Part Four: The Importance of an IAQ Baseline and IAQ Sensors

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In the fourth part of my series, 'Clearing the Air for Our Kids: School Ventilation Guidance,' I'm discussing the importance of indoor air quality (IAQ) sensors in schools to create a platform for recurring HVAC adjustments to ensure the highest level of continued indoor air quality. The sensor array must be paired with a robust data aggregation platform.

Across the nation's schools, a budding awareness about air quality is forming. Similar to school nutrition or lead in the water, a new struggle requires empowered decision makers. Decisions such as testing for lead or removing vending machines in schools are all driven by what is best for the students. We have entered such a paradigm for air quality in our schools.

The air quality in classrooms and our schools was not as an important topic of discussion before COVID-19 hit. School lunches, class sizes, test scores, daylighting, water quality and other items were what administrators, teachers, and parents thought were the most important and budgets were deployed accordingly. Once COVID-19, an airborne virus, shut down schools, air quality and filtration shot to the top of everyone's list. We are in a new paradigm where air quality can be spoken in the same breathe as life safety. We have to move to a more active indoor air quality monitoring and adjusting in real time.

In the new paradigm of indoor air quality in schools, attention must be given to what the actual ventilation and airside distribution values are within the contiguous building environs. Leveraging our firm's experiences across several million square feet and thousands of HVAC units during the last year, we have learned how to adjust TAB and verification approaches to be more relevant. Performing these enhanced assessments of the systems are simple, yet necessary to determine how well the HVAC is distributing ventilated and/or filtered air while identifying the mechanisms for real time airside adjustments.

There has been in the HVAC engineering community a push and pull between the advocates of energy efficiency and improved indoor air quality. With the introduction of more ventilation (fresh air), in most

outside conditions there will be increased energy usage to heat and cool the ventilation air. While energy efficiency strategies must be maintained, in the new paradigm of advanced indoor air quality, precedence must be given to increased ventilation during the occupied hours. Building engineer operators must have the ability to both increase ventilation as well as reduce energy consumption by reducing the ventilation air during unoccupied times. A pragmatic approach to effective ventilation reduction to code minimum levels can only be done with the inclusion of air quality sensors.

Minimizing the risk of COVID-19 and other airborne viruses isn't the only reason to keep a close eye on air quality in school. In fact, significant IAQ problems can arise from a combination of common minor problems. For example, a school might not get enough outdoor air because a fan belt is broken or a damper motor is not engaging. I have encountered a seldom used drain

trap drying out, resulting in sewer gases being drawn into the mechanical room. In some areas of the country, like the West, during fire season, we have to have the ability to close our outdoor dampers to avoid entraining fire particulate into the building's air.

The first step to establish your IAQ baseline is to establish where your HVAC system stands in terms of ventilation, filtration, and deferred maintenance. Identify the proper team to perform the assessment. A qualified team includes a skilled technician, who can perform the physical assessment in coordination with facilities personnel, as well as a design professional. Make sure to hire technicians that are certified by a TAB certification agency, such as AABC or NEBB. Once you've identified the right qualified personnel, then what should they do?

First, the technician should perform a physical assessment of the HVAC infrastructure to verify operation and conditions of the existing systems. The team has to know the actual values for ventilation and airflow distribution. Once complete, the assessment should be submitted to an engineering design professional to determine critical system adjustments, replacements, repairs, and upgrades to optimize IAQ. School districts, individual schools, and building owners then can make the educated budget driven decisions on improvements.

The National Energy Management Institute has sample Ventilation Verification Assessment test sheets and Method of Operations (MOP) to help guide technicians through assessments. Sample procedures should be altered to meet local requirements, updated recommendations, and site specific equipment. Ask your technician to correlate their findings to this standard, and remember to make sure to have your ventilation systems tested yearly.

