Procedure for Determination of Contaminant Clearance Rate of Laboratory Ventilation Zones

Purpose	This tracer gas procedure is used to determine the contaminant clearance rate in a single ventilation zone with single pass air. The carbon dioxide (CO_2) level in the space is raised to levels above 10,000 ppm by release of CO_2 from fire extinguishers. The change in CO_2 concentration over time is measured in selected locations around the room. The locations selected for measurement are based on professional judgement to address specific questions of concern in this space. From this data, a concentration decay curve for each location can be determined and the air exchange rate at different locations in this zone calculated. Questions of concern that can be addressed with this procedure include: 1. What is the actual average air change rate in the space compared to design specifications? 2. How effective is the ventilation in this space and how much variation is there in this effectiveness? 3. Is the ventilation system in this space adequately balanced? 4. Are there unexpected pathways of air movement within or between spaces? 5. Are there specific locations in the space which are more highly or less ventilated than others?
Background	The procedure below is based on the ASTM Standard E741 for Concentration Decay Test Method of analysis using carbon dioxide gas as the tracer. Non-linear regression analysis is used to calculate the air exchange rates under normal ventilation conditions. This procedure uses carbon dioxide levels between 10,000 and 2500 ppm in order to minimize the impact of incoming CO_2 in the supply air to the room and maintain safe levels of CO_2. Data analysis can be conducted with standard Excel spreadsheet functions or applications on specific web sites.

Materials	• Enough CO_2 fire extinguishers to raise CO_2 levels in the room over 10,000 ppm. The required number and size of the extinguishers will depend on the volume of the zone being assessed, but generally a 5 pound fire extinguisher will release enough CO_2 for a single test in a well-mixed room of 500 square feet or less. • Portable CO_2 meters with data-logging capability. • Floor plans of the space being investigated and the locations and types of air inlets and outlets • Video of the release as it performed is quite likely to be helpful when assessing flow patterns in the room visually

General Hazards Associated With This Procedure

1. **Noise:** Release of the CO_2 gas creates significant noise levels and hearing protection is highly recommended.
2. **Release of dry ice particles:** In addition to CO_2 gas, dry ice particles will be released from the fire extinguisher. These can present skin and eye hazards for people in the area. Eye protection and long sleeves and pants should be worn by everyone in the area. These dry ice particles can also impact any electronic equipment it lands on; such equipment should be protected from the extinguisher spray with drop cloths.
3. **Ergonomics:** Fire extinguishers are heavy; they should be transported on carts and care should be used in handling them.
4. **Static electricity discharge:** As the CO_2 gas is released from the extinguisher, static charges build up on the release horn and can lead to sparks between the extinguisher and the floor. For this reason, the extinguisher should be in contact with the floor when the release occurs.
5. **Potential CO2 exposures:** In some circumstances, unexpectedly high levels of CO_2 have been observed, near the NOISH IDLH level of 40,000 ppm (note that the chosen IDLH is based on the statements by ACGIH [1971] that a 30-minute exposure at 50,000 ppm produces signs of intoxication, and a few minutes of exposure at 70,000 ppm and 100,000 ppm produces unconsciousness). For this reason, the size of the extinguishers used should be conservatively estimated, as a space may have less ventilation than suggested by the control system. All people participating in the testing should be made familiar with the symptoms of significant CO_2 exposure and the work should not be conducted alone.

Procedure

1. Calibrate the meters per manufacturer's instructions.
2. Define as precisely as possible the question(s) to be answered with regard to the ventilation in the space.
3. Identify location to be used to assess the ventilation – Using professional judgment, review the room to assess the parameters of the test, such as

whether the ventilation system will be in occupancy or unoccupied operation, potential leakage or cross-contamination pathways, and the location of passive ventilation systems (such as non-operating biosafety cabinets).

