Using%20a%20fixed%2Deffects%20strategy,the%20school%2Dterm%20average%20daily ,18 Jan 2023 “Indoor Air Quality and Student Performance: Evidence from A Large Scale Field Study in Primary Schools”

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IotaComm offers a comprehensive platform from wireless data access to visualization dashboards and provides an analytics framework to improve the viability of students, schools and community.

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