Here is a quick look at what must be included in an airside TAB HVAC assessment:

- Verify existing filtration MERV ratings
- Document any filter bypass air conditions at the HVAC unit
- Document Actual Ventilation Rates and Supply Air Rates in cfm
- Verify Demand Control Ventilation (DCV) status and the ability to override
- Measure 10% of all inlets/outlets for a sampling for a sampling of Air Distribution
- Determine motor HP capability to handle higher MERV filters
- Verify ability to increase ventilation above scheduled values
- Determine Operational Controls and ability to change set points and run times
- Sample VOC's in the building space per NIOSH, we recommend one sample per 5000 sf

Establish a baseline of the six EPA-defined common air pollutants:

- Particulate matter
- Photochemical oxidants
- Carbon monoxide
- Sulfur oxides
- Lead
- Nitrogen oxides

Second, establish a baseline of the indoor air quality and the components of the air. Pay special attention to VOC's, particulate matter (PM2.5), carbon monoxide, and ambient Ozone levels in your space. TAB professionals have not been required to take actual air quality readings but should establish this practice moving forward. Introducing the design changes is essential to ensuring the necessary decisions for the new paradigm of proper indoor air quality.

As we move beyond COVID-19, schools' focus must be on the indoor air quality as measured by the HVAC building industry. In the school environment with our younger more sensitive populations, school administrators and facility personnel must adhere to a basic philosophy: Do no harm. Establishing the IAQ baseline helps them ensure that they are not over sanitizing, flushing properly with clean air, and are ventilating for the correct amount of time. VOC's and CO2 will be two of the main measurable low-cost air quality parameters to be used in adjusting our HVAC ventilation rates and run times.

Table 1 – Typical Indoor Contaminants (VOCs) and Their Source

Contamination Source	Emission Source	VOC
Human Being	Breath	Acetone, Ethanol, Isoprene, CO_2
	Skin Respiration & Perspiration	Nonanal, Decanal, alpha-Pinene
	Flatulence	Methane, Hydrogen,
	Cosmetics	Limonene, Eucalyptol
Consumer Products	Household Supplies	Alcohols, Esters, Limonene
Office Equipment	Printers, Copiers, Computers	Benzene, Styrene, Phonole
Combustion	Engines, Appliances, Smoke	Unburnt Hydrocarbons, CO, CO_2
Building Materials	Paints, Adhesives, Solvents, Carpets	Formaldehyde, Alkanes, Alcohols, Aldehydes, Ketones, Siloxanes
Furniture	**P**oly **V**inyl **C**hloride (PVC)	Toluene, Xylene, Decane

Source: BAPI sensors

As an indoor air quality baseline is created by building, we can give operators the ability to adjust the HVAC airside components to ensure the highest levels of air quality. While we must comply with ASHRAE 62.1 code mandates, we must also give building operators the ability to close outdoor air dampers when the outside air would actually degrade the indoor air quality. Outside air does not always equal clean air. Real world scenarios such as the fire season in the Western United States, or buildings near sewage treatment plants, or outdoor intakes adjacent to idling diesel buses, lower the air quality in the building when introduced.

And the best way to balance IAQ and energy efficiency is to deploy a suite of IAQ sensors to provide a data driven approach to proper HVAC operations. At the minimum, schools and education buildings should

have IAQ sensors deployed at all HVAC main central air handling stations. These sensors should read carbon dioxide (CO2) levels, particulate (PM2.5, PM 1.0) and Total Volatile Organic Compounds (TVOC) at a minimum. The CO2 is our benchmark of ventilation effectiveness in the space. As the CO2 is expelled from occupants, the levels rise. As the HVAC runs with the introduction of outside air, the level of CO2 will decrease. When the indoor level reaches within 10% of the outdoor level (in DC 415 ppm), we know that our HVAC

did its job and has ventilated the building. PM2.5 positive readings demonstrate that our filters are filtering well and provides us with an indication of filter change needs.

As we begin the unravel the onion of indoor air quality, a great resource is the Berkeley lab which has aggregated many studies of VOCs from across the world. Some of the key findings of the various studies indicated that VOC concentrations indoors is much higher than outdoors. This must be addressed with our HVAC systems and how we think about air in our schools.