- The locations where the sensors are put depends on the area to be sampled. This may be where the air is well-mixed and indicative of open spaces throughout the lab. They may be at specific workspaces where there may be pocketing of airborne contaminants, such as sinks.
- In small rooms, with simple layouts, it can be expected that horizontal arrays within the room are likely to produce similar results and make data analysis more straight forward. However, vertical arrays produce widely varying results, probably due to vertical stratification of ventilation patterns. However, in situations where vertical stratification of airflow is likely (for example, air change rates below 4 ACH), assessment of vertical variations may be called for.
- In large labs with numerous work stations and equipment that may block ventilation sweeping, the sensors may be put in areas close to contaminant emissions or where exhaust points are needed.

4. Tracer gas injection volume- Estimate the volume of the zone to be measured in order to determine the target concentration of the gas of 10,000 ppm. This concentration should be at the upper detection limits of the gas analyzer.
5. Document the test conditions. This information should include, as a minimum:
   - Photographs of the location of each sensor;
   - Volume of the zone (may need to estimate the volume displaced by large equipment);
   - Information from the building control system about the supply and exhaust ventilation rates;
   - Types and locations of fume hoods or biological safety cabinets in the area;
   - Other features that may impact air mixing within the zone, for example, location of large furniture or equipment relative to the sensors.
6. The vapor density of CO_2 is 1.53, so it is likely to sink to the floor. It is also cold when initially released. Due to volume expansion, as it warms there may a lag on the up-side of the curve, so the math should be performed on the decay portion of the curve. For this reason, the CO_2 should be released in a sweeping, upward direction to assure it is entrained in the general air flow of the room. Also, dry ice crystals will be distributed in the room; if one lands next to a sensor, it should be swept away to assure that it doesn’t create a local concentration peak that will affect the sensor’s decay curve. Any sensitive

electronic equipment in the space should be protected from ice crystal fallout.

7. The sampling duration will vary depending on the rate of removal of the gas. The CO_2 concentration will rise quickly, peak above 10,000 ppm and then begin falling and eventually level off at about 400 ppm. Because CO_2 is being added to the room in the supply air at about 400 ppm, the suggested values for analysis are between 10,000 ppm and 2500 ppm, in order to minimize the effect of this outdoor air source. Readings should be recorded at least every five seconds.

8. With the CO_2 data-logger collecting data, discharge the fire extinguisher until the meter reads above 10,000 ppm. Then close the fire extinguisher and leave the room. Movement within the room during the sampling period is likely to disrupt the decay curves.

9. Allow the ventilation system to decay the CO_2 below 2500 ppm. Save the data collected by the data logger to an external file. This can be expected to take between 10 and 30 minutes, depending on the ventilation rate and effectiveness in the room.

Complementary Tests

This procedure assumes that the space being assessed is balanced and the ventilation system is well controlled. Observation of the fog release from the fire extinguisher can help assess this concern. However, if there is any question about the operation of the ventilation system in the space in this regard, use of theater smoke to visualize the current air movement in the space is recommended.

If the general clearance rate of the space as a whole in a spill scenario, rather than comparing clearance within the space, is the parameter of interest, use of volatile organic compounds can be considered. Calculations associated with this process is similar for CO_2, but less of the material will be used due to flammability concerns, so the signal is likely to be weaker and more ambiguous.

Calculations Using the Regression Method

Correlation coefficient (R^2): An R^2 value less than 0.95 indicates a reason for concern about unrecognized variables for this run, such as an insufficient volume of CO_2 released or poor mixing within the space.

Appendix A- Air Quality Egg Data Loggers

Wicked Device, LLC[1,2] created Air Quality Eggs for the purpose of monitoring air contaminants inside the home. The units that used for this CO_2 tracer gas test are equipped with an NDIR (non-dispersive infrared lamp)[3] sensor that is drawn into the Egg and passed the detector by a small fan. A data logger is also located inside the unit records the parts per million of CO_2 measured by the IR lamp and records this to a ScanDisk (SD) card.

Download the data and then upload it in order to graph the air exchange rates (ACH) using the webpage found at this link: https://airqualityegg.wickeddevice.com/co2/

[1] https://shop.wickeddevice.com/
[2] https://www.youtube.com/channel/UCKmoBepZhgOwGKvltAhzWM
[3] https://www.co2meter.com/blogs/news/6010192-how-does-an-ndir-co2-sensor-work

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