AER Calculation – updated 6/24/2024

**1. CO2 decay rate (ACH) calculation using linear regression fitting**

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Ref.

Batterman, S.. (2017). Review and Extension of CO2-Based Methods to Determine Ventilation Rates with Application to School Classrooms. *International Journal of Environmental Research and Public Health*, *14*(2), 145. <https://doi.org/10.3390/ijerph14020145>

Claude-Alain, R., & Foradini, F.. (2002). Simple and Cheap Air Change Rate Measurement Using CO2Concentration Decays. *International Journal of Ventilation*, *1*(1), 39–44. <https://doi.org/10.1080/14733315.2002.11683620>

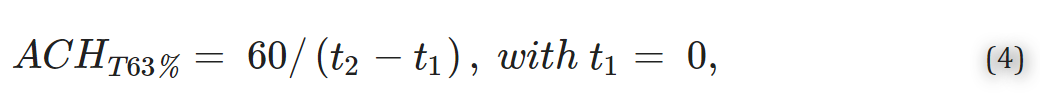
Huang, Q., Marzouk, T., Cirligeanu, R., Malmstrom, H., Eliav, E., & Ren, Y.-F.. (2021). Ventilation Assessment by Carbon Dioxide Levels in Dental Treatment Rooms. *Journal of Dental Research*, *100*(8), 810–816. <https://doi.org/10.1177/00220345211014441>

CO2 tracer gas concentration decay method for measuring air change rate. (2015/01/01). Building and Environment, 84. <https://doi.org/10.1016/j.buildenv.2014.11.007>

* Used CO2 data from 5:30 pm (after all workers left the office) to the last point above 475 ppm (400 ppm is the outdoor CO2 range, and 75 ppm is the standard deviation indicated on the Awair Element website (CO2 accuracy information))
* If the peak of the CO2 level is not high enough, the error of decay rate calculation could be huge.   
  Ref. (Betterman, S.. ,2017)  
  “The concentration change over the period must be large relative to the variation in CR and CO2 measurement error; typically, changes of 100 ppm or more may be sufficient, but at least several hundred ppm are desirable given the performance of typical instrumentation. (Many CO2 instruments report accuracies of ±50 ppm plus 1% to 2% of readings.).”
* Therefore, in our case, if the excess CO2 range(=CO2 peak (5:30 pm)-CO2 outdoor) was not above 200 ppm (= original CO2 level at 5:30 pm did not meet 600 ppm), the decay rate calculation was assumed to be not accurate. Below table, the yellow filled dates were the date having not enough excess CO2 range (not over 200 ppm).

**2. CO2 decay rate (ACH) calculation using time to 63% Removal of Excess CO2**

- Based on a commonly used formula for rate of purging airborne contaminants, 1 complete air change will replace 63% of airborne contaminants in the room with outdoor air ([Nardell et al. 1991](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8120146/" \l "bibr17-00220345211014441); [Fernstrom and Goldblatt 2013](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8120146/#bibr8-00220345211014441); [Jimenez 2020](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8120146/#bibr14-00220345211014441)).



Ref.

Huang, Q., Marzouk, T., Cirligeanu, R., Malmstrom, H., Eliav, E., & Ren, Y.-F.. (2021). Ventilation Assessment by Carbon Dioxide Levels in Dental Treatment Rooms. *Journal of Dental Research*, *100*(8), 810–816. <https://doi.org/10.1177/00220345211014441>

Jimenez J-L. 2020. How to quantify the ventilation rate of an indoor space using an affordable CO2 monitor [accessed 2021 Feb 4]. [https://medium.com/@jjose\_19945/how-to-quantify-the-ventilation-rate-of-an-indoor-space-us ing-a-cheap-co2-monitor-4d8b6d4dab44](https://medium.com/@jjose_19945/how-to-quantify-the-ventilation-rate-of-an-indoor-space-us%20ing-a-cheap-co2-monitor-4d8b6d4dab44).

* Used the same CO2 data at 5:30 pm (after all workers left the office) for t1.