Collecting and analyzing the reading daily is imperative but if you have the funding, I highly recommend pulling all the data into an aggregation platform. Real-time analysis is the best way to closely monitor IAQ. This platform will be set up with critical alarm thresholds and a real time alert system for building operators to adjust the HVAC systems. At the most simplistic level, we have two main levers to improve the indoor air quality in real time, increased ventilation and longer HVAC run times. We don't want to overthink the solution when our sensors cross the thresholds. To be effective in real time, use one or both of the simple solutions. Then do a deeper dive of why the thresholds were crossed so we can formulate a longer lasting IAQ solution. In some cases, we are finding the cleaning staff has not followed the dilution rates of the cleaning solutions, there are off gassing events with new furniture or even painting causing a degradation in the air quality. The good news is the HVAC systems can operate and ventilate until the air quality gets below our thresholds. Our sensors can direct the HVAC unit operational protocols.

The sample protocol that I developed is our first step in our direction from the sensors to real time HVAC adjustments. The establishment of the thresholds should be completed locally at each school site and in most cases will be very similar based on the geographical area.

3) CO2 levels for more than 60 minutes:	**Unoccupied mode**	**This assumes the outdoor AQI is better then IAQ**
CO2 < 1000ppm plus ambinet ppm (approx. 1500 ppm)	Green	HVAC units run in normal occupied/unoccupied mode
2000ppm < CO2 < 4000ppm	Yellow	Continue to run HVAC units in fresh air mode till ppm drops
CO2 > 4000ppm	Red	Temporaily leave room until CO2 ppm drops to previous band, Open windows
PS: CO2 level trending needs to take average across all ten sensors, to establish our baseline non-occupied CO2 level.		
4) TVOC for more than 180 minutes:	**Unoccupied mode**	**This assumes the outdoor AQI is better then IAQ**
TVOC > 1000ppb for (24) hours	Yellow	Investigate ventilation
TVOC > 2200ppb for (24) hours :	Red	Do not use that room until ventilation reduces TVOC to below 1000 ppb
PS: TVOC spikes will happen when cleaning products are used but we need to establish trending first to see who the spikes occur and degrade.		
5) PM2.5:	**Occupied mode**	**This assumes the outdoor AQI is better then IAQ**
PM2.5 < 50 for (24) hours or PM2.5 < 12µg/m³ for (24) hours	Green	No Action
51 < PM2.5 < 100 for (12) hours or 12.1 12µg/m³ < PM2.5 < 35.4 12µg/m³ for (12) hours :	Yellow	Replace filter and increase ventilation
101 < PM2.5 < 150 for (12) hours or 35.5 12µg/m³ < PM2.5 < 55.4 12µg/m³ for (12) hours :	Orange	Replace filter and increase ventilation
PM 2.5 > 151 or 55.5 12µg/m³ any reading/any time	Red	Temporaily leave room until filtration issue is fixed

As engineers and school facility managers finalize IAQ sensor planning, there are two levels of recommendations: Base Minimum and Advanced IAQ. Here's a quick overview of the recommendations for both levels:

Base Minimum

- IAQ sensors deployed at all HVAC main central air handling stations.
- Readings should be taken daily and trending data shared with a BMS.
- Monitor PM2.5, CO2, temperature, TVOC's, and humidity.
- Advanced IAQ
- IAQ sensors deployed throughout the building at no less than one sensor per 3000 sf or one per classroom.
- Readings should be taken every five minutes and trending data shared with a BMS.
- Data aggregation and analysis software to create a IAQ daily profile
- Monitor PM2.5, CO2, temperature, TVOC's, humidity
- Create baseline algorithms that take IAQ alarms and adjust HVAC sequences for flushing, higher ventilation or air flow changes to improve the IAQ in real time.

Following these recommendations will make monitoring and managing IAQ much easier as we maneuver our new post-COVID19 normal. By thinking about our local environments, as well as occupant impacts on air quality, school leaders can make the sound data driven decisions to treat our air and adjust how they operate systems. Varying ventilation rates based on flushing out indoor contaminants or increasing ventilation run times to lower VOC's concentration even after the CO2 levels reach ambient, or even driving the choice in cleaning products, will all be part of the toolbox for proper IAQ management in the new paradigm.

As HVAC specialists, we know that proper ventilation in classrooms is essential and will help support the health and productivity of students and teachers. As communities start opening schools in the wake of COVID-19, it becomes even more important to ensure school leaders are in fact providing the proper indoor air; the air that we all deserve.