**3. AER calculation using CO2 sensor data (4 seasons) - linear regression method**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Mon** | **Tue** | **Wed** | **Thu** | **Fri** | **Summary (AER)** | |
| **April** |  | **3-Apr** | **4-Apr** | **5-Apr** | **6-Apr** | **~~7-Apr~~** |  |  |
| CO2 decay rate (k, AER) | Sensor1 | 0.21 | 0.20 | 0.21 | 0.16 |  | average | 0.21 |
| Sensor2 | 0.24 | 0.23 | 0.22 | 0.18 |  | stdev | 0.03 |
| Occupancy | | 10 | 15 | 18 | 13 |  | median | 0.21 |
| Temp (°F) | Max | 83 | 59 | 68 | 79 |  | min | 0.16 |
| Avg | 67 | 51.2 | 52.6 | 60.8 |  | max | 0.24 |
| Min | 48 | 42 | 33 | 41 |  |  |  |
| **August** |  | **7-Aug** | **8-Aug** | **~~9-Aug~~** | **10-Aug** | **11-Aug** |  |  |
| CO2 decay rate (k, AER) | Sensor1 | 0.34 | 0.32 | 0.43 | 0.34 | 0.35 | average | 0.37 |
| Sensor2 | 0.37 | 0.33 | 0.38 | 0.40 | 0.47 | stdev | 0.05 |
| Occupancy | | 16 | 20 | 23 | 19 | 16 | median | 0.34 |
| Temp (°F) | Max | 102 | 98 | 103 | 101 | 93 | min | 0.32 |
| Avg | 92.4 | 85.7 | 90.6 | 90.4 | 87.4 | max | 0.47 |
| Min | 84 | 78 | 76 | 81 | 82 |  |  |
| **October** |  | **23-Oct** | **24-Oct** | **25-Oct** | **26-Oct** | **27-Oct** |  |  |
| CO2 decay rate (k, AER) | Sensor1 | 0.57 | 0.41 | 0.30 | 0.39 | 0.54 | average | 0.46 |
| Sensor2 | 0.66 | 0.45 | 0.27 | 0.46 | 0.55 | stdev | 0.12 |
| Occupancy | | 16 | 22 | 20-22 | 15 | 12 | median | 0.45 |
| Temp (°F) | Max | 88 | 78 | 77 | 82 | 85 | min | 0.27 |
| Avg | 77.3 | 67.4 | 66.7 | 68.7 | 70.3 | max | 0.66 |
| Min | 67 | 60 | 57 | 58 | 58 |  |  |
| **February** |  | **12-Feb** | **13-Feb** | **14-Feb** | **15-Feb** | **16-Feb** |  |  |
| CO2 decay rate (k, AER) | Sensor1 | 0.21 | 0.20 | 0.24 | 0.14 | 0.08 | average | 0.17 |
| Sensor2 | 0.18 | 0.20 | 0.23 | 0.13 | 0.09 | stdev | 0.06 |
| Occupancy | | 12 | 19-22 | 21 | 17-19 | 11 | median | 0.19 |
| Temp (°F) | Max | 66 | 71 | 69 | 72 | 71 | min | 0.08 |
| Avg | 49.5 | 53.6 | 53.9 | 55.4 | 55.1 | max | 0.24 |
| Min | 36 | 40 | 40 | 42 | 42 |  |  |

\* Sensor1: CO2 data collected from the sensor1 on the bookshelves, Sensor2: CO2 data collected from the sensor2 on the side top table.

\* August 9th data wax excluded due to the cleaning service event at the WebMO office after the office hour.

\*October 25th data had a sudden unknown high peak from 6:50 pm to 7:30 pm. Therefore, tail data from 8:00 pm to time to meet the 75 ppm CO2 level was used for the AER calculation.

**4. AER calculation using CO2 sensor data (4 seasons) – using time to 63% removal of excess CO2 (for Supporting materials, for comparison w. linear regression methods)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Mon** | **Tue** | **Wed** | **Thu** | **Fri** | **Summary (AER)** | |
|  | **3-Apr (Mon)** | **4-Apr (Tue)** | **5-Apr (Wed)** | **6-Apr (Thu)** | **~~7-Apr (Fri)~~** | average | 0.22 |
| Sensor 1 | 0.32 | 0.18 | 0.19 | 0.20 |  | stdev | 0.05 |
| Sensor 2 | 0.27 | 0.22 | 0.19 | 0.22 |  | median | 0.21 |
|  |  |  |  |  |  | min | 0.18 |
|  |  |  |  |  |  | max | 0.32 |
|  | **7-Aug (Mon)** | **8-Aug (Tue)** | **~~9-Aug (Wed)~~** | **10-Aug (Thu)** | **11-Aug (Fri)** | average | 0.37 |
| Sensor 1 | 0.29 | 0.34 | 0.55 | 0.38 | 0.36 | stdev | 0.04 |
| Sensor 2 | 0.39 | 0.41 | 0.43 | 0.39 | 0.40 | median | 0.38 |
|  |  |  |  |  |  | min | 0.29 |
|  |  |  |  |  |  | max | 0.41 |
|  | **23-Oct (Mon)** | **24-Oct (Tue)** | **25-Oct (Wed)** | **26-Oct (Thu)** | **27-Oct (Fri)** | average | 0.41 |
| Sensor 1 | 0.55 | 0.43 | 0.29 | 0.32 | 0.40 | stdev | 0.11 |
| Sensor 2 | 0.63 | 0.46 | 0.32 | 0.31 | 0.43 | median | 0.41 |
|  |  |  |  |  |  | min | 0.29 |
|  |  |  |  |  |  | max | 0.63 |
|  | **12-Feb (Mon)** | **13-Feb (Tue)** | **14-Feb (Wed)** | **15-Feb (Thu)** | **16-Feb (Fri)** | average | 0.17 |
| Sensor 1 | 0.22 | 0.17 | 0.19 | 0.14 | 0.12 | stdev | 0.04 |
| Sensor 2 | 0.21 | 0.16 | 0.18 | 0.14 | 0.11 | median | 0.17 |
|  |  |  |  |  |  | min | 0.11 |
|  |  |  |  |  |  | max | 0.22 |

\* Sensor1: CO2 data collected from the sensor1 on the bookshelves, Sensor2: CO2 data collected from the sensor2 on the side top table.

\* August 9th data wax excluded due to the cleaning service event at the WebMO office after the office hour.

**5. Figures**

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